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Performance of transgenic *Bt* cotton of different *Bt* events under IPM in rainfed situation

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ABSTRACT

The field experiment was carried out at ARS, Dharwad farm, Karnataka, India during 2010-11 to study the performance of *Bt* cotton hybrids, viz. Bunny BG-I, Bunny BG-II, JK Durga and Nathbaba developed through different *Bt* events under IPM practices. The performance of the *Bt* hybrids with IPM practices (module) was compared with farmers practices. IPM module encompassed, *Bt* cotton seeds treated with imidacloprid 70WS, sowing of redgram as a refuge, detopping of shoot tip, installation of pheromone traps, and selective use of chemicals for sucking pests control, whereas farmers practice relied only on chemical interventions. The results revealed that among the *Bt* genotypes, Bunny BG-II under IPM, recorded lower population of aphids, thrips, leaf hopper and mirid bugs (3.94,9.09,2.07/3 leaves and 3.10/25 squares respectively) followed by Bunny BG-I(4.44, 9.74, 2.26/3 leaves and 3.12/25 squares respectively). However non-significant variation among the genotypes was observed under IPM. Further, irrespective of the modules, bollworm population was not observed in any of the *Bt* cotton genotypes. Although the larval population of *Helicoverpa* was recorded in Non *Bt*, the population was considerably low with IPM practice (0.98/plant) as compared to the farmers practice (1.96/plant) due to target specific interventions. The fruiting bodies damage was negligible in both the modules with hybrids containing two genes compared to hybrids with single *Bt* gene. On the contrary, modules with non *Bt* cotton registered significantly higher fruiting bodies damage. Among the genotypes, Bunny BG-II integrated in IPM registered higher seed cotton yield of 25.20 q/ha followed by 24.57 q/ha in Nathbaba with more profit. It is evident from the results that performance of Bunny BG-II was found to be better as indicated by lower infestation and higher seed cotton yield under IPM practice.

Key words: *Bt* events, IPM, Sucking pests and bollworms, Transgenic cottons

Bt cotton which confers resistance to lepidopteron pests of cotton, was first adopted in India during 2002 for commercial cultivation. Under Indian conditions the transgenic cotton offereded a great resistance to all three kinds of bollworms both under lab and field situation (Kranthi and Kranthi 2004). The *Bt* genotypes have an edge over conventional cotton both in terms of yield and economic advantage apart from satisfactory control of bollworms. As a reflection of growing acceptance of *Bt* cotton by cotton farmers throughout the country more than 1000 *Bt* hybrids covering six events, viz. MON 531 featuring *cry1Ac* gene and MON 15985 feautred two stacked *cry1Ac* and *cry2Ab* genes developed by Mayhco-Monsanto Biotech Limited and sourced by Monsanto, Event 1 for *cry1Ac gene* developed by JK Agri Genetics Seed Limited and sourced from IIT, Kharagpur and GFM event, featured fused genes of *cry1Ab* and *cryAc* genes developed by Nath seeds and sourced from China, MLS-9124 featured *cry1C* gene developed by Metahelix and BNLA 601 event for *cry1Ac* gene by CICR (ICAR) and UAS, Dharwad and gene sourced from NRCPB New Delhi have been approved by the GEAC for commercial cultivation. This increase in number of hybrids developed from different events has provided much more choice to the farmers. Given the choice, the cotton farmers have selected a handful of best performing *Bt* cotton hybrids suitable to local conditions and planted 9.4 million hectares of *Bt* cotton (86%) of cotton area of 11 million hectares in 2010 (James 2010).

Through the *Bt* cottons, offer inherent toxicity to bollworms the expression of cry protein appears to be not uniform at different crop growth stages. The variation in overall expression levels of Cry1Ac among the cultivars have been correlated to survival of lepidopteron pests indicates that cultivars do not provide the same level of control. The spatio temporal variations in eight Indian *Bt* cultivars have been reported by Kranthi *et al.* (2005). The possible survival of bollworms population and its development of resistance can't be ignored (Kannan 2004).

Further, with the large scale adoption, a change in the pest scenario has been observed particularly the sucking

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pests assumed pests status as the chemical interventions targeted to bollworm have been reduced. The feedback since the commercialization of *Bt* cotton indicated that the technology is not a panacea for all the pests instead integrated approach would be necessary to draw maximum benefits and to sustain the technology. The adoption of the IPM system will be immensely beneficial for economic, effective and eco-friendly management of insect pests in *Bt* cotton. With its intrinsic resistance to bollworms, *Bt* cotton can become an ideal component for integrated pest management quite effectively. Hence effort has been made to evaluate the performance of different *Bt* cotton genotypes developed through different events under the umbrella of IPM at the farmers fields.

MATERIAL AND METHODS

Field experiment was carried out under at ARS Dharwad farm in medium deep black cotton soil under rainfed situation following all recommended agronomic practices. The experiment was unreplicated and comprised transgenic *Bt* cotton hybrids developed from different events, viz. Bunny BG-I, Bunny BG-II, JK Durga and Nathbaba Bt hybrids (representing MON-531, MON-15985, Event-1 and GFM event which featuring *cry1Ac, cry1Ac* + *cry2Ab*, *cry1Ac* and *cry1Ab-cry1Ac* genes respectively) were considered. Each module was laid out on an area of 0.2 ha and separated by a row of maize. The performance of each hybrid in IPM of the respective event was compared with the farmers practice (FP). Further, performance of these modules was also compared with Non *Bt* IPM. IPM module comprised different components, viz. *Bt* cotton seed treated with imidacloprid, spraying of neem based insecticides, Acetamiprid-20 SP, and *Verticillium* for sucking pest management, red gram row as a refuge crop, detopping of shoot tip at 80 DAS, pheromone traps for monitoring and neem based insecticides spray for sucking pests as well as bollworms (Table 1). Chemical interventions were on ETL basis. Whereas, farmer practice comprised only chemical interventions for management of both sucking pests and bollworms.

Observations on the incidence of sucking pests, viz. leafhoppers, aphids and thrips were recorded on ten randomly selected plants. After 60 DAS, the late season sucking pest, viz. mirid bug was recorded and the population was expressed as number of mirid bugs per 25 squares. Similarly, the incidence of *Helicoverpa armigera* (Hubner) larvae was also made on whole plant basis from 60 DAS. The damage to fruiting bodies (squares/bolls) was recorded from 60 DAS and expressed as percent fruiting body damage.

In order to record the pink bollworm incidence, the number of PBW larvae were observed by dissecting 50 green bolls from each treatment and expressed as number of PBW larvae per 50 green bolls. During the observation on PBW larval counts, the number of damaged bolls due to PBW were also counted and expressed as per cent green boll damage. At the time of each picking, 100 fully opened bolls were collected randomly from each treatment. Based on total number of locules and damaged locules observed, percent locule damage was calculated.

Table 1 Components of IPM module

IPM components		Farmers practice
Bt	Non Bt	
Bt seeds treated with imidacloprid 70 WS @ 10 g /kg of seeds	Non Bt seeds treated with imidacloprid 70 WS @ 10 g /kg of seeds	Imidacloprid 70 WS treated Bt and Non Bt seeds
Okra as trap crop at 20:1	Okra as trap crop at 20:1	
Pigeonpea as refuge crop in border rows	Maize as ecofeast crop around the borders	
ETL based spraying of 1. NSKE 5% 2. *Verticillium* @ 2 kg/ha 3. Imidacloprid 200 SL @ 0.25 ml/l 4. Acetamiprid 20 SP @ 0.2g/l 5. Acephate 75 SP @ 1.0 g/l for sucking pests management	ETL based spraying of 1. NSKE 5% 2. Imidacloprid 200 SL @ 0.25 ml/l 3. *Verticillium* @ 2 kg/ha 4. Acetamiprid 20 SP @ 0.2g/l 5. Acephate 75 SP @ 1.0 g/lt for sucking pests management	Sprayings of 1. Imidacloprid 200 SL @ 0.25 ml/l 2. Acetamiprid 20 SP @ 0.2g/l 3. Acephate 75 SP @ 1.0 g/lt for sucking pests management
Installation of pheromone traps @ 5 for monitoring of bollworms	Installation of pheromone traps @ 5 for monitoring of bollworms	
Detopping of cotton shoot tip	Detopping of cotton shoot tip	
ETL based spraying of Proenophos 50 EC @ 2 ml/l or thiodicarb 75 WP @ 1.0 gm/l for bollworm management	ETL based sprayings of 1. *Ha*NPV @ 5 ml/ha 2. Proenophos 50 EC @ 2 ml/l for bollworm management	Sprayings of 1. Quinolphos 25 EC @ 2 l/ha 2. λ Chyalothrin 5 EC @ 500 ml/ha 3. Endosulfan 35 EC @ 2.5 ml/l for bollworm management

Bt hybrids: 1. Bunny BG-I (MON 531 Event); 2. Bunny BG-II (MON 15985 Event); 3. JK-Durga (Event-1); 4. Kashinath (GFM Event); *Non Bt:* Bunny Non Bt

The population of predator's, viz. *Crysoperla carnea* (grubs), Coccinellids (grubs and adults) were recorded on whole plant basis from 10 randomly selected plants in each treatment and averaged to population per plant.

Before harvesting, the number of good opened (GOBs) and bad opened bolls (BOBs) were recorded from 10 randomly selected plants. The data presented as GOBs/plant and BOBs/plant. The seed cotton harvested from each treatment excluding the border rows was extrapolated and presented as seed cotton yield in q/ha for the respective module. Finally, the cost economics (Net profit) of each module was worked out considering the cost of plant protection, total cost cultivation and value of the seed cotton yield of the respective module.

RESUSTS AND DISCUSSION

Sucking pests

The observations on the incidence of sucking pests revealed that the IPM block registered lower population of sucking pests as compared to FP owing to the integration of various ecofriendly approaches and need based application of selective insecticides. Among the cultivars under IPM, Bunny BG-II recorded lower population of aphids, thrips, leafhoppers/ 3 leaves and mirid bugs/25 squares (3.94, 9.09 2.07/3 leaves and 3.10/25 squares, respectively) followed by Bunny BG-I (4.44, 9.74, 2.26/3 leaves and 3.10/25 squares, respectively) (Table 2). On the contrary, the genotype JK Durga, harboured more of sucking pests (6.55, 10.83, 3.42/3 leaves and 4.71/25 squares respectively). However, the variation among the cultivars under IPM was non-significant. Badiger *et al.* (2012) reported non-significant variation of sucking pests between BG-I and BG-II hybrids under IPM. Similarly, under protected condition, non-variation in sucking pests incidence among the BG-I and BG-II hybrids was also reported by Mann *et al.* (2010). The lower incidence of sucking pests under IPM was attributed to target specific interventions which kept the population below the damaging level. The present findings are in accordance with Patil *et al.* (2011) who elucidated the effectiveness of IPM components, viz. seed treatment with imidacloprid 70 WS, target specific insecticides against sucking pests in *Bt* cotton.

Bollworms and their damage

Irrespective of the modules, bollworm population was not observed in any of the *Bt* cotton genotypes. Although the larval population of *Helicoverpa* was observed in Non *Bt* cotton, the population was considerably low in IPM (0.98/plant) as compared to FP (1.96/plant). The lower population of *Helicoverpa* in non *Bt* IPM was due to integration of target specific interventions, viz. okra as trap crop, detopping of shoot tip at 80 days, red gram as a border row and need based application of selective chemicals which reduced the larval population to an extent of 49.49 per cent over FP. All the *Bt* genotypes across the modules, registered negligible level of fruiting body damage. Among

Table 2 Mean population of sucking pests and natural enemies in different Bt hybrids under IPM practices

	Treatment		Sucking pest complex				Natural
			Aphids/ 3 leaves	Thrips/ 3 leaves	Jassids/ 3 leaves	Mirid bugs/25 squares	enemies/ plant
	Bunny BG-I	IPM	4.44	9.74	2.26	3.16	0.84
			–2.28	–3.2	–1.78	–2.04	–1.35
		FP	5.02	10.04	2.3	7.07	0.71
			–2.37	–3.25	–1.79	–2.84	–1.3
Bt	Bunny BG-II	IPM	3.94	9.09	2.07	3.1	0.86
			–2.14	–3.18	–1.73	–2.02	–1.36
		FP	4.12	10.62	2.11	8.12	0.78
			–2.19	–3.34	–1.75	–3.02	–1.35
	JK Durga	IPM	6.55	11.89	3.42	4.71	0.85
			–2.75	–3.5	–2.1	–2.39	–1.36
	Nathbaba	FP	7.61	10.68	4.58	11.12	0.75
			–2.93	–3.29	–2.36	–3.48	–1.32
		IPM	4.48	10.1	3.29	3.79	0.83
			–2.29	–3.25	–2.07	–2.19	–1.35
		FP	7.24	10.43	3.41	8.18	0.75
			–2.87	–3.29	–2.1	–3.03	–1.32
Non Bt	Bunny non Bt	IPM	4.55	10.83	2.34	3.61	0.78
			–2.27	–3.44	–1.8	–2.15	–1.33
		FP	5.82	12.43	2.55	7.11	0.57
			–2.61	–3.57	–1.86	–2.85	–1.25
			Per cent increase over FP				*Percent reduction over FP*
Bunny BGI IPM vs Bunny BG I FP			9.36	2.99	1.74	S (55.30)	18.82
Bunny BGII IPM vs Bunny BG II FP			4.37	4.99	1.9	S	10.75 (61.82)
JK Durga IPM vs JK Durga FP			3.47	3.28	6.2	S (57.64)	13.33
Nathbaba IPM vs Nathbaba FP			14.5	3.16	4.98	S (53.66)	11.11
Bunny Non Bt IPM vs Bunny Non Bt FP			7.88	4.34	8.24	S (49.22)	38.24
Bunny Non Bt IPM vs Bunny BGI IPM			2.42	18.08	3.42	NS	6 (12.46)
Bunny BGII IPM vs Bunny Non Bt IPM			11.26	15.14	11.54	NS (14.12)	8
JK Durga IPM vs Bunny Non Bt IPM			0.22	13.12	3.31	NS (23.35)	7
Nathbaba IPM vs Bunny Non Bt IPM			0.89	15.05	2.14	NS (4.73)	5
Bunny BG–I IPM vs JK Durga IPM			2.2	5.71	6.61	NS (32.90)	1
Bunny BG–I IPM vs Nathbaba IPM			1.54	3.56	1.31	NS (16.62)	1
Bunny BGII IPM vs Bunny BGI IPM			13.41	3.47	8.41	NS	2 (1.89)
Bunny BGII IPM vs JK Durga IPM			11.46	2.32	14.46	NS (35.88)	1
Bunny BGII IPM vs Nathbaba IPM			12.05	0.1	9.61	NS (18.20)	3
JK Durga IPM vs Nathbaba IPM			0.67	2.23	5.37	NS (19.53)	2

In between modules and hybrids "t" test found non-significant with respect to sucking pests except for mirid bugs between IPM and FP. FP: Formers practice. Figures in parentheses are square root(x+1) transformed values

Table 3 Mean incidence of bollworms in different cotton hybrids under IPM practices

Treatment			Bollworms and their damage				
			Helicoverpa armigera larva/ plant*	Fruiting body damage (%) **	PBW larvae/ 50 green bolls*	Green boll damage (%)**	Locule damage (%)**
1	2	3	4	5	6	7	8
Bt	Bunny	IPM	0	1.17	0	2.34	2.67
	BG–I		–1	–5.4	–1	–8.75	–9.35
		FP	0	1.45	0	2.61	2.93
			–1	–5.92	–1	–9.24	–9.81
	Bunny	IPM	0	0.08	0	0	0
	BG–II		–1	–1.07	–1	0	0
		FP	0	0.09	0	0	0
			–1	–1.17	–1	0	0
	JK Durga	IPM	0	0.62	0	1.2	2.17
			–1	–3.68	–1	–6.29	–8.46
		FP	0	0.65	0	1.26	2.45
			–1	–3.75	–1	–6.44	–8.99
	Nathbaba	IPM	0	0.4	0	0.71	0
			–1	–2.93	–1	–4.54	0
		FP	0	0.4	0	0.76	0
			–1	–2.93	–1	–4.74	0
Non	Bunny	IPM	0.99	6.74	6.86	8.88	18.31
Bt	non Bt		–1.39	–14.39	–2.71	–17.23	–25.31
		FP	1.96	9.1	10	11.2	20.9
			–1.68	–16.71	–3.2	–19.16	–27.19
"t" test							
Bunny BGI IPM vs Bunny Non Bt IPM			S (100)#	S (60.07)#	S (100)#	S (73.65)#	S (73.65)#
Bunny BGII IPM vs Bunny Non Bt IPM			S (100)	S (98.81)	S (100)	S (100)	S (100)
JK Durga IPM vs Bunny Non Bt IPM			S (100)	S (90.80)	S (100)	S (86.49)	S (100)
Nathbaba IPM vs Bunny Non Bt IPM			S (100)	S (94.07)	S (100)	S (80.86)	S (100)
Bunny BG–I IPM vs JK Durga IPM				NS (47.01)		S (54.02)	NS (18.73)
Bunny BG–I IPM vs Nathbaba IPM				S (65.81)		S (34.87)	S (100)
Bunny BGII IPM vs Bunny BGI IPM				S (93.16)		S (100)	S (100)
Bunny BGII IPM vs JK Durga IPM				S (87.10)		S (100)	S (100)
Bunny BGII IPM vs Nathbaba IPM				S (80.00)		S (100)	S (100)
JK Durga IPM vs Nathbaba IPM				NS (35.48)		NS (29.41)	S (100)
Bunny BGI IPM vs Bunny BGI FP				NS (4.56)		NS (10.34)	NS (8.87)
Bunny BGII IPM vs Bunny BGII FP				NS (11.11)			
JK Durga IPM vs JK Durga FP				NS (4.62)		NS (4.76)	NS (11.43)
Nathbaba IPM vs Nathbaba FP						NS (3.41)	NS (12.39)
Bunny Non Bt IPM vs Bunny Non Bt FP			NS (49.49)	NS (25.93)	NS (31.40)	NS (20.71)	S (57.51)

IPM: Integrated Pest Management, FP: Farmers practice, S: Significant, NS: Non significant, Fruiting bodies includes squares and bolls, * Figures in parentheses are square root(x+1) transformed values, ** Figures in parentheses are arc sin transformed values, # Figures in parentheses are per cent reduction

the *Bt* genotypes, the duel gene *Bt* hybrid, Bunny BG-II, registered lower fruiting body damage of 0.08% followed by 0.40% in Nathbaba, whereas, Bunny BG-I recorded 1.17 per cent fruiting body damage (Table 2). The negligible level of spotted bollworm incidence was noticed during the study period and hence the data on spotted bollworm was excluded for the analysis. Irrespective of the modules, the pink bollworm population was not observed in any of the *Bt* genotypes. Further, green boll and locule damage was nill in Bunny BG-II followed by Nathbaba (0.71 and 0.00%, respectively). The significantly higher green boll and locule damage of 2.34 and 2.67 per cent respectively was recorded in Bunny BG-I followed by JK Durga (1.20 and 2.17% respectively). In case of Non *Bt*, the population of PBW and damage was low in IPM block (6.86 PBW/ 50 green bolls, 8.88 and 18.31% green boll and locule damage, respectively) as compared to Farmers' practice (10 PBW/ 50 green boll, 11. 20% and 20.90% respectively). Strickland and Annells (2005) reported the excellent efficacy of Bollgard II® against lepidopteran pests. Similarly Sagar and Patil (2011), reported lower fruiting bodies damage (0.91 and 1.11%) in NCS 145 and MRC 7918 BG-II genotypes as compared to NCS 144 and MRC 7918 BG-I genotypes under protected conditions. The advantage of *Bt* genotypes with dual gene has also been reported by Adamczyk *et al.* (2001) and Jackson *et al.* (2003) where in DP 50 B-II, the genotype with Cry1Ac + Cry2Ab was

Table 4 Impact of IPM on yield and economics

Particulars	Bunny BG–I		Bunny BG–II		JK Durga		Nathbaba		Bunny non Bt	
	IPM	FP	IPM	FP	IPM	FP	IPM	FP	IPM	FP
GOBs/plant	39	37	40	38	36.6	34.5	39.15	37.1	29.51	25.55
BOBs/plant	0.67	0.77	0	0	0.57	0.73	0.15	0.29	9.6	12.7
Seed cotton yield (q/ha)	24.5	23.31	25.2	23.9	22.05	20.8	24.57	23.37	17.65	16.1
No. of insecticide sprays	5	7	4	7	5	7	4	7	6	8
Cost of plant protection (₹/ha)	4595	4595	4302	5282	4595	4595	3865	4845	4220	4700
Total cost of cultivation (₹/ha)	19675	19675	19382	20362	19675	19675	18945	19925	22240	22720
Value of yield (₹/ha)	122500	116550	126000	119500	110250	104000	122850	116850	88250	80500
Net profit (₹/ha)	102825	96875	106618	99138	90575	84325	103905	96925	66010	57780
Net profit increase over FP (₹/ha)	5950		7480		6250		6980		8230	

Average rate of kapas during 2010–11: ₹ 5000/ha

found better than DP 50 B (Cry1Ac) with enhanced efficacy over wide range of lepidopteran pests.

The lower incidence of bollworms and fruiting body damage across the *Bt* genotypes integrated in IPM module, certainly convinced the suitability of *Bt* genotype as critical component. In addition, the use of okra as trap crop and nipping of shoot tip in IPM module are in accordance with the finding of Patil *et al.* (2011). The better performance of *Bt* genotypes under protected conditions has been also endorsed by Udikeri *et al.* (2003) and Venugopal *et al.* (2002).

Natural enemies

Further observation made on beneficial fauna clearly indicated that higher population of beneficial fauna was observed in IPM compared to farmers' practice due to integration of ecofriendly components and use of safer insecticides (neem based insecticides) and avoidance of chemical insecticides in the initial growth stage which supported higher population of beneficial fauna in IPM modules (Table 2). The present findings are in corroboration with the reports of Patil *et al.* (2011) who reported higher predatory population in *Bt* IPM and Non *Bt* IPM modules as compared to *Bt* RPP.

Yield and economics

The response of *Bt* genotypes as a component of IPM was found to be appreciable in terms of yield. Among the *Bt* genotypes in IPM module, Bunny BG-II recorded more number of good opened boll (40.00/plant) followed by Nathbaba (39.50/plant). In case of Non *Bt*, also more number of good opened bolls were realized in IPM blocks (29.51/ plant) as compared to farmers' practice (25.53/plant). The *Bt* genotypes registered significantly lower number of BOBs as compared non *Bt* (Table 4).

The *Bt* genotypes which afforded protection against bollworms, resulted in retention of more number of good opened bolls which inturn contributed for higher seed cotton yield. Among *Bt* genotypes with IPM, Bunny BG-II registered higher seed cotton yield of 25.20 q/ha followed by 24.57 q/ha in Nathbaba. Lack of target specific chemical interventions in farmers' practice, non *Bt* hybrid harboured more of bollworms/sucking pests which reduced the seed cotton yield (15.14 q/ha) to an extent of 36.24 per cent compared to IPM (17.65 q/ha).

Among the *Bt* genotypes under IPM technology, higher net profit was realized from Bunny BG-II (₹ 106 618.00/ ha) followed by Nathbaba (₹ 103 905.00/ha). On the contrary, net profit in Non *Bt* IPM module was more compared to the farmers' practice. These results are comparable with the findings of Bamabawale *et al*. (2004), Patil *et al*. (2004) and Patil *et al.* (2011) who reported higher seed cotton yield in *Bt* IPM plots with more net profit compared to *Bt* RPP and non-*Bt* IPM block. Superiority of BG-II genotype over BG-I genotypes was reported by Gore *et al*. (2001), Strickland and Annells (2005) and Bheemanna *et al.* (2008). The literature on comparative efficacy of different cotton hybrids developed from different *Bt* events under IPM practices are lacking.

It is evident from the above results that among the four *Bt* hybrids the performance of Bunny BG-II was found better as indicted by significant low infestation and higher yield as compared to other hybrids especially under IPM practices.

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