Journal of Entomology and Zoology Studies 2017; 5(4): 1775-1779

Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2017; 5(4): 1775-1779

Received: 20-05-2017
Accepted: 21-06-2017

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Identification of prediction model on population buildup of *Dactynotus carthemi* HRL on safflower (*Carthamus tinctorius* L.) for timely intervention

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Abstract
The present study was aimed to identify the prediction model on population buildup of major insect-pest of safflower, the safflower aphid, *Dactynotus carthemi* HRL for timely intervention for its management. The study was carried out in the Instructional farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India during December, 2013 to May, 2014. The result showed that the abiotic factors altogether contributed 95.7% variation in aphid infestation. The maximum temperature had 69% contribution in the population buildup. Temperature regime between 16-20 °C minimum temperature to 31-36 °C maximum temperature was found most important for population buildup of safflower aphid. Prajneshu growth model (IASRI model) was found to be most suitable non-linear growth model for prediction of the pest population build up. The pest population starts increasing on and from 13th standard week. The optimum time to take control measure was in the 15th standard week as a prophylactic measure to check the peak pest population, which was attained at the 16th week (103.26/5cm) and maintained at higher level till 17th week as evidenced from pattern of population growth. So, the Prajneshu growth model can be explored for predicting the population buildup of the pest as well as exact time for intervention through insecticidal application to avoid the crop loss.

Keywords: Safflower aphid, temperature, non-linear growth model

Introduction

Safflower (*Carthamus tinctorius* L.) a member of the family Compositae or Asteraceae is an ancient oilseed crop. In India its common name is 'kusum' that is derived from Sanskrit word 'kusumbha'. It is mainly used as a source of dye and oil [4, 23] and its seeds contain 30 to 45% oil [16]. India is the leading producer of safflower in the world. The area is 2.71 lakh ha with a production of 1.71 lakh tonnes of seed accounting to average productivity of 632 kg/ha [6].
Safflower oil has highest content of linoleic acid (75%) that is used for cardiovascular disease, for its anti-cholesterol effect [20, 2] and suitable for biodiesel production [17]. *Cartharmin*, obtained from the flowers, is an important natural raw material of dye [15]. Safflower oil cake is a valuable animal feed [28].
A total of 101 pests are known to attack safflower at different stages of crop growth and development [26]. Amongst the various pests, the safflower aphid, *Uroleucon compositae* is the most destructive and regular pest. Among the biotic stresses it is the major constraint in safflower production [1, 19, 8]. In different parts of the country the pest caused 20 to 80 per cent loss in seed and oil [27]. Nymphs as well as adults of the aphid suck cell sap from the lower surface of the leaves, tender shoots, flower bud and flower and impair the vitality of the plants. Besides sucking the sap from the plants, the aphids also excrete honeydew which attracts a black sooty mould that adversely affects the photosynthesis. The aphid infestation was found to have an increased trend in late sown crop mainly during pre-flowering and flowering stage of the crop [14]. They further reported positive relation between the aphid population and temperature and negative relation of aphid population with relative humidity.
Recently, the emphasis is being given on ecological basis of control based on suitable integrated pest management strategies [6]. Seasonal incidence helps in planning need based application of insecticides as it clearly reveals the insect peak activity as well as insect free periods during crop growth. To achieve satisfactory suppression of this destructive pest, forecasting of peak period of activity of the pest for timely application of control measures and evaluation of different insecticides are necessary.

In view of the above the research programme has been drawn to study the population buildup of the pest and elucidate the crop-pest-weather relationship, so, the optimum time for insecticidal application could be determined for effective control of the pests in the peak period of infestation.

Materials and Methods

The present experiments were conducted in the Instructional farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India during 2013-14. The experimental domain comes under terai agro-climatic zone of West Bengal; situated between 25°57`N and 27°N latitude and 88°25`E longitude.

The visual observation on occurrence of aphid was carried out on safflower variety Prabhani. The crop was raised in a plot size of 9m X 4m, having a spacing of 75cm X 30cm in a randomized block design. This was replicated thrice. Standard agronomic practices were followed for better growth and development of plants.

To record the aphid population 20 plants were chosen randomly from each replication. The observations were taken from 5 cm terminal part/plant from December, 2013 to May, 2014.

Weekly data of abiotic factors such as maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity and total rainfall were collected from the Agro-Meteorological Centre of the University. Correlation and regression studies were carried out between aphid population and weather parameters to elucidate their relationship. The contribution of each factors were also calculated. Five (5) non-linear growth models [7, 10, 11, 21, 22, 24] were used. They were compared to find out the best fit non-linear growth model for prediction of aphid population buildup.

For the purpose of finding out the best model, two measurements were used and these are namely, root means square error (RMSE) and coefficient of determination (R2). Further the main assumptions of randomness and normality of residuals were examined by using well known run test and Shapiro- Wilk test [5].

The optimum time for insecticidal application was calculated by the mathematical expression derived from Prajneshu model (1998) [22].

- $X(t) = (a \exp(bt))/(1+c \exp(bt))^2 + e$

$t^* = (-1/b)(\ln[(3(1+ab)+(9a^2b^2+30ab+1)^{1/2})/2c(-2+3ab)])$

Where X(t), the aphid population at time t; a, b, c, d the parameters, e, the error term and

t*, the optimum time for spraying insecticide.

Statistical analysis

Data computation and statistical analysis was done in SAS-9.2.

Results and Discussion

The relationship between the weather parameters and aphid population build up is presented in figure Fig. 1, 2 and 3.

The data on the incidence of aphid (*Dactynotus carthemi* HRL) population revealed that, the population was initiated on 3rd week of February (8th SW) (3.46/5cm terminal shoot/plant) at 57 days after sowing (DAS). The population was then increased steadily after 1st week of March, *i.e.,* 10th SW, at pre-flowering stage of crop (71 DAS) and cross ETL (64.50/5cm terminal shoot/plant) on last week of March (14th SW) at the crop age of 99 days. The highest number of aphid population (103.26/5cm) was recorded during flowering stage of crop during 2nd week of April (16thSW) at 113 DAS. At the time of maximum population, the temperature ranged from 19.860C to 36.330C, RH from 35 to 45.71% and no rainfall was recorded. The population then decreased gradually and maintained at low level till harvest during 1st week of May (19thSW).

A steady increase of temperature was noticed from 8th SW and it continued upto the end of the crop. The insect also came into the field on 8th SW. The RH fell down to 49.29-56.43% on and from 14th SW and continued upto 17th SW. The insect population crossed the ETL level from 14th SW maintained the population level till 17th SW. The result confirmed the negative impact of RH on the aphid infestation. It is revealed from the data that the weather parameters had immense influence on population build up of safflower aphid. The highest population was observed during higher temperature regime without any rainfall. The correlation and regression studies were done between the abiotic factors of the climatic parameters (independent variables) and aphid population (dependent variables) and presented in Table 1. A significant positive correlation was found between aphid population level (Y) with maximum (X1) and minimum temperature (X2) having correlation co-efficient (r) value 0.935 and 0.845 both significant at 1% level. The correlation co-efficient (r) value of 0.237 indicates the non-significant positive relation between aphid population build up and average daily rainfall (X5). The maximum (X3) and minimum RH (X4) had non-significant and negative relation with aphid infestation as depicted by the correlation co-efficient (r) value of -0.416 and -0.195. The results clearly indicated that an increase of temperature and rainfall and decrease of RH increased the aphid infestation level on safflower.

The multiple regression equation (step down) relating to aphid population (dependent variable) with abiotic factors (independent variables) was presented in Table 2. Equation A showed that 1unit increase in maximum and minimum temperature, maximum RH and average daily rainfall resulted in 0.45, 0.27, 0.14 and 0.27 unit increase in aphid population, while 0.24 unit increment in aphid population build up was observed with 1 unit decrease in minimum RH. The coefficient of determination (R^2) was found 0.957, indicates that 94.0% variability in aphid population is explained by the regression model. It means that the abiotic factors altogether contributed 94.0% variation in aphid infestation. The maximum temperature and minimum RH alone contributed 57% and 50% of total variation of aphid population, while minimum temperature, maximum RH and rainfall contributed 26%, 35% and 14% respectively.

The step wise regression equation B supported the outcome of multiple correlation studies. The value of co-efficient of determination (R2) was found as 0.930, showing 93% variation in aphid population contributed by the abiotic factors of the environment. 1 unit increase in maximum temperature, maximum RH and average daily rainfall resulted in 0.62 and 0.33 unit increase in aphid population, while 0.19 unit increments in aphid population build up was observed with 1 unit decrease in minimum RH. So, it signifies that the maximum temperature was the most important abiotic factor, which imparted major influence (69%) in variation of aphid population. However, rainfall (15%) and relative humidity (27 & 34%) had minor but significant role in the population build up of safflower aphid.

The population of aphid was positively correlated with temperature and negatively correlated with relative humidity [14] supports the present results. The negative relation between temperature and the aphid population was also reported by many workers [13, 6, 3, 18, 12]. The similar congenial condition for aphid population built up on safflower as recorded in the present investigation was also reported by other workers [25, 9, 12].

Five non-linear growth models were compared on the basis of the weekly average aphid population data for identifying the best fit model for prediction of the pest population build up and determining optimum spraying time. The results of the experiment are represented in Table 3.

Prajneshu model (IASRI model) was found to be most attractive having highest R2 (0.976) and lowest RMSE (5.789) followed by Logistic model (R2=0.779, RMSE = 17.416), Gompartz model (R2=0.770, RMSE = 17.779), Monomolecular model (R2=0.593, RMSE = 23.658) and Weibull model (R2=0.414, RMSE= 28.385).

For examination of the assumptions of residuals, run test statistic and Shapiro-Wilk test statistic were calculated and was presented in Table-3. At the 5% significance level, a Z-score with an absolute value less than 1.96 indicates randomness. The calculated value of run test statistic $|Z|$ is less than the tabulated value at 5% level for Logistic and Prajneshu model (IASRI model) but it is not true for other models.

The calculated value for Shapiro-Wilk statistic lie in the acceptance region over 5% level of significance particularly for two best fitted models namely, Prajneshu (0.124) and Logistic (0.081). So, considering the above all criteria it may be concluded that Prajneshu model (IASRI model) was the best model for prediction of population build up of aphid on safflower. The predicted value of aphid population was shown against the observed value in figure Fig 4.

The opportunity for determining the optimum time for insecticidal spray from Prajneshu model (IASRI model) was also explored and it was found that optimum time for insecticidal application was in the 15th standard week (16th week after sowing) as a prophylactic measure to check the peak pest population, which was attained at the 16th week and maintained at higher level till 17th week.

Table 1: Relation between weather parameters and aphid infestation on safflower (Y=Aphid /5cm terminal shoot/plant).

Regression equation	Correlation co-efficient (r value)	Probability
$Y = -11.5194 + 0.57279 X_1$	0.935	0.0000***
$Y = -6.1825 + 0.69191 X_2$	0.845	0.0000 ***
$Y = 12.5618 - 0.13187 X_3$	-0.416	0.0678
$Y = 7.9790 - 0.07479 X_4$	-0.196	0.4087
$Y = 3.6189 + 0.05196 X_5$	0.237	0.2938

X_1=maximum temperature, X_2=minimum temperature, X_3=maximum RH, X_4=minimum RH, X_5=rainfall

Table 2: The multiple regression equation (step down) relating to safflower aphid population (dependent variable) with abiotic factors (independent variables).

Step down	Multiple regression equation	(R^2)	Contributions (%)				
			X_1	X_2	X_3	X_4	X_5
A.	$Y= -8.460+0.446 X_1$**$+0.269 X_2+0.141 X_3$*$-0.242 X_4$*$+0.266 X_5$*	0.940	57.35	25.92	35.14	49.79	14.26
B.	$Y= -10.832+0.617 X_1$***$+ 0.124 X_3$*$-0.191 X_4$*$+0.328 X_5$*	0.930	68.62	-	26.69	33.97	15.25

X_1=maximum temperature, X_2=minimum temperature, X_3=maximum RH, X_4=minimum RH, X_5=rainfall

Table 3: Estimated model equations, diagonistic checks and different precision criteria for five growth models.

S. No.	Non-Linear Mechanistic Growth Model	Model Expression	Goodness of Fit		Run-test	Shapiro- Wilk test(W)
			RMSE	R^2	$\lvert Z \rvert$	
1.	Gompartz model	X(t)=c exp(-b exp(-at))+e	17.779	0.770	2.004	0.786 (0.043)
2.	Logistic model	X(t)=c/(1+b exp(-at))+e	17.416	0.779	1.948	0.739 (0.081)
3.	Prajneshu model (IASRI model)	X(t)=(a exp(bt))/ (1+c exp(bt))2 +e	5.789	0.976	1.845	0.836 (0.124)
4.	Weibull model	X(t)=a-b exp(-ctd) +e	28.385	0.414	3.145	0.918 (0.020)
5.	Monomolecular model	X(t)=c-(c-b) exp(-at) +e	23.658	0.593	2.136	0.936 (0.014)

Figure in the parenthesis indicates exact probability level

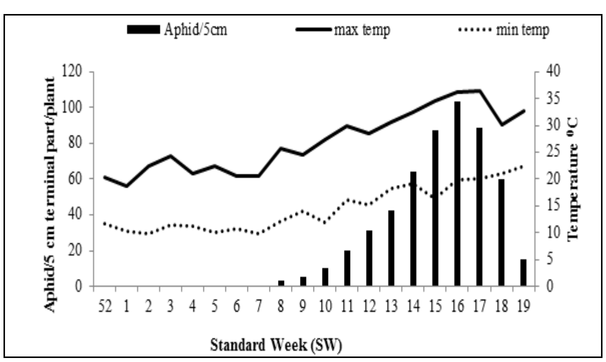

Fig 1: Influence of temperature on population fluctuation of safflower aphid.

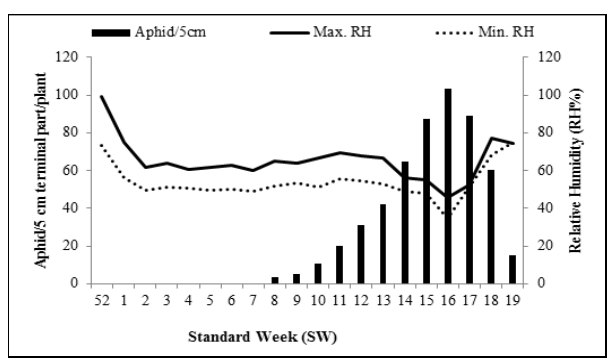

Fig 2: Influence of relative humidity (RH) on population fluctuation of safflower aphid.

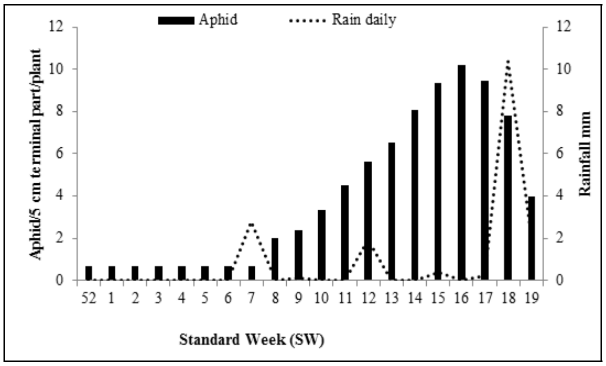

Fig 3: Influence of rainfall on population fluctuation of safflower aphid.

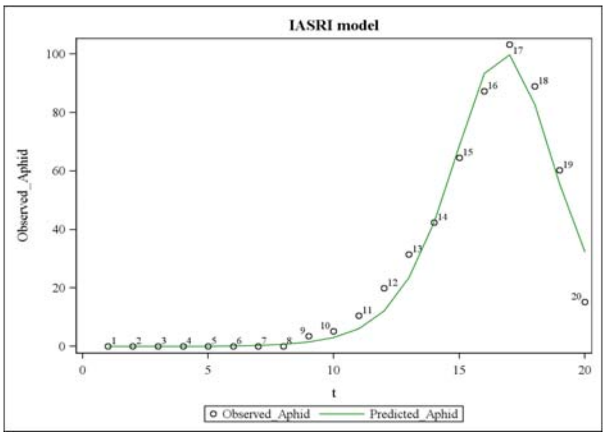

Fig 4: Observed versus predicted value of safflower aphid population in Prajneshu Model (IASRI model).

Conclusion
It is clearly noticed that temperature is the most important factor for population buildup of safflower aphid. The pest population starts increasing on and from 13th standard week. So, the Prajneshu growth model [22] can be explored for predicting the population buildup of the pest as well as exact time for intervention through insecticidal application to avoid the crop loss.

Acknowledgement
Authors are thankful to the Head, Department of Agricultural Entomology and the Director of Farms Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India, for providing the necessary facilities.

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