Journal of Entomology and Zoology Studies
Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2018; 6(4): 994-998

Received: 23-05-2018
Accepted: 25-06-2018

Raghunandan BL
AICRP on Biological Control of Crop Pests Anand Agricultural University, Anand Gujarat, India

Godhani PH
AICRP on Biological Control of Crop Pests Anand Agricultural University, Anand Gujarat, India

Patel MV
AICRP on Biological Control of Crop Pests Anand Agricultural University, Anand Gujarat, India

Patel NM
AICRP on Biological Control of Crop Pests Anand Agricultural University, Anand Gujarat, India

Mehta DM
AICRP on Biological Control of Crop Pests Anand Agricultural University, Anand Gujarat, India

Correspondence
Raghunandan BL
AICRP on Biological Control of Crop Pests Anand Agricultural University, Anand Gujarat, India

Field evaluation of microbial bio-pesticides for the management of sucking pests in Bt cotton

Raghunandan BL, Godhani PH, Patel MV, Patel NM and Mehta DM

Abstract
A field experiment was conducted to assess the efficacy of different microbial biopesticides against major sucking pests of Bt cotton at agronomy farm, B.A. College of Agriculture, Anand Agricultural University. Anand (Gujarat) during three successive years (2014-15 to 2016-17). The population of sucking pests *viz*., aphid, jassid, whitefly and thrips reduced significantly in the plots treated with microbial biopesticide *Lecanicillium lecanii* @ 4g/l and *Beauveria bassiana* @ @ 4g/l. Enhancement of natural enemies of cotton pests *viz.,* chrysopids, coccinellids, geocoris bug and spiders was registered due to microbial biopesticides have been found ultimately suppressed the pest complex and thereby reflected on seed cotton yield. The present study signifies the importance of microbial biopesticides for eco-friendly and sustainable pest management indicating their potential utility in supplementing the integrated pest management strategies of Bt cotton.

Keywords: Bt cotton, Sucking pests, Pest population, Microbial biopesticide

Introduction
Cotton (*Gossypium hirsutum* L.) is one of the important commercial crops popularly known as 'King of fibre' and 'White gold' of India. It provides 65% raw material to the textile industry and contribute 1/3rd of total foreign exchange earning of India. At global level India is the largest cotton growing country with area of 110.3 lakh hectares and production of 350.10 lakh bales [1] still the productivity is low (503 kg lint/ha) as compared to world's approximate average (766 kg lint/ha) [2]. Among the various factors responsible for low productivity, insect pests are considered as major ones. In India about 184 insect pests have been reported to attack cotton crop causing 30-80% yield loss and constitute as one of the major limiting factor in cotton production [3, 4]. The problem of bollworms has been overcome with the introduction of Bt cotton, but the sucking pests *viz*., aphid, jassid, thrips and whitefly have become serious constraint and potential threat to Bt cotton with very high biotic potential [5, 6, 7]. Sucking pests cause damage throughout the crop period with significant decline in yield by being assimilate sappers, stand reducers and light stealers. The yield loss of up to 21.2 per cent [8] and 28.13 per cent [9] has been reported due to sucking pests in Bt cotton. Heavy infestation of sucking pests results in yellowing of leaves leading to wrinkling and distortion. Further, secretion of honeydew leads to growth of sooty mould which affects photosynthetic activity of the plants and eventually seed cotton yield.

For the management of sucking pests use of insecticides is the permanent solution. Recent trend of organic farming and deleterious effect of chemical insecticides on natural enemies has necessitated the alternative approach for economical and eco-friendly management of insect pests. In this context microbial biopesticides attract considerable attention and significant findings have been documented on efficacy of microbial biopesticides in Bt cotton and other various crops [10][11][12]. As far as Gujarat state is concerned serious studies have not been made to check the efficacy of microbial biopesticides for the management of sucking pests in Bt cotton. Keeping this in view an investigation was conducted to evaluate the bioefficacy of different entomopathogenic fungi based microbial biopesticides against sucking pest complex in Bt cotton.

Materials and Methods
To assess the efficacy of different entomopathogenic fungi on sucking pests of Bt cotton, field experiments were conducted at agronomy experimental farm, B.A. College of Agriculture, Anand Agricultural University, Anand (Gujarat) during the year *Kharif* 2014-15, 2015-16 and

2016-17. Bt cotton variety G Cot Hy 6 (BG II) was dibbled at spacing of 120x60 cm and raised by adapting standard agronomic practices except plant protection. There were eight different treatments comprising of entomopathogenic fungi *Beauveria bassiana* (Bb-5), *Lecanicillium lecanii* (Vl-8), *Metarhizium anisopliae* (Ma-1), chemical insecticide check Thiomethoxam 25WG and untreated control (Table 1). Pure cultures of entomopathogenic fungi were obtained from National Bureau of Agriculturally Important Insects (ICAR-NBAIR) Bengaluru, India. The wettable powder formulation (1% WP – $2x10^8$ cfu/g) of entomopathogenic fungi was prepared and used for the study. All the treatments were replicated thrice in randomized block design (RBD)

Considering the economic threshold level (ETL) of pest during the experimental period three sprays were given in the interval of 15 days and observations were recorded on 3rd and 7th day after spraying. Five plants were randomly selected from each net plot area and tagged for recording observations. Population of sucking pests *viz.,* aphid (*Aphis gossypii* G.), jassid (*Amrasca biguttula biguttula* Ishida.), whitefly (*Bemisia tabaci* Gen.) and thrips (*Scirtothrips dorsalis* Hood.) was recorded from three leaves (top, middle and bottom) of each tagged plant and mean population of each sucking pest was worked out. Addition to this, whole plant incidence of major predators was sampled *viz.*, spiders, coccinellids, chrysopids and geocoris bug. Seed cotton yield was calculated on net plot basis and expressed as q/ha. The data obtained was subjected to statistical analysis following square root transformation [13]

Table 1: Details of treatments used in the experiment

Treatments	Microbial insecticides
T_1	*Beauveria bassiana* (1% WP - 2 x 10^8 cfu g^{-1}) @ 3g /l water
T_2	*Beauveria bassiana* (1% WP - 2 x 10^8 cfu g^{-1}) @ 4g / l water
T_3	*Lecanicillium lecanii* (1% WP - 2 x 10^8 cfu g^{-1}) @ 3g /l water
T_4	*Lecanicillium lecanii* (1% WP - 2 x 10^8 cfu g^{-1}) @ 4g / l water
T_5	*Metarhizium anisopliae* (1% WP - 2 x 10^8 cfu g^{-1}) @ 3g /l water
T_6	*Metarhizium anisopliae* (1% WP - 2 x 10^8 cfu g^{-1}) @ 4g / l water
T_7	Thiamethoxam 25 WG @ 2 g/ 10 litres water
T_8	Control (water spray)

Results and Discussion

Aphid population (Table 2) recorded in different treatments under study revealed the significant suppression in all microbial biopesticide treatments over control treatment. However, chemical check treatment showed highest pest suppression. Among biocontrol treatments *B. bassiana* @ 4g/l registered significantly low population (4.21 aphid/3 leaves) followed by *L. lecanii* @ 4g/l (4.84 aphid/3 leaves) during 2014-15. In the year 2015-16 similar trend was observed in the efficacy of entomopathogens wherein the treatment *L. lecanii* @ 4g/l registered low aphid population (5.16 aphid/3 leaves) followed by *B. bassiana* @ 4g/l (5.31 aphid/3 leaves) and both the treatments found statistically at par with each other. Superiority of the treatments *L. lecanii* @ 4g/l (6.56 aphid/3 leaves) and *L. lecanii* @ 3g/l (7.28 aphid/3 leaves) was observed during the third year of experimentation followed by *B. bassiana* @ 4g/l (8.14 aphid/3 leaves). Pooled results acknowledged the treatments *L. lecanii* @ 4g/l with significantly low population (5.50 aphid/3 leaves) followed by *B. bassiana* @ 4g/l (5.75 aphid/3 leaves). Ghelani *et al.* [14] reported 70 per cent reduction in aphid infestation with sequential application of chemical insecticide, *L. lecanii*, *B. bassiana* and Azadirachtin in Bt cotton. Similarly Nemade *et al.* [15] documented the efficacy of *L. lecanii* and *M. anisopliae* in suppressing sucking pest complex in Bt cotton With respect to jassid population all treatments differed significantly during the study. During 2014-15 *L. lecanii* @ 4g/l recorded significantly low population (3.07 jassid/3 leaves) followed by *M. anisopliae* @ 4g/l (3.26 jassid/3 leaves). This observation registered the efficacy of *M. anisopliae* in suppressing jassid population. Moreover, the treatment *B. bassiana* @ 3g/l showed low population (4.43 jassid/3 leaves) compared to the treatment *B. bassiana* @ 4g/l (7.28 jassid/3 leaves). During the year 2015-16 and 2016-17 observations with respect to efficacy of microbial biopesticides in suppressing jassid population revealed significant pest suppression in the treatment *L. lecanii* @ 4g/l followed by *B. bassiana* @ 4g/l. Similarly pooled results confirmed the superiority of the treatment *L. lecanii* @ 4g/l (1.78 jassid/3 leaves) followed by *B. bassiana* @ 4g/l (1.87 jassid/3 leaves). The efficacy of entomopathogens in suppressing white fly and thrips followed the similar trend as registered in efficacy against aphid and jassid population (Table 3). Further, the competence of the treatments *L. lecanii* @ 40g/10 liters and *B. bassiana* @ 40g/10 liters was noticed. The pooled data of white fly population revealed the superior performance of *L. lecanii* @ 4g/l (2.63 white fly/3 leaves) followed by *B. bassiana* @ 4g/l (2.85 white fly/3 leaves) in reducing the population below ETL. The efficacy of *M. anisopliae* @ 3g/l against whitefly of Bt cotton was observed by Ambarish *et al.* [16] and claimed that *M. anisopliae* found next best to the chemical insecticides Flunicamid 50WG and Diafenthiuron 50WP for the effective management of whitefly. Chinna Babu Naik *et al.* [17] highlighted the pest suppression ability of *L. lecanii* against jassid and whitefly in Bt cotton. Recently, Mensah and Young [18] reported the efficacy of naturally occurring entomopathogenic fungus *Aspergillus* sp. in the management of whitefly in cotton with minimal effects on natural enemies.

Likewise the effectiveness of microbial treatments in reducing the population of thrips was documented during experimental period. Pooled data of three years study indicated the lowest population in treatment *L. lecanii* @ 4g/l (2.29 thrips/3 leaves) and *B. bassiana* @ 4g/l (3.30 thrips/3 leaves). These findings are in conformity with the report of Kapadia *et al.* [19] wherein highest mortality of thrips infesting onion *Thrips tabaci* recorded in the treatment *L. lecanii* (7 g/l) followed by *B. bassiana (*8 g/l). Boricha *et al.* [20] documented the combined effect of *L. lecanii* (1.25 kg /ha) and *B. bassiana* (1 kg/ha) with thiomethoxam (0.004%) against thrips of cotton. Similarly, the combined application of *L. lecanii* + *B. bassiana* proved better in reducing thrips population in tomato as compared to individual application of biopesticides (Naga Bharani *et al*. [21]

Treatment wise natural enemies of cotton pests were recorded during three years of study. Mean population of major natural enemies was calculated and presented in Table 4. Data revealed the higher population of natural enemies in all biocontrol treatments compared to chemical check treatment and signifies the beneficial effect of biopesticides in enhancing population of natural enemies. Improvement in population of natural enemies due to microbial biopesticides observed in the present study is in conformity with the report of Kristen [22] who opined that fungal entomopathogens *B. bassiana* and *M. anisopliae* were effective for microbial control of mirids in mungebean and cotton with little impact on natural enemies and documented the effective field rate of $1x10^{13}$/ha which had no negative effect on natural enemies. In parallel Sunil *et al.* [23] highlighted that microbial agent *B. bassiana* 5% WP was less harmful to coccinellid beetles as Azadirachtin 0.03% EC and jatropha oil. Similar findings were reported by Anitha 2007 [24], Ghelani [25], Sujatha and Bharpoda. [26]

Influence of microbial biopesticides in suppressing sucking pest population is reproduced in seed cotton yield harvested from different treatments under study (Table 5). The treatment *L. lecanii* which showed significant pest suppression recorded highest seed cotton yield among biopesticide treatments. However, it is observed that yield recorded in this treatment was at par with the yield of chemical check treatment during the year 2014-15 and 2015-16. The pooled data of yield followed the similar trend as registered in bioefficacy against pest population. Treatment *L. lecanii* @ 4g/l recorded highest seed cotton yield (27.44 q/ha) followed by *B. bassiana* @ 4g/l (26.12 q/ha). These reports are in accordance with the findings of Boricha [27] and Somnath [28]. Economics of the study is presented in Table 6 and among biopesticide treatments highest ICBR (1:30.86) was registered in the treatment *L. lecanii* @ 4g/l followed by *B. bassiana* @ 4g/l (1:27.42). Although the chemical check treatment recorded highest ICBR (1:41.95) the microbial treatments found to be promising from the perspective of eco-friendly and sustainable management of pest and indicate their potential utility in supplementing the integrated pest management programmes of Bt cotton.

Table 2: Efficacy of different microbial biopesticides against aphid and jassid infesting Bt cotton

Treatments	No. of insect / 3 leaves							
	Aphid				Jassid			
	2014	2015	2016	Pooled over year	2014	2015	2016	Pooled over year
B. bassiana @ 3g /l	2.84^{d} (7.57)	2.70^{c} (6.79)	2.95^{c} (8.20)	2.83^{cd} (7.50)	2.22^{c} (4.43)	1.28^{de} (1.14)	1.91^{d} (3.15)	1.80^{bc} (2.74)
B. bassiana @ 4g /l	2.17^{b} (4.21)	2.41^{b} (5.31)	2.94^{c} (8.14)	2.50^{bc} (5.75)	2.79^{e} (7.28)	1.12^{bc} (0.75)	1.72^{bc} (2.46)	1.54^{ab} ˆ(1.87)
L. lecanii @ 3g /l	3.03^{d} (8.68)	2.76^{c} (7.12)	2.79^{bc} (7.28)	2.86^{cd} (7.68)	2.34^{cd} (4.98)	1.38^{e} (1.40)	1.80^{cd} (2.74)	1.84^{b} (2.89)
L. lecanii @ 4g /l	2.31^{bc} (4.84)	2.38^{b} (5.16)	2.66^{b} (6.56)	2.45^{b} (5.50)	1.89^{b} (3.07)	1.04^{ab} (0.58)	1.61^{b} (2.09)	1.51^{ab} (1.78)
M. anisopliae @ 3g /l	3.13^{e} (9.30)	2.85(7.62)	3.26^{d} (10.13)	3.08^{d} (8.99)	2.39^{d} (5.21)	1.42^{e} (1.52)	2.32^{e} (4.88)	2.04^{c} (3.66)
M. anisopliae @ 4g /l	2.49^{c} (5.70)	2.64^{c} (6.47)	3.21^{d} (9.80)	2.78^{bc} (7.23)	1.94^{b} (3.26)	1.20^{cd} (0.94)	2.18^{e} (4.25)	1.77^{bc} (2.63)
Thiamethoxam @ 2 g/ 10 l	1.73^{a} (2.49)	1.92^{a} (3.19)	2.44^{a} (5.45)	2.03^{a} (3.62)	1.32^{a} (1.24)	0.94^{a} (0.38)	1.32^{a} (1.24)	1.19^{a} (0.92)
Untreated control	4.31 (18.08)	4.61^{d} (20.75)	5.18^{e} (26.33)	4.70^{e} (21.59)	2.95^{e} (8.20)	2.85^{f} (7.62)	2.64^{f}(6.47)	2.81^{d} (7.40)
S.Em± Treatment (T)	0.07	0.07	0.06	0.12	0.05	0.06	0.05	0.13
T x Y				0.07				0.05
C. D. at 5% T	0.20	0.21	0.18	0.36	0.15	0.16	0.13	0.39
T x Y				0.19				0.14
C. V. (%)	10.82	11.11	8.57	10.11	10.75	16.76	10.01	12.08

Note: Figures outside the parenthesis are transformed values and those inside are retransformed values.

Table 3: Efficacy of different microbial insecticides against whitefly and thrips infesting Bt cotton

Treatments	No. of insect / 3 leaves							
	Whitefly				Thrips			
	2014	2015	2016	Pooled over year	2014	2015	2016	Pooled over year
B. bassiana @ 3g /l	2.10^{cd} (3.91)	1.78^{bcd} (2.67)	2.31^{d} (4.84)	2.06^{bc} (3.74)	2.16^{d} (4.17)	1.55^{d} (1.90)	2.73^{d} (6.95)	2.14^{cd} (4.07)
B. bassiana @ 4g /l	1.67^{b} (2.29)	1.66^{b} (2.26)	2.15^{c} (4.12)	1.83^{d} (2.85)	1.90^{c} (3.11)	1.38^{bc} (1.40)	2.57^{cd} (6.10)	1.95^{bc} (3.30)
L. lecanii @ 3g /l	2.21^{de} (4.38)	1.89^{cd} (3.07)	2.10^{c} (3.91)	2.07^{bc} (3.78)	2.05^{cd} (3.70)	1.52^{cd} (1.81)	2.41^{bc} (5.31)	2.00^{bc} (3.50)
L. lecanii @ 4g /l	1.74^{b} (2.53)	1.72^{bc} (2.46)	1.86^{b} (2.96)	1.77^{b} (2.63)	1.49^{b} (1.72)	1.31^{b} (1.22)	2.21^{b} (4.38)	1.67^{b} (2.29)
M. anisopliae @ 3g /l	2.30^{e} (4.79)	1.96^{d} (3.34)	2.57^{e} (6.10)	2.28^{c} (4.70)	2.33^{e} (4.93)	1.71^{e} (2.42)	3.13^{e} (9.30)	2.39^{d} (5.21)
M. anisopliae @ 4g /l	1.99^{c} (3.46)	1.79^{bcd} (2.70)	2.41^{d} (5.31)	2.06^{bc} (3.74)	2.14^{d} (4.08)	1.47^{cd} (1.66)	3.00^{e} (8.50)	2.20^{cd} (4.34)
Thiamethoxam @ 2 g/ 10 l	1.24^{a} (1.04)	1.39^{a} (1.43)	1.25^{a} (1.06)	1.29^{a} (1.16)	1.10^{a} (0.71)	1.01^{a} (0.52)	1.37^{a} (1.38)	1.16^{a} (0.85)
Untreated control	2.88^{f} (7.79)	3.24^{e} (10.00)	3.01^{f} (8.56)	3.04^{d} (8.74)	2.89^{f} (7.85)	2.94^{f} (8.14)	3.75^{f} (13.56)	3.19^{e} (9.68)
S.Em± Treatment (T)	0.05	0.06	0.05	0.11	0.05	0.05	0.08	0.12
T x Y				0.05				0.06
C. D. at 5% T	0.15	0.16	0.15	0.33	0.14	0.13	0.23	0.37
T x Y				0.15				0.17
C. V. (%)	11.25	12.52	10.04	11.22	10.59	12.31	13.12	12.52

Note: Figures outside the parenthesis are transformed values and those inside are retransformed

Table 4 Mean population of major natural enemies in different treatments

Treatments	Av. number/plant**			
	Chrysopids	Coccinellids	Geocoris bug	Spiders
B. bassiana @ 3g /l	1.26 (1.09)	1.62 (2.12)	1.18 (0.89)	1.36 (1.35)
B. bassiana @ 4g /l	1.30 (1.19)	1.58(2.00)	1.19 (0.92)	1.32 (1.24)
L. lecanii @ 3g /l	1.24 (1.04)	1.56 (1.93)	1.15 (0.82)	1.25 (1.06)
L. lecanii @ 4g /l	1.17 (0.87)	1.54 (1.87)	1.11 (0.73)	1.26 (1.09)
M. anisopliae @ 3g /l	1.16 (0.85)	1.67 (2.29)	1.10 (0.71)	1.30 (1.19)
M. anisopliae @ 4g /l	1.14 (0.80)	1.54 (1.87)	1.14 (0.80)	1.15 (0.82)

Thiamethoxam @ 2 g/ 10 l	1.02 (0.54)	0.89 (0.29)	0.92 (0.35)	0.80 (0.14)
Untreated control	1.24 (1.04)	1.52 (1.81)	1.09 (0.69)	1.12 (0.75)
S.Em ± T	0.01	0.06	0.03	0.02
C.D @ 5%	0.03	0.17	NS	0.06
S.Em ± TxY	0.02	0.04	0.01	0.02
C.D @ 5%	NS	0.14	0.03	0.04

** Average of three seasons, NS – Non significant

Table 5: Influence of microbial insecticides on seed cotton yield

Treatments		Seed cotton yield (q/ha)			
		2014	2015	2016	Pooled
T1	*B. bassiana* @ 3g /l	23.91	23.43	23.11	23.48
T2	*B. bassiana* @ 4g /l	28.35	25.99	24.14	26.16
T3	*L. lecanii* @ 3g /l	22.43	22.93	23.51	22.95
T4	*L. lecanii* @ 4g /l	26.93	28.97	26.43	27.44
T5	*M. anisopliae* @ 3g /l	22.13	21.84	20.01	21.32
T6	*M. anisopliae* @ 4g /l	25.67	25.29	21.14	24.03
T7	Thiamethoxam @ 2 g/ 10 l	29.70	31.27	31.26	30.74
T8	Untreated control	16.71	15.13	16.07	15.96
	S. Em.	1.13	1.42	1.08	0.71
	C. D. at 5%	3.44	4.31	3.29	2.03
	C. V. %	8.02	10.10	8.09	8.81

Table 6: Economics of different microbial insecticides in Bt cotton

Treatments		Total biopesticides/ insecticide equired (kg / ha)	Cost of biopesticides/ insecticide (Rs/kg)	Total cost of treatments including labour charges (Rs/ha)	Yield (Kg/ha)	Net gain over control (Kg/ha)	Realization over control (Rs/ha)	ICBR
T1	*B. bassiana* @ 3g /l	1.350	150	1978.5	2348	752	41360	1: 20.90
T2	*B. bassiana* @ 4g /l	1.800	150	2046	2616	1020	56100	1: 27.42
T3	*L. lecanii* @ 3g /l	1.350	150	1978.5	2295	699	38445	1: 19.43
T4	*L. lecanii* @ 4g /l	1.800	150	2046	2744	1148	63140	1: 30.86
T5	*M. anisopliae* @ 3g /l	1.350	150	1978.5	2132	536	29480	1: 14.90
T6	*M. anisopliae* @ 4g /l	1.800	150	2046	2403	807	44385	1: 21.69
T7	Thiamethoxam @ 2 g/ 10 l	0.090	1800	1938	3074	1478	81290	1: 41.95
T8	Untreated control	--	--	--	1596	--	--	--

Note:
1. 450 liters of spray solution / hectare
2. Labor charges: Rs 296 /day x 2 labours = Rs 592 x 3 sprays = 1776/ ha
3. Price of cotton: Rs. 5500/quintal

Conclusion
On the basis of findings of study it is concluded that three sprays of *L. lecanii* @ 4g/l or *B. bassiana* @ 4g/l at fortnightly interval starting from initiation of sucking pests found effective for biological control in Bt cotton

Acknowledgment
Authors sincerely acknowledge

- Director of Research and Dean (Post Graduate Studies), Anand Agricultural University, Gujarat, India for providing necessary facilities and financial grants to conduct experiment
- Director ICAR-NBAIR (National Bureau of Agriculturally Important Insects, Bengaluru, India) for supplying entomopathogens and financial grant under ICAR-AICRP (All India Co-ordinated Research Project on Biological Control of Crop Pests) scheme.

Conflicts of Interest
Authors declare that there is no conflict of interest

References
1. Anonymous. http://www.citiindia.com/wp-content/uploads/2018/02/Cotton-Data.pdf, 2018.
2. Abbas G, Farhan M. Efficacy of the new chemistry pesticides on nymph and adult of whitefly *Bemisia tabaci* Gen. and their effect on naturally existing beneficial fauna of cotton in Punjab, Pakistan. International Journal of Science and Research. 2014; 4(10):421-426.
3. Sundarmurthy VT. Abundance of adult males of *Helicoverpa armigera* in poly crop system as affected by certain abiotic factors. Proceedings of fifth All India Co-ordinated Workshop on Biological Control of Crop Pests and Weeds, 1985, 177-179.
4. Kranthi KR, Kranthi S, Ramesh K, Nagrare VS, Anupam Barik. Technical Bulltein: Advances in cotton IPM. Central Institute for Cotton Research, Nagpur, 2009; 27.
5. Hofs JL, Schoeman A, Vaissayre M. Effect of Bt cotton on arthropod biodiversity in South African cotton fields. Communications in Agricultural and Applied Biological Sciences. 2004; 69:191-194.
6. Sharma HC, Pampapathy G. Influence of transgenic cotton on the relative abundance and damage by target and non-target insect pests under different protection regimes in India. Crop Protection. 2006; 25:800-813.
7. Biradar VK, Vennila S. Pest management for Bt cotton: Need for conservation biological control. Current Science. 2008; 95(3):317-318.
8. Dhawan AK, Sindhu AS. Assessment of losses due to the attack of cotton jassid on *hirsutum* cotton. Indian Journal of Plant Protection. 1986; 14:45-50.
9. Chavan SJ, Bhosle BB, Bhute NK. Estimation of losses due to major insect pests in desi cotton in Maharashtra. Journal of Cotton Research and Development. 2010; 24(1):95-96.

10. Luo S, Naranjo SE, Wu K. Biological control of cotton pests in China. Biological Control. 2014; 68:6-14.
11. Rajashekhar M, Kalia VK. Native Bt strains efficacy against cotton aphid *Aphis gossypi* Glover. Journal of Pharmacognosy and Phytochemistry. 2017; 6(5):938-940.
12. Chattopadhyay P, Banerjee G, Mukherjee S. Recent trends of modern bacterial insecticides for pest control practice in integrated crop management system. 3 Biotech. 2017; 7(1):60.
13. Steel RGD, Torrie JH. Principles and Procedures of Statistics. McGraw Hill Book Company, New York, 1980; 137.
14. Ghelani YH, Jhala RC, Vyas HN. Bioefficacy of botanicals and microbial insecticides against cotton aphid *Aphis gossypii* (Glover). Advances in Indian Entomology. 2006; 2(3):149-152.
15. Nemade PW, Rathod TH, Deshmukh SB, Ujjainkar VV, Deshmukh VV. Evaluation of new molecules against sucking pests of Bt cotton. Journal of Entomology and Zoology Studies. 2017; 5(6):659-663.
16. Ambarish S, Shashikumar C, Shekara BG, Somu G. Field evaluation of bio-pesticides and insecticides against sucking insect pests of Bt-cotton under rainfed condition. Journal of Entomological Research, 2017; 41(4):383-386.
17. Chinna Babu Naik, Kranthi S, Rahul Viswakarma. Impact of newer pesticides and botanicals on sucking pest management in cotton under high density planting system (HDPS) in India. Journal of Entomology and Zoology Studies. 2017; 5(6):1083-1087.
18. Mensah RK, Young A. Microbial control of cotton pests: use of naturally occurring entomopathogenic fungus *Aspergillus* sp. (BC 639) in the management of *Bemisia tabaci* (Genn.) (Hemiptera: Aleyrodidae) and beneficial insects on transgenic cotton crops. Biocontrol Science and Technology. 2017; 27(7):844-866.
19. Kapadia MN, Gajera RC, Jethva DM. Bio-efficacy of mycoinsecticides against *Thrips tabaci* Lindeman on garlic. Agricultural Science Digest. 2009; 29(4):294-296.
20. Boricha HV, Raghvani, KL. Joshi MD, Makadia RR, Varmora JM, Babariya PM. Bio-efficacy of bio-pesticides against thrips Thrips tabaci infesting cotton. International Journal of Plant Protection, 2010; 3(1):43-45
21. Naga Bharani S, Kohilambal H, Sivasubramanian P, Banuprathap G. Comparative efficacy of bio pesticides and insecticides against tomato thrips (*Thrips tabaci* Lind.) and their impact on coccinellid predators. The Bioscan. 2015; 10(1):207-210.
22. Kristen K. The development of biopesticides for integrated management of sucking pests. PhD thesis, School of Biological Sciences, The University of Queensland, 2013.
23. Sunil KY, Shweta Patel, Meena Agnihotri, Bisht RS. Efficacy of insecticides and bio-pesticides against sucking pests in black gram. Annals of Plant Protection Sciences, 2015; 23(2): 223-226.
24. Anitha KR. Seasonal incidence and management of sucking pests of okra. M.Sc (Agri.) thesis, University of Agricultural Sciences, Dharwad, Karnataka, 2007.
25. Ghelani MK, Kabaria BB, Chhodavadia SK. Field efficacy of various insecticides against major sucking pests of Bt cotton. Journal of Biopesticides, 2014; 7(Supp):27-32.
26. Sujatha B, Bharpoda TM. Bio-efficacy of biopesticides against sucking pests in green gram grown during Kharif. International Journal of Pure and Applied Bioscience, 2017; 5(4):1827-1834.
27. Boricha HV. Bioefficacy of biopesticdes against major sucking pests of hybrid cotton. M.Sc (Agri.) thesis, Junagadh Agricultural University, Junagadh, Gujarat, 2009.
28. Somnath MS. Sesonal abundance of sucking pests and their management with bio-pesticides on Bt-cotton hybrid. M.Sc (Agri.) thesis, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, 2014.