Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

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Population dynamics of cotton jassid, *Amrasca biguttula biguttula* (Ishida) and natural enemies in relation to weather parameters under rainfed conditions

RK Patel and GG Radadia

Abstract
Investigations on population dynamics of cotton jassid, *Amrasca biguttula biguttula* (Ishida) and natural enemies were carried out under field condition during *Kharif* 2015 and 2016 at Regional Cotton Research Station, Navsari Agricultural University, Maktampur farm, Bharuch, Gujarat. Population dynamics study revealed that cotton jassid was observed throughout the crop period during both seasons. Jassid population crossed economic threshold level during 36th and 35th Standard Meteorological Week (SMW) and continuously found above ETL till 2nd SMW (19 weeks) and 51st SMW (17 weeks) during 2015-16 and 2016-17, respectively. The peak population of jassid was recorded in 43rd SMW (37.22 jassids/3 leaves) and 46th SMW (38.48 jassids/ 3 leaves) during 2015-16 and 2016-17, respectively. Among natural enemies, lady bird beetle was observed during 38th to 4th SMW (0.04 to 1.34/ plant) and 33rd to 2nd SMW (0.06 to 1.60/ plant) with its peak in 48th SMW and 50th SMW whereas, chrysoperla was observed during 37th to 2nd SMW (0.04 to 0.48/ plant) and 36th to 51st SMW (0.04 to 0.36/ plant) with its peak in 46th SMW and 40th SMW during 2015-16 and 2016-17, respectively. The population of spider was found almost entire crop period ranging from 0.06 to 0.46 per plant and 0.08 to 0.54 per plant with its peak in 45th SMW and 43rd SMW during 2015-16 and 2016-17, respectively. The jassid population showed significant positive correlation with maximum temperature, evaporation and sunshine hours whereas, significant negative correlation with wind speed and rainy days. The jassid population showed highly significant positive correlation with chrysoperla and spider population while, non-significant positive correlation with lady bird beetle population on cotton crop. The population of lady bird beetle had highly significant negative correlation with minimum and average temperature, morning, evening and average relative humidity, wind speed, rainfall and rainy days while significant positive correlation with sunshine hours and evaporation. The chrysoperla and spider population had significant positive correlation with maximum temperature and evaporation while significant negative correlation with wind speed and rainy days. The spider population also showed significant positive correlation with sunshine hours. The step wise regression analysis indicated that the influence of weather parameters was upto 69.0 percent, 49.6 percent and 42.5 percent on the incidence of jassid during *kharif* 2015, *kharif* 2016 and mean of two seasons, respectively.

Keywords: Cotton, jassid, *Amrasca biguttula biguttula,* natural enemies, lady bird beetle, spider, chrysoperla, population dynamics, weather parameters

Introduction
Cotton plays a vital role in agricultural, industrial, social and monetary affairs of the country. Within India, two-thirds of cotton is produced in the central cotton growing zone; including, the states of Maharashtra, Madhya Pradesh, Gujarat and Odisha where much of the crop is rainfed. In India, cotton is grown under 40 percent irrigated and 60 percent rainfed conditions. About half of the cotton area in Gujarat is grown under rainfed conditions. India ranks first in cotton production (27.0 million bales of 480 lb.) as well as area (10.85 million hectares) in global scenario. However, the productivity of cotton crop in India (542 kg/ha) is still far less than world average (781 kg/ha) as well as many other cotton growing countries (highest in Turkey *i.e.* 1742 kg/ha) of the world in 2016-17 (Anonymous, 2018a) [1]. Among cotton growing states, Gujarat leads in production with 95.00 lakh bales. The provisional cotton productivity of Gujarat is 671 kg/ha from an area of 24.05 lakh hectares in 2016-17 (Anonymous, 2018b) [2]. There are many reasons responsible for the low yield of cotton but insect pest infestation is one of the major reason. Gouda *et al.* (2014) [8] noted that the lower

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productivity of cotton was mainly due to crop grown under rainfed situation and incidence of insect pest (15-20%). The pest spectrum of cotton is quite complex and as many as 1326 species of insects have been recorded in the world (Hargreaves, 1948) [10]. In India, cotton crop is attacked by 12 major insect pests resulting in more than 50 percent of yield losses (Rao and Reddy, 1999) [23]. American cotton (*Gossypium hirsutum*) is highly susceptible to sucking insect pests and of which jassid, *A. biguttula biguttula* (Homoptera: Cicadellidae) is the most important and very serious pest reported to cause retardation in plant growth, deterioration of lint quality resulted in loss of cotton yield. The incidence of sucking pests was more or less similar in both *Bt* and non *Bt* hybrids. Reddy and Raju (1987) [24] reported that among 10 species of plant hoppers attacking cotton, the predominant cicadellids were *A. biguttula biguttula* [*A. devastans*] and *Batracomorphus* sp. Singh and Lakra (1992) [26] assessed the average reduction in yield of seed cotton due to *A. biguttula biguttula* [*A. devastans*] was 15.9 percent. Atakan (2009) [5] observed the numbers of fruit and cotton yield were significantly reduced due to leafhopper complex. Total losses of the fruiting parts (square plus boll) were ranging from 35 to 55 percent as well as cotton losses varied from 35 to 50 percent. Keeping these in view, attempts have been made to comprehensive information on population dynamics and correlation coefficient of *A. biguttula biguttula* and its natural enemies with weather parameters under rainfed conditions.

Materials and Methods

To study the effect of abiotic factors on population fluctuation of cotton jassid, the cotton variety GSB-21 were raised under rainfed condition in 413.10 m^2 size plot (20.40 m X 20.25 m) during *kharif* seasons of 2015-16 and 2016-17. The crop was sown under a spacing of 120 x 45 cm with 120 kg/ha nitrogen fertilizer application. During both *kharif* seasons, the crops were sown on 30th July, 2015 and 4th July, 2016. The experiment was conducted at Regional Cotton Research Station, Navsari Agricultural University, Maktampur farm, Bharuch, Gujarat (Plate-1). The geographic location of experiments was 21.712114° N latitude, 73.012777° E longitude and 21.711852° N latitude, 73.012114° E longitude during *kharif* seasons of 2015-16 and 2016-17, respectively. The plot was kept without any insecticidal spray to allow cotton jassid to multiply throughout the season.

Method of recording observations

For this study, fifty plants were randomly selected from net plot area. The populations of jassid were recorded at weekly interval staring from the 30 days after sowing till crop period. The numbers of nymph and adult of jassids were recorded from three leaves *i.e.* top, middle and bottom of each plant. The populations of natural enemies *viz.*, lady bird beetle, spider and *Chrysoperla* were also recorded. Weather data *viz.*, maximum temperature (°C), minimum temperature (°C), average temperature (°C), morning relative humidity(%), evening relative humidity(%), average relative humidity(%), wind speed (km/hr), sunshine hours, evaporation (mm), rainfall (mm) and rainy days recorded as per Standard Meteorological Week (SMW) at Meteorological Observatory, Regional Cotton Research Station, Navsari Agricultural University, Maktampur, Bharuch were obtained and used for the present study. The weather data thus obtained were correlated with population of jassid and natural enemies. Step wise regression analysis were worked out between above

listed weather parameters (X_1 to X_{11}) and population of jassid on GSB-21 cotton.

Results and Discussion

The results obtain during present studies are presented in Table 1 to 8 and depicted in Figure 1 and 2.

Population of Jassid

Being a key sucking pest of cotton, jassid was observed throughout crop season during 2015-16 (Table 1 and Figure 1). The lowest jassid population (3.14 jassids/3 leaves) was recorded during earlier crop season of 34th Standard Meteorological Week (SMW) and it remain active till end of crop season *i.e.* 4th SMW (end of January). Jassid population crossed ETL (> 6 jassids/ 3 leaves) first time during 36th SMW and continuously found above ETL till 2nd SMW (19 weeks *i.e.* first week of September to second week of January). The peak population (37.22 jassids/3 leaves) of jassid was recorded in 43rd SMW (end of October) and second peak (36.26 jassids/3 leaves) in 46th SMW (mid of November).

During second season of 2016-17; jassid population was below ETL ranging from 0.80 to 4.82 jassids per 3 leaves during initial crop stage *i.e.* 31st to 34th SMW (Table 4 and Figure 2). During younger crop stage, the population of jassid attained high (30.24 jassids/ 3 leaves) in 38th SMW (third week of September) while reached to its peak (38.48 jassids/ 3 leaves) in 46th SMW (mid of November). Population of jassid crossed the ETL first time during 35th SMW and continuously found above ETL till 51st SMW (17 weeks *i.e.* end of August to third week of December). Jassid population (5.78 to 3.44 jassids/ 3 leaves) was decreased towards crop maturity *i.e.* 52nd SMW onwards.

More or less similar trends of jassid incidence were reported by Prasad *et al.* (2008) [20] who observed the peak activity window of cotton leafhoppers from 37th to 47th standard week (first fortnight of September to November) in five different seasons at Guntur. The present findings are also in conformity with the findings of Neelima *et al.* (2012) [17] who reported that the cotton leafhopper, *A. devastans* was active all throughout the season and has crossed ETL several times. They observed three peaks population of leafhoppers *i.e.* 19.25, 23.80 and 15.80 per 3 leaves during 45th, 41st and 40th standard week in DCH 32, Bunny Bt and Bunny non Bt cotton, respectively. Further, Laxman *et al.* (2014) [14] have noted that leaf hopper infestation started from 3rd week of crop and acquired its peak in 21st week of crop. Panwar *et al.* (2014) [19] recorded the occurrence of jassid started in 31st MSW (ending 30th July) *i.e.* after three week of sowing and it remained throughout the crop growth period both in *Bt* and non *Bt* cotton variety Tulsi-171 at Indore. The pest population reached its peak with 1.25 and 2.5 jassids/leaf, respectively in 46th MSW (ending 12th November). Madankar *et al.* (2015) [15] noticed the population of jassid throughout the cotton growing season starting from seedling stage (SMW 29) to late harvesting in SMW 52 in RCH-2 *Bt* cotton hybrid at Akola. Moreover, Rajasekhar *et al.* (2015) [22] noticed the leafhopper population crossed economic threshold level (ETL) (6 no./3 leaves) during 39th (Sept. 24-30) to 50th (Dec.10-16) std. weeks in any of RCH 2 BG II, Mallika BG II hybrids and L 604 non-Bt variety.

Population of natural enemies

Among three natural enemies recorded during season of 2015-16, the lady bird beetle was observed during 38th to 4th SMW ranging from 0.04 to 1.34 per plant (Table 2 and Figure 1). The population of lady bird beetle was higher during later crop stage with its peak (1.34/ plant) in 48th SMW. Chrysoperla was observed during 37th to 2nd SMW ranging from 0.04 to 0.48 per plant with its peak in 46th SMW (mid of November). The population of spider was found almost entire crop period ranging from 0.06 to 0.46 per plant with its peak in 45th SMW.

During 2016-17, lady bird beetle was observed during 33rd to 2nd SMW ranging from 0.06 to 1.60 per plant (Table 5 and Figure 2). Higher population of lady bird beetle was recorded in later crop stage of 49th to 1st SMW (December and early January). Chrysoperla was observed initially from 36th SMW (0.04/ plant) and remained up to 51st SMW with peak population in 40th SMW (0.36/ plant). The population of spider was coincided with jassid incidence during entire crop season *i.e.* 31st to 2nd SMW ranging from 0.08 to 0.54 per plant with its peak in 43rd SMW (end of October).

The present findings are partially in agreement with the Radhika and Reddy (2007) [21] who reported that among natural enemies, ladybird beetle, green lacewing and Syrphid fly were the potential predators found to feed on the sucking pests attacking cotton. Furthermore, Gosalwad *et al.* (2009) [7] recorded the average population of cotton leafhopper and natural enemies and observed the maximum population of ladybird beetle (*Coccinella* spp.) in second week of September and November during two years, while green lace wing (*Chrysopa* spp.) in the second week of October. The present findings are contradictory to those of Ashfaq *et al.* (2011) [4] who recorded the highest density of 1.42 ladybird beetle, *Coccinella septempunctata* per leaf on 10th August, 0.56 spider, *Dictyna* sp. per leaf on 19th September. The pest of cotton and their natural enemies completely disappeared after mid-October. The present findings are in line with the findings of Kumar *et al.* (2016) [13] reported that the population of spiders was present throughout the crop season on all three cotton hybrids with mean number of 0.20 per plant. They also reported comparatively lower number of *Chrysoperla* (0.08/ plant) and *Coccinellid* (0.03/ plant), which are contrastingly with the present findings.

Correlation of weather parameters with population of jassid and natural enemies

Correlation study during 2015-16 revealed that jassid population showed highly significant positive association with maximum temperature (r= 0.669) and evaporation (r= 0.814) while significant negative association with wind speed (r= -0.509). The other weather parameters showed non-significant effects with jassid population. The jassid population showed highly significant positive correlation with chrysoperla (r= 0.821) and spider (r= 0.569) population however, non-significant positive correlation with lady bird beetle population. Among natural enemies, the lady bird beetle population showed highly significant negative correlation with minimum and average temperature, morning, evening and average relative humidity, wind speed and rainy days while significant positive correlation with sunshine hours. Chrysoperla and spider population showed significant negative correlation with wind speed while highly significant positive correlation with evaporation. Chrysoperla population also showed highly significant positive correlation with maximum temperature (Table 3).

The correlation study during 2016-17 indicates that jassid population showed highly significant positive association with maximum temperature (r= 0.623) and significant positive association with sunshine hours (r= 0.406) while significant negative association with wind speed (r= -0.440). The other weather parameters showed non-significant effects with jassid population. The jassid population showed highly significant positive correlation with chrysoperla (r= 0.759) and spider (r= 0.827) population however, non-significant positive correlation with lady bird beetle population. Among natural enemies, the lady bird beetle population showed highly significant negative correlation with minimum and average temperature, morning, evening and average relative humidity, wind speed and rainy days; significant negative correlation with rainfall while highly significant positive correlation with sunshine hours and significant positive correlation with evaporation. Chrysoperla population only showed significant positive correlation with maximum temperature. Spider population showed highly significant positive correlation with maximum temperature and significant positive correlation with sunshine hours while significant negative correlation with rainy days (Table 6).

The pooled data of two years revealed that jassid population showed highly significant positive association with maximum temperature (r= 0.537) and evaporation (r= 0.439) as well as significant positive association with sunshine hours (r= 0.326). Jassid population also showed highly significant negative correlation with wind speed (r= -0.464) and significant negative correlation with rainy days (r= -0.293). The population of jassid showed non-significant positive correlation with minimum and average temperature while non-significant negative correlation with morning, evening, average relative humidity and rainfall. The jassid population showed highly significant positive correlation with chrysoperla (r= 0.725) and spider (r= 0.707) population implying increase in jassid population with corresponding increase of chrysoperla and spider population and *vice-versa*. The jassid population showed non-significant positive correlation with lady bird beetle population. The correlation between weather parameters and natural enemies revealed that, the population of lady bird beetle showed highly significant negative association with minimum and average temperature, morning, evening and average relative humidity, wind speed, rainfall and rainy days while highly significant positive association with sunshine hours and significant positive association with evaporation. The population of chrysoperla showed highly significant positive correlation with maximum temperature and significant positive correlation with evaporation while highly significant negative correlation with wind speed as well as significant negative correlation with rainy days. The population of spider showed highly significant positive correlation with evaporation as well as significant positive correlation with maximum temperature and sunshine hours while highly significant negative correlation with wind speed as well as significant negative correlation with rainy days. The other weather parameters showed non-significant effects with the population of chrysoperla and spider (Table 7).

More or less similar correlations of weather parameters and jassid population are reported by many workers. Gosalwad *et al.* (2009) [7] studied that the cotton leafhopper incidence showed significant positive correlation with evapotranspiration while significant negative correlation with

morning and evening relative humidity. Ashfaq *et al.* (2010) [3] indicated significant positive correlation between the air temperature and jassids, on all cotton genotypes tested however, the relative humidity and rainfall showed non-significant negative correlation on seven and eight genotypes, respectively. Further, Shivanna *et al.* (2011) [25] and Bhute *et al.* (2012) [6] showed significant positive correlation of maximum temperature with jassids population in transgenic cotton. Kadam *et al.* (2015) [11] noticed that cotton jassid showed significant positive correlation with maximum temperature whereas, significant negative correlation with relative humidity and rainfall.

However, the present findings are not in support with the findings of Radhika and Reddy (2007) [21], Mohapatra (2008) [16] and Kalkal *et al.* (2013) [12]. They reported that effect of rainfall was favourable for the activity of cotton leafhopper. Further, Laxman *et al.* (2014) [14] noted that leaf hopper infestation in Bt and non Bt cotton showed significant negative correlation with maximum, minimum temperature and rainfall.

The present finding of correlation of weather parameters and natural enemies with jassid incidence is in close agreement with Madankar *et al.* (2015) [15] who observed that green lace wing showed positive correlation with jassid peak incidence in RCH-2 *Bt* cotton hybrid at Akola. Similarly Nemade *et al.* (2015) [18] reported that the maximum temperature was significantly positively correlated with chrysopa and spider population on *Bt* cotton. Among natural enemies, the coccinellid and spider showed significant positive whereas chrysopa showed non-significant positive correlation with leaf hopper population. Contrastingly, they reported that the rainfall was very favourable for the population buildup of leaf hoppers and coccinellids on *Bt* cotton.

Step wise regression equation

The step wise regression analysis presented in Table 8 indicated that the influence of weather parameters was high, it was upto 69.0 percent (R^2= 0.690) on the population of jassid during *Kharif* 2015 while the influence of weather parameters was low, it was upto 49.6 percent (R^2= 0.496) on the population of jassid during *Kharif* 2016. The step wise regression analysis of two seasons indicated that the influence of weather parameters was upto 42.5 percent (R^2= 0.425) on the population of jassid.

Present results are more or less supported by Prasad *et al.* (2008) [20] showed the multiple linear regression analysis indicated that the total influence of all the weather parameters was high and significant, it was upto 51.78 percent (R^2=0.5178) on the population of leafhoppers. Further, Hameed *et al.* (2014) [9] noted the multi variable 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 percent role.

Table 1: Population of jassid on GSB-21 cotton as well as weather parameters under rainfed condition at Bharuch during 2015-16

SMW	Period	WAS	Mean number of jassids/ 3 leaves	Temperature (^{0}C)			Relative humidity (%)			Wind speed (km/hr)	Sun shine (hr)	Evaporation (mm)	Rainfall (mm)	Rainy days
				T Max.	T Min.	T Av.	RHM or.	RHE ve.	RHA v.					
33	13.08.15 to 19.08.15	-	-	32.3	25.4	28.9	85.3	72.0	78.6	7.8	2.4	4.2	14.8	2
34	20.08.15 to 26.08.15	3	3.14	33.9	26.1	30.0	78.3	54.0	66.1	10.7	7.6	4.9	0.0	0
35	27.08.15 to 02.09.15	4	5.86	34.0	25.5	29.7	82.6	56.4	69.5	7.9	7.5	5.3	14.6	2
36	03.09.15 to 09.09.15	5	9.20	34.3	24.6	29.4	79.7	46.6	63.1	4.9	8.4	5.7	0.0	0
37	10.09.15 to 16.09.15	6	13.88	35.3	25.9	30.6	83.1	54.6	68.9	4.8	5.0	6.3	6.8	2
38	17.09.15 to 23.09.15	7	9.32	31.3	24.9	28.1	89.0	80.0	84.5	8.5	3.0	5.3	115.6	4
39	24.09.15 to 30.09.15	8	12.26	33.1	24.2	28.6	74.9	50.6	62.7	2.8	7.7	5.8	0.0	0
40	01.10.15 to 07.10.15	9	17.28	36.4	24.6	30.5	77.3	40.9	59.1	2.5	8.0	6.9	0.0	0
41	08.10.15 to 14.10.15	10	15.02	37.3	24.4	30.9	77.3	37.7	57.5	2.1	7.6	7.6	0.0	0
42	15.10.15 to 21.10.15	11	23.06	38.1	24.0	31.1	67.1	31.6	49.4	1.4	8.9	7.8	0.0	0
43	22.10.15 to 28.10.15	12	37.22	36.7	22.8	29.7	71.0	36.7	53.9	2.1	8.4	7.7	0.0	0
44	29.10.15 to 04.11.15	13	32.60	34.0	20.7	27.3	66.9	42.0	54.4	5.1	8.6	7.6	0.0	0
45	05.11.15 to 11.11.15	14	31.44	35.4	20.2	27.8	66.6	29.6	48.1	0.7	7.8	6.4	0.0	0
46	12.11.15 to 18.11.15	15	36.26	35.1	19.8	27.5	60.3	28.3	44.3	2.9	8.3	6.3	0.0	0
47	19.11.15 to 25.11.15	16	32.32	34.1	19.9	27.0	67.4	40.0	53.7	3.7	6.3	6.0	0.0	0
48	26.11.15 to 02.12.15	17	26.58	33.1	19.7	26.4	65.9	31.3	48.6	2.9	7.3	6.6	0.0	0
49	03.12.15 to 09.12.15	18	21.20	33.5	15.9	24.7	68.6	27.1	47.9	1.4	8.6	5.1	0.0	0

50	10.12.15 to 16.12.15	19	15.68	29.5	14.8	22.2	63.9	30.7	47.3	4.6	8.3	5.4	0.0	0
51	17.12.15 to 23.12.15	20	12.04	28.8	12.5	20.6	54.6	25.9	40.2	4.8	8.8	5.3	0.0	0
52	24.12.15 to 31.12.15	21	7.74	30.6	13.0	21.8	56.6	22.4	39.5	3.8	8.5	4.6	0.0	0
01	01.01.16 to 07.01.16	22	6.56	32.8	15.1	24.0	64.1	23.0	43.6	2.1	8.9	5.3	0.0	0
02	08.01.16 to 14.01.16	23	6.10	31.2	15.2	23.2	73.4	30.4	51.9	2.7	8.6	5.2	0.0	0
03	15.01.16 to 21.01.16	24	5.16	29.0	13.8	21.4	69.5	27.0	48.3	3.7	7.7	5.0	0.0	0
04	22.01.16 to 28.01.16	25	4.64	29.5	12.5	21.0	56.7	22.8	39.8	3.4	9.4	5.2	0.0	0

SMW- Standard Meteorological Week, WAS – Weeks after Sowing, T $_{Max}$.- Maximum temperature, T $_{Min}$.- Minimum temperature, T $_{Av}$.- Average temperature, RH $_{Mor}$.- Morning relative humidity, RH $_{Eve}$.- Evening relative humidity, RH $_{Av}$.- Average relative humidity

Table 2: Population of jassid and natural enemies on GSB-21 cotton under rainfed condition at Bharuch during 2015-16

SMW	Period	WAS	Mean number of jassids/ 3 leaves	Number of natural enemies/ plant		
				Lady bird beetle	Chrysoperla	Spider
34	20.08.15 to 26.08.15	3	3.14	0	0	0
35	27.08.15 to 02.09.15	4	5.86	0	0	0.06
36	03.09.15 to 09.09.15	5	9.20	0	0	0
37	10.09.15 to 16.09.15	6	13.88	0	0.08	0.14
38	17.09.15 to 23.09.15	7	9.32	0.04	0.06	0.38
39	24.09.15 to 30.09.15	8	12.26	0.18	0.10	0.22
40	01.10.15 to 07.10.15	9	17.28	0.36	0.26	0.14
41	08.10.15 to 14.10.15	10	15.02	0.56	0.40	0.36
42	15.10.15 to 21.10.15	11	23.06	0.74	0.18	0.26
43	22.10.15 to 28.10.15	12	37.22	0.60	0.34	0.20
44	29.10.15 to 04.11.15	13	32.60	0.92	0.46	0.34
45	05.11.15 to 11.11.15	14	31.44	1.08	0.20	0.46
46	12.11.15 to 18.11.15	15	36.26	1.02	0.48	0.30
47	19.11.15 to 25.11.15	16	32.32	1.16	0.24	0.40
48	26.11.15 to 02.12.15	17	26.58	1.34	0.38	0.24
49	03.12.15 to 09.12.15	18	21.20	1.26	0.34	0.38
50	10.12.15 to 16.12.15	19	15.68	1.20	0.16	0.42
51	17.12.15 to 23.12.15	20	12.04	1.04	0.26	0.20
52	24.12.15 to 31.12.15	21	7.74	1.24	0.08	0.26
01	01.01.16 to 07.01.16	22	6.56	1.30	0	0.14
02	08.01.16 to 14.01.16	23	6.10	1.02	0.04	0.22
03	15.01.16 to 21.01.16	24	5.16	0.94	0	0.10
04	22.01.16 to 28.01.16	25	4.64	0.72	0	0.14

SMW- Standard Meteorological Week, WAS – Weeks after Sowing

Table 3: Correlation of weather parameters and natural enemies with population of jassid on GSB-21 cotton at Bharuch during 2015-16

Parameters	Correlation coefficient ('r' values)											
	Jassids	Weather parameters										
		Temperature (^{0}C)			Relative humidity (%)			Wind speed (km/hr)	Sun shine (hr)	Evapo-ration (mm)	Rainfall (mm)	Rainy days
		Max.	Min.	Av.	Mor.	Eve.	Av.					
Jassids	-	0.669**	0.215	0.407	-0.262	-0.222	-0.244	-0.509*	0.262	0.814**	-0.148	-0.295
Lady bird beetle	0.351	-0.185	-0.765**	-0.607**	-0.866**	-0.798**	-0.850**	-0.623**	0.514*	0.183	-0.345	-0.583**
Chrysoperla	0.821**	0.535**	0.151	0.311	-0.237	-0.232	-0.241	-0.570**	0.201	0.703**	-0.172	-0.336
Spider	0.569**	0.332	-0.111	0.049	-0.341	-0.343	-0.353	-0.513*	0.231	0.610**	-0.105	-0.229

* Significant at 5% level of significance, ** Significant at 1% level of significance, Total number of observations = 23, r (0.05) = 0.412
r (0.01) = 0.526

Table 4: Population of jassid on GSB-21 cotton as well as weather parameters under rainfed condition at Bharuch during 2016-17

SMW	Period	WAS	Mean number of jassids/ 3 leaves	Temperature (^{0}C)			Relative humidity (%)			Wind speed (km/hr)	Sun shine (hr)	Evaporation (mm)	Rainfall (mm)	Rainy days
				TMax.	TMin.	TAv.	RHMor.	RHEve.	RHAv.					
30	23.07.16 to 29.07.16	-	-	31.3	25.9	28.6	87.7	74.1	80.9	5.9	1.2	6.7	17.7	4
31	30.07.16 to 05.08.16	4	0.80	30.6	25.8	28.2	88.4	79.7	84.1	9.1	1.3	3.6	28.2	6
32	06.08.16 to 12.08.16	5	4.24	29.2	25.5	27.3	89.9	81.7	85.8	10.4	1.1	3.9	38.6	6
33	13.08.16 to 19.08.16	6	3.66	32.9	25.5	29.2	79.6	62.0	70.8	11.2	4.2	6.8	0.0	0
34	20.08.16 to 26.08.16	7	4.82	30.8	25.5	28.1	87.3	73.4	80.4	10.2	2.4	3.6	9.6	2
35	27.08.16 to 02.09.16	8	10.16	30.6	25.7	28.2	89.9	70.1	80.0	5.4	3.3	4.2	15.8	4
36	03.09.16 to 09.09.16	9	7.90	32.0	24.9	28.5	85.3	59.6	72.4	7.2	5.9	6.5	11.6	2
37	10.09.16 to 16.09.16	10	27.56	33.1	25.0	29.0	83.9	58.0	70.9	4.4	7.5	8.5	12.0	1
38	17.09.16 to 23.09.16	11	30.24	29.7	24.6	27.2	81.0	79.9	80.4	2.9	1.4	2.8	62.2	4
39	24.09.16 to 30.09.16	12	18.50	31.8	24.6	28.2	89.9	66.0	77.9	4.8	6.1	7.6	18.4	1
40	01.10.16 to 07.10.16	13	27.02	30.6	24.9	27.8	91.3	76.9	84.1	3.1	2.8	3.9	111.4	4
41	08.10.16 to 14.10.16	14	26.36	31.7	24.6	28.2	88.6	65.3	76.9	1.3	6.3	6.8	3.2	1
42	15.10.16 to 21.10.16	15	27.42	33.6	20.5	27.1	76.6	40.6	58.6	0.6	8.5	7.0	0.0	0
43	22.10.16 to 28.10.16	16	30.92	33.3	19.6	26.4	73.0	36.1	54.6	0.5	8.9	8.8	0.0	0
44	29.10.16 to 04.11.16	17	36.04	33.4	15.9	24.6	65.4	30.3	47.9	0.5	9.0	6.5	0.0	0
45	05.11.16 to 11.11.16	18	34.10	33.0	13.9	23.4	76.4	28.6	52.5	0.3	8.2	5.5	0.0	0
46	12.11.16 to 18.11.16	19	38.48	32.7	15.9	24.3	66.6	32.6	49.6	0.5	8.7	6.5	0.0	0
47	19.11.16 to 25.11.16	20	29.34	33.1	13.1	23.1	72.3	24.4	48.4	0.5	9.1	7.9	0.0	0
48	26.11.16 to 02.12.16	21	18.90	33.4	13.7	23.5	68.6	27.0	47.8	0.3	9.4	7.6	0.0	0
49	03.12.16 to 09.12.16	22	21.12	31.8	14.6	23.2	71.3	34.9	53.1	1.6	8.6	7.4	0.0	0
50	10.12.16 to 16.12.16	23	10.88	32.1	13.5	22.8	69.0	31.3	50.1	1.0	8.9	7.1	0.0	0
51	17.12.16 to 23.12.16	24	9.20	31.1	13.5	22.3	71.4	29.6	50.5	0.5	8.7	6.0	0.0	0
52	24.12.16 to 31.12.16	25	5.78	30.3	11.5	20.9	76.1	32.4	54.3	1.3	8.7	7.6	0.0	0
01	01.01.17 to 07.01.17	26	3.38	31.3	11.9	21.6	75.1	32.7	53.9	0.5	8.6	7.7	0.0	0
02	08.01.17 to 14.01.17	27	3.44	27.3	12.3	19.8	70.7	33.6	52.1	2.6	8.2	6.1	0.0	0

SMW- Standard Meteorological Week, WAS – Weeks after Sowing, T $_{Max.}$- Maximum temperature, T $_{Min.}$- Minimum temperature, T $_{Av.}$- Average temperature, RH $_{Mor.}$- Morning relative humidity, RH $_{Eve.}$- Evening relative humidity, RH $_{Av.}$- Average relative humidity

Table 5: Population of jassid and natural enemies on GSB-21 cotton under rainfed condition at Bharuch during 2016-17

SMW	Period	WAS	Mean number of jassids/ 3 leaves	Number of natural enemies/ plant		
				Lady bird beetle	Chrysoperla	Spider
31	30.07.16 to 05.08.16	4	0.80	0	0	0.12
32	06.08.16 to 12.08.16	5	4.24	0	0	0.10
33	13.08.16 to 19.08.16	6	3.66	0.06	0	0.16
34	20.08.16 to 26.08.16	7	4.82	0	0	0.22
35	27.08.16 to 02.09.16	8	10.16	0.14	0	0.18
36	03.09.16 to 09.09.16	9	7.90	0.10	0.04	0.20
37	10.09.16 to 16.09.16	10	27.56	0.16	0.12	0.36

38	17.09.16 to 23.09.16	11	30.24	0.22	0.10	0.24
39	24.09.16 to 30.09.16	12	18.50	0.14	0.18	0.16
40	01.10.16 to 07.10.16	13	27.02	0.24	0.36	0.44
41	08.10.16 to 14.10.16	14	26.36	0.36	0.14	0.24
42	15.10.16 to 21.10.16	15	27.42	0.54	0.22	0.40
43	22.10.16 to 28.10.16	16	30.92	0.80	0.26	0.54
44	29.10.16 to 04.11.16	17	36.04	0.76	0.16	0.48
45	05.11.16 to 11.11.16	18	34.10	1.02	0.30	0.36
46	12.11.16 to 18.11.16	19	38.48	0.98	0.14	0.42
47	19.11.16 to 25.11.16	20	29.34	0.82	0.10	0.46
48	26.11.16 to 02.12.16	21	18.90	1.06	0.18	0.20
49	03.12.16 to 09.12.16	22	21.12	1.44	0.04	0.28
50	10.12.16 to 16.12.16	23	10.88	1.60	0.06	0.22
51	17.12.16 to 23.12.16	24	9.20	1.32	0.10	0.08
52	24.12.16 to 31.12.16	25	5.78	1.46	0	0.14
01	01.01.17 to 07.01.17	26	3.38	1.14	0	0.22
02	08.01.17 to 14.01.17	27	3.44	0.90	0	0.18

SMW- Standard Meteorological Week, WAS – Weeks after Sowing

Table 6: Correlation of weather parameters and natural enemies with population of jassid on GSB-21 cotton at Bharuch during 2016-17

Parameters	Jassids	Temperature (^{0}C)			Relative humidity (%)			Wind speed (km/hr)	Sun shine (hr)	Evapo-ration (mm)	Rainfall (mm)	Rainy days
		Max.	Min.	Av.	Mor.	Eve.	Av.					
Jassids	-	0.623**	-0.027	0.117	-0.189	-0.251	-0.239	-0.440*	0.406*	0.251	-0.006	-0.354
Lady bird beetle	0.114	0.385	-0.922**	-0.881**	-0.826**	-0.894**	-0.893**	-0.792**	0.839**	0.486*	-0.456*	-0.715**
Chrysoperla	0.759**	0.418*	0.043	0.146	-0.070	-0.107	-0.099	-0.390	0.279	0.212	0.050	-0.259
Spider	0.827**	0.592**	-0.042	0.097	-0.170	-0.280	-0.253	-0.366	0.437*	0.368	-0.236	-0.440*

* Significant at 5% level of significance, ** Significant at 1% level of significance, Total number of observations = 24, r (0.05) = 0.403, r (0.01) = 0.515

Table 7: Correlation of weather parameters and natural enemies with population of jassid on GSB-21 cotton (Pooled of 2015-16 and 2016-17)

Parameters	Jassids	Temperature (^{0}C)			Relative humidity (%)			Wind speed (km/hr)	Sun shine (hr)	Evapo-ration (mm)	Rainfall (mm)	Rainy days
		Max.	Min.	Av.	Mor.	Eve.	Av.					
Jassids	-	0.537**	0.071	0.249	-0.181	-0.212	-0.207	-0.464**	0.326*	0.439**	-0.061	-0.293*
Lady bird beetle	0.212	0.054	-0.845**	-0.697**	-0.801**	-0.837**	-0.848**	-0.707**	0.711**	0.358*	-0.413**	-0.644**
Chrysoperla	0.725**	0.548**	0.108	0.286	-0.257	-0.226	-0.243	-0.403**	0.268	0.352*	-0.110	-0.313*
Spider	0.707**	0.314*	-0.078	0.045	-0.178	-0.248	-0.230	-0.424**	0.305*	0.453**	-0.152	-0.294*

* Significant at 5% level of significance, ** Significant at 1% level of significance, Total number of observations = 47, r (0.05) = 0.287 r (0.01) = 0.372

Table 8: Step wise regression analysis between weather parameters and population of jassid on GSB-21 cotton under rainfed condition at Bharuch

Regression equation	R^2
***Kharif* 2015**	
$Y = -42.065 + 0.675\ X_1 - 0.706\ X_7 + 6.596\ X_9$	0.690
***Kharif* 2016**	
$Y = -202.268 + 7.562\ X_1 - 1.828\ X_7 - 2.249\ X_8$	0.496
Mean of two seasons *Kharif* 2015 and 2016	
$Y = -60.291 + 2.424\ X_1 - 1.523\ X_7 - 0.420\ X_8 + 1.060\ X_9 + 0.773\ X_{11}$	0.425

Where   Y - Jassid population (number of jassids/ 3 leaves)

X1 - Maximum temperature

X7 - Wind speed

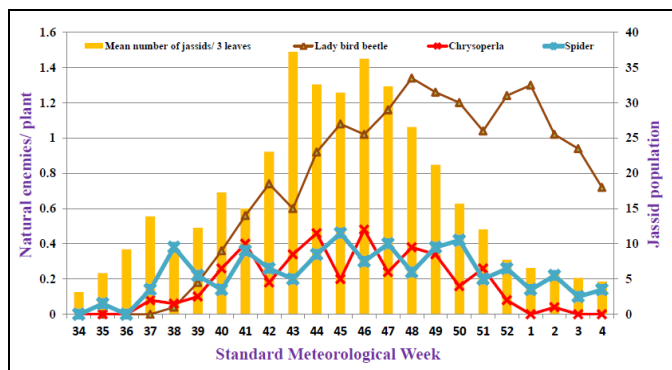X8 - Sunshine

X9 - Evaporation

X11- Rainy days

Fig 1: Population of jassid and natural enemies on GSB-21 cotton under rainfed condition during 2015-16
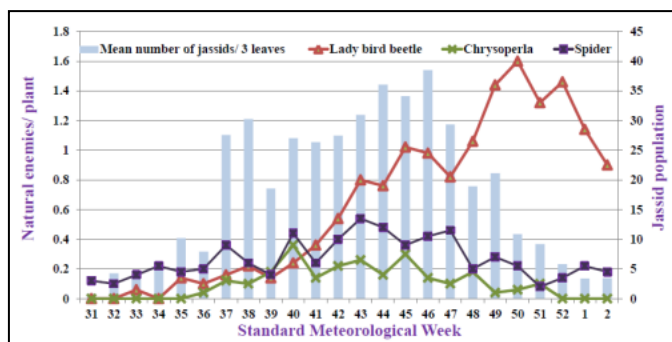

Fig 2: Population of jassid and natural enemies on GSB-21 cotton under rainfed condition during 2016-17

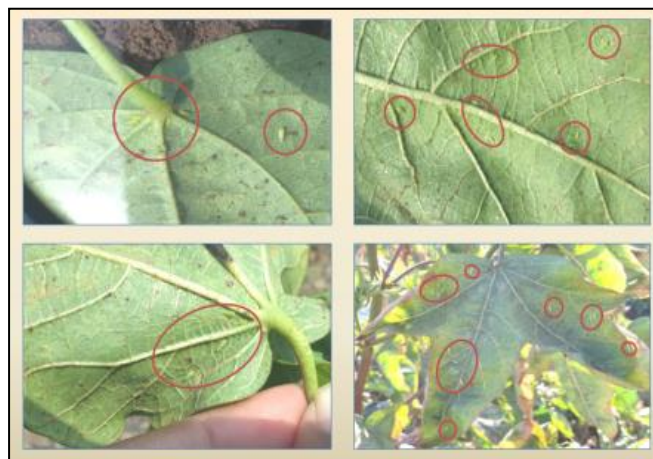**Plate 1:** General view of population dynamics experimental plot

Plate 2: Population of *A. biguttula biguttula* on cotton leaves

Plate 3: Population of natural enemies on cotton plant

Conclusion

Jassid, a key sucking pest of cotton was observed throughout crop season and remained above threshold level during many weeks. The jassid population showed significant positive correlation with maximum temperature, evaporation and sunshine hours whereas, significant negative correlation with wind speed and rainy days. The jassid population showed highly significant positive correlation with chrysoperla and spider population while non-significant positive correlation with lady bird beetle population on cotton crop.

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