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Weather based prediction of Chickpea *Helicoverpa armigera* population in Bundelkhand agroclimatic zone of Madhya Pradesh

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सार – मध्य प्रदेश के बुंदेलखंड कृषि जलवायविक क्षेत्र में चने की फसल में इल्ली के प्रकोप एवं इसकी अधिकतम संख्या तथा इसकी वृद्धि पर वर्षा, तापमान एवं जी.डी.डी. के प्रभाव का पता लगाने का प्रयास किया गया है। इसके अतिरिक्त इस कीट की संख्या में कमी तथा वृद्धि की मौसमी प्राचलों के साथ संबंध की जाँच भी की गई है। यह पाया गया कि सितम्बर तथा अक्तूबर माह में होने वाली कुल वर्षा का इस कीट की संख्या पर कोई प्रभाव नहीं पड़ता है। परन्तु जनवरी एवं फरवरी माह में होने वाली कुल वर्षा का चने की इल्ली पर महत्वपूर्ण प्रभाव पड़ता है। साथ ही साथ जी.डी.डी. की इस कीट की संख्या बढ़ाने और घटाने में अहम भूमिका रहती है। न्यूनतम तापमान एवं वर्षा का इस कीट के आगमन एवं बढ़ोतरी में महत्वपूर्ण योगदान रहता है। 1 जनवरी से 15 फरवरी तक के जी.डी.डी. की गणना कर इस कीट की उच्चतम संख्या के साथ इसके संबंध को दर्शाया गया है। मौसमी कारकों का इल्ली की संख्या के साथ सहसंबंध भी प्रस्तुत किया गया है तथा इस कीट की संख्या के अनुमान तथा प्रबंधन के लिए विभिन्न प्रकार के मौसमी कारकों को विकसित किया गया है। साथ ही साथ बहु समाश्रयण समीकरण भी विकसित किया गया है। यह पाया गया है कि 1 जनवरी से 15 फरवरी की अवधि के दौरान यदि संचयी जी.डी.डी. 350 या इससे अधिक, साप्ताहिक न्यूनतम तापमान 6 से 12 डिग्री सेल्सियस के बीच रहने तथा वर्षा होने की घटना 5 दिनों से कम होने पर चने में इस कीट की इल्ली की संख्या अधिक होगी तथा इसके विपरीत परिस्थिति होने पर कीट की संख्या कम होगी। यह अध्ययन चने में इल्ली की अधिकतम संख्या के पूर्वानुमान लगाने के साथ साथ इस कीट के प्रभावी प्रबंधन की रूपरेखा बनाने में भी सहायक होगा।

ABSTRACT. An attempt was made to find out the impact of rainfall, temperature and growing degree day (GDD) on the larval incidence and peak population of *Helicoverpa armigera* on chickpea and its growth in the Bundelkhand Agroclimatic zone of Madhya Pradesh. Besides, an attempt was also made to examine the association with weather variables of rising and falling phase of the larval population of *Helicoverpa armigera*. It was found that there was not any significant impact of monthly (September and October) rainfall on the larval population but the monthly rainfall of January and February significantly influenced the incidence of the pod borer and GDD plays a vital role in increasing and decreasing of its peak population. Minimum temperature and rainfall play a crucial role for larval incidence and its population growth. Growing degree day from 1st January to 15th February were presented in relation to the number of peak larval population in chickpea. The correlation of weather factors with larval population was also presented and different weather parameters were screened for its prediction and management. A multiple regression equation was also developed. It was found that if the cumulative growing degree day from 1st January to 15th February $\geq$350 degree day and weekly minimum temperature ranged from 6 to 12 °C along with number of rainfall events < 5 days, then number of larval population of *H. armigera* in chickpea is high and *vice-versa*. This study will be very useful not only for forecasting the peak larval population of *H. armigera* in chickpea but in formulating effective pest management strategies too.

Key words – Temperature, Rainfall, Growing degree day, *Helicoverpa armigera*, Chickpea, Weather rules.

1. Introduction

Chickpea (*Cicer arietinum* L.) is an important pulse crop of Madhya Pradesh and accounts for 33 per cent of total area and 38 per cent of total production of chickpea in India. The crop is grown in *rainfed* conditions during *rabi* seasons (October- March) on an area of about 31000 hectares with an annual production of 34000 tones in Tikamgarh (Anonymous, 2012). Insect-pest is one of the major limiting factor in the Bundelkhnad region of Madhya Pradesh for low yield (1250kg/ha) and Chickpea is one of the important crop hosts of *H. armigera* (Multani and Sohi, 2002). Gram Pod borer (*Helicoverpa armigera*) is the major and most devastating pest of chickpea which results into losses up to 80 per cent under congenial weather conditions (Singh, 2012).

Weather plays significant role in fluctuation of pest population and hence used as main factor for prediction and forecasting of pest population. In India, prediction and forecasting of *H. armigera* population was attempted and weather based models were developed by using various biotic and abiotic factors. Das *et al.* (2001) first attempted to develop a simple rule for prediction of *H. armigera* in India and developed a thumb rule to predict *H. armigera* population on cotton crop using surplus/deficit rainfall in different months in Andhra Pradesh. Trivedi *et al*. (2005) have validated the Das *et al*. (2001) thumb rule, in chickpea-pigeonpea-based ecosystem at Gulbarga, Karnataka and found that the population observed only one year out of 10 years. Vishwa Dhar *et al*. (2007) have also developed a modified weather based model on minimum temperature and rainfall for prediction of adult moth catches of *H. armigera*. Khalique and Khalique (2002) used thermal concept and calculated Growing Degree Day (GDD) and forecast the adult population trap catch of *H. armigera* on chickpea in Pakistan. Yadav *et al*. (2009) have also used GDD and rainfall for prediction of the outbreak of *H. armigera* in western Uttar Pradesh.

Srivastava *et al*. (2010) have reported that for forecasting of *H. armigera* population, different weather parameters are important for different location of India. Vaishampayan (1988) developed a rainfall and temperature based outbreak model for pod borer of chickpea in Madhya Pradesh. Hence, location-specific and season-specific models are required to be developed for prediction of *H. armigera* population for operational purpose. Information on forecast and prediction of *H. armigera* in Bundelkhand agroclimatic zone of Madhya Pradesh was not attempted earlier. Therefore, this study was undertaken to develop a weather rules for prediction and forecast of peak larval population at least one week in advance, so that effective pest management options may be utilized. An attempt was also carried out to evaluate the Vaishampayan weather based model and also the impact of variability of long term monthly rainfall and temperature on the pest population.

2. Materials and method

Weekly observation on larval population of chickpea pod borer per meter row length (MRL) were recorded at three spots in each five plots selected randomly in different fields on college farm, Tikamgarh (24° 40′ N latitude, 77° 80′ E longitude and 324 meter height above m.s.l.) from 2006-07 to 2013-14, except the year 2008-09. The mean of weekly observations were calculated for analysis. The cultivars JG 315 and JG 322 were sown each year during second week to last week of November during 2006-07 to 2008-09 and on 10th to 17th November in 2009, 30th October to 4th November in 2010, 22nd October to 2nd November in 2011, 1st to 7th November in 2012, 10th to 30th November in 2013 and 26th October to 7th November in 2014. One pre-sowing and one post sowing irrigation (flooded) at 40 day after sowing (DAS) were given in the crop to supplement the moisture. Line to line distance is 30 cm and 20:60:20 kg/ha N, P, K were applied at the time of sowing. No pesticide application was done on the selected plots for the observations. Daily weather data were recorded in the college meteorological observatory from 2010-2014 and converted on standard meteorological week-wise for the study. For calculation of growing degree-day, daily temperature (maximum and minimum) were used and calculated by formula

$$\text{Growing degree days (GDD)} = [(A+B)/2]-C$$

where,

A = daily maximum temperature (°C)

B = daily minimum temperature (°C)

C = Base temperature (8 °C) *i.e.*, lowest development threshold (Vaishampayan, 1988)

Different researches have used different base temperature for calculation of GDD for *H. armigera* population. The base temperature was taken to be 9.5 °C by Khalique and Khalique (2002) of Pakistan for GDD calculation. Younis and Ottea (1993) have taken the lower developmental threshold of 13.8 °C for all stages and individual stage degree day (DD) for GDD estimation of *H. armigera*. Yadav *et al*. (2009) used 10 °C as base temperature for GDD calculation of chickpea pod borer.

In the present study, the base temperature for GDD calculation was slightly modified after reviewing the lowest temperature and was taken 8 °C as reported by Vaishampayan (1988). For prediction of pod borer; January to mid February were taken as Biofix for sake of convenience. The growing degree days was calculated from 1st January to 15th February for each year.

Long term daily temperature(1971-2009) and rainfall (1951 to 2009) data of Tikamgarh was collected from India Meteorological Department and monthly and weekly mean of maximum, minimum temperature and total rainfall were calculated for this study. Correlation between weather factors and larval populations were worked out and their significant were tested using *t* test.

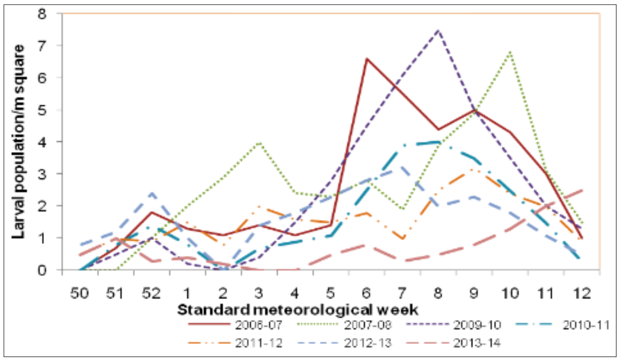

Fig. 1. Pattern of weekly larval population in chickpea Tikamgarh

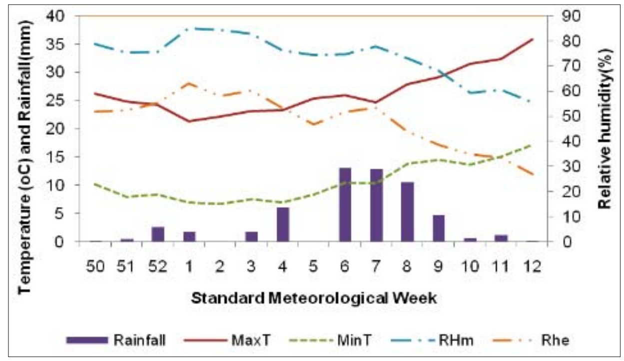

Fig. 2. Pattern of mean weekly weather parameters at Tikamgarh

3. Results and discussion

3.1. *Larval population and weather*

The weekly larval population of *Helicoverpa armigera* and mean weekly (2006-2014) weather parameters were presented in Figs. 1 and 2 respectively. The first appearance of *H. armigera* was recorded during 50th standard meteorological week (SMW) during 2011-12, 2012-13, 2013-14, 51st SMW in 2006-07, 2009-10, 2010-11 and 52nd SMW in 2007-08 (Fig. 1). The mean weekly maximum and minimum temperatures during the first larval record were ranged from 24.2 to 26.1 °C and 7.9 to 10.1 °C respectively (Fig. 2). The weekly relative humidity in the morning and evening were ranged from 75 to 79 and 52 to 55 per cent respectively. The weekly rainfall was varied from 0.3 to 2.7 mm (Fig. 2).

Slight increase in larval population was observed just after 1 to 2 weeks after their appearance, when the mean weekly maximum and minimum temperatures were ranged 21.3 to 24.2 °C and from 6.6 to 8.2 °C respectively (Fig. 2). Thereafter larval population declined gradually up to 3rd, 4th and 5th SMW.

Again slight increase in larval population was observed from 6th to 8th SMW onwards, when maximum and minimum temperatures were varied from 25.8 to 27.8 °C and 10.4 to 13.7 °C respectively. Relative humidity in the morning was varied 73 to 78 and evening was from 44 to 53 per cent.

Towards the maturity of the crop, the population gradually declined. After the 10th and 11th SMW declining trend in larval population was observed except the year 2013-14, when maximum temperature varied from 31.4 to 32.2 °C and minimum temperature varied from 13.5 to 15.0 °C (Fig. 2). Relative humidity in the morning was ranged from 59 to 61 and evening from 34 to 35 per cent. Vaishampayan (1988) reported that in Madhya Pradesh (20-23° N) *H. armigera* migrates from Andhra Pradesh (13-20° N) and Maharashtra (20-21° N) through cyclonic winds and outbreak on chickpea crop were observed in February and March.

3.2. *Bio-model pattern and its association with weather*

The perusal of the Fig. 1 indicates that the larval population of *H. armigera* is bio-model shape. It was observed that the first peak population of *H. armigera* generally occurred during the ending week of December and beginning week of January months (52 to 02 SMW), when the crop was at end of vegetative and in flowering stages and the second peak was observed generally after 6th SMW (except 2006-07) at pod filling stage.

The larval population of *H. armigera* reached its first peak during 51st SMW in 2013-14 , during 52th SMW in 2006-07, 2009-10, 2010-11, 2012-13, during 01st SMW in 2011-12 and during 02th SMW in 2007-08, respectively. When larval population of *H. armigera* reached its first peak; the maximum and minimum temperature were ranged from 21.4 to 27.5 °C and 5.7 to 10.6 °C, respectively (Table 1A). Relative humidity in the morning and evening were varied from 62 to 97 and 42 to 77 per cent respectively.

Patnaik and Senapati (1996) have reported that peak oviposition of *H. armigera* during 52nd standard week, coinciding with the late vegetative to flower initiation of chickpea. They found that larval activity peaked between the 50th and 2nd SMW and weather conditions was observed within the thermal ranges of 24.6 °C (mean maximum) to 11.5 °C (mean minimum) and at a relative humidity of 72 per cent. A positive correlation existed between relative humidity and fist peak larval incidence.

TABLE 1A

Occurrence of first peak larval population in Chickpea and corresponding weekly weather during different years at Tikamgarh

Year	SMW	Maximum temerature (°C)	Minimum temerature (°C)	Rainfall (mm)	Relative humidity morning (%)	Relative humidity evening (%)
2006-07	52	25.0	8.5	0.0	-	-
2007-08	02	27.5	10.5	0.0	62	42
2009-10	52	25.2	9.7	0.0	71	61
2010-11	52	25.7	10.6	1.5	60	54
2011-12	01	21.4	10.4	10.2	97	77
2012-13	52	21.7	5.7	0.0	89	50
2013-14	51	23.6	10.1	0.0	84	53

TABLE 1B

Occurrence of second peak larval population in Chickpea and corresponding weekly weather during different years at Tikamgarh

Year	SMW	Maximum temerature (°C)	Minimum temerature (°C)	Rainfall (mm)	Relative humidity morning(%)	Relative humidity evening(%)
2006-07	06	27.9	13.9	27.0	-	-
2007-08	10	33.3	16.8	0.0	42	29
2009-10	08	29.7	12.4	31.0	65	41
2010-11	07	27.0	11.7	6.7	67	51
2011-12	09	28.5	8.4	0.0	85	37
2012-13	07	22.3	11.2	66.6	92	70
2013-14	12	32.7	14.2	1.5	72	31

TABLE 2

Monthly rainfall distribution and peak larval population in chickpea at Tikamgarh

Year	Total rainfall (mm) in November	Total rainfall (mm) in December	Total rainfall (mm) in January	Total rainfall (mm) in February	Peak larval population/per meter row length
2006-07	0	0	0	6.0	6.6
2007-08	0	2	0	2.0	6.8
2008-09	5	0	0	14.0	N.A.
2009-10	52	4.4	0	0.0	7.5
2010-11	15.6	1.5	0	24.0	4.0
2011-12	0	0	10.2	3.1	3.2
2012-13	0	0	0	0.0	3.2
2013-14	0	17.3	58.1	70.8	2.5

N.A. = Not available

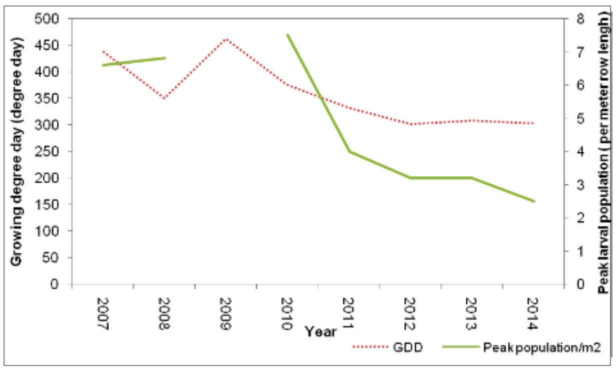

Fig. 3. Distribution of GDD and peak larval population at Tikamgarh

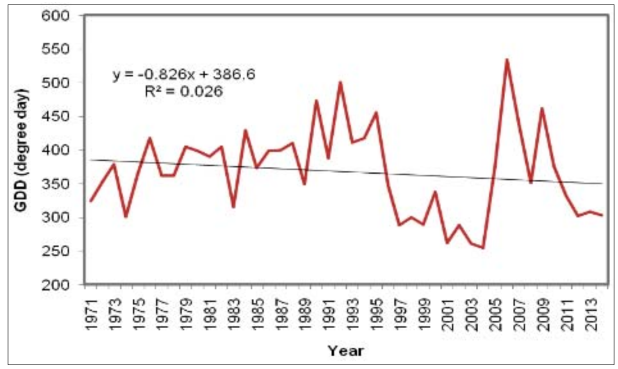

Fig. 4. Growing degree day and its trend from 1st January to 15th February at Tikamgarh

The larval population of *H. armigera* reached its second and highest peak during 6th, 10th, 8th, 7th, 9th, 7th and 12th SMW during the years 2006-07, 2007-08, 2009-10, 2010-11, 2011-12, 2012-13 and 2013-14 respectively. During this peak period the maximum and minimum temperature were ranged from 22.3 to 33.3 °C and 8.4 to 16.8 °C, respectively (Table 1B). Relative humidity in the morning and evening were varied from 42 to 92 and 29 to 70 per cent respectively. Vaishampayan (1988) reported that the pod borer infestation on chickpea initiated from the second week of February and reached a peak in the first week of March.

The above finding was supported by Shah and Shahzad (2005), they reported that *H. armigera* population was low during 49th to 6th SMW but increased from 7th SMW onwards and declined again during 14th standard week. Vishwa Dhar *et al*. (2007) reported that a considerable adult moth catches (above 15/weeks) during 5th to7th SMW, trigger a major rise in the pest population during 10th to14th SMW.

The analysis of mean weekly weather factors (2006-14) indicates that temperature and relative humidity pattern were observed to be different during the first and second peak period of the larval population (Table 1A & 1B). The monthly rainfall and peak larval population during 2006-07 to 2013-14 was calculated and presented in Table 2. The rainfall data reveal that the total rainfall during January and February month influenced the peak larval population too. The rainfall and very low temperature (below 2 °C) were not only shifted the peak larval population in 12th SMW but also suppressed its peak value (bio-model shape) during the year 2013-14.

3.3. *Growing degree day and peak larval population*

The growing degree day (GDD) was calculated from 1st January to 15th February from the year 2007 to 2014 and plotted with peak larval population and shown in Fig. 3. It reveals that whenever the GDD value was > 300 degree day the peak larval population was above 3 per meter row length. When the GDD value was ≥350 degree day; the peak larval population ranged between 4 and 7.5 per meter row length. The larval population was recorded low (2.5 / meter row length) in the year 2013-14, though the GDD was 303 degree day. This may be due to receipt of higher rainfall (60.2 mm) during 1st January to 15th February. The above finding was slightly deviated from the finding of Yadav *et al*. (2009). They reported that when GDD > 450 degrees day, along with rainfall (>75 mm) in January and February and lower evening relative humidity (<60%) during 1-10 SMW were found to be congenial for outbreak / peak level of the emergence of male moths of *H. armigera* during winter season on chickpea. Jallow and Matsumura (2001) calculated GDD for different stage of *H. agmigera* and found that to reach larvae stage, the pest requires 215.1 degree-days (based on thermal constant of 11.3 °C). Khalique and Khalique (2002) calculated GDD for chickpea *H. agmigera* adult trap catch and reported that the average degree day 181 (base temperature 9.5 °C) may be used to predict the start of the trap catch.

Based on the above finding it is seen that when the GDD from 1st January to 15th February is ≥ 350, then the peak larval population *H. armigera* was more and vice versa. To test this findings long-term (1971 to 2014) GDD (1st January to 15th February) was estimated and presented in Fig. 4. The population of *H. armigera* was recorded almost nil in the Tikamgarh district during the year 2004, when the GDD was 255 and very high during the year 1995 when the GDD was 456 degree day (as per Tikamgarh district office record). The above results showed a positive and close association between GDD and larval population of *H. agmigera* and hence this factor is suitable for weather based forewarning of the pest.

TABLE 3

Correlation between weather factors and larval population in chickpea at Tikamgarh

Year	Maximum temperature	Minimum temperature	Relative humidity (morning)	Relative humidity (evening)	Rainfall
2006-07	0.118	0.517*	-0.253	-0.056	0.708*
2007-08	0.465	0.278	-0.541	-0.549	-0.394
2009-10	0.288	0.371	-0.267	-0.421	0.625*
2010-11	0.285	0.506*	-0.263	-0.415	0.477
2011-12	0.377	0.288	-0.278	-0.233	-0.027
2012-13	-0.297	0.001	0.167	0.448	0.586*
2013-14	0.915**	0.774**	-0.805	-0.779	-0.350

** Significant at 1% level , * Significant at 5% level

TABLE 4

Association between pooled weather factors and larval incidence at Tikamgarh

Statistic	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity morning (%)	Relative humidity evening (%)	Rainfall (mm)
Correlation coefficients	0.36	0.43	-0.40	-0.39	0.17
Significance (%)	1%	1%	-	-	NS

3.4. *Correlation between larval population and weather factors*

To quantify the association between weather factors and larval population, correlation analysis was carried out for each year separately (Table 3) and for pooled data also (Table 4). Maximum and minimum temperatures have consistent positive correlation with larval population during all the years. There was a strong correlation (0.77) between minimum temperature and larval population during the year 2013-14 and 0.52, and 0.51 during the year 2006-07 and 2010-11 respectively (Table 3). Though rainfall has a low and positive and negative relationship with larval population (Table 3), but higher rainfall amount has affected the larval population during 2013-14 (Table 2). Relative humidity of morning and evening were negatively correlated with larval population except during the year 2012-13. The correlation between peak larval population and GDD was 0.68.

Patnaik and Senapati (1996) found a negative correlation between mean temperature ranges and larval incidence of *H. armigera.* Reddy *et al*. (2009) found that there is significant positive correlation between chickpea pod borer (larval) population with minimum and maximum temperature and negative correlation with afternoon relative humidity. They reported that the larval population showed non-significant positive correlation with rainfall in eastern U. P. region.

Pandey *et al.* (2012) studied the seasonal incidence of larval population of gram pod borer (*H. armigera)* in Varanasi and reported that the population has significantly positive correlation with both minimum (0.62) and maximum (0.64) temperature. The correlation coefficient of morning (-0.76) and evening relative humidity (-0.73) was negative. The rainfall and larval population showed negative correlation coefficient (-0.09) but it was non significant.

3.5. *Selection of highly correlated weather variables*

The perusal of the year wise weather factors and their association with larval population, it was found that though the maximum temperature has highest and significant correlation coefficient with larval population only in 2013-14, but in other years its association was very poor and also non-significant. Hence, this weather factor was not selected for formulation of weather rules. The minimum temperature has shown significant correlation in number of years with larval population and

TABLE 5

Weekly population of *H. armigera* on chickpea during 2013-14 at Tikamgarh

SMW	Recorded on selected plants	Recorded on Pheromone trap
50	0.5	0.50
51	1.0	0.80
52	0.3	1.00
1	0.4	1.50
2	0.2	0.50
3	0.0	0.50
4	0.0	0.33
5	0.5	0.80
6	0.8	3.00
7	0.3	3.80
8	0.5	3.50
9	0.8	3.00
10	1.3	3.00
11	2.0	5.00
12	2.5	4.60

influenced the larval population. Both relative humidity (morning and evening) have weak and changing association (negative and positive) with larval population (Table 3), therefore not suitable for weather rules. Similarly, rainfall has also changing association with larval population but association was significant in many years and its amount and numbers of events have influenced the larval population and its peak timing (Table 2), therefore selected for weather rules. The above reported results showed that three factors, namely GDD, minimum temperature and rainfall (amount and number of events) were suitable for formulation of weather based models for peak larval population prediction.

Tripathi and Sharma (1985) reported that the probability of a population build up of *Heliothis armigera* (Hubner) on gram was due to low relative humidity (below 70%) and low rainfall, since heavy rainfall tended to wash the noctuid eggs off the plant and break down pupation chambers in the soil, preventing adult emergence. Excessive rainfall in December and January is detrimental to early instars (negative impact). Fluctuating minimum temperature between 8 and above 11 °C in December and January accelerate *H. armigera* population on Chickpea (Vaishampayan, 1988). Many workers related the pod borer population fluctuation with temperature and humidity (Yadav *et al*., 1991) rainfall (Tripathi *et al*., 1998) in India.

3.6. *Threshold values for prediction of larval population*

To screen the threshold weather values for larval population prediction, the seven year weather and population data were analyzed. The weather factors; selected for weather rules formulation were clubbed during 1st January to 15th February and threshold valued were screened and shown below. These threshold values were assumed to be congenial weather conditions for peak larval population.

Weather factors	*Threshold value*
GDD	> 300 and ≥ 350° days
MT	5 < and ≤ 12 °C
RF	≤ 50 mm
RE	< 5

where

GDD is growing degree day, MT is weekly minimum temperature in °C and RF is total rainfall in mm and RE is number of rainfall event. With help of these threshold values, a place will be predicted; whether it comes in epidemiological area or not. Vaishampayan (1988) reported that outbreak of *Helicoverpa* will occur; if winter rains were around 25 mm or more every month, and winter are warm with mean daily minimum temperature exceeding 10 °C.

Vishwa Dhar *et al*. (2007) also shown that a sudden rise in the minimum temperature (>5 °C) around 7-8 SMW and rainfall during 1-9 SMW along with a considerable adult moth catches (above 15/weeks) during 5-7 SMW, trigger a major rise in the pest population during 10-14 SMW.

Yadav *et al*. (2009) have reported that outbreak of *H. armigera* in western Uttar Pradesh might occur if during 1st to 10th SMW, when GDD ≥ 450 degree day, rainfall >75 mm and evening relative humidity ≤ 60 per cent. They also depicted that mean weekly minimum temperature did not have any effect on population build up. These results contradict the findings of Vaishampayan (1988).

The very low minimum temperature has shown detrimental effect on larval population. Analysis of minimum temperature events below 2 °C during 1st January to 15th February was carried out in seven years and presented in Table 6. The results indicated that whenever the events are greater than 5 during a year, peak

TABLE 6

Threshold values of weather factors (1st January to 15th February) at Tikamgarh

Year	Total rainfall (mm)	Number of rainfall events	Number of day when minimum temperature > 8 °C	Number of day when minimum temperature < 2 °C
2007	39.0	4	20	0
2008	0.0	0	23	0
2009	0.0	0	03	0
2010	19.0	2	20	0
2011	0.0	0	30	8
2012	10.2	1	29	2
2013	53.5	4	29	7
2014	60.2	8	14	0

TABLE 7

Monthly rainfall events (≥ 25mm) during *rabi* season at Tikamgarh

Data Base	November rainfall events ≥ 25 mm	December rainfall events ≥ 25 mm	January rainfall events ≥ 25 mm	February rainfall events ≥ 25 mm
1951-2014	08	02	14	04

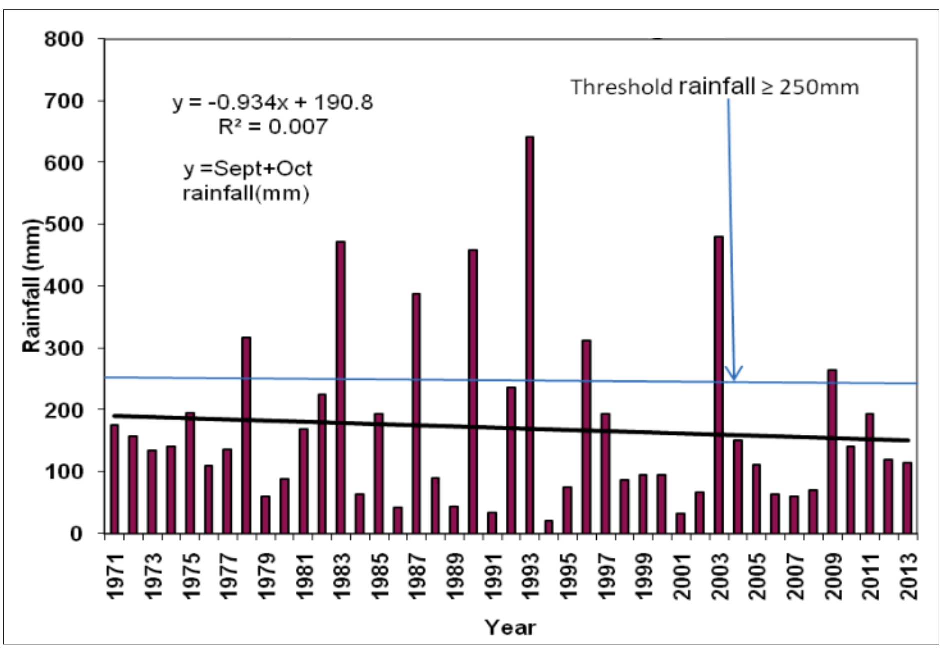

Fig. 5. Total rainfall during September and October and their trend at Tikamgarh

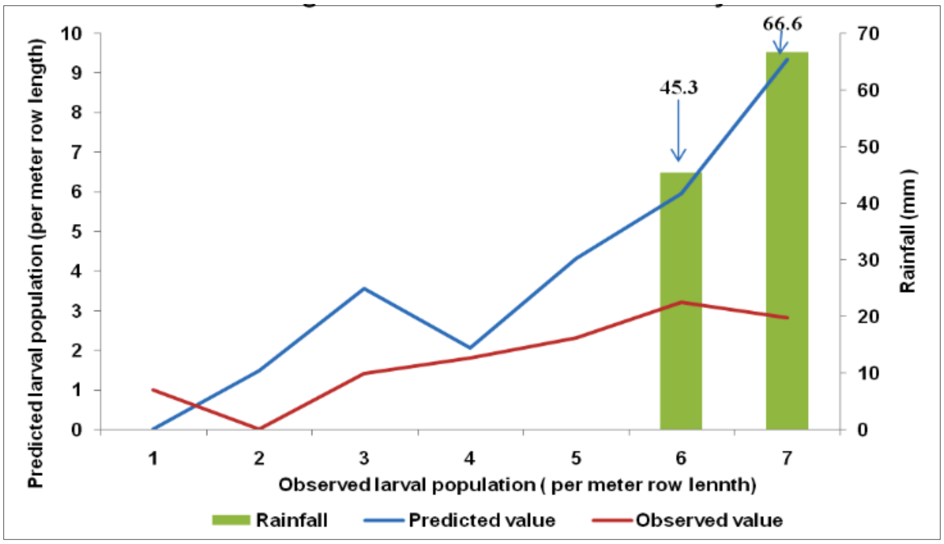

Fig. 6. Weekly distribution of larval population and rainfall during 1st January to 15th February, 2013 at Tikamgarh

larval population was low. Vaishampayan (1988) also reported that persistence of low temperature below 8 °C for prolonged period during November - January is detrimental to the pest.

3.7. *Evaluation of past weather rules*

In past studies, researchers (Das *et al.*, 2001; Khalique and Khalique; 2002; Yadav *et al*., 2009; Vishwa Dhar *et al*., 2007 and Srivastava *et al.*, 2010) mostly used light and pheromone traps population data of *H. armigera* for prediction or model development for the pest, *H. armigera*. But in the present study it was found that data recorded on chickpea crop (plant) and pheromone trap (on the same crop field) were exhibited different pattern of *H. armigera* population (Table 5). Earlier, Vaishampayan (1988) has used the mixed data light trap and data collected on chickpea plant at fortnightly interval for model development. He developed a model for outbreak of *Helicoverpa,* which holds good for the state of Madhya Pradesh (between 20-24° N latitude and 78-80° E longitude). Following the location and type of data collection, Vaishampayan hypothesis was selected for present evaluation. He had proposed that the total rainfall in September and October (≥ 250 mm), monthly rainfall in November, December, January or February (≥ 25 mm) and daily minimum temperature is above 10-11 °C than the pod bored population in chickpea would be high.

To evaluate the above proposed rules, the long term (1971-2014) total rainfall of September and October were calculated and presented in Fig. 5. A closer look of the data indicates that during 44 years of rainfall record of Tikamgarh only 8 years have rainfall ≥ 250 mm. To examine the monthly rainfall of November to February a monthly rainfall and number of years when the rainfall ≥ 25 mm were calculated and presented in Table 7. The data reveals that during 64 years; the years which have monthly rainfall ≥ 25 mm varied between 2 (December) and 14 years (January), though the larval populations were higher in much more years. The daily minimum temperature events > 8 °C and < 2 °C were calculated from 2006-2014 and presented in Table 6. From the table, it was clear that whenever the number of events of daily temperature (during 1st January to 15th February) was greater than 8 °C it found not to be closely associated with number of larval population. The proposed hypothesis was failed under test because it was validated with average of fortnightly interval and use of light trap data. The light and pheromone traps act as artificial attracters for *H. armigera* and hence the population recorded on these traps are deviates from the data collected on crop fields (natural attracters).

Kumar and Durairaj (2012) reported from the field experiments at Coimbatore that the emergence of *H. armigera* adults had a significant negative association with minimum temperature that contradicts the result of Vaishampayan (1988), which may not be valid under Bundelkhand Agroclimatic conditions.

3.8. *Weather based larval prediction model*

A stepwise regression model was developed using the GDD, weekly minimum temperature, weekly rainfall amount and rainfall events during 1st January to 15th February except the year 2012-13 data and given below :

$$Y = -1.54 + 0.016\, X_1 + 0.354\, X_2 + 0.041\, X_3 - 0.743\, X_4$$

R^2 = 0.69*

* = Significant at 5 % level

where,

Y = weekly larval population (per meter row length)

X_1 = GDD

X_2 = Weekly minimum temperature (°C)

X_3 = Weekly rainfall total (mm)

X_4 = Weekly rainfall events

3.9. *Validation of quantitative and qualitative pest population prediction*

3.9.1. *Quantitative validation*

The above developed regression model was used to predict the larval population for an independent data set (year 2012-13) and weekly values of observed and predicted larval population was presented in Fig. 6. The figure revels that the peak larval population was captured by the model, but the impact of rainfall amount was not accounted for and hence the larval population was predicted high in the 7th SMW and shown below:

Independent data set (year 2012-13)

SMW	1	2	3	4	5	6	7
Observed larval population	1.0	0.0	1.4	1.8	2.3	3.2	2.8
Predicted larval population	0.0	1.47	3.54	2.04	4.30	5.94	9.33
Rainfall amount (mm)	0.0	0.0	0.0	0.0	0.0	45.3	66.6
Rainfall events	0	0	0	0	0	3	1

3.9.2. *Qualitative validation*

The quantitative model does not account the cause and effect relationship, hence not suitable for pest forecasting though the above mentioned regression equation explain the 69 per cent variability. The negative impact of rainfall events and amount have restricts the larval population upto 2.8 in the 7th SMW in the quantitative approach, but in regression approach larval population has increased upto 9.33.

3.10. *Weather parameters screened for larval population management*

Based upon three weather variables and their threshold values a chickpea pod borer watch and tactical management box was prepared and is presented below :

$A^+B^+C^+$ Outbreak-Control measures	$A^+B^+C^-$ Alarm- Prophylactic spray
$A^+B^-C^-$ Congenial-Keep watch	$A^-B^-C^-$ No threat - No Action

where,

A^+ : When weekly minimum temperature during 1st January-15th February is ranged between 6 and 12 °C

A^- : When daily minimum temperature during 1st January to 15th February is below 2 °C

B^+ : When number of rainfall events during 1st January to 15th February is < 5

B^- : When number of rainfall events during 1st January to 15th February is ≥5

C^+ : When the cumulative GDD value from 1st January to 15th February ≥ 350 degree day

C^- : When the cumulative GDD value from 1st January to 15th February < 300 degree day

These weather variables are forecasted at medium range scale for almost every district of India under the umbrella of District Agromet Advisory Services (DAAS) of India Meteorological Department twice a week, which may be utilized for estimation of outbreak of the larval population of *H. armigera* for its timely and judicious management.

The above simple rules may be utilized in formulation of bi-weekly district level agromet advisory bulletins and also by extension workers to make tactical decisions for larval population of *H. armigera* control measures.

4. Conclusions

(*i*) The economic threshold of the pod borer is 3 larval/meter row length. It is observed that GDD is capable to forewarn the larval population and its highest value. The reported observations of this study enable the scientists to device a system to monitor and develop management strategies of larval population of *H. armigera* in semi-arid region of Bundelkhand Agroclimatic zone.

(*ii*) Six week periods from 1st January to 15th February are the most critical period for growth and spread of chickpea pod borer. The weekly minimum temperature ranged from 2 to 12 °C and rainfall amount less than 50 mm and rainfall events less than 5 during 1st January to 15th February may be utilized for forecasting of peak larval population. It was also found that population data of *H. armigera* collected through pheromone tarp and on chickpea plants had shown different pattern and number of pests. Larval population collected on chickpea plants may be more suitable for formulation of prediction models and weather rules.

(*iii*) From the present study, it was concluded that minimum temperature and rainfall had significant correlation with larval population. Very low daily minimum temperature (below 2 °C) and high rainfall amount/events were not conducive for growth of larval population. These findings can be used to forecast the peak larval population for judicious application of chemicals.

(*iv*) A multiple weather based regression model was developed based on weekly minimum, temperature, rainfall amount and rainfall events during 1st January to 15th February, which described 70 variability of the pest population, but does not account the impact of rainfall amount on the pest.

(*v*) Since this model is a conceptual model developed under specific climatic conditions, its validity is location specific and hence may not be applicable for other locations of India. Long term data on larval population of *H. armigera* should be utilized for refinement of this predictive model and its validation under different thermal and moisture regimes before putting it into operational use.

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