An Evaluation of Insecticide Resistance Management of Cotton Pink Bollworm Pests and Diseases in India

B. Kritha Karuni[1], Dr. Kuldeep Yadav[2]

[1]Research Scholar, Sunrise University, Alawar
[2]Professor, Sunrise University, Alwar

Abstract

Cotton is the most important crop producing natural fibre which has been under commercial cultivation for domestic consumption and export needs of about 111 countries in the world and hence called "King of fibres" or "White gold". The crop is attacked by 1326 species of insect pests throughout the world, of which about 130 different species of insects and mites found to devour cotton at different stages of crop growth in India. Among the bollworms, pink bollworm assumed major pest status in recent past and has known to cause loss in seed cotton yield, oil content, loss in normal opening of bolls, damage of locules, and reduction in seed cotton yield. The authors tried here to collect the information about the status of PBW, its source of abundance, life history, nature of damage, symptoms, mechanism of resistance, reasons of occurrence of this pest in BG II as well as control measures including IPM strategies. This information may helpful to the scientists to plant their research on this most devastating pest. Managing biotic stress in cotton has been dependent on the various pesticide molecules that are becoming available for cotton where farmers took extra-care to see that all the fruiting forms are retained intact to be harvested fully. This paper discusses the solutions that have arisen out of the country-wide monitoring of insecticide resistance in key pests as well and the use of alternate strategies such as biological control and host-plant resistance.

Keywords: *Cotton, Pink Bollworm, Pectinophora gossypiella.*

1. INTRODUCTION

India is one of the two countries of origin of cotton the other being Peru. Fifty years ago India grew cotton over 5.89 million hectares of land with a production of 3.1 million bales. Today, cotton occupies an area of 8.87 M hectares with a total production of 14.5 M bales of cotton (CICR Annual report 2001-2002). With increasing population, the requirement for cotton rose dramatically and in 1999-2000 productivity was 320 kg lint ha-1. Over the last 50 years productivity increased by 221 kg ha-1 from an extremely low 88 kg ha-1 (Agrl. statistics at a glance, 1999). This phenomenal growth in cotton productivity was attributed largely to hybrid cotton technology (Paroda and Basu, 1990). About 20 major popular hybrids occupy nearly 40 % of the total cotton area and contribute to over 50 % of the total cotton production. With successful exploitation of this technology on a commercial scale, further increases can be brought about through integrated crop management programs of which IPM is a crucial component. This is especially true since there has been no significant expansion in the area under cotton cultivation in recent years and the targets can now be met through good management programs. While India has the largest area in the world under cotton (Table 1), it still ranks amongst the lowest in its productivity. India is perhaps unique in its cotton cultivation. The four commercialized Gossypium species are grown commercially in different regions of the country. G. hirsutum and G. arboreum are grown in the North Zone comprising the Punjab, Haryana, Rajasthan, and parts of Uttar Pradesh. The Central Zone comprising of Gujarat, Madhya Pradesh, and Maharashtra is home to G. hirsutum, G. arboreum and G. herbaceum while all four species (including G. barbadense) are grown in the South Zone (Basu, 1995). Table 2 indicates the expected area under the four species in the years to come. Sixty-five percent of the area under cotton is predominantly rainfed, while the remainder is irrigated. The irrigated cotton belt is largely confined to northern India. Changes in the cultivars and cultivation practices have effected changes in the dominance of various pest species. Intense efforts to thwart herbivory in cotton crop made it notorious as a pesticide intensive crop in the last few decades, in India as elsewhere in the world. Today, India uses chemicals including pesticides in public health and agriculture to a total of US $640 M of which US $560 M worth pesticides are used in agriculture alone. Of this, insecticides worth US $320 M are used for the control of bollworms and sucking pests and US $222 M of this is apportioned to bollworm control (Ghosh, 2001). In this context, alternate methods of pest management, such as IPM becomes relevant, as there is emphasis on the judicious use of pesticides in combination with other methods of control.

Seasonal abundance

Korat and Lingappa (1996) reported that larval activity of PBW on tender bolls began in mid-November and continued till harvest of the crop. Sangareddy and Patil (1997) at Raichur reported that incidence of PBW commenced from October onwards which gradually increased and reached to a peak during February and declined thereafter. Venilla et al. (2007) at Nagpur studied seasonal abundance of PBW for five years and reported maximum population during 27th week of crop emergence in 2001, while comparatively lower population was observed in subsequent years. Significantly lower number of pink bollworm larvae and green boll damage were recorded in Bt cotton hybrid compared to non-Bt cotton hybrid (Nadaf and Goud, 2007).

2. STATUS OF PBW

Channakeshava and Patil (2009) observed that NCS-145 recorded higher larval population during 2nd standard week with a mean of 2.25± 0.34/boll, whereas there was no larval population was observed in MECH-184 Bt during the entire cropping period. Manjunatha et al. (2009) studied the incidence of PBW on different Bt and Non Bt hybrids and reported that all the Bt cotton hybrids registered significantly lower per cent of rosette flowers (0.01-1.57%) due to PBW throughout the season. Non-Bt cotton hybrids had lower per cent of rosette flowers in the initial stage, later it was gradually increased and reached to peak level at 140 DAS with damage ranging from 8.72 to 11.57 per cent. Santhosh et al. (2009) studied the impact of Bt cotton on PBW infestation and the results revealed that Bt cotton registered significantly lower number of larvae (3.35 larvae/30 bolls) as compared to non Bt cotton (10.03/30 bolls). Prasad et al. (2009) evaluated three Bt hybrids along with their non Bt cotton in comparison to standard check and reported that RCH 2 Bt (6.7%), RCH 20 Bt (6.9%), RCH 144 Bt (10.0%) and MECH 162 Bt (8.5%) recorded the lower per cent green boll damage and statistically on par with each other. Further, this Bt varieties found superior to other non Bt hybrids in the experiment in which boll damage ranged from 18.3 to 34.7%. Badiger et al. (2011) studied the comparative efficacy of interspecific cotton hybrid containing single and stacked Bt genes against PBW under rainfed condition and observed that among the stacked Bt hybrids, Steplon BG II and Kashinath hybrids proved better compared to other hybrids and also found that all the stacked Bt hybrids recorded significantly lower PBW larval population, green boll and locule damage compared to single gene Bt hybrids. Chinna Babu et al. (2013) evaluated Bt hybrids with their non Bt version in which RCH 2 was found significantly superior over all Bt and non Bt varieties. In Vadodara and Kheda districts, the infestation of PBW was found up to 94 per cent and 27 per cent irrespective of the Bt cotton varieties (Anonymous, 2014). PBW larval survival on BG-II was recorded significantly higher during 2012, 2013 and 2014 mainly in Amreli and Bhavnagar districts in Saurashtra, while the damage ranged between 0-80 per cent on BG II in Bharuch, Vadodara, Anand, Bhavnagar, Amreli, Junagadh, Rajkot, Surendranagar and Ahmedabad districts (Kranthi, 2015). The infestation of PBW was observed up to 100 per cent in Vadodara and 14.05 per cent incidence in Kheda district (Anonymous, 2016).

Life history

Eggs: Eggs are white when first laid but then turn orange, and later the larval head capsule is visible prior to hatching. Eggs hatch in about three to four days after they are laid. Eggs measure about 0.5 mm long and 0.25 mm wide (Venilla et al., 2007).

Larvae: The mature larvas are 10-12 mm long and have broad horizontal bands of red/pink colour. The larvae turn pink in the fourth and final instar of development only. Young larvae are tiny, white caterpillars with dark brown heads up to second instar. It becomes pinkish in third and fourth instar. Larval period lasts for about 10- 14 days (Venilla et al., 2007).

Pupae: The pupa is light brown and approximately 7 mm long (Venilla et al., 2007). The pupal period is 7-10 days.

Adult: Adults are small, greyish brown, inconspicuous moths (Anonymous, 2013). The wing tips are conspicuously fringed. There is a time period of 2-3 days after emergence during which the female mates and prepares to lay eggs.

Pre-oviposition period is about ten days. Adults may live for one to two months. The moths are about 7-10 mm with a wing span of 15-20 mm.

Nature of Damage

After hatching, the young larvae penetrate in ovaries of flowers or young bolls within two days of hatching. Larvae prefer feeding on developing seeds and generally pupate inside the seeds and bolls. Affected bolls either open prematurely or get badly affected due to rotting. Fibre length and strength are lowered. Furth er the cotton lint in the insect infested bolls gets damaged by secondary fungal infection (Kranthi, 2015).

3. INTEGRATED PEST MANAGEMENT

Cultural control: Watson and Larsen (1968) reported that not a single moth was emerged in Rotoilled 6 cm depth, while maximum (46.5 %) moth emerged in deep ploughing without covering attachments. According to Atwal and Singh (1969), minimum emergence of PBW was observed when seed was buried at 15 cm depth.

Physical control: Cent per cent mortality was observed when seeds were exposed for 20 min at 48.9^0C temperature.

Mechanical control: Nandihalli and Patil (1993) recommended that nine traps per acre were optimum for mass trapping the PBW moths. Korat et al. (1994) reported that the number of moths trapped/trap/night were 9.60 and 10.47 in check and 5.75 and 7.44 in insecticidal treated block during 1989- 90 and 1990-91, respectively. Application of PB rope LLT in cotton @ 150/ha caused effective mating disruption of PBW (Anonymous, 2007).

Biological control: PBW were effectively controlled by Rogas and Apanteles spp. (Anonymous, 1979). Chelonus blackburni was effective as uni-parental egg-larval parasite (Jackson et al., 1979). Apanteles angaleti was effective parasitoid of PBW (Singh et al., 1988). Malik (2001) reported that total parasitization of pink bollworm eggs by Trichogramma bactrae in two replications was 19.56 and 26.84 per cent, respectively. Trichogramma evinces efficiently parasitized PBW eggs under field condition (Saad et al., 2012).

Botanicals: Borkar and Sarode (2011) reported that application of botanicals, NSE 5%, azadirachtin 1500 ppm and neem oil 1% proved to be the most effective. Neem oil at 1.5 and 2% and neem seed water extract at 2 and 3% resulted into significantly lower damage than control (Rashid et al., 2012).

Chemical control: Beta-Cyfluthrin (24.11%), spinosad (25.33%) and indoxacarb (26.43%) were promising for control of PBW (Gopalswamy et al., 2000). According to Patil et al. (2009), both thiodicarb 70 SP (750 g a.i/ha) as well as profenophos 50 EC (500 g a.i/ha) effectively controlled PBW by registering significantly lower per cent loculi damage of 8.88 and 9. 50. Rani et al. (2010) reported that deltamethrin 1% EC + triazophos 35% EC at the rate of 360 g a.i/ha was the best followed by triazophos 40 EC (400 g a.i/ha), deltamethrin 10 EC (25 g a.i/ha), thiodicarb 75 SG (562 g a.i/ha) and lamda cyhalothrin 5 EC (25 g a.i/ha) for the control of pink bollworm. Thiamethoxam 25% WDG (40 g/ ha) was the most effective insecticide followed by chlorantraniliprole 20% SC and spinetoram 12% SC for the control of PBW (Sabry et al., 2014).

Pest losses in cotton

Insects, mites, pathogens, weeds, nematodes, rodents and birds constitute the pest complex of cotton. Of the biotic stresses, insect pests cause by far, the highest economic losses. Of the 1326 species of insects found on cotton, the sucking pests (jassids and whitefly) and the bollworm complex are designated as the key pests of cotton. Apart from a direct effect in the reduction of yield by these pests, it has been realiszd that their damage contributes to a high trash content in the lint resulting in lower international prices for Indian cotton. Losses due to bollworms are more or less consistent throughout the sub- continent. However, losses due to sucking pests are variable. During the year 2001- 02 heavy losses due to bollworms were reported in Punjab (20%), Haryana (50%) and Rajasthan (70%) (AICCIP annual report, 2001-02). During 1999-2000 and 2000-01 the avoidable losses due to all major pests were 32.3% and 26.2%, respectively. Sucking pests, in two years, caused a loss of 18.1% and 13.5% respectively while bollworms caused loss of 26.57% and 16.23% respectively (CICR Annual Report, 2001). A special mention should be made of the cotton whitefly Bemisia tabaci that has been reported to be a major pest in 16 of the 27 major cotton growing countries of the world, especially during the mid to late cotton growing season. It has also become a serious pest of cotton in recent years in several cotton growing regions of India, especially in the northern parts of India.

The problem assumes a serious dimension in relation to the Cotton Leaf Curl Virus (CLCuV) being transmitted by the whitefly. Losses caused by CLCuV have seen a reduction in the number of harvestable bolls 15ñ87% and a loss in boll weight of upto 39% (Singh et al., 1999). Bacterial blight and gray mildew are diseases that affect cotton in rainfed and dryland conditions while root rot and cotton leaf curl, are diseases that affect irrigated cotton in the north zone in India. These diseases limit productivity of lint to the extent of 12-23%. Many of them need critical favorable climatic and host conditions to emerge as a biotic threat for yield destabilization. Diseases in cotton have low yield reducing impact unless they become epidemic. Due to the consistent breeding efforts, we now have inbuilt resistance to bacterial blight, grey mildew and traditional wilts. Loss estimates due to plant parasitic nematodes have been put between 9-15% in India.

ntegrated pest management refers to the intelligent selection and use of pest management tactics that results in favorable ecological, sociological and environmental consequences (Rabb, 1972). It has also been defined as one or more management activities carried out by farmers that result in the density of potential pest populations being maintained below levels at which they become pests, without endangering the productivity and profitability of the farming system as a whole, the health of the farm family and its livestock, and the quality of the adjacent and down stream environment (Whiteman et al., 1995). IPM recognizes that complete control of a pest is neither required nor desired. It emphasizes the maintenance of pest populations below the economic threshold level (current figures for cotton insect pests has been presented in Table 3) and demands the initiation of pest management tactics before the economic injury level is reached. This concept is coherent with administrators and scientists in India. However its implementation under field situations has not been easy since the average Indian farmer has a low literacy level and fragmented land holdings with multiple crops. Therefore cotton pest management strategies for India have to be designed in such a way so as to ensure that they are in consonance with ground realities of the Indian farming system. Plant protection specialists in various research institutions have to assemble their technologies to fit it into this complex and heterogeneous cropping environment of Indian farms.

4. MANAGEMENT STRATEGIES

Pest monitoring

Monitoring of pests and diseases is necessary for timely action to be initiated. Use of light traps and pheromone traps to monitor insect populations is being recommended. Regular scouting is undertaken by progressive farmers for determining bollworm populations in the egg stage for effective management.

Seed treatment

This is a practice that has been followed primarily for protecting the young seedlings from disease. Historically, organomercurial compounds dominated the seed treatment market. This was gradually replaced with new chemicals such as Thiram, Mancozeb, Carbendazim etc. Today we have new generation compounds that offer excellent sucking pest control. Jassids, aphids and other sucking pests are better managed with seed treatment allowing a delay in the application of broad spectrum foliar sprays (Russell et.al., 1998). Imidaclorprid (Gaucho 70 WS) is a chloronicotinyl molecule used at 7.5 g a.i/ kg of seed and offers protection upto 45 days after sowing against sucking pest such as aphids and jassids. Thiomethoxam (Cruiser 70 WS) and acetamiprid are newer products useful for seed dressing (Leicht, 1993). However, imidacloprid, on account of its high toxicity has been discouraged as a seeddressing agent for farmer application by the government of India. Approval has been granted for its application by seed companies for seed treatment prior to sale. It has, however, been permitted for use as an early season spray (ConfidorÆ) as and when required. Use of these neonicotinoids is being recognized as a popular technology especially for cotton hybrids as it is cost effective on account of the low seed rate for hybrids. Bt hybrids (MECH 12, 164, 184) seeds are also being treated with imidacloprid. The use of neonicotinoid treated seed is an important component of leaf curl virus management where it has been reported effective in vector management. Seed treatment chemicals like imidacloprid 600 FS, imidacloprid 70 WS, thiomethaxam 70 WS and carbosulfan 25 DS, reduced both the CLCuV and vector incidence for two consecutive years (Singh et al., 2002). Seed treatment with carboxin, carbendazim, or carbosulfan protects the cotton crop against fungal soil borne diseases. Mancozeb seed treatment was reported to keep root rot disease to low levels in infected soils (Monga and Raj, 2000). In addition, protection against seed borne diseases is ensured by storing seeds under low moisture conditions and by the use of acid delinted seed.

Host plant resistance

The basis for any sound IPM program is the choice of an appropriate cultivar that fits well into the production system. The most desirable characteristics of a cotton cultivar or hybrid is that it should possess reasonable pest tolerance, short and early duration, good fiber qualities, coupled with high yield. Both morphological and biochemical mechanisms in Gossypium spp. have been found to mediate resistance against jassids, whiteflies and the bollworms. Morphological characters such as hairiness of leaves, toughness of leaf veins, thickness of leaf lamina, length of hair and angle of insertion are reported to be associated with jassid resistance. The pubescent genes H1 and H2 has been used to provide jassid resistance to cultivars in India. However extreme pubescence has been reported to have an adverse effect on agronomic traits (Uthamasamy, 1995). Of the cultivated cottons, G. arboreum and G. herbaceum are resistant to the leaf hopper. Among the wild cottons G. tomentosum, G. armourianum and G. raimondii by virtue of their pubescence are resistant to sucking pests. Gossypium arboreum types as compared to Gossypium hirsutum types are more resistant to jassids and whiteflies. Morphological attributes such as red leaf, glabrousness, okra leaf and fregobract are known to confer a high degree of tolerance to Helicoverpa and whiteflies. Red leaf has an adverse effect on agronomic characteristics especially in environments with high yield potential. Most of these attributes have been used by breeders to screen for resistant sources and cultivars, such as Kanchana, LK861 and Supriya, have been developed which have considerable tolerance to whitefly. Cotton genotypes, DHY286, Mahalakshmi, MCU15, Krishna, Sujatha have been identified for resistance against jassids. These sources of resistance can be used as parents in crosses. Some exotic hybrids (six G. hirsutum x G. barbadense interspecific hybrids, five from Israel and one from India, and two intraspecific G. hirsutum hybrids (Fateh and LHH144) were tested for their resistance to white flies under field conditions. Table 4 lists the prominent cotton cultivars that have resistance to pests and diseases.

Insecticide resistance management (IRM)

A novel strategy was devised to provide a practical, robust plant protection package to ensure favorable economic, sociological and ecological consequences. This involved the use of insecticides highly compatible with IPM while taking into cognizance the existence of resistance to insecticides in various insects of the cotton ecosystem. A wide database on the inseason changes in resistance and between years has been generated across North, South and Central India against the major cotton pests (Kranthi et al.,2001, 2002). This was established with the setting up of five major insecticide resistance laboratories across the country in a networking project. Details of this are not discussed in this paper. On the basis of the data base insecticide resistance management strategies have been formulated and implemented in parts of Andhra Pradesh, Tamil Nadu, Maharashtra and Punjab through funding by the Indian Council for Agricultural Research, Natural Resources Institute, UK, Department of International Development, UK and ICRISAT, Hyderabad and Punjab and Tamil National Agriculutral Universities. Currently, the Government of India is funding an US $350 000 project for the implementation of IRM strategies in the 26 newest insecticide using cotton-growing districts of India, in the year 2002-03. CICR is coordinating the inputs from government institutes, agricultural universities and the Indian Council of Agricultural Research in expanding this work to the 260 villages, which between them use almost 80% of the insecticides applied on cotton. The basic concepts of IRM suggest that particular insecticides should be used when resistance to that material is low, that natural enemy populations should be disturbedas little as, that different groups of chemicals are alternated and that sucking pest tolerant genotypes are grown to avoid early season insecticide sprays. Summarised, IRM means cultivation of sucking pest tolerant cultivars, zero insecticides till 60 days after emergence of the crops, adoption of window strategies with no endosulfan beyond 90 days, no organophosphates till 90 days, use of bio-rationals if available between 70-90 days and the use of pyrethroids only after 110 days (CICR, 1999). IRM strategies draw strength from the fact that it is supported by voluminous, meaningful, peer reviewed and published laboratory and field data. Its sustainability is enhanced by the fact that it does not rely on the supply of free inputs to the farmer

New molecules for IPM

New molecules are likely to appear in the Indian market in the next two to three years. Some are being tested under the All India Co-ordinated Cotton Improvement Project (AICCIP) while others, like Spinosad and Indoxacarb, are already available in the market. The advantages of the new generation compounds are that, in addition to being effective at low dosages, like pyrethroids, they are reasonably safe to natural enemies. Essentially, they are highly IPM compatible. Several molecules such as chlorphenapyr, IGRs, pymetrozine, avermectins and resistance breaking pyrethroids are in the pipeline. However, two molecules need special mention- since they are commercially available in India. New molecules need to be introduced with caution. Generation of base line toxicity data for any new molecule that may shortly be introduced in the market is an important prerequisite to enable the detection of any development of resistance. This is especially important for the cotton ecosystem, which consumes more than 50% of the insecticide used in the country. On the introduction of new molecules and after intensive study under the All India Coordinated Cotton Improvement Trials insecticide resistance management programs for these new materials should be incorporated into IRM programs for cotton. This would help increase the life of the molecule by delaying the development of resistance. Short-term contractual projects are being conducted at the Central Institute for Cotton research to determine the baseline toxicity of some molecules that are in the pipeline for release.

Management of cotton nematodes

Reniform (Rotylenchus reniformis), root-knot (Meloidogyne incognita), lance (Hoplolaimus sp.) and lesion (Pratylenchus sp.) nematodes have been reported to be important in cotton. They are responsible for up to 10-12% yield losses in different regions and seasons. Many of them aggravate the damage when present in association with soil-borne pathogens such as Rhizoctonia, Fusarium and Pythium. Low cultural practices cost, have been effective in keeping damage at low levels. Rotations with crops like Capsicum, Tagetes, Zinnia and natural rotations with field crops have had a great impact in reducing nematode populations. Current emphasis of management has been on resistance breeding and biological control. Variety B4 Empire has been found to be highly resistant to root- knot nematodes. Similarly, Paecilomyces lilacinus, which parasitises the eggs of the root-knot nematode has shown good promise as a bio-control agent. Pasteuria penetrans has been suggested as a potential bio-control agent against root-knot nematode for the last decade.

5. CONCLUSION

PBW is a major problem in India, primarily because of long duration varieties and absence of any potent control measures. The simplest and most potent way to overcome the problem is to take up timely sowing and cultivate early maturing varieties of about 150 days duration. All other management strategies such as pheromone traps, PB rope, botanicals, bioagents and insecticides (Profenophos 50 EC 10 ml, cypermethrin 25 EC 4 ml, alpha cypermethrin 10 EC 10 ml, spinosad 45 SC 3 ml, emamectin benzoate 5 SG 3 g, deltamethrin 1%+ triazophos 35 EC 10 ml, chlorpyriphos 16% + alpha cypermethrin 1% EC 10 ml, fenpropethrin 30 EC 10 ml, chlorpyriphos 50% + cypermethrin 5% EC 10 ml in 10 lit of water) alone and with integration can be effective for control of PBW. In the next five years cotton cultivation in India will emerge strengtened by the availability of Bt transgenics varieties and hybrids. Resistance management strategies which are being developed for the transgenic technology, specifically designed for the Indian farming systems will be disseminated. Pesticide consumption may reduce drastically with sustainable, cost effective, pest management programs in cotton. Awareness about new innovative technologies among the farming community will increase. Emphasis will be on parameters such as fiber quality in an endeavour to attract the international market. The cotton farmers and the cotton industry need to be suitably geared-up to meet the challenges of globalisation.

REFERENCES

1. Anonymous (2014). Annual Report. Department of Entomology, BACA, AAU, Anand. Pp. 8- 9.
2. Anonymous (2016). Annual Report. Department of Entomology, BACA, AAU, Anand. Pp. 33- 34.
3. Anonymous (2015). Cotton Production and Balance Sheet. The Cotton Corporation of India Ltd., October, 2015.
4. Attique, M. R.; Ahmad, M. M.; Ahmad, Z. and Rafiq, M. (2001). Efficacy of botanicals and bio-pesticides on population dynamics of bollworm complex and their safety to the predators in nonBt cotton. Crop Prot., 20: 421-426.
5. Badiger, H. K.; Patil, S. B.; Udikeri, S. S.; Biradar, D. P.; Chattannavar, S. N.; Mallapur, C. P. and Patil, B. R. (2011). Comparative efficacy of interspecific cotton hybrids containing single and stacked Bt genes against pink bollworm, Pectinophora gossypiella (Saund.) and tobacco caterpillar, Spodoptera litura (Fab.). Karnataka J. Agri. Sci., 24 (3): 320-324.
6. Borkar, S. L. and Sarode, S. V. (2011). Evaluation of botanicals and biopesticides in the management of bollworm complex in cotton. Indian J. Ent., 73(3): 263-269.
7. Bravo, A. and Soberon, M. (2008). How to cope with insect resistance to Bt toxins? Trends in Biotech., 26 (10): 573-579.

8. Channakeshava, R. and Patil, B. V. (2009). Seasonal Incidence and Management of Bollworm complex in Bt cotton under Irrigated ecosystem. Ann. Pl. Protec. Sci., 17(2): 275-278.
9. Chinna Babu, V.; Prasad, N. V. V. S. D. and Rao, G. R. (2013). Incidence of Pink Bollworm on Bt and non Bt hybrids. Ann. Pl. Protec. Sci., 21 (2): 416-417.
10. Ghosh, S. K. (2001). GM Crops: Rationally irresistible, Curr. Sci., 6: 655-660.
11. Gopalswamy, S. V. S.; Rao, N. H. P. and Rao, V. H. (2000). Insecticides in the control of pink bollworm P. gossypiella (Saunders) in cotton. Pestology, 24 (7): 7-11.
12. Prasad, N. V. V. S. D.; Rao, M. and Rao, N. H. (2009). Performance of Bt cotton and non Bt cotton hybrids against pest complex under unprotected conditions. J. Biopesti., 2(1): 107-110.
13. Rani, S.B.; Prasad, N.V.V.S.D.; Rao, P.A. and Rao, S. (2010). Performance of insecticides and transgenic Bt cotton for the management of pink bollworm, Pectinophora gossypiella (Saunders) in cotton. J. Ent. Res., 34(2): 125-129.
14. Rashid, M. M.; Khattak, M. K. and Abdullah, K. (2012). Evaluation of Botanical and Synthetic Insecticides for the management of Cotton Pest Insects. Pakistan J. Zool., 44(5): 1317-1324.
15. Saad, A. S. A.; Tayeb, E. H. M.; Awad, H. A. and ElBassiunoy, H. M. (2012). The release of the parasitoid Trichogramma evancens to control the pink bollworm Pectinophora gossypiella (Saunders) and the side-effect of certain insecticides on it. Alexandria Sci. Exchange J., 33: 1-9.
16. Sabry, A. H.; Hassan, K. A. and Rahman, A. A. (2014). Relative toxicity of some modern insecticides against the pink bollworm, Pectinophora gossypiella (Saunders) and their residues effects on some natural enemies. Int. J. Sci. Environ. Tech., 3(2): 481-491.
17. Sangareddy, N. K. and Patil, B. V. (1997). Studies on pink bollworm, Pectinophora gossypiella (Saunders) incidence and its natural enemies on cotton in Tungabhadra. Karnataka J. Agri. Sci., 10 (1): 226-228.
18. Santhosh, B. M.; Patil, B. V.; Udikeri, S. S.; Awaknavar, J. S. and Katageri, I. S. (2009). Impact of Bt cotton on pink bollworm, Pectinophora gssypiella (saunders) infestation. Karnataka J. Agri. Sci., 22(2): 322-326.
19. Singh, J.; Sandhu, S. S. and Sindhu, A. S. (1988). Adult emergence pattern of parasitoid Apanteles angaleti and its known hosts during offseason in Punjab. Biocontrol, 33(3): 309-314.
20. Venilla, S.; Biradar, V. K.; Sabesh, M. and Bambawale, O. M. (2007). Know your cotton insect pests: Pink bollworms. Crop Protection Folder Series, 7 of 11. CICR, Nagpur.