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Review

AN OVERVIEW ON SUITABILITY OF ECO-FRIENDLY IPM APPROACH FOR MANAGEMENT OF *BT*-RESISTANCE IN PINK BOLLWORM ON COTTON

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ABSTRACT

Pink Bollworm *(Pectinophora gossypiella*) member of the family Gelechiidae is known to be among the most destructive insect pest of cotton, causing huge damage to the cotton seed as well as heavy loss in fiber quality of the crop. Its larvae are active feeder of the reproductive parts of cotton and conceal in the damaged bolls. Large scale cultivation of transgenic cotton that produces Cry1Ac resulted in development of resistance in pink bollworm against Cry1Ac. A single control tactic even chemical control remains ineffective for their management and all possible tactics are integrated for their effective control. For its monitoring Sex pheromone traps, PB Ropes and light traps are installed. Growing of non Bt refugia also play an effective role for the management of pink bollworm. Keeping in view, the importance of Integrated Pest Management (IPM) is an ecofriendly and effective technique as compared with the use of conventional insecticidal technique.

Keywords: *Pectinophora gossypiella*: Bt resistance: Management Strategies

INTRODUCTION

Pectinophora gossypiella (Saunders) (Lepidoptera: Gelechiidae), known as destructive boll worm of cotton in the entire world Costly chemical control resulting in economic crises, destruction of biological agents and environmental constrains. Emphasizes is on the operation of eco-friendly oriented PBW management strategies. Advance research has revealed the initiation of extensive management strategies through cultural, behavioral control, genetic modification and monitoring, biological control, alternate hosts served as the base of integrated PBW control systems. The life history of the *P. gossypiella* is complex mobility of adults, indicates that there is a need for implementation of IPM, Components should be operational all over the world (Khidr *et al*., 1990; Sarfraz et al., 2020). It includes target management of hot spots with the adoption of integrated pest management relay on Pink Boll worm population density, crop growing methods and country stability. Ratio of control is highly dependent on planning assessment phases of the programmed, site selection, and implementation. Extension department play a critical role in PBW management. The benefits of Pink boll worm population suppression on wide basis have positive effects in favors of cost reduction costs, better control, less environmental contamination and other constraints linked with conventional control (Vaissayre, 1987). The characteristics of fields include presence of high PBW population densities, social and environmental considerations in cotton crop, arthropod group comprise of parasitoids, predators, primary consumers. Moths of the genus Pectinophora are numerically a small group of the family Gelechiidae consisting of three species, *P. gossypiella* (Saunders), *Pectinophora scutigera* (Holdaway) and P. endema (Common). Both Pectinophora have the potential for economic losses. PBW has become a major problem because its larval stage is suddenly diapased when in seed capsules (Simwat *et al.,* 1988).

Distribution and origin of *Pectinophora gossypiella*: It was proposed that the PBW as the eastern Indian Ocean bordered on the east by northwestern Australia and on the west by various Indonesia-Malaysia islands. W.W. Saunders in 1842 reported *P. gossypiella* from specimens damaging different cotton fields across India. Around 1911 and 1913 it reached the Western hemisphere in cotton seed shipped from Egypt to Brazil, Mexico, West Indies and the Philippine Islands. It is generally believed that the insect reached Egypt in damaged cotton seed from India about1906-1907. Damage was reported in East Arizona in 1926 and later in other parts of the state. In short it can be quoted that Pink boll worm is distributed across all cotton growing regions.

Biology of *Pectinophora gossypiella*: The life cycle consists of four stages of development, including larvae, pupae, adult and eggs. Time required from hatch to hatch varies depending on tempera-ture and other conditions, but generally it is about 30 days during the summer months. Pink bollworm larvae cause fruit shedding, lint damage, seed loss

and failure of buds to open (Kabissa 1990). Eggs are pearl white, flattened, oval, and laid singly or in cluster of 4 to 5. 1st and 2nd are white in color and 3rd instardevelops pink color. Immature of *P. gossypiella* consist of distinct dark brown head. Pupae are approximately about 7 mm in length. Moths are nocturnal in nature, hiding in soil waste or holes during the day. Adults of PBW are usually in grayish brown color with having blackish bands present across forewings while the hinds are usually silvery grey. PBW 4th instar feeds on the full-grown seed, sometimes this pest also exhibits an Inter-loculi movement. Sometimes, it has also been observed that many larvae infesting one boll. Small existing holes showed the presence of *P. gossypiella* imamture. Stained lint result in reduced of quality. Improper boll opening with damaged seeds. Punctures are visible between locules of open bolls (Kabissa, 1990). Hibernation occurs in cold season. Diapause larvae mostly go to cervices, soil and plant debris near cotton heaps. Adults live for 56 and 20 days after the appearance of moths. Insects are highly adaptable to various weather conditions and larvae hide in empty cotton seeds during adverse season in which they are well cove-red and remain alive for several months. Pest survival is entirely by wintering larvae in seeds, soils and plant waste from one season to another. P. gossypiella occurrence in the season starts with the moth coming from the wintering larvae during the summer. This is the only plague that occurs in agriculture. Seasonal dynamics, incidence and infestation levels vary according to the maturity of crops. The successful population growth starts after 100 to 110 days of cultivation and after 140 days of peak infestations. The cultivation with late maturity experienced extreme attacks with 50-75% of the pellets displaying weakened locules in open pellets. Given the lower frequency, higher damage rates are attributed to the small number of bullets available at the end of the time span. If the pink bollworm emerges early in the harvest season because of the favorable weather, the damage is much more severe in the late season.

Pink boll worm monitoring: Pheromone traps are very useful for monitoring purpose. El-Sayed et al., (2015) reported that activity of moth depends upon the environmental factors. Moth catches (Males) in the traps were on its peak from January to March and less from April to July in every year. August to December Moths population in traps were also on its high. The trapped population fluc-tuates every year. Highest moth catches were observed during the month of October.

Figure 1: Damage and life stages of Pink Boll Worm

Bt resistance development risk in herbivorous arthropods: With the advancement and comercialization of Bt Technology community of arthropods has been altered many folds as a result targeted lepidopterous populations has also been affected and reduced drastically. This disruption is primarily due to the absence of availability of prey for predators/parasitoids. It was reported by Dutton et al., (2002) that a higher death rates along with delays in growth in lepidopterous larvae followed Bt feeding while comparing to the control (non-Bt plants). In order to get more clear results researchers have been suggested to monitor long term effects of transgenic crops owing to the arthropod community and use some specific measures like Simpson waiver index (SWI). For finding species

richness and related measurements SWI index widely being used (Flint et al., 1995). Insect pest deteriorate the quality and quantity of the produce (Shahid et al., 2017a).

It has been widely believed that development of field resistance to the Bt sprays as well as Bt Crops found in targeted arthropods is consequently from this enormous widespread in adoption of the transgenic crops by growers (Schnepf et al., 1998). In recent years, several targeted lepidopteron species have found to evolve such field resistance problems (Tabashnik et al., 1990; Ayra-Pardo et al., 2015). Spodoptera exigua, Pectinophora gossypiella, Plutella xylostella and Helicoverpa armigera are most considered to have with evolved Bt field resistance (Li et al., 1997; Jiang et al., 2015; Xia et al., 2014; Wang et al., 2005). Studies conducted by Obrist et al., (2006) showed that a Spodoptera exigua Bt-susceptible larvae contained around 2.7 folds lower Bt toxin as compared to resistant larvae collected through commercial Bt cotton fields. Similar findings were reported by him Obrist et al., (2006) while studying Tetrany-chus urticae that exhibited 10-fold higher toxin level followed by feeding Bt.

Resistance of *Pectinophora gossypiella* to Bollgard1 &Bollgard2 in different countries:

***P.gossypiella* resistance reported against Bollgard1**	**Bollgard2**	**Year of reported**	**Country of reported**	**Reference**
P.gossypiella resistance reported against Bollgard1	-	1998-1999	Argentina	Simmons et al., 1998a,b
P.gossypiella resistance reported against Bollgard1	-	1996-1997	Australia	Olsen et al., 2000
P.gossypiella resistance reported against Bollgard1	-	2005-2006	Brazil	Tabashnik et al., 2000
P.gossypiella resistance reported against Bollgard1	-	2008-2009	Burkina Faso	Carrière et al., 2001
P.gossypiella resistance reported against Bollgard1	-	1997-1998	China	Liu YB et al., 2001
P.gossypiella resistance reported against Bollgard1	-	2004-2005	Colombia	Tabashnik et al.,2002
P.gossypiella resistance reported against Bollgard1	-	2002-2003	India	Kranthi et al., 2006
P.gossypiella resistance reported against Bollgard1	-	2002-2003	Indonesia	Blanco et al., 2009
P.gossypiella resistance reported against Bollgard1	-	1996-1997	Mexico	Fabrick et al., 2011
P.gossypiella resistance reported against Bollgard1	-	2010-2011	Myanmar	Wan et al., 2017
P.gossypiella resistance reported against Bollgard1	-	2010-2011	Pakistan	Llewellyn et al., 2007
P.gossypiella resistance reported against Bollgard1	-	2012-2013	Paraguay	Mahon et al., 2012
	-	1998-1999	South Africa	Tabashnik et al., 2010
-	*P.gossypiella* resistance reported against Bollgard2	2009-2010	Brazil	Zhang et al., 2013
-	*P.gossypiella* resistance reported against Bollgard2	2007-2008	Colombia	Jurat et al., 2003
-	*P.gossypiella* resistance reported against Bollgard2	2009-2010	Cost Rica	Tabashnik et al., 2002

Adoption of IPM techniques: Integrated Pest Control (IPC) through integrated pest management (IPM) both used as collectively for scientific principles. It involves such as habitat modifications, application of cultural practices and use of resistant varieties. Which focuses on long term management of pest and non-hazardous to environment. Biological as well as chemical control through pesticides also seen to be successfully effective. It is recommended that use of *Trichogramma chilonis* Ishii while combined with artificial chemicals found to have a good control of *P. gossypiella* (Shahid *et al.*, 2007; Sana-Ullah *et al.*, 2011). Integrated control uses SIT (sterile insect technique), cultural, Exclu-

sive monitoring through gossyplure baited traps specifically used for male adults as well as boll sampling, disruption mating, lower use of chemicals as well as excessive genetically modified cotton use (Shahid et al., 2019).

Cultural control: Cultural strategies play a significant role in management of overwintering population of PBW. There is eighty percent decrease in moth emergence from fields that have been rotavated and exposed to sun light. Picking of last season immature bolls have a critical role in reduction of diapausing larvae. Shredding of stalks, ploughing, winter irrigation and disking result in high levels of mortality of hibernate immature. Deep cultivation exposed soil born pupae of PBW which are exposed to hot sun result in mortality of 4th instar larvae and delayed planting of crops helps to escape pest attack.

Pesticides: Application of insecticides have greatly reduced the control of PBW by biological agents in the entire world. The primary goal of insecticides is to control PBW on priority basis within short interval of time. Since last over forty years of application, insecticides did not consider as on priority basis (Gao et al., 1992). Every year of cotton growing season Pink Boll Worm develop resistance against toxic compounds. Chemical Control is limited to PBW larvae because of its internal feeding behavior and resistance to insecticides make it more expensive methods. The efficacies of chlorpyriphos, asymethrin, teflubenzuron, carbaryl, esfenvalerate, fenpropathrin, indoxacarb (steward), cyhalothrin, fluvalinate, synthetic pyrethroids, fenvalerate, lambda-cyhalothrin, spinosad, and thiamethoxam have been tes-ted. Pink bollworm moths are nocturnalin nature hence, generally, they remain active between late night through 3:00 AM, hence insecticide application through afternoon or evening are more efficient as compared to application in the morning (Sarwar and Sattar, 2016).

Effect of plant extracts against larvae of pink boll worm: Input costs by of local farmers are usually found to be increased through frequent use of repetitive pesticide application, hence serious problem of pest resistance is also aroused (Arain *et al*., 2018). *Pectinophora gossypiella* (Saund) has been considered as the major insect pest of cotton throughout the world. Its population has been significantly suppressed during last two decades after the introduction of transgenic cotton which played a prominent role in this population differential. Yet, so may indigenous botanical extracts being effectively used in order to control various cotton sucking pests but unfortunately a few studies have attempted to address their mode of action to control bollworms (Rasool et al., 2015). According to Gao et al., (1992) organic insecticides having contact action proved very suitable against targeted arthropods. Application of Plant extracts at different dosage reveal that there is reduction in pest population as a result of tobacco then by neem and then by datura in both and same results were recorded for next year (Gao *et al*., 1992). The effect of extracts was last for 48 hours, which showed that these bio-pesticides need to apply on regular basis. The present study revealed that botanical-extracts are safe for both environment and biological agents. Through recent studies it can be considered that the population of PBW effected by different extract on Bt cotton as well as non-Bt. Cotton in bio-extracts extracts, tobacco extract last for 48 hours when it is applied.

Biological control: There are lot of natural enemies that prey the insect pest (Farooq et al., 2018, 2020). During the last few years, many groups of joint body segments attack PBW naturally, they include mites, Coleoptera, predaceous Hemiptera Dermaptera and Neuroptera. Eggs are most susceptible to attack because these are opened as compared to other life stages. According to (Cheema et al., 1980; Nizamani et al., 2020) the *Labidura riparia* (Pallas) is found to attack almost all stages of immature pink bollworm. *Apanteles angaleti* has a greater effect on larva, whereas, others included *Microchelonus blackburni* as well as Bracon *Chelonus curvimaculatus.* Predators and parasite sone eggs or might be larvae are common; *T. chilonis* parasitize eggs *or Trichogrammatoidea bactrae, Zelus renardii* is considered as a predator, *Polybia ignobilis* and *Pardosa milvina* are adult's predators even Orius and Nabisalso also predates. Green and Lyon (1989) reported that the genera, *Bracon, Chelonus* and *Apanteles* among the Braconidae are the major parasitoids. Coleoptera include beetles that are mostly predators of eggs and larvae in early stages (Shahid et al., 2013). Pathogen *Bacillus thuringiensis* and nematodes serve as control agents.

Planting and harvesting time: Agricultural practices usually play a prominent role in the management of insect pests (Shehzad *et al.*, 2012). Changes in planting as well as harvesting time is helpful in discontinuing food supply to different species of insect pests (Shahid et al., 2014), and is termed as "phenological asynchrony". In this practice's crops are managed to mature slightly before or little later to the onset of occurrence in the insect pest incidence. It this way insect pest attack is escaped and hence farmers can easily able to manage population of insect pests in various crops (Shahid *et al.*, 2017). In a similar way plant spacing as well as planting density can also be effective to control

pest population due to the searching behavior in insect pests to the food as well as oviposition site.

Refuge crop for pest: A genetic change is usually observed in arthropod population resulting through the death of susceptible arthropods which is assumed to be induced through continuous exposure to the Bt-toxins. Out of these organisms some organisms manage to survive due to inherent natural tolerance to resist Bt toxin. Intercrossing of these tolerant insects with others potentially develop individuals with enhanced ability to survive across and hence a change in population behavior ultimately results in development of a complete resistant population. Growing of non-Bt as refugia at least at 5% area around Bt crops is usually recommended in order to avoid the above-mentioned problem of Bt resistance. Non-Bt refugia help and allow these targeted insect pests to survive and reproduce without failing to find food. Hence availability of susceptible alleles is continuous resulting in suppression of resistance alleles (Shahid *et al.*, 2017).

CONCLUSION

It has been concluded here that IPM's recommendations were and ought to be mandatory for long-term pink bollworm control. As stated earlier, the single approach for the managing of pink bollworm persists inadequate and therefore we should rely on environmental, host plant resistance and biological control strategies for the management of pink bollworm. Changes in planting as well as harvesting time is helpful in discontinuing food supply to different species of insect pests. This technique is called "phenological asynchrony. In this practice's crops are managed to mature slightly before or little later to the onset of occurrence in the insect pest incidence. In this practice's crops are managed to mature slightly before or little later to the onset of occurrence in the insect pest incidence. It this way insect pest attack is escaped and hence farmers can easily able to manage population of insect pests in various crops In a similar way plant spacing as well as planting density can also be effective to control pest population due to the searching behavior in insect pests to the food as well as oviposition site. Use of non-Bt refugia as well as Phenological asynchrony can also be considered as effective management strategies for pink bollworm.

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