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Impact of weather factors on population dynamics of *Anosia chrysippus* Infesting *Calotropis procera*, A Medicinal plant in Jammu region of Jammu and Kashmir, India

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Abstract
The impact of weather factors on seasonal abundance and population dynamics of *Anosia chrysippus*, a serious pest of *Calotropis procera* in Jammu region was studied during August, 2010 to July, 2012. The pest remained active throughout the year and attained two population peaks first in the month of October (3.04 larvae/twig) and second during April (4.94 larvae/twig). Correlation studies revealed a significant positive correlation between increase in temperature and pest infestation (R=0.720; $P \leq 0.01$). All other weather factors viz. average relative humidity and average rainfall had a negative correlation with incidence of the pest. The regression model developed indicated that the variation in pest population is strongly influenced by maximum temperature (R^2=0.519) and average relative humidity (R^2=0.594). The results indicated that weather parameters played an important role in the population build-up of the pest.

Keywords: Anosia chrysippus, Correlation, Infestation, Humidity, Population, Pest.

1. Introduction
Anosia (*Danaus*) *chrysippus* (L) belonging to family Nymphalidae is one of the devastating pests of a commercially and medicinally important plant species, *Calotropis procera* (Ait.) R. Br. (Asclepidaceae) in various locations of Jammu region. The larval stages of the pest inhabits apical portion of the shoot feeding on the soft tender leaves, buds and flowers of *C. procera* leading to their destruction, resulting in stunted growth. The pest is already reported from different host plants in different parts of India like Assam [1], Uttar Pradesh [2, 3], Andhra Pradesh [4- 6], Rajasthan [7], Jammu and Kashmir [8, 9] and the world like England [10], Iran [11] and Spain [12, 13].

The population build-up and infestation of *A chrysippus* is greatly influenced by weather parameters like temperature, relative humidity and rainfall. The variations in weather parameters exert a profound influence in the fluctuations of insect numbers and also have a dominating effect on the survival, development and reproductive potential of the pest. Some preliminary studies on the population build-up of this pest on *C procera* in Rajasthan Desert and Gorakhpur (U.P.) are carried out by [7] and [14]. While [15] reported that temperature influences the duration of larval instars and the overall developmental time of *Danaus chrysippus*.

The aim of this work is to study, the seasonal abundance and to correlate the important weather factors viz, temperature, relative humidity and rainfall with the pest population so as to estimate the role of weather and to make an effort to evolve an appropriate and timely management strategies for *A chrysippus* in Jammu and Kashmir state of India.

2. Materials and Methods
2.1 Study Location
The study was conducted from August 2010 to July 2012 under field conditions at Solki station (District Rajouri) of Jammu region. The station experiences mild summer, fair monsoon during summer and relatively wet winter. *C procera* plants grow well in the areas having soil deposition along the dry banks of rivers and streams.

2.2 Sampling
The sampling was done using the methodology as described by [16]. The field was divided into five blocks and a total of 50 branches were considered from 10 randomly selected plants

Thereby counting the number of insects on each selected plant. The data was tabulated in different months for two years (2010-2011 and 2011-2012) and *A. chrysippus* infestation for each month was calculated. Data of two years was pooled together to find out the mean population dynamics of the pest.

2.3 Statistical Analysis

The influence of weather factors on population density of *A. chrysippus* was analyzed by a correlation and regression analysis (both linear and multiple) for a period of two years. Analysis of data was performed using statistical software version SPSS 20.

3. Results

3.1 Seasonal Abundance and Population Dynamics

An overview of the two year observation from August, 2010 to July, 2012 for the incidence of plain tiger butterfly, *A chrysippus* revealed that the pest population attained two distinct infestation peaks and the highest infestation was noticed during August, 2011 to July, 2012 than the previous year (Table-1). This higher infestation was apparently due to heavy rainfall the area received during the preceding months which led to sufficient availability of fresh vegetative flush. The first population peak was attained after monsoon period during October in all the two years, however, there was a difference in the intensity of infestation which was maximum during the year August, 2011 to July, 2012 (3.22 larvae/twig) because of heavy rainfall as compared to 2.86 larvae/twig during the year August, 2010 to July, 2011. Thereafter, there was a steep decline in the population till the end of February that coincided with the rise in temperature and decrease in relative humidity. With the resurgence of vegetative flush stimulated by mild showers during March, the population started building up again resulting in the formation of second population peak during April with an average infestation of 5.02 larvae/twig which was the highest peak attained during the year August, 2011 to July, 2012 as compared to 4.86 larvae/twig during the previous year i.e. August, 2010 to July, 2011 (Table-1). Thereafter a gradual decrease in the population was noticed during monsoon due to the mortality of larvae because of heavy rainfall.

Mean population fluctuation of *A chrysippus* on *C procera* inferred two peaks that synchronized with the new vegetative flush. The first peak was observed in the month of October with an average infestation of 3.04 larvae/twig. This peak was in accordance with the availability of new vegetative flush and decrease in temperature after the rainy showers but the intensity of the infestation was not as severe as noticed in the spring flush. Thereafter a steep decline in the larval infestation was observed during the winter months i.e. till February with very low infestation during December and January. New growth of vegetative flush stimulated by mild showers received during March led to a sharp increase in the larval population of *A chrysippus* which resulted into another major infestation peak during April (4.94 larvae/twig) that coincided with the availability of new vegetative flush and an increase in temperature.

Table 1: Population (No. Of Larvae per Twig) Of *Anosia Chrysippus* on *Calotropis Procera* during Different Months for Two Consecutive Years (August, 2010 to July, 2012).

Years	Aug.	Sept.	Oct.	Nov.	Dec.	Jan	Feb.	Mar.	April	May	June	July
2010-11	0.70 (1.30)	2.24 (1.80)	2.86 (1.96)	1.36 (1.53)	0.22 (1.10)	0.20 (1.09)	0.02 (1.00)	2.00 (1.73)	4.86 (2.42)	4.08 (2.25)	3.34 (2.08)	0.92 (1.38)
2011-12	1.14 (1.46)	2.88 (1.96)	3.22 (2.05)	1.56 (1.60)	0.26 (1.12)	0.12 (1.05)	0.20 (1.09)	0.92 (1.38)	5.02 (2.45)	4.26 (2.29)	3.38 (2.09)	0.96 (1.40)
Pooled	0.92 (1.38)	2.56 (1.88)	3.04 (2.00)	1.46 (1.56)	0.24 (1.11)	0.16 (1.07)	0.10 (1.04)	1.46 (1.56)	4.94 (2.43)	4.17 (2.27)	3.36 (2.08)	0.94 (1.39)

Figures in parentheses are $\sqrt{(x + 1)}$ transformed values

3.2 Correlation between Abiotic Factors and Incidence of Pest Population

Table 2: Correlation analysis of the population of *Anosia chrysippus* with weather parameters for two consecutive years (August, 2010 to July, 2012).

Years	Maximum Temperature	Minimum Temperature	Average Temperature	Average Rel. Humidity	Average Rainfall	Multivariate Factors
	(X_1)	**(X_2)**	**(X_3)**	**(X_4)**	**(X_5)**	**(X_3, X_4, X_5)**
2010-11	0.719**	0.698*	0.716**	-0.708**	-0.177	0.873**
2011-12	0.715**	0.697*	0.711**	-0.759**	-0.093	0.908**
Pooled	0.720**	0.696*	0.716**	-0.771**	-0.123	0.890**

** Significant at 0.01 level (2-tailed); *Significant at 0.05 level (2-tailed)

The infestation of *A chrysippus* showed a great sensibility to weather fluctuations prevailing over the period under study. A highly significant positive correlation was observed between the larval population density and maximum temperature (R= 0.719; $P \leq 0.01$) in the year 2010-2011 and R= 0.715; $P \leq 0.01$ in the year 2011-2012. The analysis also revealed a highly significant positive correlation between the pest infestation and average temperature (R= 0.716; $P \leq 0.01$ in 2010-2011 and R= 0.711; $P \leq 0.01$ in 2011-2012). However, a significant positive correlation was recorded between the infestation and minimum temperature (R= 0.698; $P \leq 0.05$ in 2010-2011 and R= 0.697; $P \leq 0.05$ in 2011-2012) recorded from the area under study (Table-2). Similarly, correlation studies were worked out between infestation of the pest and average relative humidity and average rainfall recorded during different months for a period of two consecutive years. A highly significant negative correlation was recorded between the infestation and average relative humidity (R= -0.708; $P \leq 0.01$ in 2010-2011 and R= -0.759; $P \leq 0.01$ in 2011-2012) and an insignificant negative correlation with average rainfall (R= -0.177; P= 0.582 in 2010-2011 and R= -0.093; P= 0.773 in 2011-2012). The results of the analysis indicated that weather parameters have greatest

importance upon the population fluctuation of the pest.
Analysis of correlation between pooled larval population of *A chrysippus* and different abiotic factors (Table-2) also revealed that a highly significant positive correlation existed with maximum temperature (R= 0.720; $P \leq 0.01$) and average temperature (R= 0.716; $P \leq 0.01$) whereas, minimum temperature (R= 0.696; $P \leq 0.05$) had a significant positive correlation towards the larval population. However, a highly significant and negative correlation with average relative humidity (R= -0.771; $P \leq 0.01$) and an insignificant negative correlation was noted with average rainfall (R= -0.123; $P \leq 0.703$) with the larval population.

3.3 Regression Model

Linear regression analysis revealed that weather parameters have highly significant effects ($P \leq 0.01$) on the population densities of the pest confirming the results of correlation analysis. The stepwise regression analysis of two consecutive year study to investigate the abiotic factors contributed the most to the variance of the leaf roller population has been presented in the Table-3. Regression analysis showed that the maximum and average temperature contributed highly and positively significant to the pest population fluctuation (51% in the two years study). Similarly, minimum temperature significantly and positively contributed to the fluctuations in the pest population (48% in the two years study). Analysis also showed that average relative humidity is highly and negatively significant to the variations in the population build-up (50%, 56% and 59%) for the year 2010-2012, 2011-2012 and 2010-2012 respectively.
Multiple regression models revealed that average temperature had a positive association towards the larval population during the two consecutive years. However, average relative humidity showed a positive association during the year August, 2010 to July, 2011 and a negative association during the year August, 2011 to July, 2012 towards the population. On the contrary, average rainfall had a negative association towards the pest population. The coefficient of determination (R^2) values were 0.762, 0.824 and 0.792 for the year 2010-2012, 2011-2012 and 2010-2012 respectively, thereby indicating that as much as 76%, 82% and 79% variation in the larval population of *A chrysippus* was caused by cumulative meteorological factors viz. average temperature, average relative humidity and average rainfall affecting the *C procera* plantations.

Table 3: Regression analysis of the population of *Anosia chrysippus* with weather parameters for two consecutive years (August, 2010 to July, 2012).

Years	Maximum Temperature	Minimum Temperature	Average Temperature	Average Rel. Humidity	Average Rainfall	Multivariate Factors
	(X_1)	(X_2)	(X_3)	(X_4)	(X_5)	(X_3, X_4, X_5)
2010-11	$Y = 0.115+0.059X_1$ $R^2 = 0.518^{**}$	$Y = 0.823+0.063X_2$ $R^2 = 0.487^{*}$	$Y = 0.313+0.062X_3$ $R^2 = 0.512^{**}$	$Y = 3.207-0.024X_4$ $R^2 = 0.502^{**}$	$Y = 1.687-0.001X_5$ $R^2 = 0.031$	$Y = -0.052+0.083X_3 +0.001X_4-0.002X_5$ $R^2 = 0.762^{**}$
2011-12	$Y = 0.403+0.046X_1$ $R^2 = 0.512^{**}$	$Y = 0.929+0.060X_2$ $R^2 = 0.485^{*}$	$Y = 0.621+0.053X_3$ $R^2 = 0.505^{**}$	$Y = 3.296-0.025X_4$ $R^2 = 0.567^{**}$	$Y = 1.692-0.000X_5$ $R^2 = 0.009$	$Y = 1.861+0.046X_3 -0.015X_4-0.001X_5$ $R^2 = 0.824^{**}$
Pooled	$Y = 0.128+0.053X_1$ $R^2 = 0.519^{**}$	$Y = 0.872+0.062X_2$ $R^2 = 0.485^{*}$	$Y = 0.455+0.058X_3$ $R^2 = 0.512^{**}$	$Y = 3.373-0.026X_4$ $R^2 = 0.594^{**}$	$Y = 1.685-0.001X_5$ $R^2 = 0.015$	$Y = 1.499+0.053X_3 -0.013X_4-0.001X_5$ $R^2 = 0.792^{**}$

** Significant at 0.01 level; *Significant at 0.05 level

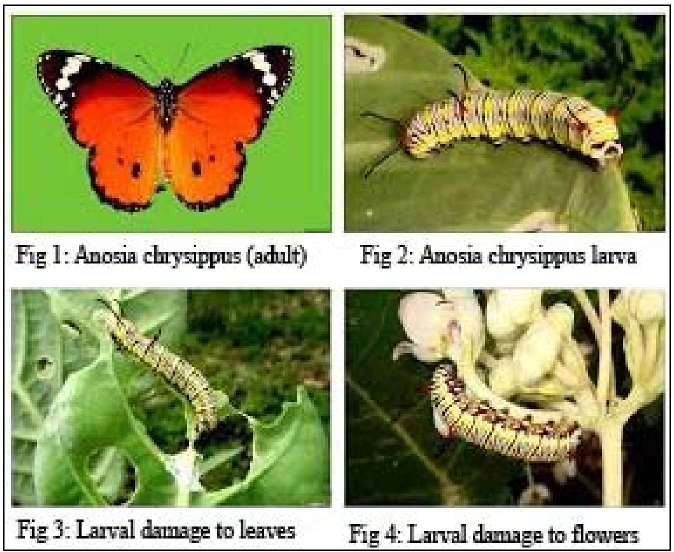

Fig 1: Anosia chrysippus (adult) Fig 2: Anosia chrysippus larva
Fig 3: Larval damage to leaves Fig 4: Larval damage to flowers

4. Discussions

During monsoon period i.e. July to August, a decrease in the population was noticed possibly due to the mortality of larvae because of heavy rainfall. Subsequently, sharp and sudden reduction in number of larvae was noticed in winter months perhaps due to pupation and emergence of the pest. However, [7] observed that the larvae were present on the shrubs throughout the monsoon season, from July to October with their peak larval population recorded in August (42.5 to 112.5/5 plants) and subsequently sharp and sudden reduction in number (7.5-85/5 plants) during September and October in Rajasthan Desert. [14] Observed that the population of the pest was abundant in first week of July to third week of August after which the pest showed a gradual decrease on *C procera* in Gorakhpur (U.P.). On the other hand, [17] reported that the population of *S pandurus* on *C gigantea* increases from the first week of march and declines in the latter half of October; the maximum population build-up being recorded during April to June (hottest season of the year in south India).
Correlation data of the present investigation depicted that there was a linear relationship of increasing atmospheric temperature and decreasing relative humidity with increased pest incidence. The significant correlation found between the pest infestation and abiotic factors definitively help to develop a predictive model by which the outbreak of this pest could be known in advance so that timely control of this pest can be taken up to curtain the problem. However, [17] recorded that maximum temperature (R= 0.848; $P \leq 0.01$) showed significant positive correlation and favours the population build-up of *S pandurus* on *C gigantea* whereas other variables such as minimum temperature, maximum and minimum relative humidity were neither consistent nor they were significant statistically.
In the present study, it was observed that the severity of infestation of *A chrysippus* on *C procera* was more pronounced on spring flush (April) rather than on autumn

flush (October). The peak incidence of pest occurs during September-October and April-May thereby affecting considerable damage of about 39% during October and 62% during April respectively with mean percentage infestation of 30.59%. The percentage influence of the climatic factors upon the population fluctuation of *S pandurus* on *C gigantea* was 81% as calculated by [17]. The regression model indicated the strong influence of maximum temperature, average temperature and average relative humidity on variation in pest population on this particular medicinal plant.

The model can be used to predict the initiation and peak incidence of the pest attack which will serve as a database for stakeholders to adopt effective protection measures at the appropriate time. [18] Observed that models for temperature-dependent development of insect pests have been widely used as tools to improve the efficiency of pest management. Forecasting the peak abundance of pest in advance helps in their timely management. The correlation and multiple regression analysis clearly depicted the importance of weather parameters in the incidence of pest.

5. Conclusion

From the findings of present study, it is evident that there were two population peaks in the pest population and was mainly affected by the weather factors and also by the availability of fresh vegetative flush.

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