The ICAC Recorder

Bt or no *Bt*, Integrated Pest Management Should be an Integral Part of Pink Bollworm Management on Cotton

Dr Mohan Komarlingam S.

Consultant. Biotech Product Development & Stewardship, India

Dr KS Mohan's entire career of >40 years has been in the area of R&D of insect-control technologies for plantation crops, horticultural crops, cotton and corn. He was involved in stewardship of *Bt* cotton and *Bt* maize in India. Dr Mohan strategized and implemented IRM for Bollgard® and Bollgard II® through partnership projects with public & private stakeholders. He established and managed *Bt* trait quality assurance testing platforms on molecular events, season-long transgene(s) expression, bollworm-control efficacy, *Bt* resistance monitoring and product trouble shooting. Dr Mohan formulated IRM strategy for *Bt* maize through partnership projects on risk assessment. He is passionate about scientific outreach and public advocacy in biotechnology. Currently Dr Mohan provides consultancy in developing transgenic cotton for insect and virus control.

Introduction

The pink bollworm (*Pectinophora gossypiella*) (PBW) is a destructive bollworm of cotton severely affecting the quality of cotton lint with presence in all cotton growing countries and a difficult pest to manage. PBW has been an invasive pest into most countries and is thought to have originated somewhere in Southeast Asia and gradually spread to the cotton fields of the southwestern USA through the middle east carried through 'fuzzy' cotton seeds infested with the resting stages of the pest (Naranjo et al., 2002). In India, PBW infestation of cotton has been recorded by entomologists in early 1900 and was so severe in south India during the British rule that a legislation was enacted in the presidency of Madras on the movement of cotton seeds from areas with PBW infested cotton (Ramachandra Rao, 1921). PBW continued to be key pest on hybrid cotton which was developed in India using the American tetraploid *Gossypium* species. Though it is a global pest, much of the content in this chapter is directed to the situation in India because it is the only country where PBW populations have evolved field-resistance to *Bt* cotton since 2010. The problem in India is quite acute in view of the large acreage of *Bt* cotton (~11.5 million acres) available for the *Bt*-resistant PBW for multiplication making India a fit case for the re-visit of Integrated Pest Management (IPM) methods for PBW management.

PBW is typically a late-season pest of cotton in India, but if the carryover population from the previous season is large enough, as is the current situation in many states, then this pest appears early enough during the initial bloom period. Among the key Lepidopteran pests of cotton, PBW is difficult to control with insecticides because of its reclusive feeding habits within the developing cotton bolls. In contrast other caterpillar pests of cotton spend a considerable portion of their time feeding on the plant surface, and hence are within the reach of insecticides. The larval stages of PBW spend their entire period within the boll, feeding on the developing seeds. Very often, the grownup larvae hibernate with the scooped-out cotton seeds to tide over the unfavourable winter season. Many grownup larvae exit through a hole made in the boll and fall to the soil where they hibernate in the cracks in soil or in the plant debris in a loosely woven silk bag. Hibernation in seeds or soil is the pest's way of tiding over unfavourable environmental conditions when no cotton crop is available for the progeny to feed and grow. When the temperature warms up and with increasing daylight, the hibernating larvae quickly complete the life cycle and emerge into the open as moths. Emergence coincides with the availability of flowers and new bolls in the new crop.

Bt-cotton (single and dual *Bt*-gene versions) had effectively managed PBW in the USA and India because of the high sensitivity of the larvae to *Bt* toxins expressed by transgenic *Bt*

cotton. However, the *Bt* cotton technology in India stood eroded with time because of evolution of field resistance to first Cry1Ac and then to Cry2Ab2, sequentially, in 2010 and 2016 (Tabashnik and Carrière, 2019). Indian cotton farmers did not plant the 20% structured refuge with *Bt* cotton, nor did they adopt the recommended Integrated Pest Management (IPM) practices along with *Bt* cotton. Both these measures, had they been adopted, could have delayed the *Bt* resistance evolution in PBW.

IPM: the forgotten strategy to manage pests in cotton cultivation

Globally cotton happens to be infested by a variety of bollworms and sap-sucking pests and thus is a fit crop for the application of IPM methods for pest management. The severity of pest incidence can be appreciated from the fact that prior to the *Bt* cotton era, ~ 45% of the total insecticides used in crop-protection in India was on cotton. Among the bollworms, the PBW is a problematic and an enigmatic pest. It is unique in the fact that PBW can multiply productively only on cotton -thus is functionally monophagous. Several malvaceous weeds have been recorded as hosts of PBW, but they are not productive; relative to cotton, okra is a good host but the total acreage relative to cotton is very small. The narrow-host preference had hastened resistance evolution to *Bt* toxins expressed by dual *Bt*-gene cotton in the absence of structured refuge or natural refuge in the form of diploid native non-*Bt* cotton varieties. *Bt* cotton with cultural practices to disrupt the pest-cycle would have managed the bollworms and the bio-control agents would have taken care of the sucking pests.

In the absence of any other disruptive technologies in the near future for the management of *Bt* resistant PBW, the only option available to the Indian cotton farmers is to rigorously adopt IPM measures as part of area-wide management aimed at disrupting the pest cycle. Fortunately, PBW can be managed with a simple to adopt cultural and cultivation practices directed at minimising the carryover of PBW population between cotton seasons and need to be dovetailed into IPM modules designed to take care of the entire pest-complex, all Lepidopterans and sap-sucking pests, inclusive.

Figure 1. Pheromone trap catch: 1035 moths in a single trap, Janthmer, Bhavnagar 2014

Management of *Bt*-resistant PBW on *Bt* cotton in India

Certain practices in cotton cultivation play a key role in managing PBW (Kranthi, 2015; Mohan, 2017) and these could be divided into post-harvest, off-season and pre-planting periods.

Deep ploughing

Soon after the last pick of cotton, ensure deep ploughing of cotton fields. This operation would not only destroy hibernating larvae of PBW in the cracks in the soil but also pupae of other bollworms like *Helicoverpa armigera*, *Spodoptera litura* and *Earias* spp. This is an important, but often overlooked, method to minimize PBW and other bollworm moths emerging from the soil.

Destroy residual immature bolls

Detach all unopened/improperly opened bolls from the cotton stalks and destroy them by burying/burning, because these bolls often contain hibernating PBW larvae in the seeds within the bolls. Extension bulletins often recommend destroying the cotton stalks using a rotavator. This is not necessary if the stalks are picked clean of the unopened bolls because cotton stalks form an important source of firewood in the villages. Sun-drying of unopened/improperly opened bolls is practiced in many parts so as to recover as much cotton fibre as possible but should be strongly discouraged.

Destroy gin waste and trash

Trash consisting of PBW-infested cotton seeds in the ginning mills form an important source of spread of PBW because harvested cotton comes from faraway places for ginning. It is a common sight to see heaps of trashed cotton seeds in cotton gins, many infested with PBW larvae/pupae. In addition to destroying such trash, the gins should install pheromone traps in the vicinity of the gin to trap all emerging PBW moths. Similarly, transport of PBW-infested cotton seed for oil extraction to adjoining districts/states should be discouraged through legislation, if possible.

Timely crop termination

New sowings of cotton should ideally consist of medium-maturity *Bt* cotton hybrids, especially in areas where PBW is endemic. Long-duration cotton crop gives ample opportunity for the PBW population to multiply further by another 3 to 5 generations after 120 days of the crop, resulting in a large carryover to the next season. If suitable short/medium maturity cotton hybrids are not available, the farmers can go for long-duration cotton, but the crop needs to be terminated after the third pick/ 120 days.

Avoid ratooning and prevent re-flush

Ratoon-cropping or 're-flush' of cotton is practiced in irrigated areas after the last pick and this practice fetches the cotton farmer some additional income by extending the cotton crop till 250 days. Re-flush cropping becomes widespread particularly when the first few pickings are impacted due to vagaries

of climate. Typically, such areas have large endemic population of PBW, built over several seasons. Thus, re-flush in cotton should be a strict NO in such areas.

Pheromone-trap monitoring

In areas with large carryover of PBW from the previous season, farmers can expect early appearance of PBW infestation in flowers and squares at 60 days. PBW pheromone traps (@ 3 to 5/ha) should be used to determine if PBW population level has reached Economic threshold level (≥ 8 moths per trap on three successive days), to decide on insecticide application, as per the advisory from the local agricultural agency. If the PBW population is large, use more pheromone traps (@ 20 traps/ha) for the purpose of pest suppression through mating disruption.

Sampling and scouting

Regular scouting for PBW infestation in flowers or bolls can help assess the infestation level and help decide on the course of mitigatory action.

Figure 2. Collection of boll samples for monitoring

Figure 3. Examining harvested cotton for diapausing larvae

Figure 4. Bioassays for resistance monitoring

It is important to remember that IPM — and specifically the component of cultural and cultivation practices to break the pest-cycle of PBW — can be better achieved through wide-area participation. It will not help if only a few farmers adopt IPM measures.

In contrast, PBW in the southwestern US has been managed judiciously by the combination of high level of compliance on structured planting and the synergy between the efficacy of *Bt* cotton and an assiduously implemented program of release sterile PBW moths leading to a formal declaration that PBW has been eradicated from the PBW-endemic areas of south-western USA (USDA, 2018; Tabashnik et al., 2021). Can this success be replicated in India? It appears to be very daunting, primarily because of the lack of efficacy of *Bt* cotton in managing PBW because of *Bt* resistance issues and the huge investment needed to setup PBW breeding labs for mass-production, sterilization and release of radiation-sterilized moths. Till we have a viable new technology to manage the *Bt* resistant PBW populations, we have no other choice but to strength the IPM approach towards managing PBW on cotton. Another hard lesson learnt is: Whatever new technologies might come, they have to be used in conjunction with IPM methods.

Conclusion

The high-level efficacy of *Bt* cotton in managing the pink bollworm in the initial years of cultivation in India had made cotton farmers slack on two important fronts: planting of structured refuge and adoption of IPM practices. Evolution has been extracting its toll in the form *Bt* resistance in PBW populations since 2010. *Bt* cotton is still effective on other Lepidopteran pests but the only way to manage *Bt*-resistant PBW is through re-adoption of IPM practices, more specifically cultural practices to break the pest cycle and cultivation practices like choosing short-duration cotton hybrids, early termination of cotton crop in case high-level PBW

infestation, discouraging 're-flush' cropping in PBW endemic areas, mating disruption through lures and constant scouting to arrive on insecticide spray decisions. Pest management through IPM is only successful only if adopted on a wide-area scale like an entire village or a cluster of villages with contiguous cropping of *Bt* cotton. Notwithstanding the challenges in wide-area adoption of IPM it is the only hope to deal with the current PBW issue in India. Finally, it would be prudent on the part of farmers to cultivate *Bt* cotton only as a component in a compatible IPM module for an ecologically and economically sustainable cotton cultivation.

References

Naranjo, S. E., Butler, G. D. and Henneberry, T. J. 2002. A Bibliography of the Pink Bollworm, *Pectinophora gossypiella* (Saunders). U.S. Department of Agriculture, Agricultural Research Service, Bibliographies and Literature of Agriculture No. 136.

Ramachandra, Rao, Y. 1921. The pink bollworm and the pest act. *Madras Agric. J*. 9(5):121-125.

Tabashnik. B. E. and Carrière, Y. 2019.Global patterns of resistance to *Bt* crops highlighting pink bollworm in the United States, China, and India. *J. Econ. Entomol*. 112, 2513 – 2523.

Kranthi, K. R. 2015. Pink bollworm strikes *Bt*-cotton. In: Cotton Statistics and News (*ed*. Amar Singh), Cotton Association of India, Mumbai, 35:1–6.

Mohan, K. S. 2017. An area-wide approach to pink bollworm management on *Bt* cotton in India–a dire necessity with community participation. *Curr. Sci*., 112(10):2016-2020

USDA. Eradication of pink bollworm proclamation. 2018.

https://www.usda.gov/sites/default/files/documents/usda-pink-bollworm-proclamation.pdf

Tabashnik, B. E., Leighton R. Liesner, L. R., Ellsworth, P.C., Unnithan, G. C., Fabrick, J. A., Steven E. Naranjo, S. E., Li, X., Dennehy, T. J., Antilla, L., Staten, R.T., Carrière,Y. 2021. Transgenic cotton and sterile insect releases synergize eradication of pink bollworm a century after it invaded the United States. *PNAS USA, 118* (1) e2019115118; DOI: 10.1073/pnas.2019115118