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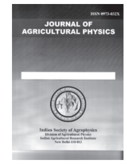

Research Article

Population Dynamics of Mustard Aphid in relation to Humid Thermal Ratio and Growing Degree Days

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ABSTRACT

To determine the relative role of weather variables and accumulated heat units on mustard aphid *Lipaphis erysimi* (Kalt) population, field experiment was conducted at research farm of Indian Agricultural Research Institute (IARI) during the *rabi* season (October-April) of 2006-07. The study revealed that throughout the ascending phase of the aphid population right up to its observed peak, the maximum temperature showed downward trend till peak aphid population reached. During the descending phase of the aphid population, weather parameters were not found to be congenial. The maximum temperature started increasing after 27th January and later remained around 25^0C. Initially when aphid population started building up, HTR ranged from 2 to 3. The population started increasing gradually from 2nd week of December, reached peak population around last week of January in both of the varieties in 15th October sowing. In 30th October sowing aphid population started building up from 1st week of January and reached peak population around 1st week of February. It was observed that HTR as well as the aphid population increased, but as aphid population reached its peak the HTR values reduced. In both early (15th October) and late sown (30th October) crop the aphid population had a significant negative correlation with growing degree days (GDD), but positively correlated with humid thermal ratio (HTR). As the growth and development of insects mainly depends upon the accumulated amount of heat, GDD and HTR computation could be used for prediction of aphid population build up.

Key words: Growing degree days, Humid thermal ratio, Mustard, Aphid

Introduction

Abiotic factors seem to influence the aphid infestation due to large variation in the date of aphid infestation and its progress. Under favourable weather conditions, mustard aphids spread very rapidly forcing the farmers to repeatedly use insecticides. However, need based application of the insecticides is desirable in order to avoid pollution related hazards.

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Several studies have been done to develop correlation between weather parameters and aphid population. They reported that the peak period of aphid activities on *B. juncea* varied from end of January to first week of March. Based on simple linear regression analysis between aphid population and the corresponding weather for 3 years, Bishnoi *et al*. (1992) reported that the either mean temperature or saturation deficit contributes significantly to the build up aphid population. Samdur *et al.* (1997) from Delhi observed that average maximum and minimum relative humidity had positive relationship with mean aphid infestation index. A minimum relative humidity of 30 to 35% and average maximum relative humidity of 85 to 88% were found to be the most congenial conditions for increase in aphid population. Kulat *et al*. (1997) found that in Nagpur, a combination of ambient maximum temperature (26.4 to 29.0^{0}C), minimum temperature (8.4 to 12.6^{0}C) and high relative humidity ranging from 75 to 85 percent in the month of January favoured aphid multiplication, whereas the activity of the aphid ceased at relative humidity of 65 per cent and below.

A lot of information is available about the relationship between various biotic and abiotic factors and incidence, multiplication and disappearance of mustard aphid. Based on the understanding of the relationship between these factors and levels of aphid infestation, the correlation studies help in developing the regression models for forecasting the aphid infestation under existing condition. Prasad and Phadke (1984) from their field studies at IARI, New Delhi, worked out semi $\log_e X$ equation to be best fit for almost all the stages of the crop growth relating the yield with aphid population. Mishra and Singh (1986) observed similar type of relationships between the yield of mustard and aphid infestation levels. Based on field observation, Prasad *et al*. (1984) from IARI, New Delhi reported that maximum, minimum and mean temperatures existing one or two preceeding weeks showed a significant and negative correlation with the prevailing population with a lower value of determination factor. From field studies conducted at IARI, New Delhi, (Subhash Chander,1995; Samdur *et al*., 1997) reported that the mean aphid infestation index was negatively correlated with maximum temperature, evaporation, sunshine and wind velocity and it was positively correlated with maximum relative humidity and minimum relative humidity in a significant way in case of timely sown crop. Prasad and Chakravarty (2000) at IARI, New Delhi, developed a typical model equation for forecasting the aphid population in *Brassica* crop, based on aphid population recorded at weekly intervals and the corresponding weather parameters viz. maximum, minimum and mean temperature, relative humidity, saturation deficit and the total rainfall. They also incorporated the aphid population at one week, two weeks and three weeks before the observation date.

Development stage of the aphids can be effectively expressed as a temperature sum or degree-day (Chakravarty and Gautam, 2002). Many workers worked out the relationship between growing degree-days and aphid growth and development and population build-up in *Brassica* crop and this relationship can be used for a computer forecast system to predict aphid population. Prasad and Phadke (1980) at IARI, New Delhi, worked out the thermal requirement for identifying the peak aphid population in Indian mustard. They observed that about 407.3 ^{0}D was required for attaining peak aphid population, considering 5^{o}C as base temperature.

However, a quantitative, effective assessment / forecast models relating the aphid population with the biotic and abiotic factors is lacking, especially under severe winter conditions. Under such conditions it was found that some factors were positively correlated whereas, in some other cases it was negatively correlated. Most often aphid population depends on the growth of the crops and it was found that growths of the crop are linearly related with growing degree days. Therefore, the present study was taken up to fill in the gaps in the research and come out with a satisfactory model to assess or forewarn the aphid population in relation to various phenological conditions in the mustard crop which would go a long way in reducing the yield losses due to this dreaded pest.

Material and Methods

In order to achieve the objectives set out, field experiments on mustard (*Brassica Juncea*) were conducted in the experimental farm of Indian Agricultural Research Institute (IARI), New Delhi during the *rabi* season (October-April) of 2006-07. The soil of the experimental site belongs to the major group of Indo-Gangetic alluvium. The soil texture is sandy clay loam and belongs to Holambi Series, which is a member of non-acidic mixed hyperthermic family of Typic Haplustepts, with medium to weak angular blocky structure.

The soil is non-calcareous and slightly alkaline in reaction.

Two cultivars of *Brassica juncea*, viz. Pusa Jaikisan (a popular variety) and BIO169-96 (developed at National Research Centre on Plant Biotechnology IARI, New Delhi) were sown during winter (rabi) seasons of 2006–07 (15th October and 30th October) following RBD with three replicates of 5×5 m^2 each plot size.The initial date of appearance of the mustard aphid in each plot was recorded. Number of aphids on 10 cm long terminal shoots was chosen as basis for estimating populations as these have been shown to be correlated best with abiotic factors (Singh *et al.*, 1984). Number of aphids on 10 cm long terminal shoots was recorded on alternative days in a week until harvest from 10 randomly tagged plants to monitor aphid population in the crop. Weather data of maximum and minimum daily temperatures, morning (0700 h Local Apparent Time or LAT) calculated on the basis of longitude of a location as per standard norms of the World Meteorological Organisation (WMO) (Doorenbos, 1976; Ghadekar, 2002) and afternoon (1400 h LAT) RH, bright sunshine hours and wind speed were recorded from the I.A.R.I. Meteorological observatory located adjoining to the experimental site (Fig. 1). From the meteorological parameters some derived meteorological parameters which affect the crop and pest population growth were also calculated.

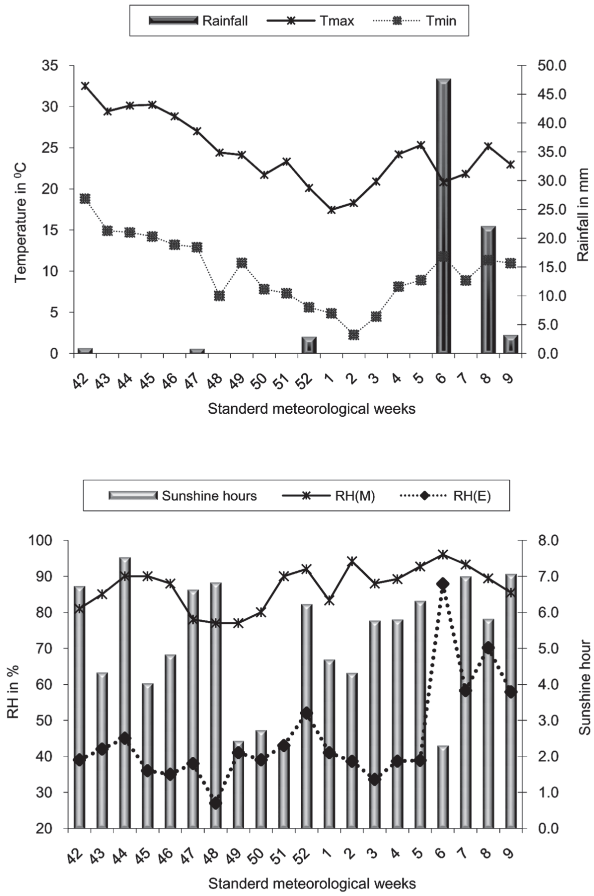

Fig.1. Mean daily weather parameters during standard weeks of the growing period of *Brassica* (2006-07)

Accumulated heat units / GDD (Growing degree days)

As the ambient daily temperatures are highly variable, the response of the plants to the thermal environment for their growth and development can be better expressed through the accumulated heat units instead of temperatures. Growing Degree Days (GDD) are the most common and simple ways of quantifying the thermal environment. Degree-day based approach is founded on the premise that living organisms need a certain definite amount of accumulated heat to fulfill their requirement for initiating phenological development. Differentiation in phenological events does not take place until this requirement is met. The basic concept of heat unit assumes a linear or logarithmic relationship between growth and temperature, which is predicted by Van't Hoff's Law. Heat unit measure is a departure of mean daily temperature from a base temperature below which the internal biochemical activity ceases.

$$GDD = (T_{Max} + T_{Min})/2 - T_{Base} \qquad (1)$$

where, T_{Max} and T_{Min} are the maximum and minimum temperatures (^{0}C) of a day and T_{Base} is the base temperature taken as 5^0C for *Brassica* (Morrison *et al*., 1989).

$$HTR = RH_{mean} / T_{mean} \qquad (2)$$

where, HTR is Humidity Thermal Ratio, RH_{mean} is mean Relative humidity and T_{mean} is Mean Temperature.

Data analysis

For each assessment date, aphid numbers on 10 randomly tagged plants from each plot were averaged to give a single aphid count. Linear prediction models based on the weather parameters as independent variables and aphid population as dependent variables were fitted by multiple regression (Draper and Smith, 1981). Based on correlation coefficients between dependent variables under study with the respective weather parameter and t test significance parameters which was correlated with aphid population were selected. The important weather indices were selected through stepwise regression. Models were fitted for prediction of the highest aphid population. Statistical analysis was done using Excel and SPSS package (Version 16.0).

Results and Discussion

Weather condition and aphid population

It was observed that for the major part of the *rabi* 2006-07 season, the weather remained conducive for the rapid multiplication of the aphid. This phase also corresponded to the period of growth of the cruciferous crops including rapeseed and mustard. It was seen that the major period of activity of the aphid population was from the middle of December to the end of February (Prasad and Chakravarty, 2000).

It was also noted that in the initial phase, when the maximum temperatures were around 25^0 C, winged, migrant adults were observed on the plants, this temperature range was congenial to the aphid multiplication as also reported by Prasad and Phadke (1987). The minimum temperature during this period remained between 10 to12^0C.

Throughout the ascending phase of the aphid population right up to its observed peak, the maximum temperature showed downward trend till peak aphid population reached. In case of 15th October sowing, peak aphid population reached when the maximum temperature remained around 18^0C. After reaching peak population aphids retained their colony for one or two weeks when the temperature were 20-22^0C. In 30th October sowing, peak aphid population reached when maximum temperature was 20^0C (Fig. 2).

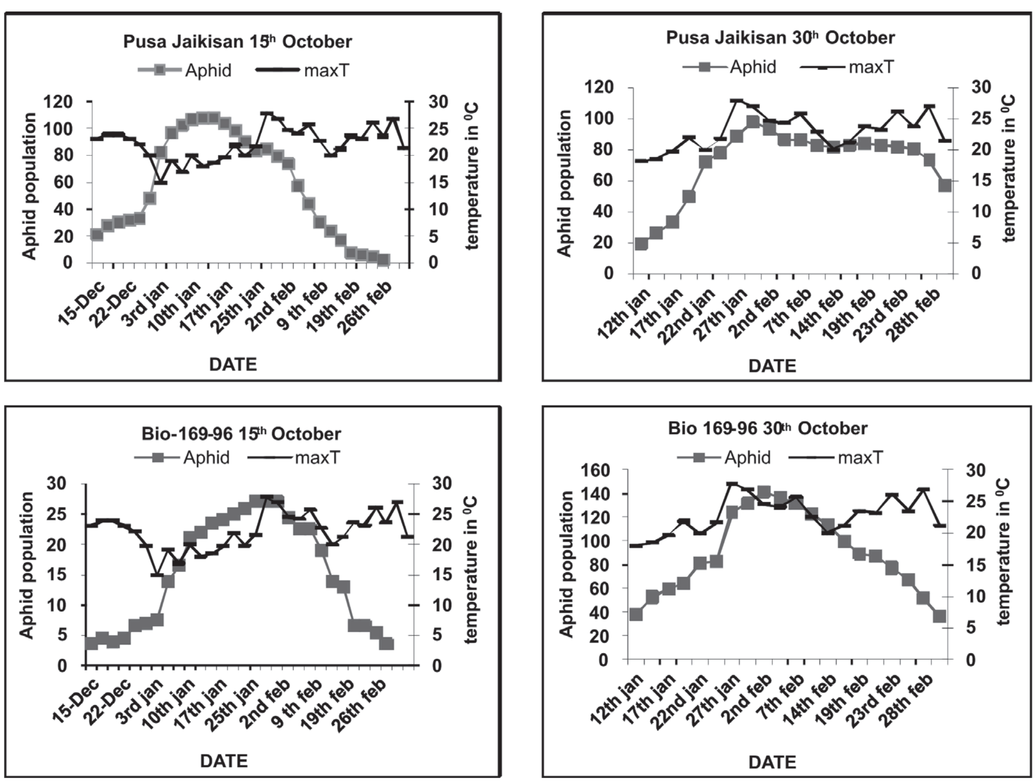

Fig. 2. Aphid population in relation to maximum temperature in first (15th October) and second sowing dates (30th October) in *Brassica varieties* grown during *rabi* 2006-07 season

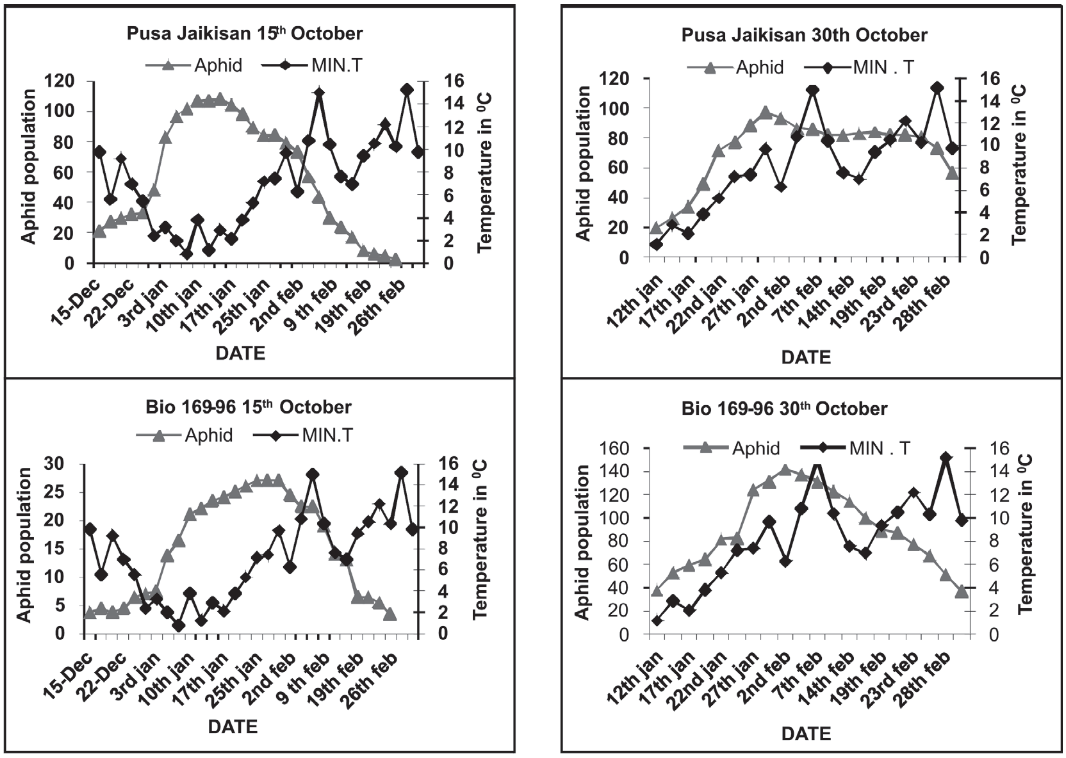

Fig. 3. Aphid population in relation to minimum temperature in first (15th October) and second sowing dates (30th October) in *Brassica varieties* grown during *rabi* 2006-07 season

Likewise the aphid population also correlated negatively with minimum temperature. The aphid population started building up when minimum temperature showed downward trend. Peak aphid population reached when the minimum temperatures remained around 0.8 to 1.0^{0}C. In 30th October sown crop, when peak aphid population reached, the minimum temperatures were around 5^{0}C (Fig. 3).

During the descending phase of the aphid population, weather parameters were not found to be congenial. The maximum temperature started increasing after 27th January and later remained around 25^{0}C. A gradual increase in minimum temperature was also observed. The relative humidity remained around 70 per cent. These ambient weather conditions caused rapid decline in the aphids.

In both the sowing dates, the range of maximum and minimum temperatures during peak aphid activities was favorable for aphid growth. After reaching the maximum population, rapid decline of population was attributed to heavy precipitation as dew (0.18 mm) at 1 m height on 2nd February and 45 mm of rain fall in between 7th to 14th February and very high wind speeds during 2nd week of February which washed away the nymphs of aphid thus causing dislodging.

The influence of abiotic factors on mustard aphid was studied by many workers at different places. Singh and Verma (1990) observed that minimum and maximum relative humidity of preceding three days of observation were the most important factors to increase the aphid population and out of these two, the minimum relative humidity played an important role in increasing the aphid population. Rohilla *et al.* (1996) observed from the field studies conducted in Haryana, that the pest incidence increased with an average temperature of about 13.7^{0}C and a relative humidity of 65 per cent. It decreased with temperature above 35^{0}C, relative humidity less than 60 per cent and rain fall more than 10 mm per day. Our studies are also in conformity with these reports.

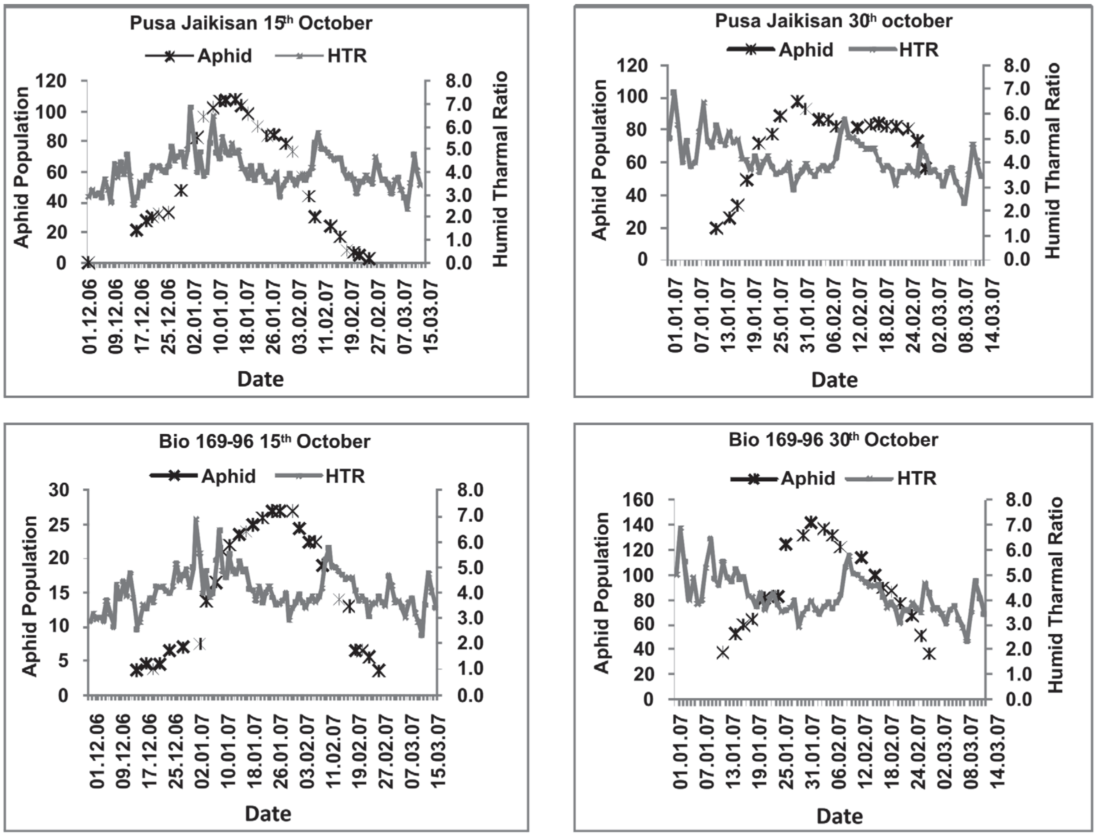

Fig. 4. Aphid population in relation to humid thermal ratio (HTR) in first (15th October) and second sowing dates (30th October) in Pusa Jaikisan and Bio 169-96

Humid thermal ratio and peak aphid population

Among the different weather parameters, temperature and relative humidity are the most important affecting aphid's multiplication and growth (Manzar *et al*., 1998). Based on daily values of temperature and relative humidity, humid thermal ratio (HTR) was computed and related to aphid dynamics.

Since the aphid population started building up during 2nd week of December, the daily HTR values were computed from 1st December to 15th March and plotted (Fig. 4). Initially when aphid population started building up, HTR ranged between 2 to 3. The population started increasing gradually from 2nd week of December and reached peak population around last week of January in both of the varieties in 15th October sowing. In 30th October sowing, aphid population started building up from 1st week of January and reached peak population around 1st week of February. It was observed that HTR as well as the aphid population increased, but as aphid population reached its peak the HTR values were reduced.

In Pusa Jaikisan when the peak aphid population reached (15th October sowing), HTR value was about 4. As the aphid population increased HTR decreased, but during 2nd week of January there was decreasing trend of aphid population as HTR value increased to 6.5 and reached its peak when the HTR was 3.5. After the 2nd week of February HTR increased while a decreasing trend of aphid population was observed. Similar to Pusa Jaikisan, in case of Bio169-96 there was similar peak and valley curve of aphid population, peak aphid population was observed when HTR value was the lowest. Similar results were also observed in 30th October sowing in both the cultivars.

In both dates of sowing and both the cultivars, peak aphid population reached when HTR values were lowest. The main reason being that, development from nymph to winged adult mostly influenced by atmospheric temperature; thereafter those adult winged insects migrate. Working at Ludhiana, Dhaliwal (2002) reported that with increase in HTR, peak aphid population decreased and peak aphid population reached when HTR value was between 3 to 4. Similar report was also made by Roy (2003) and our studies also support these reports. Thus, though the HTR seems to be a promising index, the response of aphid infestation in different cultivars, planting and different treatments further need to be studied in detail.

Regression analysis

The influence of maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, bright sunshine hours, humid thermal ratio and growing degree days on aphid population during 2006-07 was worked out through multiple regression analysis. From the backward multiple regression analysis it was

Table 1. Backward multiple regression analysis for estimating the influence of weather parameters on aphid population during 2006-07

Pusa Jaikisan

Y_{15} = - 107.2 + 9.6 MaxT – 3.1 MinT - 0.6 RHm – 0.6 RHe + 1.2 BSS – 0.1 GDD + 50.6 HTR (R^2= 0.76, p= 0.000018)

= - 55.7 + 7 MaxT - 2.8MinT - 0.6 RHe + 1.3 BSS – 0.1 GDD + 38.7 HTR (R^2 = 0.75, p= 0.000005)

= - 53.9 + 7.3 MaxT – 3.2 MinT – 0.7 RHe - 0.1 GDD + 37.6 HTR (R^2 = 0.75, p= 0.000001)

= - 78.6 + 6.9Max T – 0.9 RHe – 0.1 GDD + 47.3 HTR (R^2 = 0.74, p= 0.0000004)

Bio 169-90

Y_{15} = - 6.3 + 3 MaxT + 0.6 MinT + 1.7 RHm – 0.9 RHe + 0.8 BSS – 0.1 GDD + 4.2 HTR (R^2 = 0.49, p= 0.0231)

= 12.6 + 2.1 MaxT + 0.6 MinT + 1.9 RHm – 0.9 RHe + 0.8 BSS – 0.1 GDD (R^2 = 0.49, p= 0.0109)

= 9.8 + 2.5 MaxT + 1.9 RHm – 0.8 RHe + 0.7 BSS – 0.1 GDD (R^2 = 0.49, p= 0.0046)

= 10.1 + 2.6 MaxT + 1.9 RHm – 0.9 RHe– 0.1 GDD (R^2 = 0.49, p= 0.0017)

= 61.3 + 1.7 RHm – 0.8 RHe– 0.1 GDD (R^2 = 0.46, p= 0.0010)

= 103.1 + 1.5 RHm– 0.1 GDD (R^2 = 0.37, p= 0.0018)

= 213.6 – 0.1 GDD (R^2 = 0.29, p= 0.0020)

Pusa Jaikisan

Y_{30} = 1189.7 – 32.5 MaxT + 7.4 MinT + 12.2 RHm – 0.3 RHe – 3.9 BSS – 0.4 GDD – 242.8 HTR (R^2= 0.78, p= 0.0033)

= 1241.6 – 34 MaxT + 5.9 MinT + 12.6 RHm– 2.8 BSS – 0.4 GDD – 254.8 HTR (R^2= 0.78, p= 0.0012)

= 1287.1– 37.8 MaxT + 6.2 MinT + 13.5 RHm– 0.4 GDD – 270.3 HTR (R^2= 0.78, p= 0.0004)

= 1195.2– 33.4 MaxT + 13 RHm– 0.4 GDD – 269.3 HTR (R^2= 0.75, p= 0.0002)

= 489.8 + 4.1 RHm– 0.3 GDD – 88.3 HTR (R^2= 0.71, p= 0.0001)

Bio 169-90

Y_{30} = 1396.7 – 48.6 MaxT + 9.1 MinT + 16.8 RHm – 0.1 RHe – 2.2 BSS – 0.4 GDD – 328.4 HTR (R^2= 0.69, p= 0.02)

= 1417.5 – 49.2 MaxT + 8.5 MinT + 16.9 RHm – 1.8 BSS – 0.4 GDD – 333.2 HTR (R^2 = 0.69, p= 0.0082)

= 1447 – 51.7 MaxT + 8.7 MinT + 17.5 RHm – 0.4 GDD – 343.2 HTR (R^2 = 0.69, p= 0.0031)

= 1318.3 – 45.5 MaxT + 16.8 RHm – 0.3 GDD – 341.8 HTR (R^2 = 0.64, p= 0.0025)

= 358.3 + 4.7 RHm – 0.2 GDD – 95.5 HTR (R^2 = 0.57, p= 0.0031) observed that the combined effect of these weather parameters had the least influence on aphid population in early sown crop (15th October) as the coefficient of determination values in Pusa Jaikisan and Bio 169-96 were only 0.76 and 0.49, respectively. But, when the sowing was delayed by 15 days the combined influence of both these parameters increased with R^2 value of 0.78 and 0.69 in Pusa Jaikisan and Bio 169-96, respectively. It was observed that in early sown crop the prevailing weather conditions are not favourable for aphid multiplication, but weather conditions become favourable under delayed sowing. In the early sown crop (15th October), it was observed that growing degree days (GDD) has the most influence on aphid multiplication in both the varieties. However, in late sown crop apart from GDD, humid thermal ratio (HTR) and morning relative humidity had a profound influence on aphid population in both the varieties.

From the above findings it can be concluded that GDD and HTR can explain 60-70 percent variation in aphid population irrespective of varieties in 30th October sowing. In early sown crop, GDD and HTR account for 74 percent variation of aphid population in Pusa Jaikisan.

Growing degree-days (GDD) is a measure of the amount of heat needed for plants, insects, and microorganisms to grow and develop. The warmer the plant or insect is, the faster it grows up to a maximum temperature when growth stops. Growth and development are assumed to be roughly linear between the minimum and maximum threshold temperatures. Temperatures above the threshold maximum may cause it to stop growth and development or that the rate of change remains constant.

For each day that the average temperature is one degree above the minimum temperature, one degree day accumulates. Degree-days (24-hour period) provide an estimate of the growth stage of a plant, insect, or microorganism based on temperature measurements. The warmer the weather, the faster degree-days accumulate until the maximum threshold temperature is reached. From the detailed studies on the relationship between growing degree-days and aphid population build-up Chakravarty and Gautam (2002) developed a hypothesis as a basic theory of forewarning. The thumb rule is "aphid population may be more in a year when the degree-day accumulation is slower and vice versa (accumulated from 1st January)".

Conclusions

GDD and HTR can explain 60-70 percent variation in aphid population on both the varieties studied. As the growth and development of insects depend mainly on the amount of heat accumulated, GDD and HTR can serve as promising method for prediction of aphid population.

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