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FORECASTING AND MODELING OF SUCKING INSECT COMPLEX OF COTTON UNDER AGRO-ECOSYSTEM OF MULTAN- PUNJAB, PAKISTAN

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Weather plays a critical role in population fluctuation of insects. Pests forecasting is one of the best methods for monitoring and management of deleterious insects where pest management cost is very high. To develop pests forecasting model five years pests data was recorded by Pests Warning and Quality Control of Pesticides Department of Agriculture, Govt. of Punjab, Multan in different locations of district Multan during 2006-2010. The correlation between weather and sucking insect pests was summarized on the basis of multivariate regression and correlation analysis tactics. Mean comparison of population averages of insects was undertaken i.e., jassid (*Amrasca bigutulla bigutulla),* Whitefly (*Bemisia tabaci),* Thrips (*Thrips tabaci),* Cotton Mealybug (*Phenacoccus solenopsis),* Dusky cotton bug (*Oxycarenus laetus*) and Cotton leaf Curl virus (CLCuV). The results suggested that relative humidity alone exhibited positive correlation with all mentioned insects. Cotton mealy bug population increased steadily from 2006-2008 and then declined due to changing in environmental factors. Whereas Dusky cotton bug resurgence as a new pest on cotton crop was examined. Regression analysis revealed that maximum temperature showed negative linear relation with whitefly population having 5.9 to 21.6% role. Rainfall showed negative linear regression with jassid population having 1.3 to 3.4 % impact.
Keywords: Sucking insects, cotton, weather factors, regression, forecasting model (ARIMA)

INTRODUCTION

Sucking insects in cotton crop became fundamental pests since commercialization of transgenic cotton (Bt cotton) in world especially in Pakistan. However, pesticide use has further been enhanced with emergence of some pests. For example cotton mealy bug appeared as a primary pest whereas dusky cotton bug became pest in cotton growing areas of Punjab. On the other hand insecticides resistance has amalgamated the pest out break situation (Holt *et al*., 2007). So, to overcome such problems pest management techniques under such circumstances becomes critical void. Proper pest scouting and forecasting can only assuage from high pest pressure due to early management.

Forecasting techniques rely on abiotic factor's, simplicity and accuracy of forecasting models and complete quantitative knowledge of biology, ecology of pest attack, field studies, life history of the arthropods. Temperature is one of the most important factor which controlled insects development and hence, population numbers or population outbreak (Weisser *et al*., 1997). Rainfall on the other hand can be only reason for insect epidemic. Similarly, relative humidity above and below certain limits can augment or lessen the development of pests under certain conditions (Beirne, 1970). Theoretical and applied entomologists focus on the role of weather factors and their use in development of forecasting models (Wallner, 1987). Hence meticulous pest forecasting is required to make the farmers aware of onslaught of insect pests in advance and thus, proper remedial measure can be made and applied to control pest population. Exhaustive construction of pest forecasting model is a prime tool for better management of key pests and development of rational strategies (Atlamaz *et al*., 2007). Keeping in view the effect of weather factors on pests multivariate regression model, correlation models and Autoregressive Integrated Moving Average Methods (ARIMA) were used for estimation of relationship between weather factors and insects population for the upcoming year to devise proper pest management strategies.

MATERIALS AND METHODS

Pest population data was recorded from different selected cotton growing areas of district Multan. The following areas of Shujabad, Jalalpur Pirwala and Multan ranging from 36° to 60° north and 59° to 86° East covering 0.4 million acres areas. 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. Meteorological data was taken from Central Cotton

Research Institute, Multan

Sucking insects and CLCuV sampling: Jassid, whitefly, Thrips population were recorded on 20 leaves randomly selected from 20 plants per block; upper, middle and lower leaves, one from each plant. Cotton mealy bug population was recorded on 20 cm twig from 15 plants. Dusky Cotton bug population was recorded from 25 randomly selected plants by recording number of bugs from 5 bolls of each plant. Cotton leaf curl virus incidence was noted by observing symptoms from 100 plants.

Percent hot spot calculation and data analysis: A spot was considered hotspot where population of pest was found at or above Economic thresh hold level. From forty spots examined, from each location i.e., Multan, Shujabad and Jalalpur Pirwala. Data was analyzed by using MSTAT-C (Anonymous, 1989) software. Regression and correlation was made between weather factors and insect pests. ARIMA sequence modeling was used for future forecasts using MINITAB software (McKenzie and Goldman, 1999).

RESULTS

Jassid (Amrasca bigutulla bigutulla) (Hemiptera: Cicadellidae): Mean jassid population fluctuated between 4.58% hot spots to 15.85% from 2006-2010 (Table 1). Jassid population was lower in 2006-2008 but increased significantly higher during 2009-2010. Multivariate regression model along with coefficient of determination between weather factors and cotton insects clearly showed that highly significant linear relationship was observed between the maximum temperature and jassid population having 10.8 to 48.0% role. (Table 4) The second important factor is Rainfall which showed negative linear regression with jassid population having 1.3 to 3.4 % role.

Table 1. Population fluctuation of cotton pests during 2006-2010

YEAR	Jassid	Whitefly	Thrips	CMB	DCB	CLCu.V
2006	4.58c	19.97bc	2.78ab	10.20d	1.33d	56.77c
2007	6.93bc	11.25c	3.08ab	53.03b	2.67cd	69.32b
2008	11.49ab	30.33ab	0.42 b	67.73a	6.67bc	70.37b
2009	13.27a	16.02bc	1.89ab	26.76c	8.79b	80.02a
2010	15.85a	41.20a	5.20a	21.42d	14.44a	87.42a
LSD	5.26	16.20	3.39	7.53	2.54	8.86

Table 2. Forecasts of cotton insects for 2011

Insect	AR $Y=u+\varphi Yt\text{-}1 + €t$	MA= $Yt= u_{\text{-}1€t\text{-}1} + €t$	Back Forecasts (2011) $Yt=\varphi y_{t-1} + \varphi_2 y_{t-2} + .\varphi_p y_{t-p} - \theta_{€t-1} - \theta_{€t-2} + \theta_{q€eq} + €t$			Back Forecasts (2012) $Yt=\varphi y_{t-1} + \varphi_2 y_{t-2} + .\varphi_p y_{t-p} - \theta_{€t-1} - \theta_{€t-2} + \theta_{q€eq} + €t$		
			Forecasts	Lower Limit	Upper limit	Forecasts	Lower Limit	Upper limit
Jassid	0.296	-2.253	14.494	11.628	17.3599	12.740	4.892	20.589
White fly	-1.000	-0.705	11.643	-12.003	35.2913	32.615	7.964	57.267
Thrips	0.734	1.497	3.114	2.074	4.1541	3.453	1.284	3.980
CMB	-0.012	2.062	61.892	34.226	89.5597	39.833	-23.871	103.536
DCB	-0.203	1.959	0.863	-1.676	1.8000	3.230	0.501	3.571
CLCuV	0.691	-1.278	79.448	68.991	89.9057	85.122	70.611	90.323

Table 3. Correlation of Metrological factors with cotton insect pests

Insects	2006				2007				2008				2009				2010			
	Max temp	Min temp	RF	RH	Max temp	Min temp	RF	RH	Max temp	Min temp	RF	RH	Max temp	Min temp	RF	RH	Max temp	Min temp	RF	RH
Jassid	0.132	0.447 *	0.062	0.081	0.010	0.498 **	0.099	0.340	-0.585 **	-0.701 **	0.184	0.304	0.547 **	0.703 **	0.275	0.515 *	0.123	0.438	0.278	0.241
WF	-0.327	-0.022	-0.268	0.531 **	-0.495 **	-0.588 **	-0.057	0.040	-0.652 **	-0.717 **	-0.047	0.549	-0.360	-0.030	-0.152	0.485*	-0.355	-0.024	0.050	0.660 **
Thrips	-0.064	0.418	-0.360	0.341	0.101	0.538	-0.024	0.356	-0.036	0.189	0.594 **	0.511 *	0.123	0.463 *	0.019	0.394	0.031	-0.032	-0.101	-0.095
CMB	-0.205	-0.336	-0.270	0.292	-0.535 **	-0.420	0.020	0.239	-0.671 **	-0.589 **	0.149	0.766 **	-0.637 **	-0.319	-0.262	0.377	-0.788 **	-0.657	-0.015	0.489
DCB	-0.599 **	-0.577 **	-0.059	0.254	-0.386	-0.536 **	-0.174	0.280	-0.453 *	-0.670 **	-0.139	0.023	-0.488 *	-0.663 **	-0.145	-0.248	-0.203	-0.237	-0.201	0.092
CLCuV	-0.289	0.258	-0.349	0.690 **	-0.545 **	-0.467 *	0.046	0.171	-0.617 **	-0.537 **	0.185	0.785	-0.324	-0.044	0.020	0.761 **	-0.643 **	-0.256	0.196	0.800 **

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

Table 4. Multivariate regression models along with coefficient of determination between weather factors and cotton insect pest and CLCuV population during 2006-2010

Insects	Factor	2006			2007			2008			2009			2010		
		R2	100 R2	Role	R2	100 R2	Role	R2	100 R2	Role	R2	100 R2	Role	R2	100 R2	Role
Jassid	Max.T	0.038	3.8	3.8	0.076	7.6	7.6	0.092	9.2	9.2	0.10	10.2	10.2	0.006	0.6	0.6
	Min. T.	0.140	14.0	10.2	0.386	38.6	31.0	0.253	25.3	16.1	0.586	58.6	48.4	0.262	26.2	25.6
	R.H	0.174	17.4	3.4	0.400	40.0	1.4	0.270	27.0	1.8	0.603	60.3	1.7	0.517	51.7	25.5
	RF	0.193	19.3	1.9	0.439	43.9	3.9	0.392	39.2	12.2	0.661	66.1	5.8	0.522	52.2	0.5
Whitefly	Max.T	0.059	5.9	5.9	0.211	21.1	21.1	0.167	16.7	16.7	0.184	18.4	18.4	0.126	12.6	12.6
	Min. T.	0.077	7.7	1.8	0.438	43.8	22.7	0.245	24.5	7.8	0.346	34.6	16.2	0.140	14.0	1.4
	R.H	0.078	7.8	0.1	0.500	50.0	7.3	0.272	27.2	2.7	0.519	51.9	17.3	0.172	17.2	3.2
	RF	0.118	11.8	4.0	0.500	57.0	7.0	0.321	32.1	4.9	0.629	62.9	11.0	0.550	55.0	37.8
Thrips	Max.T	0.023	2.3	2.3	0.007	0.7	0.7	0.020	2.0	2.0	0.020	0.2	0.2	0.126	12.6	12.6
	Min. T.	0.444	44.4	42.2	0.307	30.7	30.0	0.062	6.2	4.2	0.193	19.3	19.1	0.140	14.0	1.4
	R.H	0.456	45.6	1.6	0.323	32.2	2.2	0.090	9.0	2.8	0.199	19.9	0.6	0.172	17.2	3.2
	RF	0.496	49.6	4.0	0.333	33.3	1.1	0.123	12.3	3.3	0.206	20.6	0.7	0.176	17.6	0.4
CMB	Max.T	0.041	4.1	4.1	0.402	40.2	6.9	0.252	25.2	25.2	0.468	46.8	26.2	0.331	33.1	33.1
	Min. T.	0.121	12.1	8.0	0.406	40.6	0.4	0.267	26.7	1.5	0.499	49.9	3.1	0.610	61.0	27.9
	R.H	0.151	15.1	3.0	0.606	60.6	20.0	0.375	37.5	10.8	0.598	59.8	9.9	0.659	65.9	4.9
	RF	0.181	18.1	3.0	0.623	62.3	1.7	0.397	39.7	2.2	0.674	67.4	7.6	0.663	66.3	0.4
DCB	Max.T	0.294	29.4	29.4	0.110	11.0	11.0	0.251	25.1	25.1	0.394	39.4	39.4	0.203	20.3	20.3
	Min. T.	0.347	34.7	5.3	0.622	62.2	51.0	0.262	26.2	1.1	0.458	45.8	6.4	0.497	49.7	29.4
	R.H	0.352	35.2	0.5	0.637	63.7	1.5	0.376	37.6	11.4	0.478	47.8	2.0	0.502	50.2	0.5
	RF	0.360	36.0	0.8	0.78	78.0	14.4	0.383	38.3	0.7	0.792	79.2	31.4	0.588	58.8	8.6
CLCuV	Max.T	0.062	6.2	20.4	0.390	39.0	39.0	0.001	0.1	0.1	0.192	19.1	19.0	0.060	6.0	6.0
	Min. T.	0.266	26.6	20.4	0.403	40.3	1.3	0.089	8.9	8.8	0.542	54.2	35.2	0.061	6.1	0.1
	R.H	0.269	26.9	0.3	0.585	58.5	18.2	0.093	9.3	0.4	0.543	54.3	0.1	0.070	7.0	0.9
	RF	0.350	35.0	8.1	0.605	60.5	2.0	0.124	12.4	3.1	0.549	54.9	0.6	0.091	9.1	2.1

Note: CMB= *Cotton mealybug; * DCB = Dusky cotton bug; CLCuV= Cotton leaf curl virus disease; Role = Role of individual factor

Back forecast value was 14.49. AR value was 0.30. MR value was -2.25 (Table 2). Figure 1 illustrates population dynamics of jassid with weather factors from 2006-2010. Correlation matrix (Table 3) indicated that jassid populations showed high positive correlation with maximum, minimum temperature and RH.

***Whitefly (Bemisia tabaci) (Homoptera : Aleyrodidae)*:** Mean whitefly hot spots ranged from 11.25 to 41.2 percent during 2006-2010 (Table 1). Regression analysis (Table 4) revealed that maximum temperature showed negative linear relation with whitefly population having 5.9 to 21.6% role. Minimum temperature showed significant positive relationship with whitefly population from 1.8 to 22.7%. Rainfall showed negative significant relationship with whitefly population from 0.1 to 17.3% (2006-2010). Relative humidity showed positive relationship with whitefly abundance (Table 4). Correlation matrix revealed negative correlation with rainfall and positive correlation with minimum temperature and relative humidity. Highly significant negative correlation was observed with rainfall (Table 3). ARIMA modeling forecasts revealed expected value 11.64 with AR (1.0) and MA (0.70) (Table 2). Results of present studies showed that maximum population was recorded in 2006 and 2010, respectively (Fig 1).

***Thrips* (*Thrips tabaci* I) (*Thysanoptera: Thiripidae*):** Mean thrips hot spots percent fluctuated from 0.42 to 5.2 during 2006-2010 (Table 1). Multivariate regression models along with coefficient of determination revealed that maximum temperature showed significant linear relationship (0.02 to 12.6%) with thrips population (Table 4). Minimum temperature showed positive relationship with thrips population and role of individual factor was to (6.2 to 19.3%). The results showed that thrips population increased with increase in temperature and decreased with rainfall (1.6 to 8.0%) and R.H (0.7-4.0%). Correlation matrix (Table 3) showed that high significant negative correlation (-0.064 to 0.123) relationship with maximum temperature, minimum temperature (-0.032 to 0.463) and high significant negative relation with R.H (-0.095 to 0.511) and rainfall (-0.024 to 5.4%).

***Cotton Mealy bug* (*Phennacoccus solenopsis* Tinsely) *(Hemiptera: Pseudococcidae)*:** Mean cotton mealybug percent hot spots ranged from 10.2-67.33 during 2006-2010 (Table 1). Mealybug population was higher in 2008 and decreased slowly till 2010. Multivariate regression analysis clearly demoed that CMB population showed positive highly significant relationship with maximum temperature and positive highly significant relationship with increase in minimum temperature (Table 4). Role of individual factor (Maximum temperature) varied from 1.0 to 26.2%. Role of minimum temperature was 0.40 to 25.2%. RH exhibited positive relationship (1.70-7.60%). Rainfall showed significant negative correlation with CMB population. Role of individual factor varied from 3.0-20%. Correlation matrix showed highly significant negative correlation with maximum temperature (-0.788 to -0.205%) and minimum

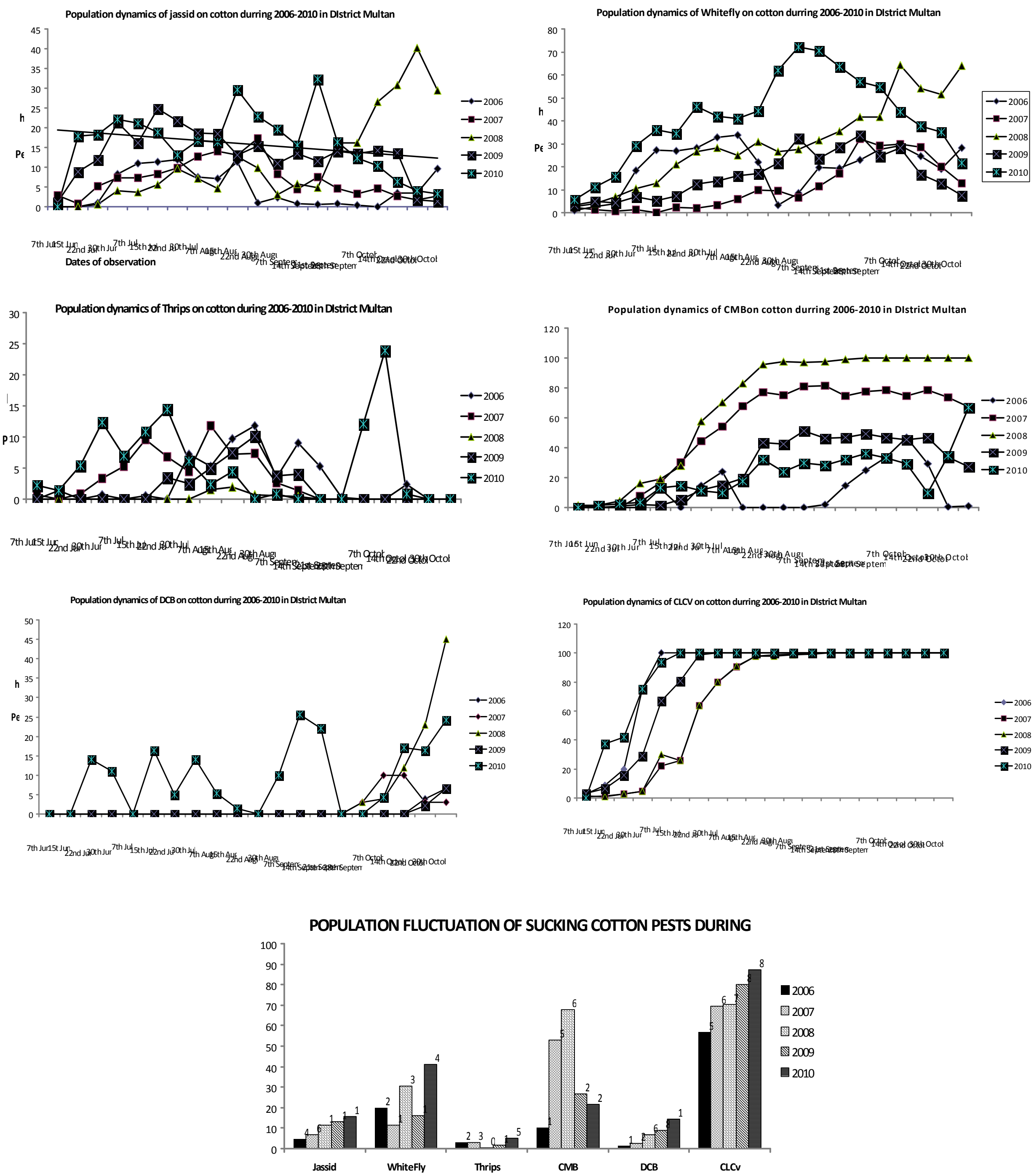

Figure 1. Population fluctuation of cotton insect pests with weather factors during 2006-2010

temperature (-0.420 to -0.320%) while RH showed significantly positive correlation (0.239 to 0.766%) with CMB population. Rainfall showed highly significant negative (-0.270 to 0.149%) correlation with CMB population (Table 3). The expected forecast damage number is 61.8928 (Table 2).

***Dusky cotton bug* (*Oxycarenus laetus* Kirby) (*Hemiptera: Lygaeidae*):** Mean Dusky cotton bug hot spots ranged from 1.33 to 14.43 percent during 2006-2010. Dusky cotton bug population increased significantly during 2008-2010

(Table 1). Dusky cotton bug population fluctuation on the basis of comparison of means clearly indicated that Dusky cotton bug population increased at its peak in 2010, while minimum population was observed in 2006-2009 (Fig 1). Multivariate regression models (Table 4) during 2006-2010 clearly indicated that dusky cotton bug showed highly significant negative linear regression with increase in maximum temperature (0.1 to 29.4%), minimum temperature (5.3 to 51.3%), rain fall (0.5 to 1.5%) and positive linear regression with relative humidity (0.6 to 8.1%). Correlation matrix revealed highly significant negative relation with maximum temperature (-0.542 to 0.036), minimum temperature (-0.773 to -0.04) and rainfall (-0.092 to 0.0333) whilst positive correlation was observed with relative humidity (0.004 to 0.250) (Table 3). Forecast of dusky cotton bug was -0.86 (Table 2).

***Cotton leaf curl virus*:** Cotton leaf curl virus data and its incidence during 2006-2010 clearly indicated that CLCV incidence reached at peak in 2010 (Table 1). Population dynamics of cotton leaf curl virus disease during 2006-2010 indicated that in 2006 it reached at peak in 1st week of September but from 2007 it reached at peak in 2nd week of July 2010 and intensity of virus also increased (Fig 1). Peak population was favored by temperature 25-35°C, 70% RH and rainfall incidence. Correlation matrix (Table 3) clearly indicated that highly significant negative correlation was observed with maximum temperature, increase in minimum temperature and rainfall while positive linear regression was observed with relative humidity (Table 4).). On the basis of ARIMA forecast model 79.44 percent hot spots are predicted (Table 2).

DISCUSSION

Cotton jassid (A. *bigutulla bigutulla* I.) remained important pest of cotton inflicting considerable yield loss (18.78%) (Ali *et al*., 1992). The results of present studies suggest that jassid population reached at peak on 2nd- 3rd week of August and 2nd week of September in all consecutive years. Arshad and Suhail (2010) also reported that population of jassid reached at its peak in 2nd week of August in 2007 but were contrary to their observations that population appeared in 2nd week of June. This may be due to dry and hot climate of southern Punjab as compared to central Punjab, Pakistan. However, results of present studies were similar to Shivanna *et al*. (2009) and Arif *et al*. (2006) who reported that leaf hopper population was maximum in the second fortnight of May followed by second fortnight of April, first fortnight of May, first fortnight of June, second fortnight of February and first and second fortnight of March. However, jassid population in linear regression relation with weather factors were confirmatory to Imtiaz *et al*. (2002) and Ashfaq *et al*. (2010). Arif *et al*. (2006) who reported that 32.4% effect of rainfall and other abiotic factors affect 53% whereas, recent studies argue rainfall and others factors effect up to 66.1%. This may be due to heavy rainfall in 2010 while rainfall was minimum in 2006.

Whitefly is serious and notorious pest of cotton and its problem is complicated because of drought retention during last four years. Various ecologists across the world have worked on population fluctuation of white flies with weather factors. The results of present studies showed that maximum population was recorded in 2006 and 2010. The results of multivariate regression models were in close association with Arif *et al*. (2006) who reported that rainfall did not have significant positive correlation with whitefly. Present studies clearly document that population reached at its peak in 2nd to 3rd week of August, which are similar to Gerling *et al*. (1997) who reported maximum population peak in 2nd to 3rd week of August in Israel.

Thrips is another sucking pest which causes stunting and weakening of host plants and reduction in yield. Its population increases or decreases with climatic changes. For example cotton seedlings are heavily infected and population reached at peak in 2nd to 3rd week of July, during 2006 (Greenberg *et al*., 2009). This pest has ability to breed retrogressively and can complete its life cycle within two weeks during warm weather (Anonymous, 2010). The pest population development with intrinsic rate magnifies the issue that probably many alternate host plants increased the exposure of pest (Kirk, 1996; Arif *et al*., 2006). The results of present studies are similar to Abro *et al*. (2004) who reported high population of thrips in early season than late season.

Cotton mealybug emerged as a key pest in Pakistan especially in 2005 (Sindh) and in 2006 (Punjab) and reached at its peak in 2007 and 2008 but then declined during 2009-2010 might be due to parasitoids prevalence. In the present studies population reached at its peak in 1st week of October in 2006; last week of August in 2007; 2nd week of September in 2008; 3rd week of September in 2009 and 1st week of October in 2010 and then declined. Similarly Hanchinal *et al*. (2010) and Dhawan *et al*. (2009) also reported maximum population in 2nd to 3rd week of September. Positive correlation of maximum temperature and relative humidity was reported by Hanchinal (2010) which were similar to present studies results. Shivana *et al*. (2009) and Dhawan *et al*. (2009) reported positive correlation between mealy bugs and maximum temperature and negative effect of relative humidity which were in confirmatory to present studies results.

Dusky cotton bug is considered as uncommon minor pest of cotton: however, its incidence remarkably increased during last two years may be due to favourable climatic factors which enhanced its multiplication, or may be due to alternate host plants, reduced use of insecticides on cotton crop. Muthyala and Patel (2004) conducted studies on dusky cotton bug and then evaluated that relative humidity effects negatively on dusky cotton bug population whereas minimum temperature serves for enhancement of pest growth which are in contradiction to present studies results. Further our findings showed that in the presence of minimum temperature and rainfall increases population of dusky cotton bug. Cotton leaf curl virus is an important disease of cotton and its incidence is increasing in Pakistan with passage of time could be due to change in climatic factors.

***Conclusion*:** Present work on population fluctuation of sucking insects conclude that jassid increased on cotton during 2006-2010 may be due to resistance to prevailing groups of insecticides. Whereas population of whiteflies and thrips increased gradually but not with intrinsic trend and population has capability to suppress with present environmentally degrading agents. Cotton mealy bug population increased steadily during 2006-2008 and then declined. Dusky cotton bug resurge as new major pest. ARIMA modeling being powerful statistical tool remained helpful in forecasting insect pests abundance in 2011.

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