The Pharma Innovation Journal 2023; 12(3): 2036-2042

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(3): 2036-2042

www.thepharmajournal.com
Received: 13-12-2022
Accepted: 14-01-2023

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Pink bollworm *Pectinophora gossypiella* (Saunders), a destructive pest of cotton: A review

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Abstract
Cotton, the important cash crop, globally known as "King of Fibre" offers an important natural fabric material to the world has been a point of fascination. Since it is grown as major cash crop in India, appears to have been the center of an important cotton industry as early as 1500 BC. Besides serving as a source of natural fiber, it is also an oilseed crop, providing raw material to the oil and textile industries, playing dominant role in the economic and social status of the people.

Amongst the various factors responsible for low yields, the losses due to pests assume significant importance as cotton crop is a heaven for insects. A total of 1326 species of insects have been recorded on cotton throughout the world. The pest spectrum of cotton crop is quite complex comprising of several species of the insects. However, main losses in cotton production are due to its susceptibility to about 162 species of insect pests. The sucking pests and bollworm complex account for a considerable yield loss up to 36.2 per cent. Chemical insecticides, are being used extensively for control of these insect pests. After the introduction of Bt cotton the use of pesticides minimized and the problem of bollworms was solved, but from last few years, pink bollworm has developed resistance against Bt toxins. Worldwide, pink bollworm has become economically the most notorious pest of cotton. Among the bollworms, pink bollworm poses greater threat to the cotton in recent past and has known to cause loss in normal opening of bolls, loss in oil content, seed cotton yield and damage locules. The authors tried here to collect the information about its distribution and origin, seasonal incidence, life history, nature of damage, symptoms, different management tools including IPM strategies. This information will helpful to the scientists to plan their research on pink bollworm which is the most destructive pest of cotton.

Keywords: Cotton, pink bollworm, *pectinophora gossypiella* (Saunders)

Introduction
Cotton (*Gossypium* spp.), a "friendly fiber" is one of the most important commercial crops that are cultivated all over the world. Cotton is one of world's most essential fiber crops having global importance, cultivated in tropical and subtropical regions of more than 70 countries (Shaheen, 2012) [30]. Global 2019-20 cotton area, production and productivity are projected at 34.50 million hectares (85.50 million acres), 121.50 million bales and 791 Kg/ha, which were nearly 4 and 6 percent greater than that of 2018-19. India is the largest cotton producer in the world with 28.50 million bales compared to 26.50 million bales in previous year followed by China (27.25 million bales), United States (20.02 million bales), Brazil (12.00 million bales) and Pakistan (8.00 million bales) (AMIC 2020) [4].

As on 26th September 2019, area under cotton during 2019-20 was 127.67 lakh ha as against 121.05 lakh ha in 2018-19 i.e. 5.46 per cent more than the previous year. Among the states, Maharashtra was reported as leading state in cotton acreage (44.05 lakh ha) followed by Gujarat (26.66 lakh ha), Telangana (18.59 lakh ha), Haryana (7.01 lakh ha) and Rajasthan (6.44 lakh ha) (AMIC 2020) [4].

The crop is globally striked by 1326 species of insect pests, out of which 130 different species of insects and mites found to devour cotton at different stages of crop growth in India. (Parmar and Patel, 2016) [22]. Among the bollworms, pink bollworm assumed major pest status in recent past (Ghosh, 2001) [12].

The pink bollworm larvae burrow through lint, penetrating deeply into the immature seeds and consume them. When one seed is destroyed, the larva tunnels through the developing lint to another seed until the locule is destroyed. The affected bolls subsequently rot and are shed, while those that are retained on plants open prematurely resulting in stained, immature fiber (Agarwal *et al*., 1984) [1].

Worldwide, pink bollworm *Pectinophora gossypiella* (Saunders) has become economically the most notorious 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) [24]. Costly chemical tactics has resulted in economic calamity, destruction of natural enemies and environmental hazards (Ayaz *et al*. 2020) [6].

Distribution and origin

The pink bollworm, *Pectinophora gossypiella* (Saunders) was described by W.W. Saunders in 1843 as *Depressaria gossypiella* from specimens found to be damaging cotton in India in 1842 (Ingram 1994) [17]. 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.

Pink bollworm is distributed throughout tropical America, Africa, Asia, Australia, asia, including subtropical regions, Pakistan, Egypt and Mexico. It has been eradicated from all cotton-producing areas of the continental USA (USDA, 2018) [34].

Seasonal abundance

Venilla *et al*. (2007) [35] studied seasonal abundance of pink bollworm for five years during 2001-2005 at Nagpur and reported that effective population buildup of pink bollworm starts after 100 to 110 days of crop emergence, while the peak infestations occur after 140 days. Further maximum population of pink bollworm was observed during 27th week of crop emergence in 2001. They revealed that levels of incidence were high during 2002 & 2003, whereas 2005 had the lowest incidence as well as damage.

Verma *et al*. (2017) [37] at Kanpur studied seasonal incidence for two years and reported pink bollworm infestation on flowers found higher in 2nd week of September during both the years. While, peak larval population on green bolls was recorded during the 2nd week of September in 2012 and peak infestation was recorded during 3rd week of September in 2013.

Yalawar and Patil (2019) [39] at vijaypura reported that during *kharif* 2017-2018 the larval activity of pink bollworm on green bolls was noticed from the first fortnight of September and increased gradually with the progression of crop growth reaching its peak incidence during the second fortnight of September.

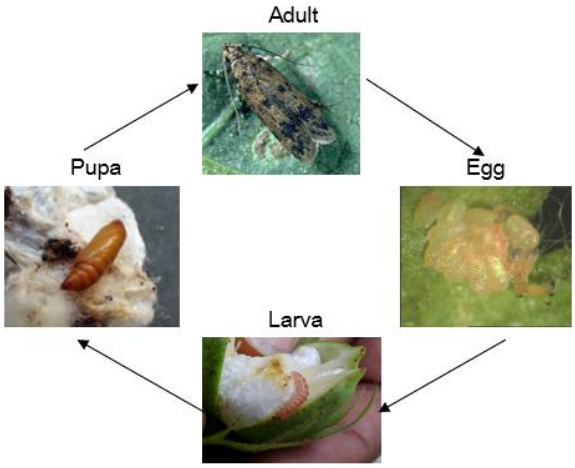
Divya *et al*. (2020) [11] studied seasonal incidence of pink bollworm at AICRP on cotton, Haradanahalli, Chamarajanagara during *kharif* 2018 and revealed that pink bollworm incidence were started during 32 SMW and attended its severity at 46th SMW.

Krishna *et al*. (2020) [18] studied impact of weather parameters on seasonal dynamics of insect pests in *Bt* and non *Bt* cotton during the years 2018 and 2019 at Regional Agricultural Research station, Nandyal and reported that peak larval population of pink bollworm and peak fruiting body damage were observed during 52nd and 51st standard week of year 2018- 2019 respectively.

Patel (2020) [11] studied effect of weather parameters on the population of pink bollworm and revealed that pink bollworm larvae was first appeared during the 5th week of September and remained active till 3rd week of January. The peak population was observed during third week of December.

Life history

Life cycle of pink bollworm was studied by served earlier workers. It consists of four stages of development, including egg, larva, pupa and adult.



Eggs: Eggs are pearl white, flattened, oval, and laid singly or in cluster of 4 to 5. (Ayaz *et al.* 2020) [6]. Eggs are white when first laid but then turn orange. The head capsule is visible prior to hatching. Eggs hatch in about three to four days after they laid. Eggs measures about 0.5 mm long and 0.25 mm wide (Venilla *et al*. 2007) [35].

Larvae: young larvae are tiny, white caterpillars with dark brown heads up to the second instar. It turns pink in the fourth and final instar of growth stages. The degree of pink colour depends on the food that the larvae eat. Dark pink results from eating maturing seeds (CAI, 2015) [9]. First two instars are white, while from third instar pink colour develops. The larvae have the characteristic dark brown head due to the sclerotized prothoracic shield. Larval period lasts for 10-14 days. The mature larva are 10-12 mm long with broad horizontal bands of red colour on body. (Venilla *et al.* 2007) [35]. Larvae hide in empty cotton seeds during adverse season in which they are well covered and remain alive for several months. The sexes of larvae can be determined in fourth larval instar by observing testes through semi-transparent dorsal abdominal region (Zinzuvadiya *et al*. 2017) [40].

Pupae: The pupal period varies from 7-10 days. The pupa is approximately 7 mm long and light brown in colour. Pupation takes inside a loose fitting cocoon with a highly webbed exit at one end (Venilla *et al.* 2007) [35].

Adult: Moths are nocturnal in nature, hiding in soil waste or holes during the day. Adults are usually grayish brown in color with blackish bands present across forewings while the hinds are usually silvery grey (Ayaz *et al.* 2020) [6]. The moths are about 7-10 mm with a wing span of 15-20 mm (Venilla *et al.* 2007) [35]. Adults may live for one to two months. Mating takes place 2-3 days after adult emergence. Pre-oviposition period is about ten days. The life cycle is completed in 3-6 weeks.

Nature of damage

Two days after hatching, the young larvae penetrate into

ovaries of flowers. Larvae prefer feeding on developing seeds and generally pupate inside the seeds and bolls (CAI 2015) [9]. Pink bollworm damage squares and bolls, the damage to bolls being the most serious. Larvae burrow into bolls, through the lint, to feed on seeds. As the larva burrows within a boll, lint is cut and stained resulting in severe quality loss. Matured 4th instar larvae feeds on the full-grown seed, sometimes this pest also exhibits an Inter-loculi movement. It has also been observed that many larvae infesting single boll (Ayaz *et al.* 2020) [6]. Under dry conditions, yield and quality losses are directly related to the percentage of bolls infested and the numbers of larvae per boll.

With high humidity, it only takes one or two larvae to destroy an entire boll because damaged bolls are vulnerable to infection by boll rot fungi.

Symptoms

1. **Rosette flowers: (**Improper opening of petals), Flowers do not open fully and They get twisted which is typical symptom of bollworm attack.
2. Excreta observed at the point of bore holes by larval feeding. When bolls are opened, damaged seed kernel would be observed.
3. **Spots on green bolls**: black spots on green bolls may often be indicative of pink bollworm damage.
4. **Stained lint:** Stained lint around feeding areas resulting in bad quality cotton is seen in open bolls. This is the distinct symptom of damage. It occurs at later stages of crop growth, once the damage is done (Kranthi, 2015).
5. **Small round holes (locule damage):** Small round holes are seen on the septa between locules of open bolls. Lint of pink bollworm attacked bolls is of inferior quality.

Rosette flower PBW in Rosette flower Exit hole Green boll damage Locule damage

Integrated pest management

The high costs of chemical control, continuing economic losses, secondary pest problems and environmental considerations suggest the need for ecologically oriented pink bollworm management strategies. Extensive research has resulted in a broad array of monitoring, biological control, cultural, mechanical, behavioral, genetic and host plant resistance methods that can serve as a base for the formulation of integrated pink bollworm management systems.

Cultural control

Watson and Larsen (1968) [38] reported that medium ploughing to a depth of 6 inches was more effective in reducing pink bollworm moth emergence than deep ploughing to a depth of 12 inches.

Atwal and Singh (1969) [5] minimum emergence of pink bollworm was observed when seed was buried at 15 cm depth.

Henneberry and Naranjo (1998) [16] suggested that use of genetic characteristics in plants that render them less susceptible to attack from insect pests is one of the most economical and acceptable methods of pest population suppression.

Ayaz *et al.* (2020) [6] reported that shredding of stalks, ploughing, winter irrigation and disking result in high levels of mortality of hibernate immature. They also stated that deep cultivation exposed soil born pupae of pink bollworm which are exposed to hot sun result in mortality of 4th instar larvae. There is eighty percent decrease in moth emergence from fields that have been rotavated and exposed to sun light.

Physical control

Atwal and Singh (1969) [5] reported that cent per cent mortality was observed when seeds were exposed to 48.9 ^{o}C for 20 minutes.

Mechanical control

Patil *et al.* (2008) [25] reported that 35 traps per ha were optimum for mass trapping of pink bollworm moths. It was also revealed that the use of pheromone traps leads to reduction in green boll and locule damage.

Shrinivas *et al*. (2019) [31, 32] evaluated different mass trapping and mating disruption tools against pink bollworm, *Pectinophora gossypiella* (Saunders) in *Bt* cotton ecosystem during *kharif* 2017 at Kurudi village, Raichur, Karnataka with different treatments like sleeve trap and delta sticky traps at recommended dosage for mass trapping and SPLAT at three different doses of 500, 750 and 1250 g per acre and concluded that Specialised Pheromone Lure Application Technology (SPLAT @ 500 g/ acre) proved significantly superior with less rosette flowers, green boll and locule damage and also recorded higher yield with more B: C ratio. They also stated that SPLAT is environmentally viable, economically feasible, slow and sustained release formulation with trap free auto confusion technology and best technology for the management of PBW and suits well in the IPM program.

Shrinivas *et al*. (2019) [31, 32] studied dissipation of pheromone from dispensers of Specialized Pheromone and Lure Application Technology (SPLAT-PBW) formulation used against pink bollworm in *Bt* cotton ecosystem and observed that it (SPLAT-PBW) has rain fastness, easy to apply, long lasting properties and cost effective. To assess its feasibility in *Bt* cotton they also studied dissipation by collecting field samples of SPLAT-PBW dispensers at weekly interval and were subjected to gas chromatography analysis, they found that even by the end of fifth week 40.36 per cent of active ingredient i.e. pink bollworm pheromone (ZZ/ZE) 7, 11-Hexadecadienyl acetate was left in the sample collected which, clearly indicates the slow release mechanism of SPLAT- PBW compared to other lures.

Naduvalakeri *et al.* (2020) [20] conducted large scale field experiments during 2005-06 and 2006-07 at Agricultural

Research Station Dharwad to evaluate the efficacy of PB Rope L (Sex pheromone based commercial product) for management of pink bollworm. PB Rope L dispensers @ 200/ha was tied to cotton stalks at pin square stage and they observed that percentage of infestation with the pink boll worm moth catches were highly suppressed (near 100 per cent) in the treated field by installation of the dispensers during the flowering growth stage. In addition, per cent of average infestation in the cotton green bolls was significantly decreased in the treated (1.51and 0.89) compared with the control field (20.54 and 12.33 per cent) in both seasons, respectively.

Meena *et al*. (2021) studied management of pink bollworm Pectinophora gossypiella using mating disruption pheromone (PB Rope L) in cotton during kharif 2016-2017at Agricultural Research Station, sriganganagar (Rajasthan) India.

Bhute *et al*. (2021) [7] evaluated solar light trap against pink bollworm, *Pectinophora gossypiella* (Saunders) in *Bt* cotton at AICCIP, Rahuri during *Kharif*-2020 and concluded that solar light trap was effective for catching considerable numbers of pink bollworm moths and it can be used for checking seasonal activity of pink bollworm and beneficial insects on *Bt* cotton.

Botanicals

Dhara jyothi (2007) [10] reported that neem product such as neem seed kernel extract 3-5 per cent and neem oil 0.5 per cent were found effective in suppressing bollworm without affecting natural balance of cotton ecosystem.

Borkar and Sarode (2012) [8] reported that application of NSE 5 per cent, neem oil 1 per cent and azadirachtin 1500 ppm proved to be the most effective in reducing the larval population of pink bollworm in green bolls.

Amer *et al.* (2014) [3] studied efficacy of two plant extracts Sweet Annie, *Artemisia annua* L. (Asteraceae) and hot pepper, *Capsicum annuum* L. (Solanaceae) against pink bollworm they observed that mixed extract of (*A. annua* + *C. annuum*) had the best efficacy against pink bollworm than usage each extract alone.they also stated that the newly hatched larvae are more susceptible than egg stage.

Rajput *et al*. (2017) [26] studied dual action of transgenic cotton and botanical plant extracts for the management of pink bollworm. They were used three local extracts such as tobacco (*Nicotiana tabacium*), neem (*Azadirachtin indica*) and datura (*Datura stramonium*) in traditional method during two consecutive growing years 2015 and 2016. They concluded that the highest pest population reduction at tobacco (17.45-15.09 per cent) followed by neem (14.58-15.33 per cent) and datura (11.72-7.81 per cent).

Biopesticides

Venugopal *et al.* (2017) [36] reported that use of entomopathogenic fungi like *Beauveria bassiana* with different concentrations helps to reduce the pink bollworm infestation.

Tomar (2009) [33] worked on comparative field efficacy of microbial and conventional insecticides against bollworms of cotton during 2004 and 2005 and found that spinosad 45 SC @ 75gai per ha proved most effective in the reducing the bollworm infestation and increasing seed cotton yield.

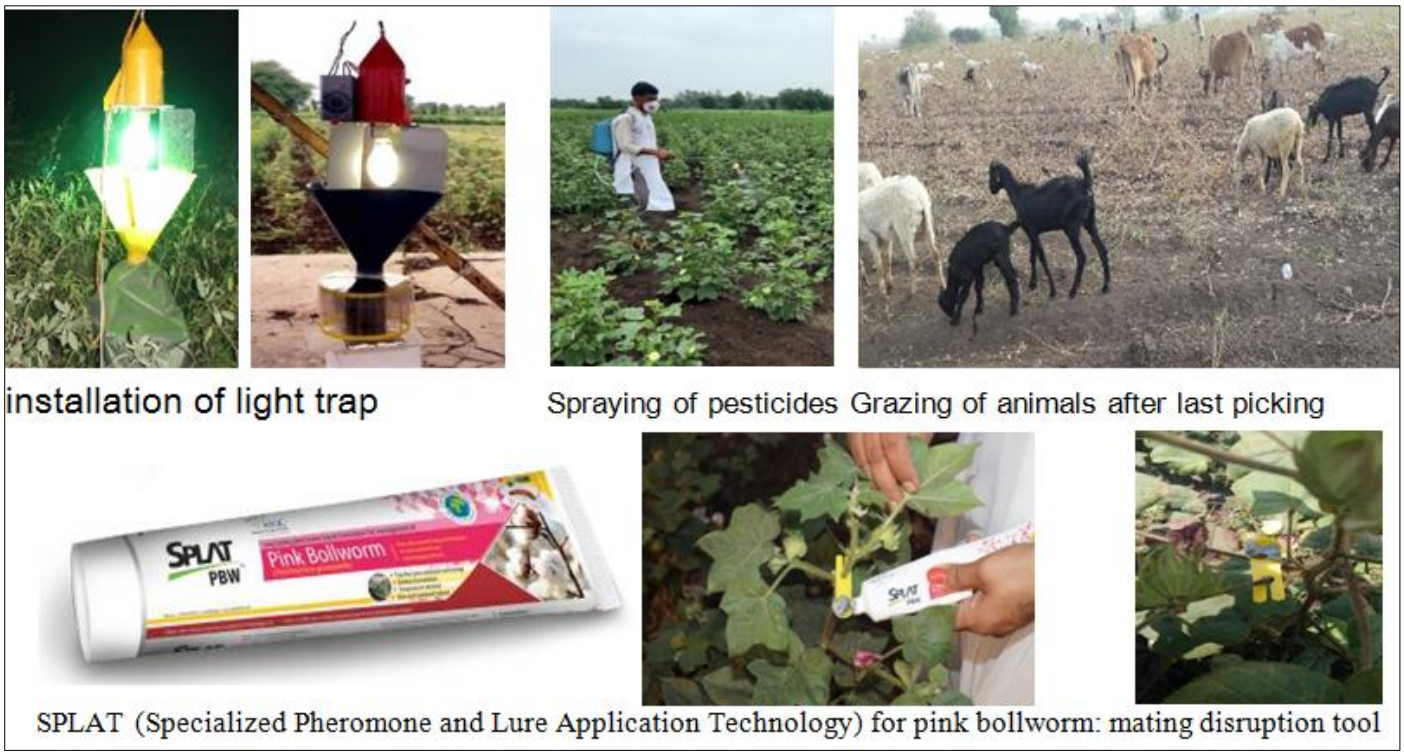
Biological control

Ahmad *et al.* (2002) [2] reported that *T. chilonis* parasitoid was more effective against pink bollworm than spotted bollworm.

Hafez *et al.* (2004) [14] reported that release of *T. evanescens* to control pink bollworm is biologically effective and could be used as an important agent in integrated pest management programs.

Mohamed *et al*. (2016) [19] evaluated the efficacy of egg parasitoid, *Trichogrammatoidea bactrae* Nagaraja during two successive cotton growing seasons 2013 and 2014 at Elwan district, Assuit Governorate (Upper Egypt) and revealed that four early releases of parasitoid before 50 per cent of flowering stage succeeded to suppress the infestation of pink bollworm in the both seasons.

Naik *et al*. (2019) [21] evaluated efficacy of egg parasitoids *T. bactrae* and *T. brasiliensis* and reported that the larval population, green boll, open boll and locule damage by pink bollworm were comparable with *T. bactrae* and *T. brasiliensis* releases.



Chemical control

Gopala Swamy *et al*. (2000) [13] conducted the efficacy of certain insecticides and reported that beta- cyfluthrin (24.11 per cent), spinosad (25.33 per cent) and indoxacarb (26.43 per cent) found equally promising against pink bollworm.

Rani *et al*. (2010) [27] reported that deltamethrin 1% EC + triazophos 35% EC at the rate of 360 g a.i/ha was most effective for the control of pink bollworm.

Sabry *et al*. (2014) [28] evaluated toxicity of three modern insecticides chlorantraniliprole, thiamethoxam and spinetoram and reported that thiamethoxam was the most effective insecticide followed by chlorantraniliprole and spinetoram agaist the 1st instar of pink bollworm.

Hanchinal *et al*. (2018) [15] studied efficacy of different insecticides for the management of bollworms of cotton during 2017-18 at MARS Raichur. They revealed that Sulfoxaflor 40%WG was effective against population of pink bollworm, which was the lowest compared to rest of the treatments.

Sasikumar and Vimala (2020) [29] evaluated different insecticides against pink bollworm in cotton and revealed that spinosad (45% SC) @ 250 ml/ha was most effective against pink bollworm infestation followed by chlorantraniliprole (18.5% SC) @ 150 ml/ha by recording lowest rosette flower incidence, larval population/20 bolls and locule damage at harvest. Highest yield was also realized in spinosad (45% SC) @ 250 ml/ha followed by chlorantraniliprole (18.5% SC) @ 150 ml/ha.

Conclusion

The gelechiid *Pectinophora gossypiella* (Saunders) is a limiting factor in *Bt* cotton production and has been reported to cause locule damage to an extent of 55 per cent and reduction in seed cotton yield in the range of 35-90 per cent. Pink bollworm, *Pectinophora gossypiella* (Saunders) is a major concern to cotton production in India. Now-a-days farmers mostly adopt chemicals for the effective pest management of cotton. However indiscriminate use of pesticides is causing adverse effect on the environment and leads to development of insecticidal resistance in pests. Long duration of varieties and absence of potent control measures are primarily the reasons sufficient to make pink bollworm a destructive pest in India. In India, total insecticides used to control bollworms alone were 9410 MT in the year 2003-04, worth of 747.6 crores. Despite such a high proportion of pesticide consumption, pink bollworm pressure could not be contained rather have made the situation worse by development of resistance to major insecticides and *Bt* toxins. Now there is need to shift from traditional management practices to a novel technique.

Cultivation of short duration varieties of about 150 days and timely sowing will be useful to overcome the threat of pink bollworm, destruction of unharvested bolls is necessary to prevent shelter for larvae because surviving bollworms will overwinter in the field and re-infest the following season.

Populations of pink bollworm is also controlled with mass trapping, mating disruption techniques like PB rope L, SPLAT technique, botanicals, biopesticides and releases of sterile males which mate with the females but fail to fertilize their eggs and release of parasitoids and predators. Use of insecticides alone or with combinations of insecticides strongly effective for the management of pink bollworm. Application of insecticides with synergists helps to manage resistant pink bollworm population. Use of IPM modules in cotton is necessary to prevent environmental hazards and for protection of natural enemies and pollinators like honey bees.

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