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Evaluation of integrated pest management modules in *Bt* cotton (*Gossypium hirsutum* L.) for major sucking pests in Marathwada region

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ABSTRACT : The field experiments were conducted during *kharif* 2007-2008 and 2008-2009 on evaluation of different integrated pest management modules for *Bt* cotton revealed that Marathwada Agriculture University and Central Institute of Cotton Research (CICR) IPM modules proved superior in suppressing sucking pests like aphids, leaf hoppers, thrips and whiteflies. It was, however, *on par* with chemical control. Significantly lowest population of mealybugs was recorded in chemical control which was *on par* with MAU module, CICR module and Biointensive IPM module (1.42). Considering the safety to natural enemies, an inference can be drawn that *Bt* cotton with IPM module is the most ideal combination. Untreated control recorded highest parasitization of mealybugs followed by BIPM module (40.27 %). MAU module recorded 38.26 per cent parasitization *on par* with CICR module (38.02 %). Besides reduction in insecticide use, it is also expected to ensure favorable ecological and economic returns in contrast to the adverse effects due to conventional insecticides and also realized highest yield IPM approach, which takes care of varying pest situation, appears to be essential for gaining higher advantage from *Bt* cotton. Two years pooled results showed higher yield (19.41 q/ha) obtained in MAU module *at par* with CICR module (19.16 q/ha), chemical control (18.75 q/ha) and BIPM module (18.27 q/ha). It may be concluded that *Bt* cotton is an important pest management tool and when blended with IPM module will increase the yield substantially in a sustainable way.

Key words: *Bt* cotton, integrated pest management modules, natural enemies, sucking pests

Cotton is an important commercial crop of India, globally known as "King of Fibre" and is grown in 3 agro climatic zones. *Bt* cotton had a huge impact on cotton production in the world. Many studies have focused on the potentially positive impact of *Bt* and the savings on pesticides targeting primary pests. In order to get benefits of *Bt* technology it is necessary to be aware about the emergence of new and secondary pests and their management. As *Bt* cotton is extremely valuable new IPM tool, it can be integrated with other pest control techniques and thus is an essential component of integrated pest management. However *Bt* cotton is not a *solo panacea* for all cotton pests and therefore insect management with other pest control approaches is necessary (Pawar *et al.*, 2003). Integrated pest management and non insecticidal approaches can play a significant role in mitigating the negative effects of insecticides and reducing the use of insecticides without any significant loss of seed cotton yield. The available tools for controlling insect pests involve a very wide range of techniques. The present study was undertaken to evaluate different IPM modules for the management of pests of *Bt* cotton in order to find out effective and economic IPM module.

MATERIALS AND METHODS

Field experiments were conducted during *kharif* 2007-2008 and 2008-2009, in randomized block design with 4 replications and 5 treatments *viz.,* M1 : MAU IPM module, M2 : CICR IPM module, M3 : BIPM module, M4 : Chemical control and M5 : Untreated control at the experimental farm of the Department of Entomology, Marathwada Agricultural University, Parbhani. The plot size was 9.9 x 9.0m with spacing 90 x 60 cm and variety/hybrid Bunny *Bt* (NCS 145). Two rows of refugia (non *Bt*) were grown around the experimental field. The treatment details are

presented in Table 1.

The module treatment was initiated after attaining ETL by the sucking pests, observations were recorded at weekly interval 20 days after sowing. After this, first applications of each IPM module treatments were applied subsequently after crossing ETL of respective pests.

The observations on sucking pests were recorded regularly in the treated as well as in control plot. Observations were recorded to assess the ETL of sucking pests for its control. Three leaves, each from top, middle and bottom of randomly selected 5 plants from each plot were observed for recording the population of sucking pests *viz.*, aphids, leaf hoppers, thrips and whiteflies. The observations were recorded at 7 days interval and the population of aphid leaf hoppers, thrips and whitefly/3 cleaves were counted. Population of mealybugs was recorded on apical 2.5cm shoot length. Also the per cent infestation on plants, leaves and bolls were recorded weekly from the selected plants/ plots.The grading of mealybug infested plants were done in 0-4 scale. The observations on natural enemies *i.e.* predators and parasitoids was recorded/plant at 7 days interval regularly in the treated as well as in control plot throughout the period of investigation

The data obtained on population of aphids, leaf hoppers, thrips whiteflies, mealybugs and natural enemies were subjected to "x + 0.5 transformation *i.e.* Poisson formula. Whereas, the data on per cent infestation by mealybugs were transformed into angular transformation values before statistical analysis. The data on seed cotton yield was subjected to statistical analysis. Data thus obtained in *kharif* 2007-2008 and 2008-2009 were pooled and presented.

Table 1. Treatment details of different IPM modules in *Bt* cotton

Sr. No.	Treatments/ IPM Components
	M1:MAU (Marathwada Agricultural University)
1	Seed treatment with imidacloprid(Gaucho) 70WS @ 5g/kg seed (Already treated seed)
2	One row of castor , maize and cowpea along with the border of plot
3	A row of *Setaria italica* along with cotton seeds of 10th row of cotton
4	Spraying of acetamiprid (Pride) 20SP 2g/10 l
5	Spraying of dimethoate 30 EC (Rogar) 10ml/10 l water
6	Spraying of 5 per cent NSKE @25kg/ha
7	Spraying of chloropyriphos 20 EC 20ml+DDVP 11ml/10 l water
	M2:CICR (Cetral Institute of Cotton Research)
1	Seed treatment with imidacloprid(Gaucho) 70WS @ 5g/kg seed (Already treated seed)
2	One row of castor, maize and cowpea as trap crops sown along with the boundary of field
3	Spraying of thiamethoxam (Actara) 20SP 2g/10 l
4	Installation of yellow sticky traps @20/ac for whitefly management
5	Spraying of 5 per cent NSKE @25kg/ha
6	Spraying of oxydemeton methyl (Metasystox) 20ml/ 10 l water
7	Spraying of chloropyriphos 20 EC 20ml+DDVP 11ml/10 l water
	M3:BIPM (Biointensive Pest Management) Module
1	Spraying of 5 per cent NSKE @25kg/ha
2	Installation of yellow sticky traps @20/ac for whitefly management
3	Spraying of *Verticillium lecanii* @3g/10 l
4	Spraying of 5 per cent NSKE @25kg/ha
5	Spraying of *Verticillium lecanii* @3g/10 l
6	Spraying of 5 per cent NSKE @25kg/ha
7	Spraying of *Verticillium lecanii* @3g/10 l
	M4:Chemical control
1	Seed treatment with imidacloprid(Gaucho) 70WS @ 5g/kg seed
2	Spraying of thiamethoxam 25WG 4g/10 l water
3	Spraying of oxydematon methyl (Metasystox) 20ml/ 10 l water
4	Spraying of dimethoate 30 EC (Rogar) 10ml/10 l water
5	Spraying of chloropyriphos 20 EC 20ml+DDVP 11ml/10 l water
6	Spraying of fifronyl 5 per cent 20ml/10 l water
7	Spraying of acephate 70 SP 10g/10 l water
	M5:Untreated control
	No plant protection measure, sprayed with plain water

RESULTS AND DISCUSSION

Sucking Pests

Aphids, *Aphis gossypii* Glover : It is evident from the data in Table 2 that all modules

were significantly superior over untreated control during *kharif* 2007-2008. Minimum aphid population was recorded in chemical control (10.86 aphids/3 leaves) which was followed by MAU module (15.23 aphids/3 leaves) and CICR (15.38 aphids/3 leaves) which were *at par* with each other. BIPM module recorded 31.28 aphids/ 3 leaves and maximum aphid population was recorded in untreated control (47.67aphids/3 leaves). Similarly, during *kharif* 2008-2009, lowest population of aphids was recorded in chemical control (9.95 aphids/3 leaves) which was followed by CICR module (14.53 aphids/3 leaves) and MAU module (14.69 aphids/3 leaves) which were *at par* with each other. BIPM module recorded 21.82 aphids/3 leaves. Maximum incidence of aphids was recorded in untreated control (34.71 aphids/3 leaves). On the basis of pooled analysis results showed that all modules were significantly superior over untreated control. Significantly lowest population of aphids was recorded in chemical control (10.41 aphids/ 3 leaves) followed by CICR module (14.96/3 leaves) and MAU module (14.96 aphids/3 leaves) which were *at par* with each other. BIPM module recorded 26.55 aphids/3 leaves and maximum population of aphids was recorded in untreated control (41.16 aphid/3 leaves). The present findings in respect of sucking complex are in line with these of Bambawale *et al.,* (2004), Puri *et al.,* (2006) and Naved Sabir *et al.,* (2008a).

Leaf hoppers, *Amrasca biguttula biguttula* Ishida : During *kharif* 2007-2008 (Table 2) all modules were significantly superior over untreated control. The lowest jassid population was recorded in chemical control (1.81/3 leaves) which was *at par* with MAU module (2.17 leaf hoppers/3 leaves) and CICR module (2.5 leaf hoppers/3 leaves). BIPM module recorded 2.8 leaf hoppers/3 leaves and was *at par* with CICR module (2.5 leaf hoppers/3 leaves). Significantly highest population was recorded in untreated control (4.66 leaf hoppers/3 leaves). During *kharif* 2008-2009 significantly lowest jassid population was recorded in chemical control (1.44/3 leaves) which was *at par* with MAU module (1.59 leaf hoppers/3 leaves) and CICR module (1.93 leaf hoppers/3 leaves). BIPM module recorded 2.46 leaf hoppers/3 leaves which was *at par* with CICR module (1.93 leaf hoppers/3 leaves). Maximum population of leaf hoppers was recorded in untreated control (3.53 leaf hoppers/3 leaves). Two seasons pooled averages indicated similar trend of jassid population (Table 2). The lowest population was recorded in chemical control (1.63 leaf hoppers/ 3 leaves) which was *at par* with MAU module (1.88 leaf hoppers/3 leaves). CICR module recorded 2.22 leaf hoppers/3 leaves and was *at par* with MAU module. BIPM module recorded 2.63 leaf hoppers/3 leaves which was *at par* with CICR module. Maximum population of leaf hoppers was recorded in untreated control (4.1 leaf hoppers/ 3 leaves). The present findings are in accordance with those reported by Bambawale *et al.,* (2004), Puri *et al.,* (2006) and Naved Sabir *et al.,* (2008a).

Thrips, *Thrips tabaci* Lind : It is seen from the data in Table 2 that all modules were significantly superior over untreated control during *kharif* 2007-2008. Significantly lowest population of thrips was recorded in chemical control (14.84 thrips/3 leaves). Population of thrips in CICR module (18.4 thrips/3 leaves) was *at par* with BIPM module (18.55 thrips/3 leaves) and MAU module (19.10 thrips/3 leaves). Maximum population of thrips was recorded in untreated control (40.64 thrips/3 leaves). During *kharif* 2008-2009 (Table 2) significantly lower population was recorded in chemical control (13.82 thrips/3 leaves) and it was *at par* with MAU module (15.26 thrips/3 leaves). Population of thrips in CICR module (16.05/ 3 leaves) was *at par* with MAU module followed by BIPM module (21.4 thrips/3 leaves). Maximum population of thrips was recorded in untreated control (37.27 thrips/3 leaves). The pooled results showed that in chemical control lowest population of 14.33 thrips/3 leaves recorded which was significantly

superior over rest of modules and untreated control. Population of thrips was 17.23 /3 leaves in CICR module which was *at par* with MAU module (17.18 thrips/3 leaves) and BIPM module (19.98 thrips/3 leaves). Significantly highest population was recorded in untreated control (38.96 thrips/3 leaves). These findings are in confirmation with those of Bambawale *et al.,* (2004), Puri *et al.,* (2006) and Naved Sabir *et al.,* (2008a).

Whiteflies, *Bemisia tabaci* Gennadius : During *kharif* 2007-2008 (Table 2) significantly lower population of whiteflies was recorded in chemical control (4.87/3 leaves). MAU module recorded 9.23 whiteflies/3 leaves which was *at par* with CICR module (9.83 whiteflies/3 leaves). BIPM module recorded 11.93 whiteflies/3 leaves *at par* with CICR module. Maximum population of whiteflies was recorded in untreated control (17.61/3 leaves /plant). During *kharif* 2008-2009 lowest population was recorded in chemical control (6.74 whiteflies/3 leaves). MAU module noticed 9.92 whiteflies/3 leaves which were *at par* with CICR module (10.87 whiteflies/3 leaves) and BIPM module (11.21 whiteflies/3 leaves). The highest population of whiteflies was recorded in untreated control (19.53 whiteflies/3 leaves). On the basis of pooled means it was indicated that whitefly count per 3 leaves was significantly lowest in chemical control (5.81 whiteflies/3 leaves). MAU module recorded 9.58 whiteflies/3 leaves which was *at par* with CICR module (10.35 whiteflies/3 leaves). BIPM module observed 11.57 whiteflies/3 leaves which was *at par* with CICR module. Maximum population of whiteflies was recorded in untreated control (18.57/3 leaves). The present findings are in conformity with Bambawale *et al.,* (2004), Puri *et al.,* (2006) and Naved Sabir *et al.,* (2008a).

Mealybug *Phenacoccus solenopsis* Tinsley

Mean population of mealybug/2.5cm apical shoot : Results obtained during *kharif* 2007-2008 (Table 3) showed that all the modules were significantly superior over untreated control. The lowest average population of mealybug was recorded in chemical control (4.89 mealybugs/2.5cm shoot length) *at par* with CICR module (5.43 mealybugs/2.5cm shoot length) and MAU module (5.49 mealybugs/2.5 cm shoot length). BIPM module recorded population of 6.04 mealybugs/2.5 cm shoot length *at par* with CICR module and MAU module. Maximum population (11.51 mealybugs/2.5 cm shoot length) was recorded in untreated control. During *kharif* 2008-2009 the overall incidence of mealybug was very low, however the results revealed lowest average population of mealybug was recorded in chemical control (0.35 mealybugs/2.5 cm shoot length) *at par* with MAU module (0.4 mealybugs/ 2.5 cm shoot length), CICR module (0.41 mealybugs/2.5 cm shoot length) and BIPM module (0.43 mealybugs/2.5 cm shoot length). Significantly highest population was recorded in untreated control (0.63 mealybugs/2.5 cm shoot length). Two seasons pooled results showed that all modules were significantly superior over untreated control. Significantly lower population of mealybugs was recorded in chemical control (2.62 mealybugs/2.5 cm shoot length) *on par* with CICR module (2.92 mealybugs/2.5 cm shoot length), MAU module (2.95 mealybugs/2.5 cm shoot length). BIPM module recorded average population of 3.24 mealybugs/2.5 cm shoot length *at par* with CICR and MAU module. Significantly highest population was recorded in untreated control (6.07 mealybugs/2.5 cm shoot length).

Grading of mealybug infested plants : Data presented in Table 3 indicated grading of mealybugs infested plants. Chemical control recorded lowest grading of plants (1.36) *on par* with MAU module (1.48). CICR module recorded 1.56 grading *on par* with MAU module followed by BIPM module (1.78). Highest grading of plants was recorded in untreated control (2.21). During *kharif* 2008-09 the data on grading of infested plants by mealybugs revealed that chemical

Table 2. Population of sucking pests in different *Bt* cotton IPM modules

IPM module	Aphids/3 leaves			Leaf hoppers/3 leaves			Thrips/ three leaves			Whiteflies/3 leaves		
	2007-2008	2008-2009	**Pooled**	2007-2008	2008-2009	**Pooled**	2007-2008	2008-2009	**Pooled**	2007-2008	2008-2009	**Pooled**
MAU IPM module	15.23*	14.69	**14.96**	2.17*	1.59	**1.88**	19.10*	15.26	**17.18**	9.23*	9.92	**9.58**
	(3.96)	(3.90)	**(3.93)**	(1.63)	(1.44)	**(1.54)**	(4.42)	(3.97)	**(4.20)**	(3.11)	(3.22)	**(3.17)**
CICR IPM module	15.38	14.53	**14.96**	2.50	1.93	**2.22**	18.40	16.05	**17.23**	9.83	10.87	**10.35**
	(3.98)	(3.88)	**(3.93)**	(1.72)	(1.56)	**(1.64)**	(4.34)	(4.06)	**(4.20)**	(3.21)	(3.36)	**(3.29)**
BIPM Module	31.28	21.82	**26.55**	2.80	2.46	**2.63**	18.55	21.40	**19.98**	11.93	11.21	**11.57**
	(5.64)	(4.70)	**(5.17)**	(1.81)	(1.72)	**(1.77)**	(4.36)	(4.68)	**(4.52)**	(3.52)	(3.42)	**(3.47)**
Chemical control	10.86	9.95	**10.41**	1.81	1.44	**1.63**	14.84	13.82	**14.33**	4.87	6.74	**5.81**
	(3.37)	(3.25)	**(3.30)**	(1.52)	(1.39)	**(1.46)**	(3.91)	(3.78)	**(3.85)**	(2.31)	(2.68)	**(2.50)**
Untreated control	47.61	34.71	**41.16**	4.66	3.53	**4.10**	40.64	37.27	**38.96**	17.61	19.53	**18.57**
	(6.94)	(5.93)	**(6.43)**	(2.26)	(2.00)	**(2.13)**	(6.41)	(6.14)	**(6.28)**	(4.25)	(4.36)	**(4.31)**
SE+_	0.07	0.05	**0.03**	0.08	0.05	**0.03**	0.09	0.08	**0.04**	0.13	0.11	**0.06**
P=0.05	0.20	0.16	0.14	**0.25**	0.17	0.14	**0.28**	0.23	0.18	**0.39**	0.33	0.28

Figures in parentheses are x+0.5 transformed values *Average of 25 meteorological weeks

Table 3. Incidence of mealybugs *Phenacoccus solenopsis* in different *Bt* cotton IPM modules

IPM module	Mealybugs/2.5 cm apical shoot			Grading of mealybugs (Infested plants)			Plants infested by mealybugs (%)			Leaves infested by mealybugs (%)			Bolls infested by mealybugs (%)		
	2007-2008	2008-2009	**Pooled**	2007-2008	2008-2009	**Pooled**	2007-2008	2008-2009	**Pooled**	2007-2008	2008-2009	**Pooled**	2007-2008	2008-2009	**Pooled**
MAU IPM module	5.49*	0.40	**2.95**	1.48*	1.03	**1.26**	18.63**	1.38	**10.01**	10.53**	0.86	**5.70**	7.32**	1.83	**4.58**
	(2.44)	(0.95)	**(1.70)**	(1.41)	(1.24)	**(1.33)**	(25.56)	(6.74)	**(16.15)**	(18.92)	(5.32)	**(12.12)**	(15.67)	(7.75)	**(11.71)**
CICR IPM module	5.43	0.41	**2.92**	1.56	0.96	**1.26**	19.22	1.35	**10.29**	10.10	0.89	**5.50**	7.39	1.66	**4.53**
	(2.43)	(0.95)	**(1.69)**	(1.43)	(1.21)	**(1.32)**	(25.98)	(6.67)	**(16.33)**	(18.52)	(5.40)	**(11.96)**	(15.75)	(7.38)	**(11.57)**
BIPM module	6.04	0.43	**3.24**	1.78	1.06	**1.42**	19.89	1.54	**10.72**	10.65	1.02	**5.84**	8.78	2.15	**5.47**
	(2.56)	(0.96)	**(1.76)**	(1.51)	(1.25)	**(1.38)**	(26.47)	(7.13)	**(16.80)**	(19.02)	(5.78)	**(12.40)**	(17.19)	(8.42)	**(12.81)**
Chemical control	4.89	0.35	**2.62**	1.36	0.89	**1.13**	16.72	1.15	**8.94**	9.37	0.83	**5.10**	6.75	1.46	**4.11**
	(2.32)	(0.92)	**(1.62)**	(1.36)	(1.18)	**(1.27)**	(24.12)	(6.15)	**(15.14)**	(17.81)	(5.22)	**(11.52)**	(15.03)	(6.93)	**(10.98)**
Untreated control	11.51	0.63	**6.07**	2.21	1.13	**1.67**	36.32	2.56	**19.44**	25.32	1.45	**13.39**	20.34	2.65	**11.50**
	(3.46)	(1.06)	**(2.26)**	(1.65)	(1.28)	**(1.47)**	(37.05)	(9.14)	**(23.10)**	(30.20)	(6.90)	**(18.55)**	(26.80)	(9.36)	**(18.08)**
SE+_	0.07	0.02	**0.03**	0.02	0.03	**0.01**	0.48	0.27	**0.19**	0.36	0.20	**0.15**	0.47	0.20	**0.13**
P=0.05	0.23	0.07	**0.14**	0.06	0.09	**0.05**	1.47	0.84	**0.88**	1.11	0.60	**0.69**	1.45	0.62	**0.60**

* Figures in parentheses are x+0.5 transformed values **Figures in parentheses are angular transformed values

* Average of 25 meteorological meteorological weeks

control module recorded lower grading (0.89) which was *at par* with CICR module (0.96), MAU module (1.03) and BIPM module (1.06) followed by untreated control (1.13). On the basis of pooled averages it was indicated that chemical control recorded 1.13 grade which was *on par* with MAU module (1.26) and CICR module also recorded grade of 1.26 and both were *at par* with BIPM module (1.42). Untreated control recorded significantly highest infestation grade (1.67).

Mealybug infested plants : Results obtained during *kharif* 2007-2008 revealed that the lowest mean infested plants by mealybug were recorded in chemical control (16.72 %) *at par* with MAU module (18.63 %). CICR module recorded 19.22 per cent infested plants *at par* with BIPM module (19.89 %). Maximum infested plants were recorded in untreated control (36.32 %). During *kharif* 2008-2009 the lowest mean infested plants by mealybug was recorded in chemical control (1.15 %) which was *at par* with CICR module (1.35 %) and MAU module (1.38 %). BIPM module recorded 1.54 per cent infested plants *at par* with CICR module and MAU module. Significantly maximum infested plants (2.56 %) were recorded in untreated control. Based on pooled means (Table 3) it was revealed that significantly lower infestation of mealybug was recorded in chemical control (8.94 %). MAU module recorded 10.01 % infested plants *at par* with CICR module (10.29 %) and BIPM module (10.72 %). Untreated control recorded significantly highest plants infested by mealybug (19.44 %).

Leaves infestation by mealybugs : During *kharif* 2007-2008 (Table 3) all the modules were significantly superior over untreated control. Significantly lower infestation was recorded in chemical control (9.37 %) *at par* with CICR module (10.10 %) and MAU module (10.53 %). BIPM module recorded 10.65 per cent leaves infested by mealybugs which were *at par* with CICR and MAU module. Untreated control showed maximum leaves infestation (25.32 %). During *kharif* 2008-2009 it is evident that all the modules were significantly superior over untreated control. Chemical control recorded minimum leaves infested with mealybug (0.83 %) *at par* with MAU module (0.86 %), CICR module (0.89 %) and BIPM (1.02 %). Untreated control recorded significantly highest infested leaves (1.45 %). Pooled results (Table 3) revealed that all modules were significantly superior over untreated control. Chemical control recorded minimum infested leaves with mealybugs (5.10 %) *at par* with CICR module (5.50 %) and MAU module (5.70 %). BIPM module recorded 5.84 per cent infested leaves and maximum infested leaves (13.39 %) were recorded in untreated control.

Boll infestation by mealybugs : During *kharif* 2007-2008 (Table 3) chemical control had recorded significantly lower boll infestation (6.75 %) *on par* with CICR module (7.39 %) and MAU module (7.32 %). BIPM module recorded 8.78 per cent bolls infested. Untreated control recorded maximum boll infestation (20.34 %). During *kharif* 2008-2009 all modules were significantly superior over untreated control. Chemical control recorded significantly lowest boll infestation (1.46 %). CICR module recorded 1.66 % boll infestation *on par* with MAU module (1.83 %), BIPM module recorded 2.15 per cent infestation. Untreated control recorded maximum (2.65 %) boll infestation. Based on pooled averages it was noticed that chemical control recorded minimum bolls infested by mealybugs (4.11 %) *at par* with CICR module (4.53 %). MAU module recorded (5.58%) infestation *at par* with CICR module followed by BIPM module (5.47 % infestation). Untreated control recorded maximum (11.50 %) boll infestation.

Natural enemies

Coccinellids (grubs + adults) : During *kharif* 2007-2008 (Table 4) untreated control recorded highest population (2.01 *coccinellids*/

Table 4. Population of natural enemies and mealybug parasitisation in different *Bt* cotton IPM modules

IPM module	*Coccinella spp* (grubs + adults)/ plant			Chrysopa (eggs +larvae)/ plant			Syrphid (maggot/ plant)			Predatory (spider / plant)			Parasitization in mealybugs (%)		
	2007-2008	2008-2009	**Pooled**	2007-2008	2008-2009	**Pooled**	2007-2008	2008-2009	**Pooled**	2007-2008	2008-2009	**Pooled**	2007-2008	2008-2009	**Pooled**
MAU IPM module	2.23*	1.65	**1.94**	1.49*	1.28	**1.39**	0.52*	0.41	**0.47**	1.03*	0.63	**0.83**	34.51**	42.00	**38.26**
	(1.65)	(1.46)	**(1.56)**	(1.41)	(1.33)	**(1.39)**	(1.00)	(0.95)	**(0.98)**	(1.24)	(1.06)	**(1.15)**	(35.97)	(40.39)	**(38.18)**
CICR IPM module	2.22	1.67	**1.95**	1.51	1.28	**1.40**	0.53	0.39	**0.46**	0.98	0.56	**0.77**	33.41	42.63	**38.02**
	(1.64)	(1.47)	**(1.56)**	(1.42)	(1.33)	**(1.40)**	(1.01)	(0.94)	**(0.98)**	(1.22)	(1.030	**(1.13)**	(35.30)	(40.75)	**(38.03)**
BIPM module	2.62	1.97	**2.30**	1.78	1.54	**1.66**	0.60	0.48	**0.54**	1.13	0.72	**0.93**	35.25	45.29	**40.27**
	(1.76)	(1.57)	**(1.67)**	(1.50)	(1.43)	**(1.49)**	(1.04)	(0.98)	**(1.01)**	1.28)	(1.10)	**(1.19)**	(36.41)	(42.29)	**(39.35)**
Chemical control	1.43	1.10	**1.27**	0.89	0.80	**0.85**	0.39	0.22	**0.31**	0.50	0.14	**0.32**	13.56	11.75	**12.66**
	(1.39)	(1.36)	**(1.38)**	(1.18)	(1.14)	**(1.17)**	(0.94)	(0.85)	**(0.90)**	(0.99)	(0.80)	**(0.90)**	(21.59)	(20.06)	**(20.82)**
Untreated control	2.74	2.01	**2.38**	2.00	1.74	**1.87**	0.78	0.67	**0.73**	1.25	0.97	**1.11**	38.14	47.43	**42.79**
	(1.80)	(1.58)	**(1.69)**	(1.58)	(1.49)	**(1.56)**	(1.13)	(1.08)	**(1.11)**	(1.32)	(1.21)	**(1.27)**	(38.13)	(43.52)	**(40.83)**
SE+_	0.05	0.06	**0.03**	0.02	0.05	**0.02**	0.02	0.02	**0.01**	0.03	0.03	**0.02**	0.41	0.27	**0.17**
P=0.05	0.16	0.18	**0.14**	0.07	0.15	**0.10**	0.04	0.07	**0.05**	0.09	0.09	**0.09**	1.27	0.82	**0.78**

Figures in parentheses are x+0.5 transformed values **Figures in parentheses are angular transformed values
*Average of 25 meteorological meteorological weeks

plant) which was *at par* with BIPM module (1.97 beetles/ plant), CICR module (1.67 *coccinellids*/ plant) and MAU module (1.65 *coccinellids*/ plant). Chemical control recorded 1.10 *coccinellids*/ plant which was *at par* with CICR module and MAU module. During *kharif* 2008-2009 results revealed that untreated control recorded highest population of *coccinellids* (2.74/ plant) which was *at par* with BIPM module (2.62 *coccinellids* / plant), MAU module (2.23 *coccinellids*/ plant) and CICR module (2.22 *coccinellids*/ plant). Chemical control recorded minimum (1.43 *coccinellids*/ plant) population. Two years pooled averages showed the similar trend of lady bird beetle population. Untreated control recorded highest population (2.38 *coocinellids*/ plant) which was *at par* with BIPM module (2.30 *coccinellids*/ plant), CICR module (1.95 *coccinellids*/ plant) and MAU module (1.94 *coccinellids*/ plant). Chemical control recorded minimum population (1.27 *coccinellids*/ plant). The present findings are in consonance with Puri *et al.,* (2006) and Naved Sabir *et al.,* (2008b).

Chrysoperla spp (eggs+larvae) : Results of *kharif* 2007-2008 revealed that untreated control was significantly superior over all other modules which recorded highest population of chrysopa (2.00/plant) followed by BIPM module (1.78 chrysopa/plant). Population of chrysopa in CICR module was 1.51 chrysopa/plant which was *at par* with MAU module (1.49 chrysopa/plant). Minimum population was recorded in chemical control (10.89 chrysopa/plant). During 2008-2009, significantly higher population (1.74 chrysopa/plant) was recorded in untreated control which was *at par* with BIPM module (1.54 chrysopa/plant). Population of chrysopa in CICR module was 1.28 chrysopa/ plant and MAU module which was *at par* with BIPM module. Chemical control was recorded lowest population (0.80 chrysopa/plant). Based on the pooled averages it was noticed that significantly higher population (1.87 chrysopa/plant) was recorded in untreated control which was *at par* with BIPM module (1.66 chrysopa/plant). Population of chrysopa in CICR module was 1.40 /plant which was *at par* with MAU module (1.39 chrysopa/ plant) and BIPM module. Chemical control recorded minimum population (0.85 chrysopa/ plant). The present findings are in accordance with Puri *et al.,* (2006) and Naved Sabir *et al.,* (2008b).

Syrphid maggots : During *kharif* 2007-2008 results revealed that untreated control (0.78 maggots/plant) was significantly superior over all other modules. BIPM module recorded 0.60 maggots /plant which was *at par* with CICR module (0.55 maggots/plant) and MAU module (0.52 maggots/plant). Significantly lower population of syrphid maggots was recorded in chemical control (0.39 maggots/plant). Similarly during *kharif* 2008-2009 untreated control (0.67 maggots/plant) was significantly superior over all other modules. BIPM module recorded (0.48 maggots/plant) which was *at par* with MAU module (0.41 maggots/plant) and CICR module (0.39 maggots/plant). Significantly lowest population of syrphid maggots was recorded in chemical control (0.22 maggots/plant). The results based on pooled data revealed that untreated control recorded highest population of syrphid maggots (0.73 maggots/plant). BIPM module recorded 0.54 maggots/plant which was *at par* with CICR module (0.46 maggots/plant) and MAU module (0.47 maggots/plant). Significantly lowest population was recorded in chemical control (0.31 maggots/plant). These findings are parallel with Puri *et al.,* (2006) and Naved Sabir *et al.,* (2008b).

Predatory spider : Results showed that all modules were significantly superior over chemical control during *kharif* 2007-2008. Highest population of spider (1.25/ plant) was recorded in untreated control which was *at par* with BIPM module (1.13 Spiders/plant) and MAU Module (1.03 spiders/plant). Population of spiders was 0.98/ plant in CICR module which was *at*

par with MAU module and BIPM module significantly lowest population was recorded in chemical control (0.50 spiders/plant). It is obvious that during *kharif* 2008-09 untreated control (0.97 spiders/plant) was significantly superior over all other module. Population of spiders was 0.72/ plant in BIPM module which was *at par* with MAU module (0.63 spiders/plant) and CICR module (0.56 spiders/plant). Chemical control recorded lowest spider population (0.14 /plant). Based on the pooled means it was revealed that untreated control recorded 1.11 spiders/plant which was significantly superior over all other modules and *at par* with BIPM module (0.93 spiders/plant). Population of spiders was 0.83/plant in MAU module which was *at par* with CICR module (0.77 spiders/ plant) and BIPM module. Lowest population was recorded in chemical control (0.32 spiders/ plant). Overall the population of coccinellids, chrysopids, syrphids and predatory spiders was more in IPM plots as compared to non-IPM plots and chemical control condition irrespective of *Bt* or non *Bt* cotton. These results in respect of natural enemies are confirmed by most of the earlier IPM workers like Puri *et al.,* (2006) and Naved Sabir *et al.,* (2008b).

Parasitization of mealybugs : The parasitation by *Aenasius bambawalei* caused mummification of mealybugs on cotton. Results of *kharif* 2007-2008 showed th*at par*asitization was significantly highest in untreated control (38.14 %) followed by BIPM module (35.25) which was *at par* with MAU module (34.51 %) and CICR module (33.41 %). Chemical control recorded significantly minimum parasitization of mealybugs (13.56 %). During *kharif* 2008-2009, the parasitization of mealybugs was significantly highest in untreated control (47.43 %) which was followed by BIPM module (45.29 %). MAU module recorded 42.00 % parasitization which was *at par* with CICR module (42.63 %). Chemical control recorded lowest parasitization of mealybugs (11.75 %). Similarly the pooled results denoted that untreated control recorded highest parasitization of mealybugs (42.79 %) followed by BIPM module (40.27 %). MAU module recorded 38.26 per cent parasitization *on par* with CICR module (38.02 %). Chemical control recorded lowest parasitization of mealybugs (12.66 %).

Seed cotton yield (q/ha) in different IPM modules : Results presented in Table 5 showed that during *kharif* 2007-2008 all modules were significantly superior over untreated control. Significantly higher yield (18.42 q/ha) was obtainedin MAU module which was *at par* with CICR module (18.12 q/ha), chemical control (18.10 q/ha), and BIPM module (17.76 q/ha). Untreated control recorded lowest yield (13.07 q/ ha). Similarly, during *kharif* 2008-2009 significantly higher yield (20.40 q/ha) was obtainedin MAU module *on par* with CICR module (20.20 q/ha) chemical control (19.40 q/ha) and BIPM module (18.78 q/ha). Lowest yield (14.09 q/ha) was obtainedin untreated control. Two years pooled results showed that higher yield (19.41 q/ha) was obtainedin MAU module *at par* with CICR module (19.16 q/ha), chemical control (18.75 q/ha) and BIPM module (18.27 q/ha). Untreated control recorded significantly lowest yield (13.58 q/ha) than all tested modules. The present findings are in agreement with those of Naved Sabir *et al.,* (2008b).

Economics and I.C.B.R. of various modules : Two years pooled results showed highest gross income Rs.14561.25/ha and net profit Rs. 12,215.75/ha were realized from the MAU IPM module followed by CICR module (Rs. 13956.25/ha and Rs. 10,785.75/ha.), chemical control (Rs. 12834.25/ha and Rs. 9,905/ha.) and BIPM module (Rs. 11607.75/ha and Rs.8,095.25/ ha.). During 2007-08, 2008-09 and on the basis of pooled data, the highest ICBR were obtained(1:3.48, 1:7.40 and 1:5.21) in MAU IPM module, followed by CICR IPM module(1:2.22, 1:4.81 and 1:3.40) and chemical control(1:2.45, 1:4.51 and 1:3.38), respectively. The lowest I.C.B.R. during 2007-2008, 2008-2009 and on the

Table 5. Details of yield, economics and I.C.B.R.* in different *Bt* cotton modules.

Year	*Treatment*	Cotton yield (q/ha)	Increased yield over control (q/ha)	Gross income (Rs/ha)	Cost of treatment (Rs/ha)	Net profit (Rs/ha)	I.C.B.R.
2007-	M.A.U. IPM module	18.42	5.35	11770.00	2625.50	9144.50	**1:3.48**
2008	C.I.C.R. IPM module	18.12	5.05	11110.00	3450.50	7659.50	1:2.22
	BIPM module	17.76	4.69	10318.00	3732.50	6585.50	1:1.76
	Chemical control	18.10	5.03	11066.00	3205.00	7861.00	1:2.45
	Untreated control	13.07	—	—	—	—	—
2008-	M.A.U. IPM module	20.40	6.31	17352.50	2065.50	15287.00	**1:7.40**
2009	C.I.C.R. IPM module	20.20	6.11	16802.50	2890.50	13912.00	1:4.81
	BIPM module	18.78	4.69	12897.50	3292.50	9605.00	1:2.92
	Chemical control	19.40	5.31	14602.50	2652.50	11950.00	1:4.51
	Untreated control	14.09	—	—	—	—	—
Pooled	**M.A.U. IPM module**	**19.41**	**5.83**	**14561.25**	**2345.50**	**12215.75**	**1:5.21**
	C.I.C.R. IPM module	**19.16**	**5.58**	**13956.25**	**3170.50**	**10785.75**	**1:3.40**
	BIPM module	**18.27**	**4.69**	**11607.75**	**3512.50**	**8095.25**	**1:2.30**
	Chemical control	**18.75**	**5.17**	**12834.25**	**2928.75**	**9905.00**	**1:3.38**
	Untreated control	**13.58**	**—**	**—**	**—**	**—**	**—**

Market price of seed cotton during **2007-2008 was Rs. 2200/q** and during **2008-2009 Rs. 2750/q**
***Incrimental Cost Benefit Ratio**

basis of pooled data highest I.C.B.R (1:1.76, 1:2.92 and 1:2.30) was obtainedin BIPM module. Thus considering the I.C.B.R., MAU IPM module gave higher I.C.B.R. than the remaining modules. These findings are in agreement with those of Naved Sabir *et al.* , (2008b).

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