Journal Home page : www.jeb.co.in ★ E-mail : editor@jeb.co.in

JEB
Journal of Environmental Biology

ISSN: 0254-8704
CODEN: JEBIDP

Mustard aphid infestation in India: Development of forewarning models

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Publication Info

Paper received:
12 November 2012

Revised received:
25 June 2013

Accepted:
31 July 2013

Abstract

Aphid *Lipaphis erysimi* (Kaltenbach) infestation on mustard (*Brassica juncea L.*) account for considerable yield losses in India. Experimental data from six north Indian locations were used to study the role of weather on the incidence and development of mustard aphid. Temperature was found to regulate the aphid appearance and population build-up. In warm humid climate, time to attain peak population was relatively shorter than in cool climates. Aphids appeared mostly when the accumulated thermal time ranged between 810-847°cd. Functional relations proposed in the present investigation between aphid incidence and peak population, using previous weeks weather and pest data for majority of the locations, could be used for taking any prophylactic/control measures.

Key words

Mustard aphid, Forewarning models, Degree days, Temperature

Introduction

Indian mustard (*Brassica juncea* L. Czern and Coss) is one of the most important oilseed crops of the country occupying, large acreage among the *Brassica* group of oilseed crops. India stands first, both in acreage and production of rapeseed and mustard in Asia. The crops are cultivated in an area of 56 lakh ha with a production of 67 lakh tonnes and an average yield of 1145 kg ha^{-1} (DRMR, 2013). The oilseed prices are on the rise worldwide and expected to move upward in future, with prospects of prolonged market tightness. Projections into 2020 are indicative of a firm rise in their prices above historical levels with growth in global production going down (OECD-FAO, 2011).

Though India occupies first position in the acreage and production of mustard in the world, the average yield per hectare is low as compared to other countries, where mustard is grown. The yield is stated to be low mainly due to its cultivation under substantial area in rice under rainfed conditions and the aphid, *Lipaphis erysimi* (Kaltenbach) infestation. In terms of economic importance mustard aphid is regarded as a national pest, causing yield loss ranging from 35.4 to 91.3% (Patel *et. al*., 2004).

Several studies have shown that weather plays an important role on the aphid appearance, multiplication and disappearance of mustard aphid (Jitendra Kumar *et. al.,* 1999 and Vekaria and Patel, 2000). A variety of field and laboratory studies indicate that insect abundance increases with rising temperatures (Cannon, 1998; Bale *et. al.,* 2002) and the effect of global warming on plant insect interactions has largely projected an increased herbivore pressure on plants (Coley, 1998 and Bale *et. al.,* 2002). Two modelling studies concluded that the effect of temperature was tightly linked with density of aphids and other sucking pests (Zhou *et. al.,* 1997 and Whittaker and Tribe, 1998).

Bale *et al.* (2002) concluded that increased temperature could also decrease the growth of some aphid species, depending on their thermal requirements and host specificity. An attempt was made to predict the appearance and development of aphids on mustard crop for northern Indian conditions, based on weather, which ultimately may culminate into a Decision Support System (DSS) for the management of aphids.

Materials and Methods

Field experiments were conducted at six locations in northern India during *rabi* season. Mustard (cultivar Varuna) was sown on several staggered dates each year (Table 1). Three plots were maintained as replications and standard agronomic practices except plant protection, were followed to ensure optimum plant vigour during the experimental period. Aphid population was recorded on 10 cm shoot apex on main stem on 10 plants from each replication at 3-day interval (twice a week i.e., Tuesday and Friday). Aphid count, from each observation, was averaged and converted to weekly average per plot for each date of sowing. Daily meteorological data on maximum temperature (T_{max}) and minimum temperature (T_{min}); diurnal temperature range (DTR); morning relative humidity (RH_1) and afternoon relative humidity (RH_2); wind speed (WS); hours of bright sunshine (SS); rainfall (RF) and open pan evaporation (EVP) for all locations were collected from meteorological observatories adjacent to the experimental plots. Daily data were then aggregated into weekly mean values except for rainfall and open pan evaporation.

Data analysis and model fitting

Estimation of degree-days for first and peak appearance : The rate of development increases as temperature exceeds the base temperature and decreases as the temperature drops. Growing Degree Days (GDD) is widely used than calendar method for estimating insect development and timing management strategies (Kowalsick and Clark, 2006 and Murray, 2008). Accumulated growing degree days (AGDD) were computed by the formula of Iwata (1984) and the role of aphid incidence was analysed.

A base temperature of 5°C (Prasanta *et al.,* 2004) was considered for mustard crop and aphid to calculate the AGDD required for initiation of flowering, 50% flowering and first appearance of aphid and attainment of peak incidence. Weekly aphid population data from first appearance till crop harvest were correlated with the weekly mean values of different meteorological parameters. Regression analysis was performed between significant weather parameters and aphid population. A composite weather variable (z_i) was computed as the weighted sum of the weather variable in different weeks starting, from the pre-sowing week up to the week of prediction, with weights being the correlation coefficients (Desai *et al*., 2004).

Individual effect of weather parameters on crop yields were studied by Jain *et al.* (1980) and yield forecast models, based on weather factors, were constructed by Agrawal and Mehta, (2007). But in this study, a modified statistical model of Jain *et al.,* (1980) was employed, considering the effect of change in weather parameter on pest incidence in a given week as a linear function of respective correlation coefficient between pest and weather variable. The trend influence, considered by Jain *et al.* (1980), was not considered in the present study as the cultivar and management practices were similar in all the years at

Table 1 : Details of the locations and field experimentation

Name of station	Geographical coordinates	Dates of sowing	Crop season
Bharatpur	27°12'N; 77°27'E	1st Oct, 8th Oct, 15th Oct, 22nd Oct, 29th Oct, 5th Nov, 12th Nov, 19th Nov, 26th Nov, 3rd Dec	2001-02; 2002-03; 2003-04; 2004-05
Mohanpur	22°57'N; 88°20'E	1st Oct, 8th Oct, 15th Oct, 22nd Oct 29th Oct, 5th Nov, 12th Nov, 19th Nov, 26th Nov, 3rd Dec, 10th Dec, 17th Dec	2001-02; 2002-03; 2003-04; 2004-05; 2005-06; 2006-07; 2007-08; 2008-09
New Delhi	28°39' N; 77°13'E	1st Oct, 8th Oct, 15th Oct, 22nd Oct 29th Oct, 5th Nov, 12th Nov, 19th Nov, 26th Nov, 3rd Dec	2001-02; 2002-03; 2003-04
Palampur	32°06' N; 76°03' E	31st Oct 1989-90; 25th Oct 1992-93; 25th Oct 1993-94; 22nd Oct 1998-99; 10th Oct, 20th Oct, 10th Nov	2003-04
Rakh Dhiansar	32°43'N; 74°52'E	10th Oct; 25th Oct; 5th Nov	2005-06; 2006-07; 2007-08
Udaipur	25°21' N; 74°38' E	5th Oct, 20th Oct, 5th Nov, 20th Nov	2004-05; 2005-06; 2006-07; 2008-09; 2009-10

Table 2. Days and thermal time required for first appearance and attainment of peak aphid population

Name of location	Initial occurrence (DAS)	Attainment of peak population (DAS)	AGDD required for initial appearance (°cd)		Mean ± SE AGDD required for attainment of peak population
Bharatpur	75	99	836	-	1098 ± 200
Mohanpur	50	89	839	1382	1382 ± 417
New Delhi	67	95	810	1053	1053 ± 237
Palampur	101	143	847	1277	1277 ± 337
RakhDhiansar	75	109	830	1138	1138 ± 202
Udaipur	65	89	939	1230	1230 ± 328

(*DAS – Days after sowing)

individual locations and pest incidences were only due to weather influence.

Results and Discussion

Large variation could be noticed across locations, both for first appearance of aphid and peak incidence. At Mohanpur, aphids appeared and attained peak population levels few days earlier than at other locations. Mohanpur, due to its geographical location, experiences warm and humid weather conditions during crop season than other locations. The mean maximum temperature during the crop season was 28.7°C, almost 9°C warmer than Palampur. Minimum temperature at Mohanpur during the season, was considerably higher and almost 5 to 8°C more than the rest of the locations. These differences in maximum and minimum temperatures might have played a role in the varying levels of incidence and development of aphids across these locations. The AGDD required for the aphids to appear and attain peak population (Table 2) across locations and sowing dates indicated that the aphids appeared with 810-847ºcd AGDD except at Udaipur. However, for attainment of peak population at different locations, a large variation in AGDD requirement was observed. At Rakh Dhiansar and Palampur, the activity of pest got delayed probably due to the influence of temperature on the pest as well as on the crop phenology. The appearance, attainment of peak, decrease and dispersal of the aphid population are dependent on crop phenological events, with flowering and pod initiation as favoured stages by aphids. Chakravarthy and Goutam (2002) observed that was yellow flowering stage is the most preferred one by aphids. In an earlier study, Patel *et al.* (2004) observed that the flowering stage was the most favoured developmental phenophase for aphid occurrence and development.

To have a more insight on the differences in AGDD requirement for appearance of aphids, the thermal time requirement for initiation and 50% flowering at some of the locations, for which the data were available, was computed and presented in Table 3. Large differences could be noticed across locations in AGDD requirement for flower initiation and 50% flowering. It can be noticed that the mean AGDD requirement for 50% flowering at Udaipur was highest and least at Rakh Dhiansar, probably due to difference in temperature. The range between minimum AGDD and maximum AGDD in the data set was narrow at Udaipur compared to other stations. The inter-seasonal differences in AGDD requirement for 50% flowering at Mohanpur resulting in a wide range might be due to temperature variability. This was also evident in large variation in AGDD requirement to attain peak aphid population across locations and associated high SE values (Table 2).

The Pearsons's correlation coefficients between weather parameters and mustard aphid population showed significant association at one or the other locations (Table 4). A positive and significant correlation with maximum temperature was observed at all locations except at Bharatpur. Minimum temperature had a positive and significant association at three locations and non-significant association at Mohanpur and Udaipur. The relative humidity showed negative association at some locations but the association was not consistent across locations. A close look at the negative and low values of correlation coefficients between temperature and aphid population for Bharatpur and Udaipur revealed that during the peak pest occurrence period, maximum temperature values at these locations were comparatively higher (30.5°C and above), whereas at rest of locations they were less than 26.6°C. It is possible that the higher temperature prevailed

Table 3: Thermal time requirement for initiation and 50% flowering at some locations

Name of location	Mean AGDD required for initial flowering (ºcd)			Mean AGDD required for attainment of 50% flowering (ºcd)		
	Minimum*	Maximum*	Mean	Minimum*	Maximum*	Mean
Mohanpur	453	1138	672	569	1532	743
Palampur	588	946	799	643	1199	945
Rakh Dhiansar	440	766	615	524	850	699
Udaipur	638	669	655	946	1054	992

*Minimum and maximum refer to the variation in AGDD across years and dates of sowing

Table 4 : Pearson's correlation coefficients between weather parameters and peak aphid population

Locations	Tmax (°C)	Tmin (°C)	RH_1 (%)
Bharatpur	-0.32*	-0.49*	0.33*
Mohanpur	0.25**	0.09	-0.05
New Delhi	0.19**	0.29**	0.03
Palampur	0.18**	0.32**	-0.14*
Rakh Dhiansar	0.72**	0.57**	-0.24**
Udaipur	0.13*	0.10	0.10

(*Significant at 5% level **Significant at 1% level) might have caused a decrease of aphid population. Although many aphid species may be limited by low temperature, others can have upper thresholds as low as 25°C (Harrington *et al.,* 1995). Unfortunately, little is known on the individual effects of maximum temperature and minimum temperature in absence of growth chamber studies. At Mohanpur and Udaipur, association between minimum temperature and aphid population was non-significant (Table 4). This could be due to the prevalence of minimum temperature around 13.8°C during the peak occurrence period at these locations as against less than 12°C at other locations which might have influenced the aphid population. Contradictory reports exist on this observation and at high latitudes or high elevation sites geographical distribution of aphid population was limited by minimum temperature rather than the maximum temperature thresholds (Hill and Hodkinson, 1995 and Strathedee *et al.* 1995). The association between mustard aphid and weather parameters seems to be location specific. For example, Gami *et al.* (2002) observed significant negative correlation with maximum and minimum temperature whilst Hassan *et al.* (2009) observed a positive correlation with maximum temperature, dew point and sun shine hours and negative correlation with relative humidity and wind speed.

Aphid population at both initial and peak incidence at various locations were computed using statistical forecast models (Table 5). Z_0, Z_2, Z_4 variables were simple products of correlation coefficients and absolute values of weather parameters Tmax, Tmin, and RH_1 respectively. Whereas Z_1, Z_3, Z_5 variables were the quadratic functions. The results showed highly significant correlation for initial and peak occurrences of aphid at Palampur and Rakh Dhiansar. The time period required for initial incidence and peak attainment was longer at both these stations compared to other stations. Low coefficient of determination (R^2) value at Mohanpur was primarily due to poor correlation coefficient with minimum temperature and RH_1. Similar reason could be extended to poor R^2 value at Udaipur for peak infestation. Agarwal and Mehta (2007) developed models on similar lines and found good applicability for them at locations like Berhampur, Pantnagar, Hisar, Ludhiana, Kanpur, Morena and Bharatpur. The coefficient of determination values of their models ranged from 0.56 to 0.99. The functional relations developed from the present study (Table 5) indicated that the aphid infestation and attainment of peak population could be predicted reasonably at Palampur, New Delhi, Bharatpur and Rakh Dhiansar. For taking up any prophylactic and control measure effectively, information on likely incidence of aphid at least 3-5 days in advance is desirable. Thus, development of regression model to address this has been attempted here.

Development of forewarning models : The aphid incidence, growth and decline in the present study appeared to be dependent mainly on temperature and hence a temperature dependent function was used to predict the population dynamics of the insect. Based on the results obtained in the present study, a forewarning model of aphid infestation and peak attainment was attempted. A forewarning model should invariably utilize past weather conditions to predict future infestation and build-up for practical application. Some studies in the past have attempted to forewarn aphid appearance. For example, Prasanta *et al.* (2004) observed that GDD of preceding three days were important to explain the dynamics of aphid population. Several authors (Chattopadhyay *et al.,* 2005; Zamani *et al.,* 2006; Klueken *et al.,* 2009) have also predicted aphid occurrence by preceeding meteorological conditions.

In the present study, regression analyses were carried out between different weather parameters and aphid development rate with lead period ranging from three to seven days and the same are presented in Table 6. Higher correlation coefficient and coefficient of determination values suggested that the parameters in these equations could explain 57% variability in aphid population build-up. Prasad and Chakravarty (2000) proposed a

Table 5 : Functional relations for prediction of aphids from composite weather indices

Name of the location		Initial	Peak	
Bharatpur	R^2=0.64	$Y= 228.9 + 1.2 Z_0 - 2.1 Z_1 - 1.4 Z_2 + 2.3 Z_3 - 0.33 Z_4 - 0.82 Z_5$	R^2=0.62	$Y = 1561.5 + 119.3 Z_0 + 82.4 Z_1 - 183.9 Z_2 + 56.5 Z_4 - 143.9 Z_5$
Mohanpur	R^2=0.20	$Y = 3.07 - 0.007 Z_0 + 0.13 Z_1 - 0.008 Z_2 - 0.18 Z_3 + 0.005 Z_4 + 0.014 Z_5$	R^2=0.16	$Y = -318.7 + 13.6 Z_0 - 94.9 Z_1 + 88.9 Z_2 + 712.1 Z_3 + 21.3 Z_4 - 22.4 Z_5$
New Delhi	R^2=0.63	$Y= -186.69 + 13.5 Z_0 + 32.3 Z_1 - 2.6 Z_2 + 17.3 Z_3 + 1.2 Z_4 + 21.1 Z_5$	R^2=0.52	$Y = -610.3 + 102.7 Z_0 - 185.3 Z_1 + 110.7 Z_2 - 64.8 Z_3 + 65.9 Z_4 + 159.4 Z_5$
Palampur	R^2= 0.99	$Y= 15.8 - 0.059 Z_0 - 0.211 Z_1 + 0.097 Z_2 + 0.298 Z_3 - 0.039 Z_4 - 0.06 Z_5$	R^2=0.99	$Y = 274.3 - 20.5 Z_0 - 42.1 Z_1 - 4.3 Z_2 - 0.90 Z_5$
Rakh Dhiansar	R^2=0.99	$Y= -226.05 - 2.7 Z_0 + 7.1 Z_1 + 4.0 Z_2 - 12.4 Z_3 + 0.032 Z_4 + 0.64 Z_5$	R^2=0.55	$Y = 19.5 - 1.3 Z_0 - 0.79 Z_1 + 1.17 Z_2 + 0.4 Z_3 + 0.53 Z_4 + 0.04 Z_5$
Udaipur	R^2=0.71	$Y = -26.3 + 0.57 Z_0 - 267.7 Z_1 + 11.1 Z_2 + 517.4 Z_3 + 0.67 Z_4 + 0.93 Z_5$	R^2=0.15	$Y = 266.7 + 8.1 Z_0 + 17.9 Z_1 - 4.2 Z_2 - 31244.0 Z_3 + 1.2 Z_4 - 20.6 Z_5$

(Variables Z_0, Z_2 and Z_4 are products of correlation coefficients and absolute values of Tmax, Tmin and RH_1; Z_1, Z_3, Z_5 are quadratic function of Tmax, Tmin and RH_1, respectively)

Table 6 : Mustard aphid early forewarning models with different lead periods

Lead period	Location	Parameters	r	R^2	Equation
7 DAYS	Bharatpur	Pest (Y), Pest(Y_{t-1}), Tmax, Tmin, DTR and Tmean	0.84	0.70	Y= 0.806 + 0.821 (Yt-1) -4.039 (Tmin) - 2.010 (DTR) + 4.032 (Tmean)
6 DAYS	Mohanpur	Pest (Y), Pest(Y_{t-1}), Tmax, Tmin, DTR and Tmean	0.75	0.56	Y= 2.071+ 0.727 (Yt-1) +0.086 (DTR) -0.149 (Tmean)
7 DAYS	New Delhi	Pest (Y), Pest(Y_{t-1}), Tmax, Tmin, DTR and Tmean	0.69	0.47	Y= 0.268 + 0.686 (Yt-1) + 0.064 (DTR) - 0.024 (Tmean)
7 DAYS	Palampur	Pest (Y), Pest(Y_{t-1}), Tmax, Tmin, DTR and Tmean	0.44	0.19	Y= 2.209+ 0.402 (Y_{t-1}) -0.058 (DTR) -0.006 (Tmean)
3 DAYS	Rakh Dhiansar	Pest (Y), Pest(Y_{t-1}), Tmax, Tmin, DTR and Tmean	0.61	0.38	Y= -4.400 -0.261 (Y_{t-1})-5.506(Tmax)- 13.307(Tmin)-3.750 (DTR) +19.106(Tmean)
7 DAYS	Udaipur	Pest (Y), Pest(Y_{t-1}), Tmax, Tmin, DTR and Tmean	0.16	0.03	Y=4.889+ 0.070 (Yt-1) -0.056 (DTR) -0.044 (Tmean)
7 DAYS	Pooled	Pest (Y), Pest(Y_{t-1}), Tmax, Tmin, DTR and Tmean	0.75	0.57	Y= 0.812+0.739(Yt-1)+0.067(DTR)- 0.068(Tmean)

(r = correlation coefficient, R^2=coefficient of determination)

model to estimate aphid population on similar lines using previous week's aphid population and weather conditions as inputs to the model. The location specific forewarning models account for 70% variability in the aphid population at Bharatpur, followed by Mohanpur (56%) and New Delhi (47%). The models developed for three locations *viz.,* Palampur, Rakh Dhiansar and Udaipur, proved to be of little use because of the poor R^2 values. This may partly be due to the smaller number of observations available for these locations. Nevertheless, models with high R^2 could be used as tools to forewarn the aphid build-up and for use in decision support system so that whenever a threshold value of population is attained, appropriate control measures could be advocated.

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