Short paper

Trend analysis of pests and diseases complex in *Bt* cotton

Palanisamy Saravanan[1*], Suhumaran Divya[1], Purusothaman Venkatesan[1], Rajkumar Tanwar[2], Ajanta Birah[2], Chirantan Chattopadhyay[2], Ponnuraj Jeyakumar[3] and Anupam Barik[4]

1. Hans Roever Krishi Vigyan Kendra, Perambalur, Tamil Nadu-621 115. India.
2. National Centre for Integrated Pest Management, NewDelhi-110 012. India.
3. National Institute of Plant Health Management, Hyderabad-500 030. India.
4. Department of Agriculture and Co-operation, Ministry of Agriculture, New Delhi-110 001. India.

Abstract: The significant reduction of bollworm infestation by the implementation of Integrated Pest Management (IPM) in *Bt* Cotton as a component of IPM led to reduction in bollworm infestation and increase in yield. However, these alterations have brought in many new biotic problems hitherto unknown or of little economic importance. Field survey of rainfed *Bt* cotton fields in Perambalur district of Tamil Nadu, India during 2008-2014 revealed that the incidence of various insect pests and plant diseases is on the rise in different *Bt* cotton hybrids. In 2008-2009, it was observed that the *Bt* cotton was damaged by cotton mealybug (*Phenacoccus solenopsis* Tinsley), green mirid bug (*Creontiades biseratance* Distant) and root rot (*Rhizoctonia solani* Kuhn) which caused severe yield losses. In addition to that, other pests like papaya mealybug (*Paracoccus marginatus* Williams & Granara de Willink) and *Alternaria* leaf spot caused more damage in *Bt* cotton during 2009-10. Besides these pests, the mirid bug (*Campyloma livida* Reuter), stripped mealybug (*Ferrissia virgata* Ckll), tobacco streak virus, grey mildew *Ramularia areola* and boll rot incidence in *Bt* cotton were noticed in 2010-12. Apart from this pest and disease problems, the *Alterrnaria* leaf blight, root rot (*Macrophomina phaseolina* Maubl) and *Myrothecium* leaf spot caused severe yield losses in *Bt* cotton during 2012-2014. The survey revealed that, the pests and disease problems are increasing year by year in *Bt* cotton which caused yield reduction and also increased the cost of cultivation. If left unchecked these pests and disease problems are capable of undoing all benefits gained due to *Bt* cotton in terms of increased yield and reduction in use of chemical pesticides.

Keywords*:* *Bt* cotton, Pests and Diseases problems, integrated pest management

Introduction

Cotton is an important crop for the sustainable economy of India and livelihood of the Indian farming community. It is cultivated in 11.0 Million hectares in the country. India accounts for about 32% of the global cotton area and contributes to 21% of the global cotton produce, currently ranking second after China. The production increased from a meager 2.3 M bales (170 kg lint/bale) in 1947-1948 to an all-time highest record of 31.5 M bales during 2007-2008 (Monga, *et al*., 2011). Many pests attack the crop, the major ones being American bollworm, *Helicoverpa armigera* Hubner, pink bollworm *Pectinophora gossypiella* Saunders, spotted bollworm *Earais*

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[*] **Corresponding author**, e-mail: vengaisaran@gmail.com
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vitella F. and tobacco caterpillar *Spodoptera litura* F. Introduction of genetically engineered crops that express endotoxins (*Cry* proteins) from *Bacillus thuringiensis* Berliner (*Bt*) can successfully control several pests. Among various transgenic crops, cotton hybrids expressing gene derived from the bacterium *Bt* have been deployed for combating cotton bollworms since 2002 (Anonymous, 2006). There are several other pests viz., *S. litura*, *S. littoralis* Boisduval and *Spodoptera exigua* Hubner which are less sensitive to *Cry* 1 Ac protein and have the potential to become major pests in the emerging scenario. Hence, in an attempt to have broader spectra of activity within lepidopterans including efficacy against many pests previously controlled effectively by single gene constructs and improved efficacy against bollworm complex, stacked gene *Bt* cottons popularly known as Bollgard-II (BG-II) were approved in both USA and Australia since 2002 and in India since 2006 as most convenient tool for the resistance management. The dual-gene cotton hybrids produce approximately the same level of the *Cry* 1 Ac protein as the single-gene Bollgard cultivars, but are further protected by *Cry* 2Ab protein (Adamczyk *et al*., 2003).

Several studies on *Bt* cotton in developing countries claim that its use brings benefits to smallholders because it decreases the number of pesticide spraying and increases yield. For instance, a study at the Makhathine Falts in South Africa stated that there had been a reduction in the average number of pesticide sprays per season for farmers who adopted *Bt* cotton. As a result, there were cost savings in the form of lower inputs for pesticide and labor (Bennett *et al*. 2003). Studies for India, Burkina Faso, and China have reached similar conclusions (Qaim, 2003; Pray, *et al*., 2001; Vitale, *et al*., 2008). The adoption of *Bt* crop led to increase in yield and caused vast reduction in insecticide use (Fitt, 2008). With *Bt* crops presently adopted in over 20 countries (James, 2009), the ecological risks of their commercial cultivation have received considerable scientific scrutiny. *Bt* cotton is currently cultivated in an area of 9.4 million hectares in India. About a thousand hybrids and one variety belonging to six different types of *Bt* cotton are available to the farmers. The area under *Bt* cotton increased from 29,309 hectares in 2002 to an estimated 9.4 million hectares (out of total cotton area of 11 million hectares) by 2010. This represents unprecedented 188-fold increase in nine years. *Bt* cotton covered an area of about 86 per cent of total cotton area in the year 2010-11 with more than 5.6 million farmers growing *Bt* cotton (Ananda Kumar, 2011). In Tamil Nadu, the area under *Bt* cotton increased from 637 ha in 2002 to an estimated 81,100 ha by 2010-11. Due to large scale adoption of *Bt* cotton, a change in pest scenario has been observed, especially sucking pests and some diseases assumed major status as the *Cry*1 Ac affords protection only for lepidopteran pests. The situation aggravated when crops remained in the fields for longer duration as the expression of *Cry*1 Ac declines with the plant age. The feedback since the commercialization of *Bt* cotton indicated that, the technology is not panacea for all pest problems (Patil *et al.*, 2011).

Cotton is known to suffer from number of diseases caused by fungal, bacterial and viral origins. There is now more relative importance for different diseases that may be airborne foliar diseases like grey mildew *Ramularia areola*, *Alternaria* leaf spot, *Myrothecium* leaf blight, Bacterial blight, Rust, cotton leaf curl virus (whitefly transmitted) or soilborne diseases like *Rhizactonia* root rot, *Verticillium* wilts and even some times *Sclerotium rolfsii* affecting cotton across India. Only the type of disease and its virulence differs with different agro-climatic regions. These changes may be due to change over from the cultivation of Asiatic (*Gossypium herbaceum* L. and *G. arboreum* L.) to American cottons (*G. hirsutum* L.) and hybrids. Most of them, even though high yielding, yet are susceptible to diseases (Shivankar and Wangikar, 1992). They caused the yield loss of

30% (Chidambaram and Kannan, 1989), 26% (Chattannavar *et al*., 2006) and 30% (Ramapandu *et al*., 1979) respectively. However, cotton crop is substantially attacked by sucking pests and diseases, which have to be controlled by other means. There are reports on increased incidence of sucking pests and diseases. Information on pest and diseases on *Bt* cotton helps to plan management strategies. Hence, the present study was aimed to identify the occurrence of emerging pests and diseases problems in *Bt* cotton.

Materials and Methods

An intensive surveillance programme was carried out to monitor and record the various pests and diseases in *Bt* cotton under Technology Mission on Cotton-Mini Mission-II Programme in collaboration with National Centre for Integrated Pest Management (ICAR), New Delhi. The survey was made in 80 cotton growing villages in Perambalur district of Tamil Nadu, India during 2008-2014. The pest and disease surveillance was carried out during the cropping season of August-March (every year) under rain-fed condition. In each village two fixed fields and two random fields were selected with major *Bt* cotton hybrids for weekly surveillance. During the first survey, the *Bt* cotton fields were marked by Global Positioning System (GPS) for periodical observations once in a week. In the selected fields, 20 plants were selected at random and observed for pests and diseases. Weekly observations were made for the status of insect pests and diseases on *Bt* cotton. Emerging pest of Mirid bug was recorded on whole plants as total numbers per plant Incidence of mealybug was recorded from 20 randomly selected plants from representative fields. The density index of mealybug was carried out as per scale of 0-4 (0–No mealy bug, 1–Scattered appearance of few mealy bugs in the plant, 2–Severe incidence of mealy bug on any one branch of the plant, 3 – Severe incidence of mealy bug on more than one branch or half portion of the plant, 4 – Severe incidence of mealy bug on the whole plant). For scoring of diseases incidence index in five spots, 20 plants were randomly selected and severity for each of *Alternaria* leaf spot, *Cercospora* leaf spot, root rot, grey mildew, tobacco streak virus and *Alternaria* leaf blight were recorded. The averages of severity of diseases indices were calculated and the nearest value to the average was considered for all diseases as the incidence of particular disease. The incidence of all disease was recorded by using 0-4 grade (Sheo, 1988) (0 = no incidence; 1 = 1-25% incidence; 2 = 25-50% incidence; 3 = 50-75% incidence; 4 = above 75% incidence). Assessment was made in 5 lower and 5 middle leaves of each plant and the grades were converted in to percent diseases index (PDI), using the formula given by Wheeler (1969).

$$DI\,(\%) = \frac{SNR}{NLO \times MDII}$$

Where DI is disease index; SNR is Sum of numerical ratings; NLO is total number of leaves observed and MDII; Maximum disease incidence index. The statistical analysis of the data was performed using AgRes (1994) Statistical software developed by Pascal International software solutions.

Results

The survey indicated that the population of green mirid bug, *C. biseratance* was recorded during 2008-2014, whereas *C. livida* was recorded during 2010-2014. The population of green mirid bug was 5.04, 5.15, 6.22, 8.27, 9.25 and 10.65 numbers/plant during 2008-2014 respectively. At the same time, the population of mirid bug, *C.livida* was 3.4, 4.65 and 7.55 numbers / plant was recorded during 2010-2014 respectively. Apart from these, the cotton mealybug, *P. solenopsis* was recorded on *Bt* cotton during 2008-2009 followed by other mealybugs viz., *P. marginatus* and, *F. virgata* during 2009-2014. The incidence of cotton and papaya mealybug severely damaged *Bt* cotton during 2008-2014 and its severity varied from grade 3 to 4. In respect to stripped mealy bug, *F. virgata*, the incidence increased from grade 1 to 3 in the year 2010 to 2014 respectively. The above mentioned pest populations were recorded above Economic Threshold Level (ETL) and caused damage to *Bt* cotton. The ETL of the Mirid bug was 0.5 mirid /meter in cool season and 1.0 mirid /meter in warm season) (Khan *et al*., 2004). The ETL of mealybugs were sparse population (grade-I Dahiya *et al*., 2008). These observations were depicted in Table 1.

The present study about the incidence of diseases in *Bt* cotton hybrids during the year 2008-12 revealed that higher incidence of bacterial, fungal and virul diseases were noticed. All the diseases were found to be in low incidence level during 2008-09 and started increasing to its severity in the subsequent years. The survey has revealed that among leaf spot diseases, the *Alternaria* leaf spot is the major disease when compared to *Cercospora* leaf spot. The *Alternaria* leaf spot disease incidence varied between 28.6 to 39.3 (PDI) during 2008-2014 whereas *Cercospora* leaf spot disease were recorded 0.7 to 7.55 (PDI) during 2008-2014. With respect to bacterial blight and *Myrothecium* leaf spot, disease incidence ranged between 1.2 to 31.8 (PDI) in the year 2008-2014. Among the major root rot diseases, the *Rhizoctonia solani* Kuehn root rot was recorded during 2008 onwards whereas *M. phaseolina* recorded from 2012 to 2014. The incidence of root rot (*R. solani*) disease increased during 2008 to 2014 and its PDI was 21.5, 24.7, 27.3, 29.0, 32.5 and 48.6. As the same, the root rot disease caused by *M. phaseolina* incidence were recorded during 2012 and 2014 in the PDI of 8.55, 14.25 respectively. The *tobacco streak virus* was also recorded in the year 2010 and the per cent incidence increased from 5.7 to 28.5 during the year 2010 and 2014. With respect to grey mildew, the higher per cent disease index of 34.5 was recorded during the year 2013-14 and the lowest incidence of 8.6 PDI was recorded during the year 2009-10. Another major problem was *Alternaria* leaf blight and its incidence was noticed during 2012-2013 in lower Per cent disease index (6.8). But its incidence increased to 54.62 PDI during 2013-2014 and caused severe yield losses in *Bt* cotton. The Per cent disease index of the diseases in the respective year is depicted in Table 2.

Table 1 Record of insect pests in *Bt* cotton in Perambalur district of Tamil Nadu, India during 2008 to 2014.

Insect species	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	Pooled mean
Mirid bug, *Creontiades biseratance* [1]	5.04	5.15	6.22	8.27	9.25	10.65	7.43
Mirid bug, *Campyloma livida* [1]	0	0	3.40	4.65	6.42	7.55	3.67
Cotton Mealybug, *Phenacoccus solenopsis* [2]	4	4	3	4	3	3	3.50
Papaya Mealybug, *Paracoccus marginatus* [2]	0	3	4	4	3	3	2.83
Stripped Mealybug, *Ferrissia virgate* [2]	0	1	1	2	3	3	1.66
SE	0.18	0.27	0.37	0.33	0.51	0.50	0.89
CD (0.05)	0.37	0.55	0.75	0.67	1.02	1.00	1.85
CV (%)	25.56	26.13	26.73	18.79	26.30	23.35	40.13

[1]. Number of insect/ plant, [2]. Insect density index (0-4).

Table 2 Record of plant disease on *Bt* cotton in Perambalur district of Tamil Nadu, India during 2008 to 2014.

Plant diseases	Percent disease index						Pooled mean
	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	
Alternaria leaf spot, *Alternaria macrospora*	29.4	28.6	31.4	34.5	36.2	39.3	33.2
Cercospora leaf spot, *Cercospora gossypina*	0.7	1.3	2.7	4.1	6.0	7.6	3.7
Myrotehcium leaf spot	1.2	0.7	2.1	3.2	12.5	31.8	8.6
Root rot, *Rhizoctonia solani*	21.5	24.7	27.3	29.0	32.5	48.6	30.6
Grey mildew, *Ramularia areola*	0	8.6	16.4	19.5	25.6	34.5	17.4
Tobacco streak virus, Ilar virus	0.0	0.0	5.7	13.4	19.5	28.5	11.2
Root Rot, *Macrophomina phaseolina*	0.0	0.0	0.0	0.0	8.6	14.5	3.9
Alternaria leaf blight, *Alternaria macrospora*	0	0	0	0	6.8	54.6	10.2
SEd	0.67	0.62	0.90	1.90	1.25	1.77	3.97
CD (0.05)	1.33	1.23	1.78	3.78	2.48	3.52	8.07
CV (%)	25.68	19.75	21.32	35.69	17.18	14.21	46.28

Discussion

The emergence of secondary pests is not a phenomenon associated with *Bt* crops, it is as old as crop protection itself. Pest resurgence and replacement are usually ascribed to alterations in pest management regimes (Dutcher, 2007). In crop rotation, when the primary pest is targeted, other species are likely to rise in its ecological place and multiply. For example, cotton aphid (*Aphis gossypii* Glover) evolved as primary pest of cotton in the mid-1970s because of intensive insecticide use for *H. armigera* management (Wu and Guo, 2005). The status of *Bt* cotton is not only associated with a decrease in insecticide use, it is also associated with the ineffectiveness of *Bt* cotton against the secondary pests. *Cry* toxins have specific activities against insects of different orders-Lepidoptera, Diptera, Coleoptera, Hymenoptera and invertebrates such as nematodes (Sarjeet *et al*., 1992). *Cry* toxins are ineffective against insects such as sap sucking and piercing insects like leaf bugs, cotton spider mites, cotton aphids, white flies and root-dwelling pests (De Maagd *et al*., 1999). Our survey reports also coincide with the findings of the above authors that state the increasing trend and severity of pests and diseases year by year from 2008-2014. In 2008-2010, the mirid bug *(C. biseratance)*, mealybug (*P. solenopsis*), leaf spots, grey mildew and root rot (*R. solani*) were recorded. Besides these pests and diseases, mealybugs like *P. marginatus*, *F. virgata*, mirid bug *C. livida*, root rot (*M. phaseolina*), *Alternaria* leaf blight and *Tobacco streak virus* incidence in *Bt* cotton were recorded during 2010-2014. Bambawale *et al*. (2004) and Patil *et al*. (2005) also reported that the *Bt* cotton is having no effect on sucking pest population and opined the need for imposition of suitable management strategy. The secondary pests are likely to increase over time because of two factors: (1) the general ineffectiveness of *Bt* cotton against pests other than the bollworm and (2) a lowered dosage of pesticides in *Bt* cotton. As a result of this, secondary pests that would otherwise not have survived have a chance to emerge and without additional pest control, could potentially evolve into primary pests (Men *et al*., 2004; Xu *et al*., 2008; Zhao *et al*., 2011)

Most polyphagous insects exhibit clear preferences for one or few host plants and may seasonally concentrate in patches on these plants. Consequently, management actions in these patches can greatly determine population dynamics of such insects at the landscape level (Kennedy and Storer, 2000). Lu *et al*. (2010) revealed that a drop of insecticide use in *Bt* cotton fields leads to a reversal of the ecological role of cotton: from being a sink for mirid bugs in conventional systems to being an actual source for these pests in *Bt* cotton growing systems. This perspective should be instrumental in developing region-wide management strategies for these polyphagous pests in northern China and elsewhere in the world. The incidence of grey mildew is assuming a serious position in central and southern zone. Majority of released *Bt* hybrids fall in moderately susceptible to highly susceptible category (Hosagoudar *et al*., 2008). Chattannavar, *et al*. (2009) reported that the grey mildew disease incidence ranged for 5-30 percent. The other diseases like *Alternaria* leaf spot and *Verticillium* wilt ranged from 5-40 percent while the bacterial blight and *Fusarium* wilt were least.

In conclusion, reduction in insecticide use associated with *Bt* cotton, increases infestation of other pests and diseases year by year. The incidence of mirid bug and mealybug was significantly higher due to a reduced number of broad spectrums of insecticide sprays against cotton boll worm complex. The sucking pests and diseases have become key problems in *Bt* cotton fields, and their incidence in *Bt* cotton may increase. Since pesticide treatment against primary pests have come down on *Bt* cotton as *Bt* produced an insecticide protein, secondary pests occupy an ecological niche without primary pests and as a consequence, with little substantial pesticide application, they can develop and cause important damage. Ironically these changes have allowed other pests to survive and emerge as important ones. Thus, the pests and diseases complex include mirids, mealybugs, tobacco streak virus, leaf spots, grey mildew, bacterial blight, *Alternaria* leaf blight etc., and their incidence increases year by year. When mirid bugs are considered, a green mirid, *C. biseratense* has appeared since 2005 in Karnataka and causes considerable damage to *Bt* cotton. This is also seen in Tamil Nadu, Andhra Pradesh and Maharastra states of India. Apart from this, *C. livida* has also been reported from Maharastra. The mirid bugs cause heavy shedding of squares and small sized bolls. Therefore it is important to address the increasing pest and diseases problems in *Bt* cotton through the development of environmentally sound and sustainable management strategies.

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پالانیسامی سروانان[1*]، سوهوماران دیویا[1]، پوروسوتامان ونکاتسان[1]، راجکومار تنور[2]، آجانتا بیراه[2]، چیرانتان چاتوپادییای[2]، پونوراج جیاکومار[3] و آنوپام باریک[4]

۱- هانس روور کریشی ویگیان کندرا، پرابالور، تامیل نادو، هندوستان.

۲- مرکز ملی مدیریت تلفیقی آفات، دهلی نو، هندوستان.

۳- مؤسسه ملی مدیریت بهداشت گیاهی، حیدرآباد، هندوستان.

۴- گروه کشاورزی و همکاری، وزارت کشاورزی، دهلی نو، هندوستان.

* پست الکترونیکی نویسنده مسئول مکاتبه: vengaisaran@gmail.com

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چکیده: کاهش معنی‌دار کرم غوزه پنبه در مزارع پنبه تراریخت حاوی ژن باسیلوس تورنجینسیس (Bt) در قالب مدیریت تلفیقی آفات موجب افزایش عملکرد گردید. اما این تغییرات مشکلات جدیدی را به‌همراه داشت که ناشناخته بودند و یا از اهمیت اقتصادی کمتری برخوردار بودند. بررسی‌ها در مزارع دیم‌کاری پنبه‌های تراریخت Bt در منطقه پرامبالور تامیل نادو، هند در طی سال‌های ۲۰۰۸ تا ۲۰۱۴ نشان داد که حشرات و بیماری‌های گیاهی گوناگون در حال افزایش هستند. در سال ۲۰۰۸ و ۲۰۰۹، مشاهده شد که در مزارع پنبه تراریخت، شپشک آردآلود پنبه (*Phenacoccus solenopsis* Tinsley)، سن سبز پنبه (*Creontiades biseratance* Distant) و قارچ پوسیدگی ریشه (*Rhizoctonia solani* Kuhn) باعث کاهش شدید عملکرد شدند. به‌علاوه، آفات دیگر مانند شپشک آردآلود پاپایا (*Paracoccus marginatus* Williams & Granara de Willink) و بیماری لکه برگی آلترناریا در طی سال‌های ۲۰۰۹ تا ۲۰۱۰ خسارت شدیدی به پنبه‌ها وارد نمود. هم‌چنین سن سبز پنبه ,(*Campyloma livida* Reuter)، شپشک آرد آلود (Ferrissia virgata Ckll)، ویروس موزائیک توتون، سفیدک خاکستری *Ramularia areola* و پوسیدگی غوزه پنبه در سال‌های ۲۰۱۰ تا ۲۰۱۲ گسترش یافته است. به‌جز این آفات و بیماری‌ها، بلایت برگی *Alterrnaria*، پوسیدگی ریشه (*Macrophomina phaseolina* Maubl) و لکه برگی Myrothecium باعث کاهش شدید عملکرد در پنبه Bt را در طول ۲۰۱۲ تا ۲۰۱۴ به‌همراه داشته است. مشکلات سال به سال در مزارع پنبه در حال افزایش است و موجب کاهش عملکرد و افزایش هزینه تولید شده است. اگر مشکلات به همین منوال پیش برود و اقدامی صورت نپذیرد تمام سودمندی‌های حاصل از پنبه تراریخت یعنی افزایش عملکرد و کاهش مصرف آفت‌کش‌ها را خنثی خواهد نمود.

واژگان کلیدی: پنبه‌های تراریخت Bt، مشکلات آفات و بیماری‌ها، مدیریت تلفیقی آفات