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Development and validation of integrated pest management strategies for Bt cotton under rainfed ecosystem

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ABSTRACT

Integrated pest management (IPM) module was developed and evaluated for transgenic *Bt* cotton during 2007–08 and 2008–09 at Dharwad and its performance was compared with the *Bt* grown under recommended plant protection and non *Bt* with integrated pest management. In integrated pest management modules for both *Bt* as well as non-*Bt* cotton hybrids, included use of imidacloprid treated seeds, two sprays with imidacloprid (70 WS) and acetamiprid (20 SP) for sucking pest complex, trap cropping with okra, *Abelmoschus esculentus* (L.) Monech, spraying of 5% neem, *Azardicta indica* (L.) Juss seed kernel extract, detopping of shoot tip at 80 days after sowing, installation of pheromone traps and need-based application of insecticides for bollworm management. Recommended plant protection module for *Bt* involved only selective insecticides for sucking pests and bollworms. Results indicated low population of sucking pests in *Bt* integrated pest management, followed by non-*Bt* and *Bt* recommended plant protection. *Bt* integrated pest management registered 0.22 to 0.30 larvae of *Helicoverpa armigera* (Hubner)/plant compared to 0.32 and 0.29 larvae/plant in recommended plant protection and 0.54 and 0.72 larvae/plant in non-*Bt* integrated pest management during 2007 and 2008, respectively. Fruiting body damage remained 3.24 and 3.57% in *Bt* integrated pest management as compared to 3.37 and 3.75% and 7.72 and 6.31% in *Bt* recommended plant protection and non-*Bt* integrated pest management, respectively. Similar trend of incidence was observed in case of pink bollworm across the genotypes and modules. *Bt* genotypes with integrated pest management resulted higher seed cotton yield of 3.13 and 2.59 tonnes/ha compared to 3.06 and 2.39 tonnes/ha in *Bt* recommended plant protection and 2.86 and 2.14 tonnes/ha in non-*Bt* with integrated pest management in 2007–08 and 2008–09, respectively. The net returns (₹ 69 970 and 61 350/ha) was more from *Bt* integrated pest management as compared to *Bt* recommended plant protection (₹ 67 676 and 55 403/ha) and non-*Bt* integrated pest management (₹ 61 155 and 43 633/ha) in both seasons.

Key words: *Bt* integrated pest management, recommended Plant Protection, non-*Bt* Integrated Pest Management, Pest incidence, Seed cotton yield

After the introduction of *Bt* cotton, a change in the pest scenario has been observed, especially sucking pests and diseases emerged as major pests because of the Cry 1Ac delta toxin present in the *Bt* cotton which provides protection only for lepidopteran pests (Kranthi and Kranthi 2004). Variations in the larval survival of lepidopteran pests had also been correlated to differential expression of Cry 1Ac in various plant parts among the commercial cultivars of *Bt* cotton (Adamczyk and Douglas 2001). Moreover, the situation aggravated in the states where the crops remained in the field for longer duration (>5 months) as the expression of Cry 1Ac declines with the plant age (Kranthi *et al*. 2005). The fruiting bodies formed in the later part of the season became prone to the attack of pink bollworm [*Pectinophora gossypeilla* (Saund.)]; therefore, the farmers have to apply chemical insecticides. Under these circumstances, there was a need to develop integrated pest management module to contain the emerging insect pests and diseases.

MATERIALS AND METHODS

An adoptable integrated pest management (IPM) module was evaluated for *Bt* as well as non-*Bt* cotton hybrids during 2007–08 and 2008–09 crop seasons at Jeerigiwad village which is situated 20 km away from Dharwad (Karnataka) following all recommended agronomic practices. The experiment was carried with three modules, viz *Bt* IPM, *Bt* recommended plant protection and non-*Bt* IPM. The Bt IPM

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integrated with Okra as trap crop, installation of pheromone traps and use of selective insecticides, viz Acetamiprid 20 SP, NSKE 5%, Acephate 75 SP and Cyhalothrin 5 EC during the cropping season 2007–08. Almost similar spray schedule in addition to Imidacloprid 200 SL and Profenophos 50 EC insecticides sprays excluding Cyhalothrin 5 EC spray were followed during 2008–09. Whereas the Bt recommended plant protection module comprised only chemicals, viz Acetamiprid 20 SP, Cyhalothrin 5 EC, Acephate 75 SP, Imidacloprid 200 SL, Profenophos 50 EC and Quinolphos 25 EC during consecutive seasons. In non-Bt IPM module, in addition to the IPM components followed in Bt IPM module additional components, viz detopping, *Tricho* release and Ha*NPV* spray were followed during both the seasons. Each module was laid out on an area of 0.4 ha and separated by a row of maize, cowpea with 1.5 m buffer area distance. Each module was divided into five equal blocks to serve as replication for recording observations and to meet statistical analysis. The pest management interventions were carried out only when the pests crossed economic threshold level. In all the modules the cotton seeds treated with imidacloprid 70 WS were sown in order to manage the early sucking pests.

Observations on the population and incidence of insect pests were recorded on 25 randomly selected plants in each block at 10 days interval in each module avoiding border rows. Thus, each module served as treatment and block as replication for statistical analysis. Population of mirid bug was recorded after 60 days after sowing. Later the population was worked out per 25 squares. The egg population of *Helicoverpa armigera* was recorded starting from 40 days after sowing and continued till 70 days after sowing on central terminal growing shoot, flower buds and squares. Similarly the incidence of *H. armigera* larvae was also recorded on whole plant basis. The damage to fruiting bodies (squares/flowers/bolls) was recorded based on the total number and damaged fruiting bodies in each plant. The fruiting bodies both shed and intact on plants were taken into account for calculating the per cent damage. The observations on flower rosetting, number of pink bollworm larvae/25 green bolls and per cent green bolls damage were recorded both in *Bt* and non-*Bt* IPM and recommended plant protection blocks. At the time of each picking, the number of good and bad opened bolls and locule damage were recorded from 25 randomly selected plants. The data was averaged to per plant and presented as good opened bolls/bad opened bolls/per plant. Cotton yield was recorded from 5 randomly selected plots of 6 m × 5 m from each demarcated replications both in integrated pest management and recommended plant protection blocks separately and from the entire block also. Later, the data was presented as seed cotton yield/ha for the respective module.

RESULTS AND DISCUSSION

In the present investigation incidence of sucking pests remained low in *Bt* integrated pest management as well as non-*Bt* integrated pest management modules as compared to *Bt* recommended plant protection (Table 1). The extent of reduction in aphids, thrips, jassids and mirid bug population in *Bt* integrated pest management block was 11.25, 19.89, 7.95 and 32.57% during 2007–08 and 2.22, 0.522, 3.15 and 6.50% during 2008–09, respectively, over *Bt* recommended plant protection and 7.43, 10.12, 10.43 and 6.50 during 2007–08 and 12.61, 3.71, 0.87 and 5.73%, respectively, over non-*Bt* IPM during 2008–09. Two additional sprays of chemical pesticides, ie imidacloprid and acetamiprid provided protection from the sucking pests. The present findings are

Table 1 Sucking pests, American bollworm population and damage in different treatments

Treatments		Aphid/3 leaves		Thrips/3 leaves		Jassids/3 leaves		Mirid bug/25 squares	
		2007–08	2008–09	2007–08	2008–09	2007–08	2008–09	2007–08	2008–09
Bt	Integrated Pest Management	13.69	3.81	17.48	10.11	2.26	3.88	8.71	1.15
	Recommended Plant Protection	17.68	5.83	21.82	11.89	2.89	3.49	6.60	1.23
Non *Bt*	Integrated Pest Management	14.95	4.37	19.45	9.50	2.17	3.41	6.83	1.22
t value	*Bt* Integrated Pest Management *vs* Recommended Plant Protection	0.87	0.06	2.58	0.61	0.56	0.41	0.73	2.28
	Bt Integrated Pest Management *vs* non *Bt* Integrated Pest Management	0.76	1.71	1.12	1.05	0.76	0.11	0.65	0.40
	ABW eggs/plant	ABW larvae/plant		Square damage (%)		Boll damage (%)			
Bt	Integrated Pest Management	4.10	3.87	0.22	0.20	1.93	1.55	3.24	3.57
	Recommended Plant Protection	8.02	6.63	0.32	0.29	2.19	1.74	3.37	3.75
Non *Bt*	Integrated Pest Management	3.98	3.93	0.54	0.72	7.16	6.48	7.72	6.31
t value	*Bt* Integrated Pest Management *vs* Recommended Plant Protection	5.26	11.56	0.94	0.29	0.17	0.06	0.26	12.33
	Bt Integrated Pest Management *vs* non *Bt* Integrated Pest Management	0.18	0.24	7.08	5.45	11.29	18.37	6.71	9.55

Table 't' value 2.02

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in agreement with the reports of Bhemanna and Patil (2003) who reported stem as well as shoot smearing of the cotton plants with imidacloprid was the best treatment in reducing the early season sucking pests without affecting the natural predatory population.

Irrespective of the modules, *Bt* genotypes registered significantly less population of American bollworm larvae due to the resistance afforded by Cry protein in *Bt* genotypes. Due to trapping of okra, significant reduction in the number of ABW eggs was observed in *Bt* integrated pest management and non-*Bt* integrated pest management blocks as compared to *Bt* recommended plant protection (Table 1). The reduction of larval population in case of ABW was to the tune of 31.25 and 31.03% and 59.26 and 63.51% over *Bt* recommended plant protection and non-*Bt* integrated pest management during both the seasons. Okra as a component of IPM has helped in reducing the American bollworm eggs in *Bt* as well as non-*Bt* integrated pest management treatments as compared to recommended plant protection. The present observations corroborate with the findings of Duraimurugan *et al*. (2005) who supported the inclusion of okra as a trap crop in cotton for suppressing the egg laying of *H. armigera.* Further Patil *et al*. (2003) and Yenagi (2006) found that okra could serve as an effective trap crop to trap bollworms egg load in transgenic cotton. Similarly, nipping has been proved as cultural paradigm for effective management of *H. armigera* at egg density as reported by Udikeri *et al*. (2004).

Modules with *Bt* genotypes registered significantly less fruiting bodies damage (squares, green bolls and shed reproductive parts) compared to the module with non-*Bt* genotypes. Among *Bt* and non-*Bt* genotypes, *Bt* recorded significantly less fruiting body damage (Table1), indicating the suitability of *Bt* genotypes as effective components of integrated pest management. Within the *Bt* treatments, *Bt* integrated pest management recorded less locule damage as compared to *Bt* recommended plant protection. The reduction in square and boll damage was to the tune of 11.87 and 3.86% and 73.04 and 58.03 during 2007 and 10.91 and 5.46 and 72.99 and 44.53% over *Bt* recommended plant protection and non-*Bt* integrated pest management during 2008–09, respectively. Retention of early formed bolls in *Bt* genotypes owing to the inherent *Bt* toxic effect and suppression of bollworm incidence resulted in more number of good opened bolls in both *Bt* integrated pest management and *Bt* recommended plant protection modules during both the seasons.

Modules with *Bt* genotypes registered significantly lower incidence of pink bollworm incidence. Both *Bt* integrated pest management as well as *Bt* recommended plant protection recorded significant lower incidence of rosetted flower, number of green boll and locule damage as compared to non-*Bt* (Table 2). The extent of reduction in per cent rosetted

Table 2 Green boll and locule damage, rosette flowers and pink bollworm larvae in different treatments

Treatments		Green boll damage (%)		Locule damage (%)		Rosette flowers/ plant		pink bollworm larvae/ 25 green bolls	
		2007–08	2008–09	2007–08	2008–09	2007–08	2008–09	2007–08	2008–09
Bt	Integrated pest management	3.22	1.72	3.64	2.29	0.10	1.09	3.07	2.50
	recommended plant protection	3.35	1.76	3.89	2.36	0.13	1.11	2.87	2.67
Non *Bt*	Integrated pest management	10.94	9.02	14.93	14.24	0.21	3.53	14.50	13.31
t value	*Bt* integrated pest management vs recommended plant protection	0.24	0.054	0.77	0.083	0.90	0.17	1.32	0.20
	Bt integrated pest management vs non *Bt* Integrated pest management	8.42	3.03	20.70	9.26	2.41	7.76	5.57	4.50

Table 't' value 2.02

Table 3 Natural enemies in different modules

Treatment		Coccinellids/plant		Chrysopha/plant	
		2007–08	2008–09	2007–08	2008–09
Bt	Integrated pest management	3.60	4.41	0.59	1.80
	Recommended plant protection	3.00	2.30	0.20	1.40
Non *Bt*	Integrated pest management	2.80	3.34	0.26	1.58
t value	*Bt* integrated pest management vs Recommended plant protection	20.0	91.87	56.1	28.57
	Bt integrated pest management vs non- *Bt* integrated pest management	28.57	32.03	126.62	13.92

Table 't' value 2.02

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Table 4 Comparative yield and economics in different modules of *Bt* cotton

Particular	2007–08			2008–09		
	Bt integrated pest management	*Bt* recommended plant protection	Non-*Bt* integrated pest management	*Bt* integrated pest management	*Bt* recommended plant protection	Non-*Bt* integrated pest management
Good opened bolls/plant	43.15	42.20	39.50	44.75	32.25	28.50
Bad opened bolls/plant	1.56	1.68	4.50	1.25	1.35	6.70
Yield (tonnes/ha)	3.13	3.06	2.86	2.59	2.39	2.14
Value of yield (₹/ha)	81 432	79 638	74 542	73 872	68 115	56 710
Protection cost(₹/ha)	3 462	3962	5 387	4 522	4 712	5 077
Cost of Production (₹/ha)	8 000	8 000	8 000	8 000	8 000	8 000
Total cost of cultivation (₹/ha)	11 462	11 962	13 387	12 522	12 712	13 077
Net returns	69 970	67 676	61 155	61 350	55 403	43 633

Prevailing average market rate for kapas RCH-2Bt: ₹ 28 500/tonne, RCH-2 non-*Bt:* ₹ 26500/tonne

flowers and incidence of pink bollworm incidence/25 bolls was 23.07, 52.38% and 17.33, 50.55% during 2007–08 and 18.18, 94.11% and 6.36, 81.21% over *Bt* recommended plant protection and non *Bt* integrated pest management during 2008–09, respectively. Further the extent of reduction in% boll damage and locule damage was 3.88, 70.56% and 6.43, 75.62% during 2007–08 and 2.27, 80.93% and 2.96, 83.91% over *Bt* recommended Plant protection and non *Bt* integrated pest management during 2008–09, respectively. irrespective of the modules, *Bt* genotypes recorded lower population of pink bollworm compared to integrated pest management with non-*Bt* cultivar indicating the effectiveness of *Bt* toxin against pink bollworm. Higher pink bollworm incidence in non *Bt* integrated pest management might be due to lack of target specific treatment for pink bollworm control which resulted in higher infestation level. These results are comparable with the findings of Bambawale *et al*. (2004). Further Hennebery and Jech (2000) who reported *Bt* cotton bolls (NuCOTN 33^B and DPL 5415) developing on plants at 180 days after planting (DAP) were toxic to pink bollworm larvae.

Significantly higher population of natural enemies comprising coccinellids and chrysopa species were observed in both the integrated pest management modules. The population of natural enemies remained low in *Bt* recommended plant protection which received more number of pesticides application for sucking pest management (Table 3).

The response of *Bt* genotype as component of 1pm was found to be appreciable in terms of seed cotton yield. More seed cotton yield was received through *Bt* integrated pest management (3.13 and 2.59 tonnes/ha) followed by *Bt* recommended plant protection module (3.06 and 2.39 tonnes/ha) in both the seasons, respectively (Table 4). In both *Bt* integrated pest management and *Bt* recommended plant protection modules, cost of the plant protection was slightly lower compared to non-*Bt* integrated pest management. These results are comparable with the findings of Bamabawale *et al*. (2004) and Patil *et al*. (2004) who reported higher seed cotton yield in *Bt* cotton integrated pest management plots compared to non-*Bt* integrated pest management plots. Further, Venkateshalu (2005) and Udikeri (2006) reported that the modules comprised of *Bt* cotton was found to be superior with respect to seed cotton yield.

In the present investigation, an effort was made to evaluate the performance of integrated pest management with and without *Bt* genotype on large scale. Integration of *Bt* with other components of integrated pest management enhances efficacy and sustenance of *Bt* technology.

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