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Forecasting and Modelling of *Helicoverpa armigera* (Hub.) in Relation to Weather Parameter in Multan, Punjab, Pakistan

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Abstract.- Weather plays a critical role in regulating abundance of cotton insects. Pests forecasting for monitoring and management of such deleterious insects particularly in developing countries where pest management is costly is very important . Keeping in view such delicate issues, pests forecasting model on the basis of past 5 years pests abundance data is proposed. Population data was taken from different locations of Multan district from 2006-2010 by Pests Warning Wing of Agriculture Department, Govt. of Punjab, Pakistan. Weather in relation to *Helicoverpa armigera* (Hub.) abundance was summarized on the basis of multivariate regression and correlation tactics. Results revealed that maximum temperature had negative impact on American bollworm population while relative humidity had highly significant positive effect on *Helicoverpa armigera* population. ARIMA model forecast American bollworm percent hot spots will decrease with minimum value -1.4 to maximum value 1.05.

Key words: American bollworm, weather factors, forecasting model.

INTRODUCTION

Cotton is principally back bone of Pakistan's economy having 2/3 share of country's export (Noreen *et al*., 2013). However, this major cash crop is affected by scores of insect pests which trigger substantial decline in cotton yield if not kept at the low ebb. Seven pests are of great economic importance among the 150 reported on cotton crop. About 40-50% losses in yield are estimated due to insect pests by direct or indirect damage as a vector to transmit diseases to cotton crop (Hill, 1975). Poor pest monitoring and forecasting escalated pest revitalization and abundance (Holt *et al*., 2007).

Weather factors play a very imperative role in regulation of American bollworm *Helicoverpa armigera* (Hub.) (Lepidoptera: Noctuiidae) under agro-ecosystems. Positive/negative correlation between weather factors and with cotton pests population exists. (Ali *et al*., 2008; Selvaraj *et al*., 2010). Eruption and resurgence of American bollworm population is linked with weather factors *i.e.*, ups and downs in temperature, abundance or scarcity of rainfall and growing of susceptible varieties in ecosystems (Aheer *et al*., 1994). Weather affects physiological and behavioral characters of pest leading to temporal and spatial dynamics (Kingsolver, 1989). Changing the focus of inquiry from mechanisms of population regulation to the interplay of biotic and abiotic factors re-establishes the conceptual importance of weather for population dynamics (Wallner, 1987; Weisser *et al*., 1997; Beirne, 1970). Climatic change clearly revs up need for developing and implementing sound pest management strategies. Population ecologists accentuate need for demographic consequences of environmental or biological changes on herbivore pest species and need for precise and exhaustive forecast models in line with environmental factors (Varley and Gradwelt, 1970).

American bollworm (*Helicoverpa armigera* (Hub.) is a polyphagous, multivoltine, highly motile, fecundative and possesses short life cycle (Khan *et al*., 2013). Pest is a serious problem on chick pea, tomato, squash, roses, crucifers and vegetable crops in Pakistan. Invasion of *Bt* crop has reduced this pest attack on non *Bt* cotton crop. However, eggs are often encountered on *Bt* cotton in Pakistan. During rainy season, pest becomes serious problem on non *Bt* crop in Pakistan because of improper management adopted by farmers in Pakistan. Hence meticulous pest forecasting is required to make the farmers aware of onslaught of insect pests in advance and thus, proper remedial

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measure can be made and applied to control pest population.

Keeping in view demand of country's agricultural system, multivariate regression model, correlation and Autoregressive integrated moving average method (ARIMA) was used for estimation of relationship between weather factors and American bollworm, *H. armigera* (Hubner) abundance and forecasting of the pest incursion for the upcoming year to devise proper management strategies. Paper concentrates *H. armigera* population dynamics in cotton crop for period of five years. The paper aims at assessment of forecasting method and its implementation for community based training to alleviate complex flow of information for the pest flare-up.

MATERIALS AND METHODS

American bollworm population data was taken from different locations of District Multan *viz.*, Tehsil Shujabad, Tehsil Jalalpur Pirwala and Tehsil Multan ranging from 36° to 60° north and 59° to 86° east covering 0.4 million acres area. Pest scouting was conducted in 40 spots (5 acre each, taken randomly from each Tehsil on weekly basis from 1st June to 31st October) each year from 2006-2010. The data from 40 spots collected from each tehsil was converted into replicates. Meteorological data was also taken from Weather record station at Central Cotton Research Institute, Multan. American boll worm population was calculated from 25 cotton plants *viz.*, 5 consecutive plants from 5 different places per block. Data of surviving larvae on Bt and non Bt cotton plants was taken.

A place was considered as hot spot where population of pest was found at and above Economic Threshold Level (ETL). Totally forty places were recorded for pest population and hot spots were separated weekly (Multan, Shujabad and Jalalpur Pirwala) were determined.

Regression and correlation was made between weather factors and insect pests was analysed by using MSTAT-C (Anonymous, 1986). ARIMA sequence modeling was used for future forecasts using MINITAB software (McKenzie and Goldman, 1999) and statistical significance was workedout at 5 % and 1 % level.

RESULTS AND DISCUSSION

Comparison of means showed that *Helicoverpa armigera* population varied from 1.794 to 1.601 during 2006-2010 (Table I). Per cent host spots of *H. armigera* were highest in 2006 (1.794) followed by 2010 (1.60) while it was decreased slowly in 2007, 2008 and 2009. Results revealed that percent hot spots of American bollworm were at par in 2008 and 2009 with value 0.62 and 0.06 respectively (Table I).

Table I.- Population fluctuation of American bollworm (*H. armigera* (Hub.) during 2006-2010.

Year	American bollworm
2006	1.794 [a]
2007	0.773 [bc]
2008	0.628 [c]
2009	0.069 [c]
2010	1.601 [ab]
LSD	**0.874**

Correlation between meteorological factor with *H. armigera* population revealed that highly significant negative correlation was observed with maximum temperature similarly significant negative correlation was observed with minimum temperature. Rainfall had significant to highly significant positive correlation with *H. armigera* outbreaks (due to heavy rains) Relative humidity had significant positive effect on H. *armigera* outbreaks in all years (Table II).

Table II.- Correlation of Metrological factors with American bollworm (*H. armigera* Hub.) population.

Year	Max. Temp	Min. Temp	RF	RH
2006	-0.796**	-0.720**	-0.351	0.655**
2007	-0.465*	-0.364	0.148	0.046
2008	-0.832**	-0.831**	-0.094	0.413
2009	-0.760**	-0.590**	-0.271	0.139
2010	-0.466*	-0.094	0.535**	0.696**

Significant * =P<0.05; Highly Significant ** P<0.0.1

Multivariate regression analysis (Table III) showed that maximum temperature had negative relation (0.5 to 11.4%) with *H. armigera* population

Table III.- Multivariate regression models along with coefficient of determination between weather factors and American bollworm population during 2006-2010.

Insect	Regression equation	R2	100 R2	Role of individual factor
2006	Y = 6.17 - 0.120*X1	0.052	5.2	5.2 x 1
	Y = 4.84 - 0.372*X1 + 0.400*X2	0.284	28.4	23.2 x 2
	Y = 4.44 - 0.324 X1 + 0.355 X2 - 0.845 X3	0.322	32.2	3.8 x 3
	Y = 2.84 - 0.297 X1 + 0.344 X2 - 0.840 X3 + 0.0138 X4	0.323	32.3	0.1 x 4
2007	Y = 11.0 - 0.273** X1	0.114	11.4	11.4 x 1
	Y = 15.8 - 0.537** X1 + 0.199*X2	0.316	31.6	19.6 x 2
	Y = 15.8 - 0.538 X1 + 0.199 X2 - 0.138 X3	0.328	32.8	1.2 x 3
	Y = 23.9 - 0.698 X1 + 0.235 X2 - 0.111 X3 - 0.0454 X4	0.355	35.5	2.7 x 4
2008	Y = 0.147 + 0.0068 X1	0.005	0.5	0.5 x 1
	Y = - 0.53 + 0.0570 X1- 0.0447 X2	0.027	2.7	2.2 x 2
	Y = - 0.52 + 0.0536 X1 - 0.0395 X2 - 0.176 X3	0.044	4.4	1.7 x 3
	Y = - 1.78 + 0.0531 X1 - 0.0317X2 - 0.140 X3 + 0.0140X4	0.063	6.3	1.9 x 4
2009	Y = 0.266 - 0.0059 X1	0.011	1.1	1.1 x 1
	Y = 0.360 - 0.0125 X1 + 0.0061 X2	0.029	2.9	1.8 x 2
	Y = 0.367 - 0.0127 X1 + 0.0064 X2 - 0.031X3	0.035	3.5	0.6 x 3
	Y = 0.449 - 0.0142X1 + 0.0066X2 - 0.028 X3 - 0.00050X4	0.036	3.6	0.1 x 4
2010	Y = - 4.55 + 0.162 X1	0.043	4.3	4.3 x 1
	Y = - 6.63 - 0.084 X1 + 0.433 X2	0.137	13.7	9.4 x 2
	Y = - 3.39 - 0.230 X1 + 0.544 X2 - 0.260 X3	0.208	20.8	7.1 x 3
	Y = 1.9 - 0.355 X1 + 0.636 X2 - 0.171 X3 - 0.0505 X4	0.239	23.9	**3.1 x 4**

X1= Min. Temperature; X2, Max. Temperature ; X3, Rainfall; X4, R.H Significant * =P<0.05; Highly Significant ** P<0.01

Table IV.- Forecasts of cotton insects for 2011.

Insect	**AR** $Y=u+\varphi Yt\text{-}1 + €t$	**MA** $Yt= u-\Theta_{1€t-1} +€t$	Back Forecasts $Yt=\varphi y_{t-1} +\varphi_2 y_{t-2} +\ldots\ldots\varphi_p y_{t-p} - \Theta_{€t-1}-\Theta_{€t-2} + \Theta_{q€eq} + €t$		
			Forecasts	**Lower limit**	**Upper limit**
ABW	-0.8721	1.0444	-0.20124	-1.46183 to	1.05935

(Table III) while, minimum temperature showed positive effect on *H. armigera* population (1.8% to 19.6%). Rainfall has negative effect on ABW population (0.6 to 3.8%) and R.H (0.1 to 2.7%) had positive effect on *H. armigera* population.

ARIMA forecast model on the basis of 5 years pest dynamics predicts that population of American bollworm is expected to decrease in forthcoming year 2011 *i.e.* -0.2 with minimum numbers -1.46 to maximum value 1.05.

Pests observations during 2006 to 2010 revealed that *H. armigera* population development was higher in 2006 and number of generations were maximum (six generations per cropping season but from 2007) it reduced to three generations per cropping season in 2008 two in 2009 one and in 2010 only two generations were observed. Pests population dynamics during 2006 to 2010 clearly revealed that *H. armigera* population increased in 2006 in 2nd week of June then declined due to high temperature again surged in 1st week of July due to presence of humidity (60%) and rainfall 10 mm which favored pest development again declined in 3rd week of August due to scarcity of rainfall, surged in 4th week of August, then stabilized and again increased in 4th week of September which favored the pests development and then declined (Fig. 1).

In 2007 *H. armigera* population was absent

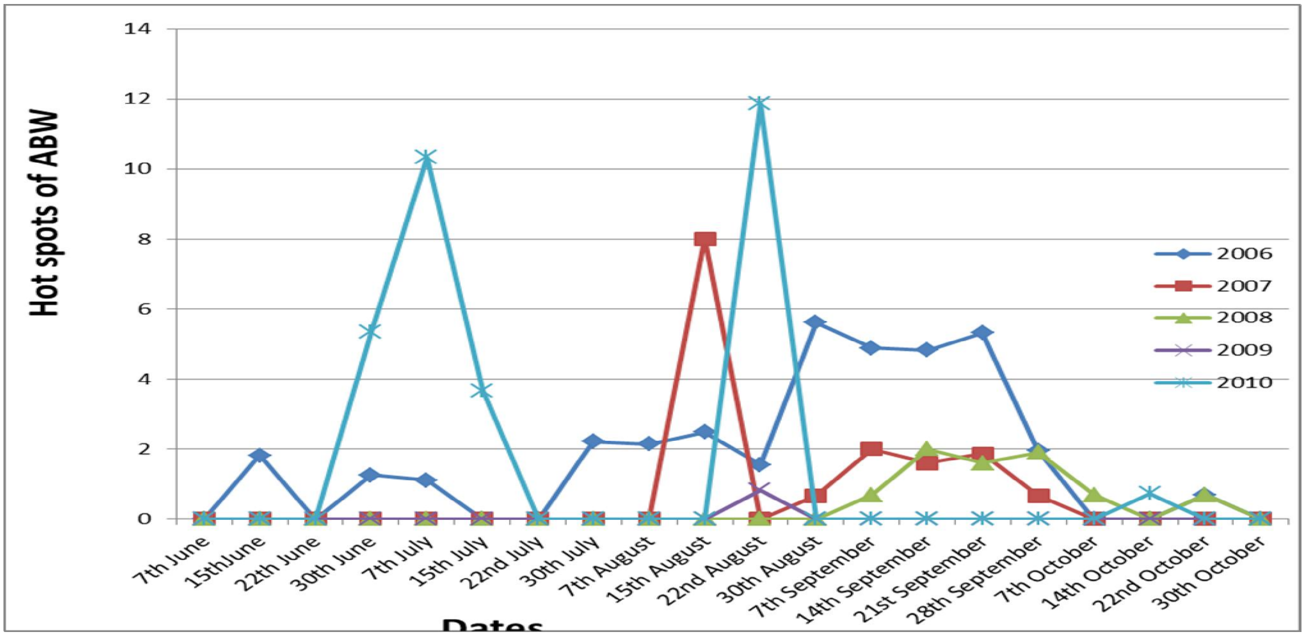

Fig. 1. Population fluctuation of American bollworm with weather factors during 2006-2010

till 2nd week of August and then declined in 3rd week of August due to management practices and again surged in 2nd week of October (Fig. 1). In 2008, population of *H. armigera* increased only in 2nd week of September and 3rd week of October. However this population abundance was low due to use of *Bt* cotton on wide area. In 2009, *Helicoverpa* population increased only in 3rd week of September however development further was not reported due to more areas under *Bt* cotton. In 2010, surgence of *H. armigera* was prominent in 1st week of July, 2nd week of August and 2nd week of December (Fig. 1). From 2009 in Pakistan *Bt* cotton was promoted by government for local farmers. Since 2007 farmers in Pakistan are cultivating *Bt* cotton for large scale production. High surgence of *H. armigera* in 2010 points the need for assessment of mode of resistance in *H. armigera* against *Bt* varieties in the subcontinent (Fig. 1).

However, this increase in pest population in 2010 can not only be attributed to resistance to Cry 1 Ac gene. Pakistan in 2010 has undergone misfortune of high floods which not only demolished Pakistan economy but also disabled farmers to apply insecticides for control of pest which again favored development of pest in suitable weather conditions. *H. armigera* Hub remained a key pest of cotton from 1980 to 2006 in Pakistan. The pest alone can reduce yield from 50-70% if unchecked (Chemeune *et al*., 2007). Invasion of *Bt* cotton in agro ecosystem of Pakistan has completely demolished pest attack on cotton crop, even incidence of pest is decreased on non *Bt* hybrids because of breaking of insect life cycle. Now its appearance is mainly in April on vegetables and Crucifers. Ali *et al*. (2008) worked on adult moths of *Helicoverpa* dynamics and evaluated maximum population in 3rd week of September, which were similar to present studies results. *Helicoverpa* is capable of completing life cycle in 30 days. Present studies clearly document two generations of *H. armigera* on cotton crop. Temperature is the most important factor which affects growth, development and diapauses of *Helicoverpa* (Fye and Poole, 1971; Attique *et al*., 2000). Our results on correlation of weather factors are similar to Ali *et al*. (2008). American bollworm populations in present studies showed positive correlation with relative humidity which was similar to Dhaliwal *et al*. (2007). Dhaliwal *et al*. (2007) further reported maximum temperature between 25-30^{o}C, minimum temperature between 15-20^{o}C, high morning relative humidity and no rainfall resulted in maximum *H. armigera* populations whereas present studies documents that population reached at its peak in between temperature 33-35^{o}C, minimum temperature 22.20-41.0^{o}C, relative humidity 68-72% and no rainfall. However pest out break started with onset of rainfall. Present studies pointed significant positive correlation of relative humidity with *Helicoverpa* population.

Our results also document that population of *H. armigera* increased in 2010 as compared to preceding years. This might be due to floods which made pests control difficult in different locations of Punjab. Hence pest prevailed because of favorable weather conditions and inability of farmers to control pest attack. We also observed that *H. armigera* population surged in 1st week of July in 2010 and then declined because of adoption of measures by farmers then population again surged in last week of August and reached to 12% hot spots due to improper management by farmers on cotton crop. In Pakistan, Cry1Ac (Bollgard) is adopted for cultivation in wide scale. We on the basis of pest observation in 2010 on Non *Bt* crop recommend that *Bt* crop should be sown with rotation to Non *Bt* hybrids. Hence resistance in *H. armigera* strains against *Bt* hybrids will develop after a long period of time.

CONCLUSION

Present work on population fluctuation of cotton insects conclude that American bollworm population suppressed with invasion of *Bt* crop. ARIMA modeling being powerful statistical tool remained helpful in for forecasting insects abundance in 2011.

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