PINK BOLLWORM: A NOTORIOUS PEST OF COTTON : A REVIEW

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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.

KEY WORDS: Cotton, Pink Bollworm, Pectinophora gossypiella

INTRODUCTION

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". India is an important grower of cotton on a global scale. In India, cotton is cultivated in an area of 126.55 lakh ha with 400 lakh bales production of cotton with an average productivity of 537 kg/ha. Gujarat is the largest producer of cotton in India having cotton cultivation in an area of 30.06 lakh ha with a production of 125 lakh bales of cotton and productivity of 707 kg/ha (Anonymous, 2015). The major cotton growing districts are concentrated in Saurashtra, followed by Central Gujarat and North Gujarat.

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 (Ghosh, 2001). Worldwide, pink bollworm *Pectinophora gossypiella* (Saunders) has become economically the most destructive pest of cotton and has

known to cause 2.8 to 61.9 per cent loss in seed cotton yield, 2.1 to 47.1 per cent loss in oil content and 10.7 to 59.2 per cent loss in normal opening of bolls (Patil, 2003). Locule damage was noted to an extent of 55 per cent and 35-90 per cent reduction in seed cotton yield have been reported by Narayanan (1962). Agarwal and Katiyar (1979) estimated the yield loss to an extent of 6525 MT annually.

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).

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. Further the cotton lint in the insect infested bolls gets damaged by secondary fungal infection (Kranthi, 2015).

Symptoms

1. Rosette flowers: Flowers do not open fully. They get twisted.

2.Spots on green bolls: Black spots on green bolls may often be indicative of PBW damage. PBW damaged bolls often predispose the occurrence of secondary bacterial infection that results in the blackening of boll rind on the outside.

3. Stained lint in open bolls: This is a distinct symptom of damage. It occurs in the later stages of crop growth, once the damage is done (Kranthi, 2015).

Carry Over

Mallah *et al.* (2000) reported that population of PBW remained in left over standing cotton throughout the year. According to Attique *et al.* (2001), 35 per cent larvae survived in the lower part of the heap in the left over bolls of cotton stalks kept horizontally. The seed cotton carried to market yards acts as a source for the pest to spread. In the absence of cotton, or as a genetically pre-disposed condition, the pink bollworm undergoes hibernation for 6-8 months, until the next season (Kranthi, 2015).

Mechanisms of resistance

Proteolytic activation of Cry toxins: Resistance to Cry1Ac was shown to be because of defects in mid gut protease activities that affected the activation of Cry1Ac protoxins (Bravo and Soberon, 2008).

Receptor binding: Cadherin is synthesized as polypeptides and responsible for the separation of the different tissue layers, and for cellular migration.

Three Cadherin alleles associated with resistance in PBW: *P. gossypiella* 90arboured three mutant

alleles of a cadherin-encoding gene linked with resistance to *Bt* toxin Cry1Ac and survival on transgenic *Bt* cotton. Larvae with two resistance alleles in any combination were resistant, whereas those with one or none were susceptible to Cry1Ac. Three cadherin allels namely r1, *r2*, and *r3* of the pink bollworm cadherin gene *BtR* confer recessively inherited resistance to *Bt* toxin Cry1Ac (Morin *et al.*, 2003).

Reasons for PBW occurrence on Bollgard II:

1.Physiological processes (Griffitts and Aroian, 2005):

a)Defective solubilisation,
b)Deficient proteolytic activation,
c)Over-proteolysis (*i.e.* degradation of toxin),
d)Sequestration of toxin molecules by non-functional binding sites,
e)Defects in functional binding sites,
f)Defective pore formation,
h)Enhanced cellular repair, etc.

2. Inadequate planting of refuge and more cultivation of *Bt*-cotton.
3. PBW is monophagous in nature.
4. Large scale planting of unapproved (illegal) *Bt*-cotton.
5. Lack of field monitoring due to *Bt* cotton.
6. Pest is concealed in nature.
7. Natural enemies are very few.
8. Less use of insecticides.

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 ^{0}C temperature. (Atwal and Singh, 1969).

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).

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.

Future Thrust

- ✓ Need to find out role of refugia with *Bt* cotton for controlling PBW.
- ✓ Exact source of carry over should be found out.
- ✓ Effective combination of botanicals and insecticides need to find out.
- ✓ Population dynamics should be studied to develop IPM strategies.

REFERENCES

Agarwal R. A. and Katiyar, K. N. (1979). An estimate of losses of *Kapas* seed due to bollworms on cotton in India. *Indian J. Ent.*, **41**(4): 143-148.

Anonymous (1979). Annual Report. AICRP on Biological Control, AAU, Anand.

Anonymous (2007). Annual Report. Department of Entomology, BACA, AAU, Anand. Pp. 70.

Anonymous (2013). University of California Pest Management Guidelines. Cotton: Pink bollworm. UC ANR Publication No. 3444.

Anonymous (2014). Annual Report. Department of Entomology, BACA, AAU, Anand. Pp. 8-9.

Anonymous (2016). Annual Report. Department of Entomology, BACA, AAU, Anand. Pp. 33-34.

Anonymous (2015). Cotton Production and Balance Sheet. The Cotton Corporation of India Ltd., October, 2015.

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 non-*Bt* cotton. *Crop Prot.*, **20**: 421-426.

Atwal, A. S. and Singh, K. (1969). Comparative efficacy of *Bacillus thuringiensis* and some contact insecticides against *Pieris brassicae* L. and *Plutella maculipennis* (Ceuits) on cauliflower. *Indian J. Ent.*, **31**(2): 361-363.

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.

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.

Bravo, A. and Soberon, M. (2008). How to cope with insect resistance to Bt toxins? *Trends in Biotech*., **26** (10): 573-579.

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.

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.

Ghosh, S. K. (2001). GM Crops: Rationally irresistible, *Curr. Sci.*, **6**: 655-660.

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.

Griffitts, J. S. and Aroian, R. V. (2005). Many roads to resistance: how invertebrates adapt to *Bt* toxins. *BioEssays*, **27**(6): 614-624.

Jackson, C. G.; Neemann, E. G. and Patana, R. (1979). Parasitization of 6 lepidopteran cotton pests by *Chelonus blackburni* [Hym.: Braconidae]. *Biocontrol*, **24**(1): 99-105.

Korat, D. M. and Lingappa, S. (1996). Monitoring of pink bollworm moths with sex pheromone traps and its relationship with larval population and field incidence. *Karnataka J. Agri. Sci.*, **9** (3): 432-437.

Korat, D. M.; Lingappa, S. and Patil, B. V. (1994). Evaluation of Stirrup-PBW (Gossyplure) in combination with insecticide for the suppression of cotton pink bollworm. *Karnataka J. Agri. Sci*., **7**(4): 476-480.

Kranthi, K. R. (2015). Pink bollworm strikes *Bt* cotton. *Cotton Statistics News*, **35**: 1-6.

Malik, M. F. (2001). Biological Control of Pink Bollworm (*Pectinophora gossypiella*, Lepidoptera: Gelechiidae) by Trichogrammatoidea bactrae (Hymenoptera: Trichogrammatidae) in cotton (*Gossypium barbadense*). *J. Bio. Sci.*, **1**(2): 56-57.

Mallah, G. H.; Soomro, A. R.; Soomro, A. W.; Kourejo, A. K. and Kalhoro, A. D. (2000). Studies on the leftover standing cotton as carry-over sources of pink bollworm in Sindh. *Pak. J. Bio. Sci.*, **3**(1): 147-149.

Manjunatha, R.; Pradeep, S.; Sridhar, S.; Manjunatha, M.; Naik, M. I.; Shivanna, B. K. and Venkatesh, H. (2009).

Comparative performance of Bt and non-Bt cotton against bollworm complex. *Karnataka J. Agri. Sci*., **22** (3): 646-647.

Morin, S.; Biggs, R. W.; Sisterson, M. S.; Shriver, L.; Kirk, C. E.; Higginson, D.; Holley, D.; Gahan, L. J.; Heckel, D. G.; Carriere, Y. Dennehy, T. J.; Brown, J. K. and Tabashnk, B. E. (2003). Three cadherin alleles associated with resistance to Bacillus thuringiensis in pink bollworm. Proc. Natl. Acad. Sci., USA, **100**(9): 5004-5009.

Nadaf, A. R. M. and Goud, K. B. (2007). Effect of Bt cotton on pink bollworm, *Pectinophora gossypiella* (saunders) infestation. *Ann. Pl. Protec. Sci.,* **15** (1): 61-67.

Nandihalli, B. S.; Patil, B. V. and Hugar, P. (1993). Optimisation of pheromone traps for cotton pink bollworm,*Pectinophora gossypiella* Saunders. *Karnataka J. Agri. Sci.,* **6**(3): 300-301.

Narayanan, E. S. (1962). Biology and method of control of some important insect pests of cotton in India. Indian Central Cotton Committee Publication, Bombay, p. 44.

Patil, S. B. (2003). Studies on management of cotton pink bollworm *Pectionophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae). Ph. D. Thesis (unpublished) submitted to University of Agricultural Sciences, Dharwad (India).

Patil, S. B.; Udikeri, S. S.; Hirecurubar, R. B.; Guruprasad, G. S. and Abhilash, C. C. (2009). Thiodicarb and Profenophos: Promising Insecticides For Management of Pink Bollworm, Pectinophora Gossypiella (Saunders) in Cotton. *Indian J. Ent*., **71**(2): 183-185.

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.

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.

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.

Saad, A. S. A.; Tayeb, E. H. M.; Awad, H. A. and El-Bassiunoy, 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.

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.

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.

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.

Singh, J.; Sandhu, S. S. and Sindhu, A. S. (1988). Adult emergence pattern of parasitoid *Apanteles angaleti* and its known hosts during off-season in Punjab. *Biocontrol*, **33**(3): 309-314.

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.

Watson, T. F. and Larsen, W. E. (1968). Effects of winter cultural practices on the pink bollworm in Arizona. J. *Eco. Ent.*, **61**(4): 1041-1043.

DIFFERENT STAGES OF PINK BOLL WORM

EGGS

LARVA

PUPA

ADULT

DAMAGE CAUSED BY PINK BOLL WORM

ROSETTED BLOOM

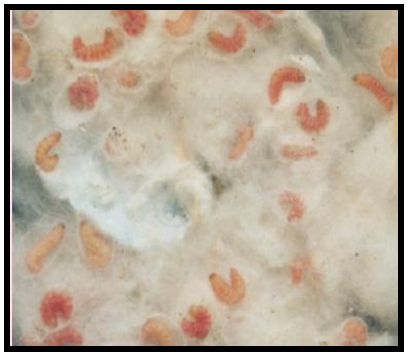
DAMAGE ON YOUNG BOLL

LARVAL FEEDING ON SEEDS

IMPROPER OPENING OF BOLL

DAMAGE IN THE BOLL

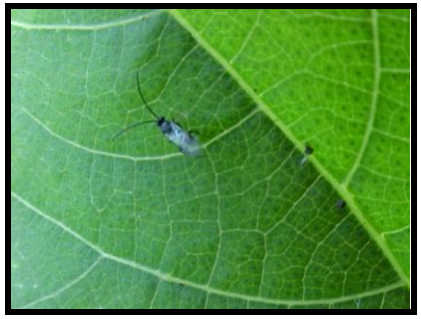
DAMAGING LINT AND SEEDS



DIAPAUSING LARVAE

PARASITES OF PINK BOLL WORM

Rogas aligarhensis



Apanteles angaleti

Trichogramma spp.

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