International Journal of Zoology and Applied Biosciences **ISSN: 2455-9571**
Volume 2, Issue 6, pp: 370-376, 2017
http://www.ijzab.com
https://doi.org/10.5281/zenodo.1312789
Research Article

WEATHER FACTORS RESPONSIBLE FOR THE POPULATION DYNAMICS OF BROWN MIRID BUG, CREONTIADES BISERATENSE DISTANT (HEMIPTERA: MIRIDAE) IN BT COTTON

P. Saravanan[1*], A. Karthikeyan[1], B. Padmanaban[2], and A. Nagasathiya[3]

[1]Department of Zoology, Government Arts College (Affiliated to Bharathidasan University), Karur-639005, Tamil Nadu, India

[2]Department of Plant Protection, ICAR-National Research Centre for Banana, Tiruchirappalli-620102, Tamil Nadu, India

[3]Department of Zoology, Government Arts College for Women (Affiliated to Bharathidasan University), Pudukkottai-622001, Tamil Nadu, India

Article History: Received 13th November 2017; Accepted 22nd November 2017; Published 14th December 2017

ABSTRACT

The brown mirid bug C*reontiades biseratense* Distant has recently emerged as a predominant pest in *Bt* cotton in central and southern parts of India. A study was carried out to determine the key weather parameters on the population dynamics of mirid bug *C. biseratense* in *Bt* cotton in Perambalur district of Tamil Nadu, India during 2014-2016. The study indicated that 0.64 miridbugs/plant was recorded during 37th standard metrological week of 2014-2015 with the weather parameters of maximum temperature (35.44°C), minimum temperature (25.53°C), relative humidity (71.29 %) and rainfall (49.0 mm) which increased to 4.32 mirid bugs/plant during 46th standard metrological week of 2014-2015 with the weather parameters of maximum temperature (31.7°C), minimum temperature (24.31°C), relative humidity (69.43 %) and rainfall (239.5 mm). Thereafter the population was agitated from 46th to 48th standard metrological week and attained the maximum incidence of 4.53 mirid bugs/plant during 49th standard metrological week with the weathers parameters of maximum temperature (31.07°C), minimum temperature (21.97°C), relative humidity (72.61 %) and rainfall (58.5 mm) during 2014-2015 whereas the maximum incidence of 4.476 mirid bugs/plant was recorded with the weather parameters of maximum temperature (28.71°C), minimum temperature (22.86°C), relative humidity (74.32 %) and rainfall (131.72 mm) during 46th standard meteorological week of 2015-2016. The population declined gradually from 50th and 46th standard metrological week during 2014-2015 and 2015-2016 respectively. The simple correlation studies indicated that the significant negative correlation with maximum temperature, minimum temperature and positive correlation with relative humidity and rainfall during the consecutive seasons from 2014-2016 in *Bt* cotton.

Keywords: *Bt* cotton, Mirid bug, C*reontiades biseratense***,** Weather parameters.

INTRODUCTION

Transgenic crops producing *Bacillus thuringiensis* (*Bt*) toxins for insect pest control have been successful and started paying lucrative returns to the farmers in terms of increased production due to low pest damage, savings in cost of pesticides and manpower involved in pest control. *Bt* cotton contains genes from *B. thuringiensis* that make the plant resistant to the cotton bollworm complex. This inbuilt insect resistant can lead to savings in chemical pest control and higher effective yields (Qaim and Zilberman, 2003). Improving the use of biotechnological and classical plant resistance for herbivore pest control with less reliance on chemicals critically depends on predictable interactions with secondary pests. The status of the minor pest can evolve according to the agricultural practices used by farmers (Lu *et al*., 2010a). In crop protection, when the primary pest is targeted, other species are likely to rise in

*Corresponding Author: Mr. P. Saravanan, Research Scholar, Department of Zoology, Government Arts College (Affiliated to Bharathidasan University), Karur-639005, Tamil Nadu, India, Email: vengaisaran@gmail.com, Mobile: +91 9944244582

its ecological place and multiply. For example, cotton aphid (*Aphis gossypii*) evolved as a primary pest of cotton in the mid-1970s because of intensive insecticide use for *Helicoverpa armigera* (Hubner) control (Wu and Guo, 2005).

Bambawale *et al*. (2004) and Arshad and Suhail (2010) reported that transgenic *Bt* cotton had no impact on the sucking pest population. Development of resistance to *Bt* cotton, resurgence of sap sucking insects and cotton stainers and poor activity of *Spodoptera* sp. are the problems associated with *Bt* cotton. The pest scenario of cotton ecosystem is changing fast and is assailed by multitude of pests as it evolves through various production levels. Adoption of *Bt* cotton has not only changed the cultivation profile, but also changed the pest scenario too, while there is a decline in the pest status of bollworms. But the sap feeders viz., aphids, jassids, mirids and mealy bugs are emerging as serious pests, and gaining an upper hand in pest spectrum (Vennila, 2008). The *Bt* cotton currently released in India is only moderately toxic to the caterpillar. It is known that the use of synthetic pyrethroids has significant negative impacts on the populations of *Spodopter*a sp. and several other miscellaneous bugs such as the mirid bugs, *Creontiades biseratense* Distant (*Megacoelum=Lygus biseretensis*). The reduction of pyrethroids and several conventional insecticides on *Bt*-cotton is expected to result in the increase of several non-target species (Berge and Ricroch, 2010). Introduction of several *Bt*-cotton hybrids, most of which were susceptible to insect pests has resulted in increased damage by sucking pests such as leafhoppers, whiteflies, thrips, mealy bugs and mirid bugs in India (Nagrarae *et al.*, 2014).

Cotton is attacked by several mirid species, which cause significant losses in quality and quantity of cotton at different phonological stages. Recently, both the occurrence of mired bugs and the damage caused by these insects has progressively increased in cotton and other host crops (Lu *et al*., 2010a). Previously these have not been historically referred as key pests of cotton but mirid bugs have assumed key status only after widespread cultivation of *Bt* cotton hybrid in Karnataka andAndhra Pradesh. The apple dimpling bug, *Campyloma livida* (Reuter) is a dominant species in Maharastra; however it is noticed in Karnataka also. *Hyalopeplus linefer* (Walker) is recorded in Karnataka and Maharastra but not as regular pest (Udikeri, 2008). Almost all the cultivated species of *Bt* cotton hybrids are affected by miridbugs. The mirid bug *Poppiocapsidea* (=*Creontiades*) *biseratense* Distant (Miridae: Hemiptera) has recently gained more attention from scientific and farming community due to its dangerous damaging symptoms. The pest was just recorded as a minor pest, but it has gained importance during recent years and it was reported in 2005 in Karnataka and resulted in considerable damage to *Bt* cotton (Patil *et al*., 2006). Also Saravanan *et al*. (2014) reported that the incidence of *C. biseratense and C. livida* in Perambalur district of Tamil Nadu occurred in 2008 and 2010 respectively and the population increased year by year. As the mirid bugs are known to attack fruiting bodies leading to shedding of squares and tender bolls, results in drastic reduction in seed cotton yield. Crop losses of up to 54 % have been reported for those stages by Stamp (1987). However, Mehdi and Mohammad (2004) reported losses as high as 82 % if the pest attacked during flowering.

Understanding insect population dynamics can be very challenging due to the large number of biotic and abiotic factors. Of these factors, temperature, rainfall and relative humidity strongly affect the survival, development, fecundity and behavior of individual insects (Wilstermann and Vidal, 2013; Dong *et al*., 2013) and the population dynamics of insects (Shang *et al*., 2010). Previous studies showed that temperature and relative humidity strongly affect survival, development, fecundity, and life-history traits of laboratory populations of miridbug *Apolygus lucorum* in China (Lu *et al*., 2010b, Lu and Wu, 2011).

However, the information on its relationship between population dynamics of brown mirid bug *C. biseratense* and weather factors is still fragmentary in India and reports are very meagre. The aim of this study was to test the hypothesis that weather factors played a pivotal role in the population dynamics of brown mirid bug *C.biseratense* in *Bt* cotton during 2014-2016 season. From the study we quantified the importance of weather variables on the population dynamics of mirid bug.

MATERIALS AND METHODS

Study area

Random surveys were performed from 2014-2015 and consecutive season in *Bt* cotton fields of Perambalur District of Tamil Nadu, India. The distance between surveyed fields with in the same location was changed upon the presence of cotton fields and phonological similarity of the crop ranged between two to twenty five kms. Ten different fields were selected from five different intensive *Bt* cotton growing villages for the study. The altitude and geographic coordinates of each selected fields were recorded with a handheld Garmin e-trex, 12 channel global positioning system (GPS). The same fields were used for the study in two consecutive seasons of 2014-2016.

Field experiment

MRC 7918 BG II *Bt* cotton hybrid (Maharastra Hybrid Seed Company Limited, Mumbai) were selected for the study. The transgenic cotton hybrid contains cry1Ac & cry2Ab genes. The *Bt* cotton hybrid seeds were dibbled in each selected field during 34th standard week of 2014-2015 and 2015-2016 season. The size of each field was about 0.4 hectare area and the seeds were sown 120 cm row to row and 90 cm plant to plant distances respectively. All recommended pre-sowing and post-sowing agronomical package of practices meant for rainfed cotton farming were followed from time to time to raise the crop successfully as per package of practices prescribed by Tamil Nadu Agricultural University, Tamil Nadu, India except pesticide spray. Two insecticidal sprays, first of Thiamethoxam 25% WG 0.2 gm/l at 78 days after sowing (DAS) and second of Acetamiprid 20 SP (0.2 gm/l) at 93 DAS to check rising population of sucking pests, and two sprays of fungicide Carbendazim 50% WP (1 g/l) at 79 & 109 DAS against fungal disease were applied.

Sampling procedures

The data on population dynamics of Mirid bug were recorded at weekly intervals throughout the season in two consecutive years (2014-2016). The number of mirid bugs per plant was recorded in 10 randomly selected plants in each fixed field and these observations were taken till harvest of the cotton crop. Simultaneously, weather parameters pertaining to maximum temperature (°C), minimum temperature (°C), relative humidity (%) and rainfall (mm) in different standard weather weeks were recorded during the cropping season of 2014-2015 and 2015-2016 with the help of weather stations in ICAR-Krishi Vigyan Kendra, Perambalur and Cotton Research Station (Tamil Nadu Agricultural University), Perambalur, Tamil Nadu, India for this study. Average population per plant in each field was calculated and converted in to district mean population. The relationship between population dynamics of brown mirid bug *C. biseratense* in *Bt* cotton and weather parameters was worked out by using simple correlation method.

RESULTS

The study indicated that 0.64 mirid bugs /plant was recorded during 37th standard metrological week with the weather parameters of maximum temperature (35.44°C), minimum temperature (25.53°C), relative humidity (71.29 %) and rainfall (49.0 mm). The incidence of brown mird bug was initiated during the initiation of square and flowering stage of the *Bt* cotton crop. The population of mirid bug increased to4.32 mirid bugs/plant during 46th standard metrological week of 2014-2015 with the weather parameters of maximum temperature (31.7°C), minimum temperature (24.31°C), relative humidity (69.43%) and rain fall (239.5 mm). Thereafter the population was agitated from 46th to 48th standard metrological week and attained the maximum incidence of 4.53 mirid bugs/plant during 49th standard metrological week with the weathers parameters of maximum temperature (31.07°C), minimum temperature (21.97°C), relative humidity (72.61%) and rain fall (58.5 mm) during 2014-2015 whereas the maximum incidence of 4.476 mirid bugs/plant was recorded with the weather parameters of maximum temperature (28.71°C), minimum temperature (22.86°C), relative humidity (74.32 %) and rainfall (131.72mm) during 46th standard meteorological week of 2015-2016 . The population was declined gradually from 50th to 7th standard metrological week and zero incidence were recorded from 8th to 12th standard metrological week during 2014-2015 whereas the mirid bug population were decreasing trend from 46th to 8th standard metrological week during 2015-2016. The results of the study were tabulated as Table 1&2. The simple correlation studies between the mirid bug population and weather parameters indicated that the significant negative correlation with maximum temperature, minimum temperature and positive correlation with relative humidity and rainfall during the consecutive seasons from 2014-2016 in *Bt* cotton (Table 3).

Table 1. Weather factors and the population dynamics of brown mirid bug, *Creontiades biseratense* in *Bt* cotton during 2014-2015.

Std Metrological week	Mirid bug Population (Nos/plant)	Maximum Temperature (ºC)	Minimum Temperature (ºC)	Relative Humidity (%)	Rainfall (mm)
35	0	36.32	24.67	65.81	208
36	0	34.3	25.97	66.98	290.1
37	0.64 (1.28)	35.44	25.53	71.29	49
38	0.85 (1.36)	35.54	24.17	67.47	19
39	1.23 (1.49)	34.65	23.94	72.06	8.5
40	1.34 (1.53)	34.56	24.07	74	15
41	2.05 (1.75)	33.81	24.26	73.86	39.5
42	3.00 (2.00)	34.33	23.56	73.05	76.5
43	4.06 (2.25)	34.17	24.25	72.58	118
44	3.21 (2.05)	31.07	24.53	73.54	45.5
45	3.24 (2.06)	32.5	22.88	74.68	30
46	4.32 (2.31)	31.7	24.31	69.43	239.5
47	1.13 (1.46)	30.91	24	78.17	67.55
48	1.04 (1.43)	30.59	23.22	62.66	24
49	4.53 (2.35)	31.07	21.97	72.61	58.5
50	3.42 (2.10)	30.21	20.68	82.67	60.5
51	1.56 (1.6)	30.75	21.43	71.98	5
52	2.66 (1.91)	34.12	21.57	73.78	0

1	2.53 (1.88)	30.34	20.43	71.76	0
2	1.32 (1.52)	30.97	30.97	70.32	0
3	1.13 (1.46)	31.05	31.05	68.7	0
4	0.56 (1.25)	31.25	31.25	64.63	0
5	0.78 (1.33)	31.14	31.14	62.52	0
6	0.43 (1.20)	31.77	31.77	57.55	0
7	0.21 (1.10)	31.37	21.36	56.54	0
8	0	35.29	23.49	68.6	0
9	0	36.27	22.63	58.96	0
10	0	35.85	23.07	63.17	0
11	0	36.37	23.54	65.43	0
12	0	35.04	24.32	59.27	0

Figures in parentheses are √x+1 transformed values.

Table 2. Influence of weather factors on the population of mirid bug, *Creontiades biseratense* in *Bt*cotton during 2015-2016.

Std Metrological week	Mirid bug Population (Nos/plant)	Maximum Temperature (ºC)	Minimum Temperature (ºC)	Relative Humidity (%)	Rainfall (mm)
35	0	35.52	25.63	68.56	87.45
36	0	35.85	24.38	69.65	0
37	0	35.46	25.42	72.34	0
38	0	34.35	23.57	68.23	15.63
39	0.06(1.03)	34.23	24.64	66.58	55.45
40	0.14 (1.07)	33.57	23.86	75.42	70.68
41	0.38 (1.17)	34.14	24.71	74.37	67.28
42	1.00 (1.41)	33.29	25.29	73.21	0.6
43	1.55 (1.60)	32.71	23.71	72.74	0
44	2.46 (1.86)	31.71	23.71	75.59	14.5
45	3.39 (2.1)	28.71	22.86	74.32	43.6
46	4.47 (2.34)	29.14	23.71	71.32	131.72
47	3.15 (2.04)	30	23.86	70.36	80.2
48	2.36 (1.83)	29.14	23.14	73.32	44
49	1.46 (1.57)	27.14	23	71.54	72.52
50	0.86 (1.36)	30.43	23.86	75.32	2
51	1.35 (1.53)	31.14	22.14	76.95	0
52	1.58 (1.61)	26.26	19	73.42	0
1	1.66 (1.63)	30.85	20.71	71.42	0
2	2.04 (1.74)	30.57	20.28	69.53	0
3	1.66 (1.63)	31.43	21.14	67.31	0
4	1.35 (1.53)	32.14	22.14	65.54	0
5	0.77 (1.33)	32.57	23.28	68.45	0
6	0.50 (1.22)	33.14	22.43	63.68	0
7	0.09 (1.04)	33.51	22.29	62.56	0
8	0.02 (1.01)	34.85	23.43	64.03	0
9	0	34.43	23.71	59.06	0
10	0	35.43	24	62.68	0
11	0	37.43	25.57	64.45	0
12	0	39.14	25.71	66.06	0

Figures in parentheses are √x+1 transformed values.

Table 3. Correlation between the mirid bug population and weather parameters.

S.No	Weather parameters	Mirid bug population	
		Correlation values	
		2014-2015	2015-2016
1	Maximum Temperature	-0.4153	-0.7565
2	Minimum Temperature	-0.3103	-0.3868
3	Relative humidity	0.6734	0.4782
4	Rainfall	0.1463	0.3536

DISCUSSION

Understanding insect population dynamics can be very challenging due to the large number of biotic and abiotic factors that must be taken into account. Of these factors, weather is generally considered to be one of the most important. For instance, temperature, rainfall, relative humidity and other weather related factors strongly affect the survival, development, fecundity and behavior of individual insects and the population dynamics of insects. In addition to such direct effects, weather can indirectly impact insect populations by affecting life history traits of their host plants, competitors and natural enemies (Day, 2006; Shang *et al*., 2010).

In the recent past, a number of new pest problems have emerged in *Bt* cotton which include mealybugs (*Phenacoccus solenopsis, Paracoccus marginatus*), mirids (*Creontiades biseratense, Campylomma livida, Hyalopeplus linefer*), flower bud maggot (*Dasineura gossypii*), safflower caterpillar (*Perigea capensis*), and tea mosquito bug (*Helopeltis bryadi*), etc. At the same time, pests like whitefly *(Bemisia tabaci*), leafhopper (*Amrasca biguttula biguttula*), thrips (*Thrips tabaci*), and tobacco caterpillar (*Spodoptera litura*) have started appearing invariably in large numbers forcing the farmers to go for repeated applications of chemical insecticides to manage them. In Central and South India, the mirid bugs are serious problem, particularly *Creontiades biseratense* which is dominant and regularly occurring species. Mirid bug infested tender bolls have a number of black patches on the rind while feeding on matured bolls leads to parrot beaking and improper opening (Saini, 2015).

Sankar *et al*. (2011) supported our study that the incidence of Mirid bugs was observed during the time of flowering and square forming stages of the crop. Rohini *et al*. (2009) reported that the peak incidence appeared on 80 days old crop and the mirid bug population gradually increased with the age of crop. The peak incidence was noticed during November second fortnight and December I fortnight. Thereafter, the population declined gradually in February I fortnight and February II fortnight. This was also correlated with the findings of Udikeri *et al.* (2009). He was reported that the incidence of mirid bugs began during September and existed till December, however the peak incidence was observed during October/November months. The maximum incidence was noticed during second fortnight of November in Karnataka. Ravi (2007) supported our findings that the mirid bug, *C. biseratense* incidence started from 50 days old cotton crop and peaked during November last week (17.2 bugs/ 10squares/plant) and population started declining from second week of December reaching 10.30 bugs/10 squares by December end and by March it disappeared totally. From the results of this study it is confirmed that the higher incidence of 4.53 and 4.47 mirid bugs was observed during 46th standard metrological week (November) of 2014-2015 and 2015-2016 season respectively**.**

According to Udikeri *et al*. (2009) the peak incidence was observed during October and November months in 2007-08. The maximum incidence (65.6 bugs/25 squares) was noticed in Haveri during second fortnight of November. Patil *et al.*, (2010) reported that the peak incidence noticed was from 3rd week of October to 2nd week of December during 2007-08 and 2008-09 in unprotected conditions whereas the peak incidence of mirid bug was observed during 4th week of September and October during 2007-08 in protected conditions of farmers field. The overall incidence was less during 2008-09 (1.26 mirids/plant) compared to 7.66 mirids/plant during 2007-08 in the farmers field. Shalini (2010) reported that the Fixed spot survey in Dharwad district of Karnataka indicated that the peak incidence of the pest was noticed during November third week (24.25 bugs/ 5 squares) coinciding with luxuriant vegetative growth stage of the crop. The earlier and present findings confirmed that the incidence of brown mirid bug *C. biseratense* begins during peak reproductive stage of the crop. Thereafter the population declines gradually till harvesting.

Rainfall was the most important weather determinant for the hatching of overwintering *A. lucorum* eggs in the dead parts of tree hosts. In addition, temperature was found to significantly hasten egg development, and relative humidity was found to greatly increase hatching rate. Overall, spring rainfall and temperature were the key factors for predicting population level and emerging period of *A. lucorum* nymphs (Pan *et al*., 2014). Wu *et al*. (2002) reported that *A. lucorum* as well as other mirid bugs prefer shady and moist environments and it has been reported that periods of high rainfall result in rapid increases of their populations during the summer. The present findings are in agreement with the Ravi (2007) on correlation studies with mirid bug population where in there was negative correlation with maximum and minimum temperature while there was positive correlation with morning/evening relative humidity and rainfall. Efil and Bayram (2009) reported that the infestation by *C. pallidus* was positively correlated with density of cotton squares and flowers. Therefore, results of the present study that the peak population of brown mirid bug *C. biseratence* occurs during 46^{th} standard weather week. This period of crop growth was aggressive reproductive stage of the cotton crop.

CONCLUSION

Use of insect-resistant transgenic plants will continue to expand, and gene pyramiding might become very common in future. However, concerns have been raised about the possibility that large scale deployment of transgenic crops for pest management might impact arthropod diversity, natural enemies, toxin flow in the insect fauna through different trophic levels, development of resistance in target insect pests, pollen flow in closely related wild relatives antibiotic resistance, etc. In the same, large scale cultivation of bollworm resistant *Bt* cottons suppressed the dreaded pests successfully worldwide. Significant reduction in usage of insecticide especially broad spectrum organophosphates and pyrethroids gave scope of emergence of new pests like mirid bugs. Mirid bugs either prevailing hitherto or newer ones have assumed key status warranting couple of sprays during reproductive phase. Weather factors, cotton plant phenology, non-spraying organophosphates and synthetic pyrethroids in *Bt* cotton cultivation leads to increase the incidence of mirids in *Bt* cotton may also give rise to host range expansion. Hence, this study will be useful to forecast the emergence of brown mirid bug *C. biseratense*and ultimately avoid the crop losses by effective management of this pest in *Bt* cotton crop.

ACKNOWLEDGEMENT

The authors thanks to Cotton Research Station, Tamil Nadu Agricultural University, Perambalur and ICAR-Krishi Vigyan Kendra, Perambalur, Tamil Nadu, India for providing weather parameters for the study.

REFERENCES

Arshad, M. and Suhail, A., 2010. Studying the sucking insect pest community in transgenic *Bt* cotton. *Int. J. Agri. Biol.*, 12,764-768.

Bambawale, O.M., Singh, A., Sharma, O.P., Bhosle, B.B., Lavekar, R.C., Dhandapani, A., Kanwar, V., Tanwar, R.K., Rathod, K.S., Patange, N.R. and Pawar, V.M., 2004. Performance of *Bt* cotton (MECH-162) under Integrated pest management in farmers participatory field trial in Nanded district, central India. *Curr. Sci.*, 86, 1628-1633.

Berge, J.B. and Ricroch, A.E., 2010. Emergence of minor pests becoming major pests in GE cotton in China: What are the reasons? What are the alternatives practices to this change of status? *GM Crops*, 1(4), 214-219.

Day, W.H., 2006. The effect of rainfall on the abundance of tarnished plant bug nymphs [*Lygus lineolaris* (Palisot)] in alfafa fields. *Trans. Am. Entomol. Soc.*,132, 445-450.

Dong, Y.C., Clarke, A.R., Pereira, R., Desneux, N. and Niu, C.Y., 2013. Pupal diapause development and termination is driven by low temperature chilling in *Bactrocera minax*. *J. Pest. Sci.*, 86, 429-436.

Efil, L. and Bayram, A., 2009. Factors affecting the distribution of two mirid bugs, *Creontiades pallidus* (Rambur) and *Campyloma diversicornis* (Reuter) (Hemiptera: Miridae) and notes on the parasitoid *Leiophron decifiens* Ruthe (Hymenoptera: Braconidae). *Entomologica Fennica,* 20, 9-17.

Lu, Y.H. and Wu, K.M., 2011. Effect of relative humidity on population growth of *Apolygus lucorum* (Heteroptera: Miridae). *Appl. Entomol. Zool.*, 46, 421-427.

Lu, Y.H., Wu, K.M., Jiang, Y.Y., Xia, B., Li, P., Feng, H.Q., Wyckhuys, K.A.G. and Guo, Y.Y., 2010a. Mirid bug outbreaks in multiple crops correlated with wide-scale adoption of *Bt*-cotton in China. *Science*, 328, 1151-1154.

Lu, Y.H., Wu, K.M., Wyckhuys, K.A.G. and Guo, Y.Y., 2010b. Temperature-dependent life history of the green plant bug, *Apolygus lucorum* (Meyer-Dur) (Hemiptera: Miridae). *Appl. Entomol. Zool.*, 45, 387-393.

Mehdi, H. and Mohammad, S., 2004. Evaluation of economic threshold of cotton shedder bug, *Creontiades palidus* Ram. (Hem., Miridae). Proceedings of the XVth International Plant Protection Congress, Beijing, China, May 11-16.

Nagrare, V.S., Deshmukh, A.J. and Bisane, A.K., 2014. Relative performance of *bt*-cotton hybrids against sucking pests and leaf reddening under rainfed farming. *Entomol. Ornithol. Herpetol*., 3, 134.

Pan, H., Liu, B., Lu, Y. and Desneux, N., 2014. Identification of the key weather factors affecting overwintering success of *Apolygus lucorum* eggs in dead host tree branches. *PLoS ONE*, 9(4), e94190.

Patil, B.V., Bheemanna, M., Patil, S.B., Udikeri, S.S. and Hosmani, A., 2006. Record of mirid bug, *Creontiades biseratense* (Distant) on Cotton in Karnataka, India. *Insect Environ.*,11(4),176-177.

Patil, S.B., Udikeri, S.S., Vandal, N.B., Modagi, S.A., Hirekurubar, R.B. and Guruprasad, G.S., 2010. Population dynamics of *Creontiades biseratense* (Distant) (Miridae: Hemiptera) on *Bt* cotton in Dharwad district. *Karnataka J. Agric. Sci*., 23(1), 157-158.

Qaim, M. and Zilberman, D., 2003. Yield effects of genetically modified crops in developing countries. *Science*, 299, 900-902.

Ravi, P.R., 2007. Bioecology, loss estimation and management of mirid bug *Creontiades biseratense* (Distant) (Hemiptera: Miridae) on *Bt* cotton. M. Sc. (Agri.) Thesis, Univ. Agric. Sci., Dharwad, Karnataka (India).

Rohini, R.S., Mallapur, C.P. and Udikeri, S.S., 2009. Incidence of mirid bug, *Creontiades biseratense* (Distant) on *Bt* cotton in Karnataka. *Karnataka J. Agric. Sci*., 22(3), 680-681.

Saini, R.K., 2015. Status of insect pest problems and their management in GM cotton. Paper presented in National Symposium on Integrated Pest Management for Sustainable Crop Protection, 24-25 February, 2015, organized by Division of Entomology, ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India, pp. 31-33.

Sankar, C., Jayakumar, P., Marimuthu, R., Tanwar, R.K., Sathyakumar, S., Saravanan, P., Bambawale, O.M. and Anupam Barik, 2011. Mirid bug-an emerging pest on *Bt* cotton in Perambalur District of Tamil Nadu. *J. Insect Sci.*, 24, 18-22.

Saravanan, P., Divya, S., Venkatesan, P., Tanwar, R.K, Ajanta Birah, Chattopadhyay, C., Jeyakumar, P. and Anupam Barik, 2014. Trend analysis of pests and diseases complex in *Bt* cotton. *J. Crop Prot.*, 4(4), 431-439.

Shalini, R., 2010. Survey, crop loss estimation and management of mirid bug, *Creontiades biseratense* (Distant) (Miridae: Hemiptera) in *Bt* cotton. M. Sc. (Agri.) Thesis, Univ. Agric. Sci., Dharwad, Karnataka (India).

Shang, Z.T., Wei, J.S., Kuai, J., Shan, C. and Chen, Y.W. 2010. Analyses of the relations between cotton mirid dynamics and meteorological conditions. *Plant Prot*., 36, 92-95.

Stamp, P.A., 1987. *Creontiades pallidus* (Rambur) (Miridae: Hemiptera) a pest of cotton along the Euphrates river and its effect on yield and control action threshold in the Syrian Arab Republic. *Trop. Pest Manag.*, 33(4), 273-276.

Udikeri, S.S., 2008. Mirid Menace- A potential emerging sucking pest problem in cotton. International Cotton Advisory Committee. *Recorder*, 26(4), 15.

Udikeri, S.S., Patil, S.B., Shaila, H.M., Guruprasad, G.S., Patil, S.S., Kranthi K.R. and Khadi, B.M., 2009. Mirid Menace - A potential emerging sucking pest problem in cotton. Proc. 4th Asian Cotton Res. Devl. Network Meeting 23-25, Sept 2008. Anoying China. www. icac. org.

Vennila, S., 2008. Pest management for cotton ecosystems or ecosystem management for cotton production. *Curr. Sci.*, 94(11), 1351-1352.

Wilstermann, A. and Vidal, S., 2013. Western corn rootworm egg hatch and larval development under constant and varying temperatures. *J. Pest Sci.*, 86, 419-428.

Wu, K.M. and Guo, Y.Y., 2005. The evolution of cotton pest management practices in China. *Annal. Rev. Entomol.*, 50, 31-52.

Wu, K.M., Li, W., Feng, H.Q. and Guo, Y.Y., 2002. Seasonal abundance of the mirids, *Lygus lucorum* and *Adelphocoris* spp. (Hemiptera: Miridae) on *Bt* cotton in northern China. *Crop Prot.*, 21, 997-1002.