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Field evaluation of selected first and second generation Bt transgenic cotton hybrids in rainfed situation*

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Abstract : Field experiment was carried out for two seasons at Agricultural Research Station, Dharwad Farm, Dharwad-580 007 (Karnataka, India) to evaluate the performance of different new generation Bt cotton genotypes under rainfed eco-system. Second generation genotypes MRC-7201 and MRC-6322 with *Cry1Ac + Cry2Ab* genes have shown high level of resistance to all the three species of bollworms. The incidence of bollworms did not cross ETL in BG-II hybrids. First generation Bt intraspecific hybrids with *Cry1Ac* have received one and interspecific hybrids received two sprays. MRC-7201 recorded 0.13 larva of *H. armigera* per plant and 4.98 per cent fruiting body damage. MRC-6322 BG-II was on par with MRC-7201. RCH-368 Bt found better with 0.1 larvae per plant of *E. vittella* and 0.54 *H. armigera* larvae per plant and 5.73 per cent fruiting body damage among genotypes with *Cry1Ac.* Interspecific Bt hybrids MRC-6918 and RCH-708 performed better under protected conditions. All Bt hybrids were effective in containing pink bollworm incidence. Seed cotton yield was 20.58q/ha and 18.47 q/ ha in MRC-7201 and MRC-6322 BG-II hybrids respectively without any protection against bollworms.

Key words : Earias, helicoverpa, pectinophora, Bt cotton

Introduction

The use of cotton, world over, has been on the upswing despite competition from synthetic and animal origin fibres. According to International Cotton Advisory Committee, Washington, DC, USA, world cotton expected consumption for current year has been estimated to reach 24 m tonnes. Unfortunately no other cultivated crop species so far reported to be as susceptible to insect pests as cotton. About 130 different species of insects and mites found to devour cotton at different stages of crop growth in India among which bollworms *viz., Helicoverpa armigera* (Hubner), the American bollworm, *Earias vittella* (Fab.), spotted bollworm *Earias insulana* (Biosdual), spiny bollworm and *Pectinophora gossypiella* (Saunders),the pink bollworm occupy major pest status contributing to lower yields (Agarwal *et al.,* 1984). A recent estimation indicated that the loss caused by *H. armigera* and leaf hopper (*Amrasca biguttula biguttala* Ishida) was 31.0 and 18.0 per cent respectively (Grover and Pental, 2003). A loss of US $ 1.0 billion worth cotton has been accounted for dreaded pest, *H. armigera* every year (Gujar *et al.,* 2000). Though cotton occupies only 5% percent of the cropped area, on an average it used to receive 48.0 per cent of the total pesticide used for agriculture purpose in India. Kannan (2004) reported that bollworm control takes a heavy toll up to ₹ 1,200 crores in a year by Indian farming community. The intensive investment on insecticide to get rid of bollworms could not pay due dividend for longer time. The sole reliance on synthetic insecticides created significant agro-ecological problems like resurgence and insecticide resistance pushing cotton cultivation to cross roads.

Based on the demand for technical solution to the quite intense bollworm problem in India, the country resorted for adoption of Bt transgenic cultivars. Three Bt hybrids of Maharastra Hybrids Seeds Co. (Mahyco) MECH-12, MECH-162 and MECH-184 were commercialized for Central and South zone cotton states with an initial planting of 24,000 ha. Later during 2003 GEAC approved three more Bt hybrids developed by Rasi Seeds Ltd., Atur (Tamil Nadu). Since then plenty of Bt hybrids being approved every year by GEAC and at present 64 Bt cotton genotypes are under cultivation (Anonymous, 2006). Thus the area under Bt cotton kept on expanding and India gained status of mega biotech country with 7.8 m ha coverage.

Preliminary figures on Bt hybrid performance in India just becoming available now. (Surulivelu *et al.,* 2003, Udikeri *et al.,* 2003a and Patil *et al.,* 2005). The data suggested that the Bt cultivars have an edge over conventional cotton both in terms of yield and economic advantage apart from satisfactory pest control. A survey conducted by MARG indicated that Bt cotton produced 22.0 per cent better yields (18.98 q/ha) over conventional cotton (14.73 q/ha) with 78.0 per cent incremental benefit.

The genotypes used in India so for belong to first generation Bt cottons expressing *Cry 1Ac* toxin gene only. The genotypes having more than one gene are becoming popular in Australia and USA as a tactic of possible resistance management to *Cry* proteins. Hence, the present investigation was carried out to assess the performance of new Bt cotton genotypes of inter specific and intra specific hybrid as well as two (*Cry 1Ac + 2Ab*) genes which are popularly called as second generation Bt cottons.

Material and methods

Field experiments were conducted during 2004-05 and 2005-06 at Agricultural Research Station, Dharwad. Different new Bt transgenic plant incorporated protectant (PIP) cottons with genes coding for either *Cry 1Ac* or *Cry1Ac + Cry 2 Ab* were involved belonging to inter specific and intra specific hybrids. These genotypes were developed by Mahyco Research Centre, Jalana (Maharsthra) and Rasi Seeds Limited, Atur (Tamil Nadu).

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A commercial Bt (RCH-2 Bt) genotype with two conventional hybrids, DHH-11 and DCH-32 were used as check.

The experiment was laid out in split-plot design with three replications. There were two main plots (un protected-UP and protected-P) each comprising of 10 genotypes as sub plots. The main plot was having 45m x 5.4m size accommodating 10 sub plots with 4.5 m x 5.4 m each. The space between each main plot was 2.4 m. The replications were placed 3.0 m apart. Different genotypes under experimentation were dibbled 90 cm apart with intra row spacing of 60 cm on 8.7.2004 and 27.6.2005 for respective seasons. In each sub-plot 60 plants were maintained with gap filling and thinning after a week of initial sowing. The fertilizer application was at the rate of 80:40:40 in the form of Urea, DAP and MoP with two splits of N. Crop was kept weed free through regular intercultural operations. Harvesting of seed cotton from each sub plot was done as a single picking.

The plant protection measures for entire experimental setup remained uniform for both years against sucking pests. Before sowing, the seeds of each genotype was treated with imidacloprid 70 WS @ 10.0 g /kg to check the incidence of sucking pests. Later one application of acetamiprid 20 SP @ 10 g a.i./ha was given between 35-40 DAS to check the buildup of thrips and also to take care of trace incidence of leaf hoppers and aphids in both main plots based on ETL. There was absolutely no protection rendered against bollworms for any genotype in unprotected (UP) main plot with an aim to know the season long incidence and damage due to bollworms and its influence on yield of seed cotton under no protection.

In the protected main plot (P) the protection against bollworms was offered based on ETL (1.0 larva/plant) in each genotype. The insecticides preferred for protection were in the consecutive order of cypermethrin 10 EC @ 50 g ai/ha (first spray), profenophos 50 EC @ 1000 g a.i./ha (second spray) and quinalphos 25 EC @ 500 g ai/ha (third spray) as per warranty in each Bt genotype. In conventional hybrids, the sequence of protection was endosulfan 35 EC @ 1050 g ai/ha, chlorpyriphos 20 EC @ 500 g ai/ha , indoxacarb 15 SC @ 75 g ai/ha, cypermethrin 10 EC @ 50 g ai/ha, profenophos 50 EC @ 1000 g ai/ha and quinalphos 25 EC @ 500 g ai/ha. The protection rendered in the main plot was aimed to know the number of sprays required to get the maximum possible yield from each genotype with ETL based protection.

All the observations were made on randomly selected 10 plants per genotype avoiding border row plants. The larval incidence of spotted bollworm, *Earias vittella* was recorded on 50 and 65 DAS (days after sowing) on whole plant basis in each genotype. Similarly, incidence of *H. armigera* larvae was also made on whole plant basis at 65, 80, 95, 110, 125 and 140 DAS. However, the observations on *E vittella* and *H. armigera* have been given as seasonal mean incidence in tables. Flower rosetting was observed at peak flowering (60-75 DAS) by counting the number of rosetted as well as total flowers per ten plants to express in percentage. The number of PBW larvae per 10 green bolls was recorded by plucking 50 bolls randomly from the subplots and counting the number of larvae in each boll by dissecting the boll. The destructive sampling for larvae has been done around 115 DAS of the crop. Similarly, immediately after harvesting the crop 50 bolls from each genotypes were collected and counted for total and damaged locules due to PBW larval infestation. The data has been presented as percentage locule damage to each genotype. Before picking of seed cotton, number of good opened bolls (GOB's) and bad opened bolls (BOB's) were recorded from 10 randomly selected plants. The data has been averaged to per plant and presented as GOB plant^{-1} and BOB plant^{-1}. The seed cotton harvested from each sub-plot (genotype) excluding border rows was extrapolated and presented as seed cotton yield (q.ha^{-1}) for respective treatment. Based on consistency in the observations of two seasons in all parameters observed only pooled analysis has been presented.

Results and discussion

Bt genotype with one gene (*Cry1 Ac*) recorded *E. vittella* larval population in fraction and those genotypes with two genes (*Cry1 Ac + Cry2 Ab*) did not record larval population throughout the season (Table 1). The average incidence of *E. vittella* was high (>ETL) during both years on conventional cotton (DHH-11 and DCH-32). As incidence of spotted bollworm larvae did not cross ETL (> 1.0/ pl) in any of *Bt* genotypes under study, no spray was given. However, two sprays were given during both the years on conventional cotton as *E. vittella* crossed ETL at 50 and 65 DAS. It appears that at 50-70 DAS, the expression of toxin producing gene could be high enough to take care of the pest incidence. The effectiveness of *Bt* cotton hybrids against *E. vittella* was endorsed earlier by Gujar (2001), Kranthi (2002), Qaim and Zilberman (2002), Udikeri *et al.* (2003a) and Hegde *et al.* (2004).

H. armigera larval population increased slowly from square formation (50 DAS) to boll maturity stage (120 DAS) across the genotypes and later decreased reaching minimum at 145 days. *H. armigera* larval population crossed ETL (> 1.0/ pl) at 110 days to receive first chemical intervention in all *Bt* genotypes except in BG-II genotypes under study. There was significant *H. armigera* larval population difference among the *Bt* genotypes screened over two season during the study. The pooled data (Table 1) clearly shows that MRC-7201 (BG-II) recorded lowest *H. armigera* larval population (0.13/ pl), which was at par with MRC-6322 Bt (BG-II) and significantly superior to all the other Bt genotypes included in the study. The next best genotype was RCH-2 Bt (0.48/ pl) which was at par with RCH 368-Bt, (0.54/ pl) in protected condition with one application of the insecticide. MRC-6918 Bt (0.64/ pl) and RCH-708 Bt (0.58/ pl) recorded higher and at par *H. armigera* larval population with two sprays, and found to be significantly inferior to all other Bt genotypes used in the study. Among the bollgard (BG) group, BG-II was proved to be superior over BG-I by recording lower *H. armigera* larval population.

Similarly, fruiting body damage was also increased slowly from 50 DAS to 125 DAS and decreased later (Fig. 1 and 2). Second chemical intervention was made on selected genotypes *viz.*, MRC-6918 Bt and RCH-708 Bt wherein per cent fruiting body damage crossed ETL. Thus interspecific Bt hybrids found to have more incidence of bollworms compared to intraspecific

Table 1. Incidence of *E. vittella, H. armigera* larvae and per cent fruiting body damage in different Bt cotton genotypes

Genotypes	*E. vittella* larvae/ plant*			*H.armigera* larvae /plant*			Fruiting body damage (%)**		
	UP	P	Mean	UP	P	Mean	UP	P	Mean
RCH-368 *Bt*	0.11	0.10	0.11	0.73	0.54	0.64	8.07	5.73	6.90
	(1.05)	(1.05)	(1.05)	(1.32)	(1.24)	(1.28)	(16.49)	(13.83)	(15.16)
RCH-362 *Bt*	0.15	0.08	0.11	0.72	0.42	0.57	8.18	5.87	7.02
	(1.07)	(1.04)	(1.05)	(1.31)	(1.19)	(1.25)	(16.61)	(14.02)	(15.32)
MRC-6322 *Bt*	0.12	0.10	0.11	0.72	0.48	0.60	9.24	6.24	7.74
	(1.05)	(1.04)	(1.05)	(1.31)	(1.21)	(1.26)	(17.69)	(14.47)	(16.08)
MRC-7201 *Bt* (BG-II)	0.00	0.00	0.00	0.13	0.13	0.13	5.05	4.98	5.00
	(1.00)	(1.00)	(1.00)	(1.06)	(1.06)	(1.06)	(13.18)	(12.86)	(13.86)
MRC-6322 *Bt* (BG-II)	0.00	0.00	0.00	0.26	0.14	0.20	5.32	5.23	5.37
	(1.00)	(1.00)	(1.00)	(1.12)	(1.06)	(1.10)	(14.05)	(13.72)	(13.88)
MRC-6918 *Bt*	0.10	0.10	0.10	1.02	0.64	0.83	12.43	8.28	10.35
	(1.04)	(1.05)	(1.05)	(1.42)	(1.28)	(1.35)	(20.63)	(16.69)	(18.67)
RCH-708 *Bt*	0.06	0.08	0.07	1.03	0.58	0.80	11.74	7.81	9.77
	(1.02)	(1.03)	(1.03)	(1.42)	(1.26)	(1.34)	(20.01)	(16.22)	(18.12)
RCH-2*Bt*	0.14	0.13	0.13	0.57	0.43	0.50	8.29	5.44	6.87
	(1.06)	(1.06)	(1.06)	(1.26)	(1.19)	(1.22)	(16.74)	(13.48)	(15.11)
DHH-11	2.62	1.05	1.83	1.50	1.02	1.26	17.60	13.72	15.66
	(1.90)	(1.43)	(1.67)	(1.58)	(1.42)	(1.50)	(24.79)	(21.72)	(23.26)
DCH-32	3.53	1.91	2.72	2.37	1.83	2.10	27.77	19.53	23.65
	(2.13)	(1.70)	(1.91)	(1.83)	(1.68)	(1.76)	(31.74)	(26.20)	(28.97)
	S.Em±	C.D. at 5%		S.Em±	C.D. at 5%		S.Em±	C.D. at 5%	
Interaction1	0.03	0.10		0.02	0.06		0.61	1.80	
Interaction2	0.04	0.11		0.02	0.07		0.58	1.72	

*Figures in the parentheses are $\sqrt{x + 1}$ transformation

**Figures in the parentheses are arc sine transformation

Interaction 1: C.D. for comparison between two genotype means at the same protection

Interaction 2: C.D. for comparison between two protection means at the same or different genotypes

Bt hybrids. The lowest per cent fruiting body damage (Table 1) was observed in MRC-7201 Bt (4.98 %) which was at par with MRC-6322 BG-II, (5.23%), RCH-368 Bt (5.73%), RCH-362 *Bt* and RCH-2 Bt, MRC- 6322 Bt and significantly superior over remaining two Bt genotypes (MRC-6918 *Bt* and RCH-708 *Bt*) in protected condition. Per cent fruiting body damage was at par in protected and unprotected plots of BG-II genotypes, on the contrast there was significant difference between the protected and unprotected treatment of all the genotypes belonging to BG-I group having *Cry1* Ac gene.

Except BG-II genotypes and RCH-2 Bt, there was significant difference in the larval population or damage between protected and unprotected treatment of the same Bt genotypes. In protected main plots Bt genotypes registered significantly lower number of larvae compared to same genotypes in unprotected plots indicating the requirement of minimum protection against *H. armigera* incidence in BG-I genotypes. The results of Rajeshkumar and Stanley (2006) and the present findings are in line with each other. The findings of Jackson *et al*. (2003) indicated that pyrethroid treatment increased the control of bollworms which survived in Bollgard-I and hence produced better results. The reports of Burd *et al.* (1999) and Radhika *et al.* (2004) also justify better results obtained in the Bollgard-I genotypes with one or two spray intervention against no chemical intervention.

Thus second generation PIPs or BG-II genotypes have emerged as easy to adopt solution for resistance problem to *Cry 1 Ac*. Two gene *Bt* (*Cry1Ac+Cry2Ab*) genotypes performance also has been convincingly acceptable in different countries tested. The inclusion of two genes to combat the resistance resulted in synergestic effect against bollworms (Chakrabarti *et al.*, 1998 and Jackson *et al.*, 2003). The dual stacking with *Cry 1Ac +Cry 2 Ab* genes reported to have 10 folds advantage over *Cry 1Ac* genotypes (Marchosky *et al.*, 2001). Performance of BG-II genotypes interms of less damage and more yield compared to BG-I genotypes has been observed by Gore *et al.*(2002), Anonymous (2003), Jackson *et al.* (2004).

The lowest flower rosetting was observed in BG-II genotypes which were found to be significantly superior to rest of the BG-I Bt genotypes. MRC-6322 BG-II recorded lowest rosetting (0.03%) and was at par with MRC-7201 Bt (0.07%) in unprotected condition and superior to the genotypes with *Cry 1Ac* (Table 2). Inter specific Bt hybrids MRC 6918 (1.90%) and RHC-708 (1.57%) have recorded significantly highest rosetting among all Bt genotypes. There was no much variation in flower rosetting between protected and unprotected main plots of each treatment as there was no spray of insecticide till observation of this parameter. MRC-7201 Bt recorded

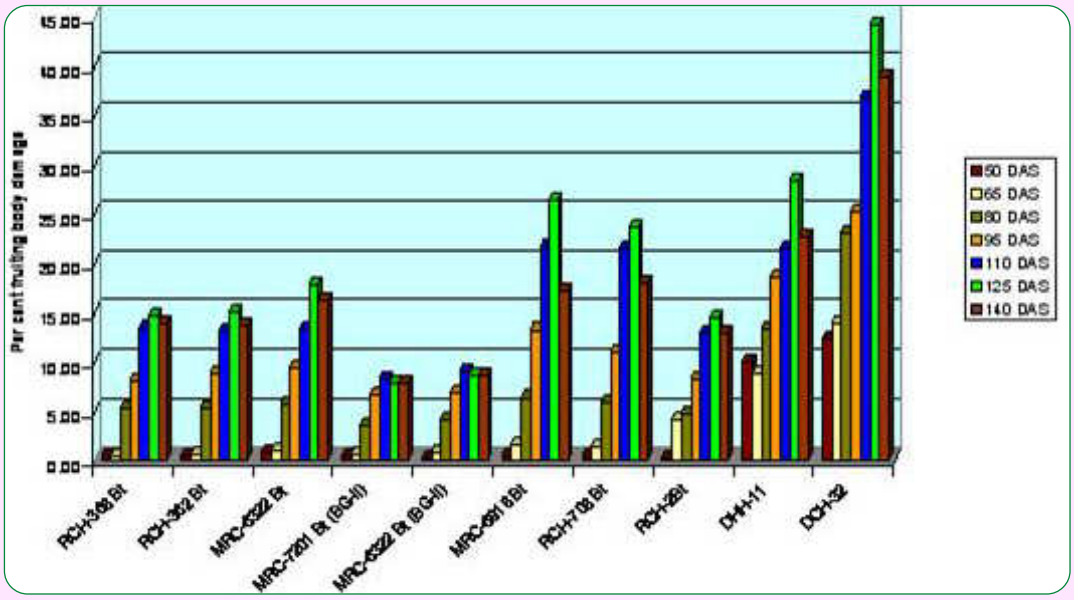

Fig 1. Fruiting body damage in Bt cotton genotypes by bollworms under unprotected condition

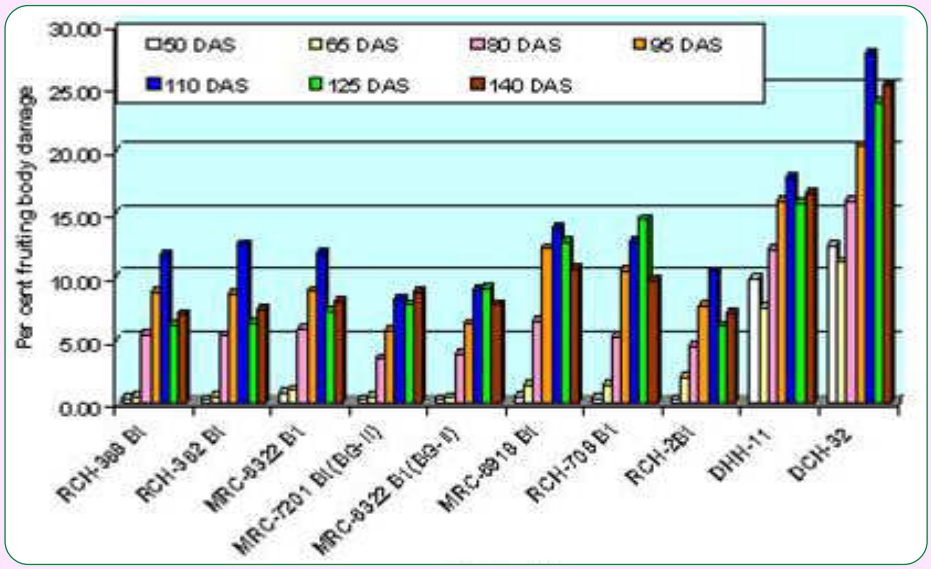

Fig 2. Fruiting body damage in different Bt cotton genotypes by bollworms under protected condition

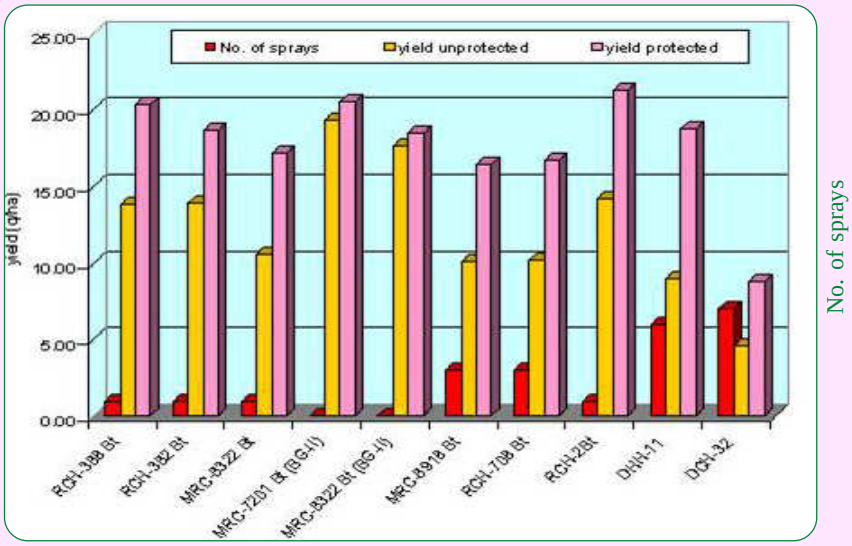

Fig 3. Number of sprays and seed cotton yield in different genotypes

Table 2. Incidence of PBW larvae, flower rosetting and locule damage in different Bt cotton genotypes (pooled)

Genotypes	PBW larvae/ 10 bolls*		Rosetting(%)**		Locule Damage (%)**	
	UP	P	UP	P	UP	P
RCH-368 *Bt*	0.54	0.14	0.34	0.38	8.53	5.72
	(1.24)	(1.07)	(3.30)	(3.53)	(16.97)	(13.79)
RCH-362 *Bt*	0.99	0.19	0.60	0.52	10.12	4.05
	(1.40)	(1.09)	(4.44)	(4.13)	(18.55)	(11.61)
MRC-6322 *Bt*	0.87	0.20	0.40	0.35	8.07	4.52
	(1.36)	(1.09)	(3.63)	(3.39)	(16.51)	(12.26)
MRC-7201 *Bt* (BG-II)	0.32	0.11	0.07	0.09	2.04	1.98
	(1.15)	(1.05)	(1.03)	(1.66)	(8.18)	(8.09)
MRC-6322 *Bt* (BG-II)	0.22	0.09	0.03	0.04	2.24	2.34
	(1.10)	(1.04)	(0.64)	(0.76)	(8.60)	(8.77)
MRC-6918 *Bt*	1.67	0.50	1.90	2.07	15.27	12.01
	(1.63)	(1.22)	(7.92)	(8.27)	(22.99)	20.28)
RCH-708 *Bt*	1.25	0.45	1.57	1.62	15.66	11.65
	(1.50)	(1.20)	(7.19)	(7.32)	(23.32)	(19.95)
RCH-2*Bt*	1.09	0.24	0.50	0.42	12.93	2.55
	(1.43)	(1.11)	(4.04)	(3.68)	(21.06)	(9.18)
DHH-11	1.94	0.28	7.32	4.70	25.23	16.95
	(1.69)	(1.13)	(15.68)	(12.53)	(30.12)	(24.16)
DCH-32	3.04	0.95	13.89	6.45	41.11	29.72
	(1.97)	(1.40)	(21.85)	(14.63)	(39.89)	(33.04)
	S.Em±	C.D. at 5%	S.Em±	C.D. at 5%	S.Em±	C.D. at 5%
Interaction 1	0.04	0.14	0.57	1.68	1.22	3.63
Interaction 2	0.05	0.14	0.54	1.59	1.18	3.49

UP: Unprotected condition P: Protected condition

*Figures in the parentheses are $\sqrt{x + 1}$ transformation

**Figures in the parentheses are arc sine transformation

Interaction 1: C.D. for comparison between two genotype means at the same protection

Interaction 2: C.D. for comparison between two protection means at the same or different genotypes

least per cent locule damage (1.98%) in protected condition which was at par with MRC-6322 BG-II (2.34%), RCH-362 Bt (4.05%) RCH-2 Bt and significantly superior to remaining genotypes in the study. The effectiveness of Bt genotypes (*Cry1Ac*) against PBW has been reported by Bhosle *et al.* (2004) (less locule damage), Henneberry and Jech., (2000) (no exit holes, less green boll infestation) and Willson *et al*., (1992) (least rosetting) in Bt cotton plants. There was no significant per cent locule damage difference between chemical sprayed and unsprayed BG-II genotypes which further confirmed the superiority of BG-II genotypes by expressing the true resistance. The results of Jackson *et al.* (2003) are in line with the present findings.

The Bt genotypes have significantly higher number of good opened bolls, lesser bad opened bolls and better yield over conventional hybrids (Table 3 and Fig.3). Under protected condition RCH-2 Bt recorded 21.31 q/ ha yield of seed cotton followed by MRC-7201 (20.58 qha^{-1}) and RCH-368 Bt (20.34 q ha^{-1}) all being on par to each other. In unprotected condition MRC-7201 recorded 19.33 qha^{-1} seed cotton which was significantly more over rest of the genotypes. Thus the second generation Bt genotypes having *Cry 1Ac + Cry 2Ab* genes could yield more than first generation Bt genotype without any spray. RCH -368 Bt and RCH-2 Bt with one application of insecticide yielded equal to two gene genotypes. Despite two rounds of insecticide spray inter specific Bt hybrids MRC-6918 (16.43 qha^{-1}) and RCH-708 (16.72 qha^{-1}) the yield level was low compared to other genotypes, but significantly more compared to same genotypes in unprotected condition as well as DCH-32. Thus the presence of *Cry 1Ac* gene was quite advantageous in intraspecific hybrids which are more susceptible to bollworms. Superiority of Bt genotypes over conventional hybrids in terms of seed cotton yield has been reported world wide and in India also (Udikeri *et al.*, 2003, Hegde *et al.*, 2004, Patil *et al.*, 2005 and Rajeshkumar and Stanley, 2006).

The *Bt* genotypes produced significantly higher yield under protected condition over the same genotype under unprotected conditions. Among the Bt genotypes RCH-2 Bt produced highest yield. The better performance of Bt genotypes under protected conditions has also been endorsed by Udikeri *et al.* (2003a), Venugopal *et al.*(2002) and Lambert *et al.* (1997). The results clearly indicated that far higher yield could be achieved with minimum protection in Bt genotypes (Fitt, 2003 and Pray *et al.*, 2002).

In the present study *Bt* genotypes could save five insecticidal sprays (Fig. 3). The *Bt* genotypes belonging to second generation (BG-II) MRC-7201 Bt and MRC-6322 Bt recorded on par yield under protected and unprotected condition indicating the inclusion of one more toxin producing gene intensified the protection. Further it could not require any additional protection

Table 3. Boll opening and seed cotton yield in different Bt cotton genotypes

Genotypes	GOB/plant			BOB/plant			Seed cotton yield(q/ha)		
	UP	P	Mean	UP	P	Mean	UP	P	Mean
RCH-368 *Bt*	15.06	21.90	18.48	3.62	4.32	3.97	13.83	20.34	17.08
RCH-362 *Bt*	14.10	18.75	16.42	3.15	4.18	3.66	13.93	18.68	16.31
MRC-6322 *Bt*	12.21	17.72	14.96	2.98	2.83	2.91	10.55	17.16	13.85
MRC-7201 *Bt* (BG-II)	25.40	27.30	26.35	2.50	2.07	2.28	19.33	20.58	19.96
MRC-6322 *Bt* (BG-II)	21.93	24.83	23.38	2.07	2.60	2.33	17.63	18.47	18.05
MRC-6918 *Bt*	16.72	20.43	18.57	4.92	5.07	4.99	10.11	16.43	13.27
RCH-708 *Bt*	14.37	19.60	16.98	4.78	4.32	4.55	10.16	16.72	13.44
RCH-2*Bt*	17.61	23.70	20.65	3.33	5.80	4.57	14.17	21.31	17.74
DHH-11	13.13	27.23	20.18	13.26	8.76	11.01	8.96	18.75	13.86
DCH-32	8.60	13.22	10.91	10.22	7.08	8.65	4.57	8.83	6.70
Mean	15.91	21.47	18.69	5.08	4.70	4.89	12.32	17.73	15.02
	S.Em±	C.D. at 5%		S.Em±	C.D. at 5%		S.Em±	C.D. at 5%	
Protection	0.23	4.21		0.07	1.26		0.15	2.72	
genotypes	1.00	2.97		0.37	1.10		0.31	0.93	
Interaction 1	1.41	4.20		0.53	1.56		0.44	1.31	
Interaction 2	1.36	4.04		0.50	1.50		0.44	1.32	

UP: Unprotected condition P: Protected condition GOB: Good Opened Boll BOB: Bad Opened Boll
Interaction 1: C.D. for comparison between two genotype means at the same protection
Interaction 2: C.D. for comparison between two protection means at the same or different genotypes

against bollworms. The advantage of Bt genotypes with two genes has been reported by Adamczyk *et al.* (2003) and Jackson *et al.* (2003). They reported that DP 50 B-II, the genotype with *Cry1 Ac + Cry2 Ab* was found better than DP 50 B (*Cry1 Ac*) with enhanced efficacy over wide range of lepidopteran pests. Thus, evaluation of new generation *Bt* genotypes in the present study clearly revealed advantage of second generation Bt (BG-II) genotypes apart from endorsing per se performance of new Bt genotypes having *Cry 1Ac*. Better performance of interspecific Bt hybrids over DCH-32 raised the hopes of interspecific hybrid cotton era again.

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