A REVIEW ON BIOLOGICAL INTERACTION AND MANAGEMENT OF COTTON PINK BOLLWORM

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ABSTRACT

Pectinophora gossypiella (Saunders) is considered a prominent example of damaging cotton pests worldwide. Larva feeds on the flower's seed and damages the cotton fibers, reducing crop yield and quality. Crops most affected include okra, jute, castor bean, and cotton completing 6 generations per year. Now at this time distributed across most of Asia, America, Northern America, Africa, Oceania, and Europe, to combat this pest, a variety of strategies have been employed, including genetically engineered crops (such as BT cotton), biological control and used synthetic insecticides (e.g., Triazophos, Deltamethrin, Spinetoram, Gamma cyhalothrin, Chlorantraniliprole, and Triazophos + Deltamethrin. In the future, management necessitates an approach to integrated pest management (IPM), wherein chemical, physical and biological management is common for efficient control.

Keywords: Biology of pink bollworm, BT cotton, Biocontrol, Insecticides resistance, pink bollworm

INTRODUCTION

Cotton (*Gossypoium hirsutum L.*) is also known as sliver fiber due to its global economic significance. Cotton is being attacked by various insect pests, which could result in a 30-40% drop in production, especially in Pakistan (Ahmed, 1980). There are 2920 thousand hectares of cultivable land, which generates a large quantity of foreign exchange, contributes around 66.01 percent of national oil output, and provides 5.6 percent of value-added in the agriculture sector, about 1.0 percent of GDP (Anonymous, 2015). It employs many people, including farmers, farm laborers, and others who work in agriculture-related sectors. Cotton crops are grown on 31.99 million hectares in more than hundreds of countries around the world (Anonymous, 2015). The first pink bollworm infestations in non-BT cotton resulted in a loss of 3.0-61% in seed cotton yield, 2.12 to 47 percent in oil content, and a loss of 10.71 to 59.22 percent in normal open bolls opening (Patil, 2003). They also inflict significant damage to various vegetables such as tori, okra, chilies, tomato, and different cucurbits arena examples of other crops (Shah *et al*., 2013).

Due to its difficult control with chemical insecticides, the pink bollworm is a prominent example of the most devastating insect pests of cotton. Flowers or bolls can be penetrated by hatching larva in half an hour or 20 hours (Hutchison *et al*., 1988 & Ingram, 1994). As a result, farmers are entirely unaware of the harm caused by PBW until the opening of the boll, and hence are unable to take any specific pest control measures (Shrinivas *et al*., 2019). However, due to the development and management of *Pectinophora gossypiella* with a review to assess the potential of the most developing and practical techniques of control, common control strategies such as chemical pesticides have not proven to be beneficial in the long run.

Distribution

At present, *P. gossypiella*is distributed worldwide and considered a severe agricultural insect pest throughout Africa (Egypt, Libya, Ethiopia, Europe, (Greece, Turkey, Portugal, Spain) in central and southern Asia (China, Pakistan, Thailand, and India), Oceania (Australia and New Zeeland) (USDA, 2018).

Host range

P. gossypiella is one of the most oligophagous pest species (Khidr *et al*., 1990). Plants worldwide distribution families and 70 species recorded as alternative hosts (Noble, 1969) including important economic crops, okra, jute, cotton, and castor bean.

Table. 1 *Pectinophora gossypiella* distribution adapted from the (CABI, 2022)

Continent	Country	Present	Current status	Reference
Africa	Angola	Yes	Widespread	EPPO (2020)
Africa	Burundi	Yes	Information not available	EPPO (2020)
Africa	Benin	Yes	Information not available	Djihinto *et al.* (2016)
Africa	Burkina Faso	Present	Information not available	EPPO (2020)
Africa	Chad	Probable	Established	Silvie and Goze (1991)
Africa	Cameroon	Yes	Information not available	Descamps (1954)
Africa	The Central African Republic	Yes	Information not available	Pierrard and Cadou, (1969)
Africa	Congo Democratic Republic	Probable	Information not available	Syedel (1929)
Africa	Ethiopia	Yes	Information not available	Legner and Medved, (1979)
Africa	Egypt	Yes	Present; not well controlled	Khidr *et al.* (1990) & Abd- Elhady and Abd-Aal, (2011)
Africa	Ghana	Probable	No information available	Badil and astane, (2012)
Africa	Kenya	Yes	Information not available	Lenger and Medved, (1979)
Africa	Libya	Yes	Widespread	USDA (2018)
Africa	Mozambique	Yes	Information not available	Baptista (1947)

Africa	Morocco	Yes	Information not available	EPPO (2020)
Africa	Madagascar	Probable	Information not available	EPPO (2020)
Africa	Mauritius	Present	Information not available	Matthews *et al.* (1965)
Africa	Niger	Yes	Information not available	EPPO (2020)
Africa	Nigeria	Yes	Present	UK, CAB International(1990)
Africa	Rwanda	Yes	Established	USDA (2018)
Africa	Senegal	Probable	No information available	UK, CAB International(1990)
Africa	Seychelles	Yes	Established	EPPO (2020)
Africa	Sierra Leone	Present	Present	USDA, (2018)
Africa	Somalia	Yes	Information not available	Schmutterer (1964)
Africa	Sudan	Yes	Information not available	Khalifa (1968); EI_Amin and Ahmed (1991)
Africa	Tanzania	Yes	Consider as an important pest	Kabissa (1990)
Africa	Uganda	Yes	Information not available	Taylor (1936)
Africa	Zimbabwe	Yes	Significant cotton pest	Matthews *et al*. (1965)
America	Argentina	Yes	No information available	Ankersmith & Adkisson (1967)
America	Bahamas	Yes	Information not available	USDA (2018)
America	Bolivia	Yes	Information not available	Flint *et al*. (1979)
America	Dominican Republic	Probable	Information not available	USDA (2018)
America	Grenada	Yes	Information not available	UK.CAB International (1990)
America	Mexico	Probable	Not reported	Wang *et al*. (2011)

America	Montserrat	Yes	Information not available	EPPO (2020)
America	Nicaragua	Not Establish	Absent pest eradicated	IPPC (2007)
America	Puerto Rico	Yes	No information available	Fife (1939)
America	United States	No	Absent pest eradicated	Wang *et al*. (2011)
America	Arizona	No	Absent	Frisbie *et al.* (1989) & Wang *et al*. (2011)
America	California	No	No information available	Wang *et al*., (2011)
America	Florida	No	No information available	Frisbie *et al*. (1989) & USDA (2018)
America	Colombia	Yes	No information available	Ankersmit and Adkisson, (1967)
America	Peru	Yes	Information not available	USDA (2018)
America	Uruguay	Present	Localized present	de Biezanko *et al.* (1957)
America	Venezuela	Yes	No information available	Ankersmit & Adkisson, (1967)

Asia	Afghanistan	Highl y presen t	Information Not available	EPPO (2020)
Asia	Bangladesh	Highl y preset	Widespread	APPPC (1987)
Asia	China	Yes	Restricted distribution	Wan Peng *et al*. (2012)
Asia	Hong Kong	Probable	Information Not available	USDA (2018)
Asia	India	Yes	Highly Widespread	Kumar *et al*. (2012)
Asia	Indonesia	Yes	Somewhat widespread	USDA (2018)
Asia	Iraq	Probable	Information not available	USDA (2018)
Asia	Iran	Probable	Information not available	USDA (2018)
Asia	Japan	Yes	Information not available	EPPO (2020)

Asia	Jordan	Possible	No available information	UK, CAB International (1990)
Asia	Myanmar	Transient	Consider one of the majorpests	Khin Nweoo and Myint Thaung, (2001)
Asia	Malaysia	Transient	Information not available	USDA (2018)
Asia	North Korea	Unknown	Information not available	EPPO (2020)
Asia	Philippines	Yes	Significant pest	Waterhouse (1993)
Asia	Pakistan	Yes	Present Widespread	Attique *et al*. (2001)
Asia	South Korea	Possible	Information Not available	USDA (2018)
Asia	Sri Lanka	Yes	Widespread	Keerthisinghe (1982) & USDA (2018)
Asia	Saudi Arabia	Yes	Information not available	Shalaby (1961)
Asia	Syria	Yes	Information available	USDA (2018)
Asia	Thailand	Yes	Unknown	Anthony and Jones, (1963)
Asia	Taiwan	Yes	No information available	Tsai and You, (1961)
Asia	Turkey	Yes	Information NOT available	Gözel and Gözel, (2013)
Asia	Uzbekistan	Yes	Pest ABSENT	EPPO (2020)
Asia	Vietnam	Yes	Information not available	Waterhouse (1993)
Asia	Yemen	Yes	Information not available	Ba-Angood (1982)
Europe	Albania	Yes	Information not available	USDA (2018)
Europe	Bulgaria	Not present	Absent confirmed by a survey	Paparisto *et al*. (2012)
Europe	Cyprus	Yes	distribution restricted	USDA (2018)
Europe	Denmark	Probable	Introduced	Karsholt (1994)

Europe	Greece	Yes	No information available	Lykouressis *et al.* (2005) & Lenger and Medved, (1979)
Europe	Italy	Probable	No information available	USDA (2018)
Europe	Malta	Yes	Established	Karsholt and Razowski, (1996)
Europe	North Macedonia	Yes	No Information available	Bincev *et al.* (1972)
Europe	Russia	Yes	Regional distribution	Karsholt (1994)
Europe	Spain	Yes	No information available	Alvarado *et al.* (1990)
Oceania	Australia	Yes	Localized	Wang *et al.* (2011)
Oceania	New Caledonia	Yes	Information not available	UK, CAB International (1990)
Oceania	Northern Mariana Islands	Possible	No information available	USDA (2018)
Oceania	Papua New Guinea	Yes	Important pest locally	Narendran & joseph (1975)
Oceania	Samoa	probable	Information not available	EPPO (2020)
Oceania	Vanuatu	possible	Information not available	UK, CAB International (1990)

Life cycle

On BT cotton, the whole life cycle of PBW took 46 days from egg to adult (Shrinivas *et al*., 2019). Females lives longer than males (Zinzuadiya *et al*., 2017). Reported (Noble, 1969) found 25 to 30 days for an egg to mature into an adult. (Gebremedhin, 1974) described the primary generation development time from egg to 37.8 ± 3.8 days and moth to moth in the natural development 34.8 ± 6.1 days. Venilla *et al*. (2007) described the total growth period as about 3- 6 weeks. Shah *et al*. (2013) described it to be 30 to 32 at 35 ± 1 °C and 51 to 58 at 27 ± 1 °C.

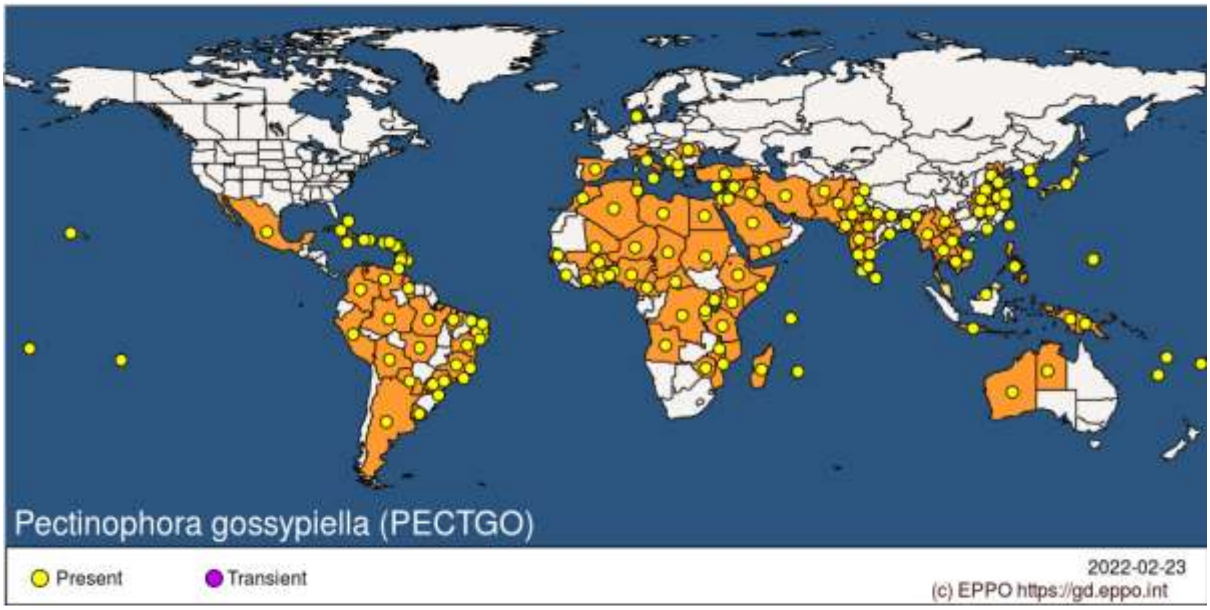

Figure 1 The distribution of *Pectinophora gossypiella*. Source (EPPO Global Database, 2022).

Eggs

Pink bollworms reported high fecundity and average 103 egg-laid female at 25°C (Zinzuvadiya *et al*., 2017). Eggs are laid singly or in groups from 4 – 6 on flower buds and leaves. Freshly laid eggs are 47 mm long, eggs are tinny whitish but later turn into orange colour flattened and oval in shape and irregular pinkish spots and longitudinal lines (Zinzuvadiya *et al*., 2017 & Umer *et al*., 2019). Hatching period of PBW eggs is 2.41 to 4.62 days, with a mean value of 3.81 ± 0.10 on BT cotton (Shrinivas *et al*., 2019).

Larvae

Larvae are white with a brown head when they are newly hatched (Sarwar, 2017b). The mature larva is 10- 12 mm long and has large pink colour bands, and the larvae change pink in the 4th development of final instars (Mapuranga *et al*., 2015). The larva is immediately boring straight into the cotton bowl and suspends entire life in the boll (CGA,1998). Young larvae are tinny whitish with dark brown heads because of the sclerotized pro-thoracic shield (Vennila *et al*., 2007). There are 4 instars (Busck, 1917). The last 10 to 15 days are feeding. Complete development in single bolls and larvae do not move between structures (Noble, 1969). Larvae will die if buds are less than 10 days old (Ingram, 1994).

Pupae

The pupae are light brown, turning dark brown as they mature, and are oval with a pointed tip. Male pupae are more petite than female pupae (Shrinivas *et al*., 2019). *P gossypiella* larvae are fully grown when they pupate beside mostly damaged fruiting bolls (damaged by PBW) and flowers in the field and lab. They also pupate near the boll because adult pink bollworm larvae primarily feed flowers and seeds of mature bolls, so they do not have as much time to go in debris or other places like *Helicoverpa armigera* and *Eariasinsulana* species. The pupal stage was a resting stage during which the moth developed. On 27 1 °C and 35 1 °C, the pupal time was 16 days and 8 days on average (Shah *et al*., 2013). 16 days at 25 °C were reported (EI- Sayed 1960) 7.42±0.020, on the other hand, according to (Cacayorin *et al*., 1993).

Adult

Adult moths are tiny, slightly brown, and measuring is about adult 10 12 acts (Umer *et al*. 2019). Irregular black patches on the forewings, hindwings are grey with no specifically marking (Shrinivas et al. 2019). Forewings are elongated, and hindwings are broader than forewings (Umer *et al*., 2019). The life span of paired male moths varied from 7.70 ±2.11 days, and female moths ranged from 13.7±2.15 days (Zinzuvadiya *et al*., 2017).

Fecundity

Zinzuvadiya *et al*. (2017) stated that pink bollworm is highly fecund, reporting an average 103 egg laid females at 25°C temperature. Shrinivas *et al*. (2019) Reported an average of 103.8 ± 16.14 in 95 to 175. Shrinivas *et al*. (2019) difference oviposition rates vary depending on the environment and the difference with the host plant. El-Sayed (1960) described the fecundity on the natural diet 224 eggs at the temperature of 25 °C.

Damage

Pink bollworm is a major destructive pest. PBW oligophagous insects and pests feed on okra, tomatoes, and vegetables (Noble, 1969). Noticed that the first larvae instars caused damaged cotton flowers in India in 1843. Naik *et al*. (2014) Reported cause of damage was 13.58% and 37.5% on BT and non-BT cotton. Ghouri (1980) said that about 20-30 percent yield loss by different bollworm. Wilson *et al*. (1979) stated that *P. gossypiella* causes infestation in Egypt and the USA. Chamberlin *et al*. (1993) PBW as the significant damage and cause Pakistan yield losses in cotton.

BIOLOGICAL CONTROL

Host plant Resistance

Host plant resistance reduces crop loss and is a critical approach (IPM) to Integrated pest management (Rahoo *et al*., 2017 & Thia *et al*., 2021). Inherited identified could improve parasitoid resistance against insect pests (Scheffler *et al*., 2003). Reduce insect pest predation through traits because damage varies depending on the traits (Scheffler *et al*., 2003). Genetically cottons are most susceptible to some insects (Wilson and Geroge, 1982) and semi-smooth leaves have sufficient trichomes to physically decrease the ability of females to lay eggs (Lee,1968 & Merdith, 1998).

Genetic modification

Akhter et al. (2018) reported Genetically modified crops could show resistance against serious pests. Perlak *et al*. (1990) stated that genes from BT produce Cry Ab Cry Ac protein that is highly toxic for lepidopterous insect pests. Bacillus thuringiensis (Bt) produces insecticidal toxins that reduce the attack and damage of bollworm larvae, and the result of the toxin causes a direct effect on the growth of larvae. Liu *et al*. (2001) stated that the concentration of Cry1Ac shows the most effective result against pink bollworm larva and low infestation of *P. gossypiella* in the field and increase the quantity and quality of cotton (Klümper and Qaim, 2014). Genetically modified crops are a more than 30% decrease in insecticide use, agriculture production increased 22%, and farmer profits are 65-68%. Tabashnik (2010) reported that the use of BT cotton provides effective controlling pest and provide economic and environmental benefit, reduce the usage of pesticide and is suitable for human health, and more minor damage to natural enemies.

Mass trapping

Sex-pheromones and other attractants are used for mass trapping of *P. gossypiella*. pheromones trapping is used to attract adult males (Because the pheromones are sex –attracted) the result is that decreasing female mate and increasing the un-fertilized eggs because sex pheromones of *P. gossypiella* female contain two compounds (Z-Z) and (Z-E) 7,11 hexadecadienyl acetates (Z-Z 7,11-16: OAc and Z-E 7,11-16: OAc) 50: 50 ratios (Hummel *et al*., 1973). These artificial synthesized and used for traps to observe the bollworm infestation, higher dosage of pheromones used in mass trapping to confuse mate (Sarwar, 2017a). Pheromones enhance insecticide efficacy, and sex-pheromones used for virelure and gossyplure are more economically workable for conventional insecticide use (Shah *et al*., 2011 & Sarwar, 2017a). PB-Rope L releases a smell that females release to attract males, which confuses the male adult

(Sarwar, 2017b). PB-Ropes for disruption mating and environmentally safe pest management technique (Attique *et al.* 2000; Harari *et al*. 2007 & Sarwar, 2017b).

Natural enemies

High use of insecticide to develop resistance in pink bollworm and insect pest species. Insects develop resistance against both BT crops and insecticide. Several native parasitoids attack pink bollworms (Jackson and patina, 1980). 16 parasitoid species, 4 families and 7 genera were released against PBW (Noble, 1969; Jackson and Patana,1980; Hennberry & Naranjo,1998).

Hymenoptera: Trichogrammatidae

The Trichogrammatidae family is the specific group of egg parasitoids and the natural enemy used for biological control of *P. gossypiella* (Sarwar and Salman, 2015). *Trichogramma attackmain* species such as budworm and pink bollworm in cotton, corn, earworm, armyworm, and other crops (Khan *et al*., 2010). Female finds egg and drill hole in eggshell through (chorion) and insert 2-3 eggs into the bollworm eggs, eggs hatch in 24 hours and parasites larvae quickly develop (Sarwar and Salman, 2015). After hatching, attack the moth egg within (Sarwar and Salman, 2015). *Trichogramma* spp. Preventive weapons for moth and caterpillar control cannot parasitize pest eggs if they hatch into larva (Buchori and Sahari, 2008). Use of chemical insecticide is harmful to the environment, kills beneficial pests, and increases the budget of benefit ratio (Henne berry and Naranjo, 1998). Another study reported that the use of *Trichogramma* cards is agronomic practice played a vital management responsibility and increased the cotton yield (Sarwar, 2017b).

Chemical control

Pesticides are traditionally the first option of protection to control insect pest species and disease. Chemical control is the primary technique for cotton protection from PBW. After release, varieties of BT cotton attack armyworm, spotted bollworm, and pink bollworm (Akhter et al. 2010; Sarwar, 2017a & Sarwar, 2017b). Observed cotton-growing areas 2 to 3 months are highly affected due to the attack of the 2nd generation of *P. gossypiella* (Hassan *et al*., 2021). With time PBW damaged the quality and quantity of cotton bolls, especially staple length and lint colour, and as a result, PBW is a significant threat to BT crops (Aslam *et al*. 2004; Hassan *et al*., 2021). If a heavy infestation occurs, then complete crop loss (Schwartz. 1983). Spinosad insecticides manage lepidopteran insects (Temerak, 2007; Gosalwad *et al*., 2009). Scientists highly recommend integrated pest management (IPM) to meet this pest (Dhurua and Gujar, 2011). However, so many reasons, sometimes trap catches do not respond to change infestation levels (Flint *et al*., 1993). insecticide pattern of Spinosad, Malathion, beta-cyfluthrin and series sequence of Spinosad, Malathion, and lufenuron are induced reduction 80 to85 percent infestation of PBW larvae (Abd El-Mageed et al. 2007). Show the highest reduction of *P. gossypiella* infestation through the synthetic pyrethroids (lambda-cyhalothrin, fenpropathrin) mix chlorpyrifos (El-metwally *et al*., 2003). Different insecticides used in rotation programs may delay resistance (Abd El-Mageed *et al*., 2007). The selection of different insecticides for successfully used against PBW includes Deltamethrin, Triazophos, Gamma-cyhalothrin, Triazophos + Deltamethrin, Chlorantraniliprole, etc. and Spinetoram (Sanghi *et al*., 2018).However, the efficacy of different chemical pesticides against *P. gossypiella* Gamma cyhalothrin 79.1%, Spinetoram 73.9% Deltamethrin 64.9%, Triazophos 59.12%, and mortality percentage of PBW was observed in the case of Triazophos + Deltamethrin 90.01% effectiveness (Sanghi *et al*., 2018).

CONCLUSION

Pectinophora gossypiella is a serious insect pest species that cause damage to economically important crops worldwide. Adult moths lay eggs within ten days and hatch in 4-5 days, 12 - 15 days larval, and 7-8 days is a pupal stage. Successful control through Genetically modified crops (BT cotton) and synthetic insecticides such as Deltamethrin, Spinetoram, Triazophos, Gamma cyhalothrin, But Triazophos + Deltamethrin are most effective against pink cotton bollworm. In the future, control necessitates approach integrated pest management (IPM). Chemical, physical, and biological management measures are common for high control.

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