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Pink Bollworm *Pectinophora gossypiella* (Saunders) [Lepidoptera: Gelechiidae] and Practices of Its Integrated Management in Cotton

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Abstract

This article pinpoints pink bollworm *Pectinophora gossypiella* (Saunders), which is a worldwide insect of cotton and in some regions of the world, it is the key pest resulting in major cause of yield loss. Adult moths lay eggs on cotton bolls, once hatched larvae eat seeds and damage fibres of cotton reducing yield and quality of produce. High yield losses can occur in cotton when *P. gossypiella* larvae emerge from eggs and quickly eat their way into squares or bolls causing major economic damage. Cotton bolls of 10-24 days old are most susceptible to pink bollworm attack, resulting in failure of buds to open, fruit shedding, lint damage and seed loss. Integrated pest management practices for pink bollworm are destroying of cotton sticks after harvest or remaining bolls, burning of affected bolls under heaps of cotton sticks, turning the heaps over to expose bolls to sunlight and after final picking letting livestock to graze on unwanted bolls to reduce the pest attack in next season. Burn the debris of cotton ginning factories, expose seed of the next crop to sunlight (sun drying) for 8 hours one week before sowing and crop irrigation should be minimise after 30th September. Deep ploughing of field after harvest by deep furrow turning plough is found magnificent and do not apply nitrogenous fertilizer after 15th of August. Monitor pest at flowering stage twice a week, look for twisted rosette flowers and bolls from the beginning of flowering stage, and eggs can be found on the boll. Direct control measures are taken when 5 bolls or flowers per 100 samples are affected. Use of *Trichogramma chilonis* cards can destroy eggs before they hatch and use 10-15 cards per acre. Combinations of biological agent *Trichogramma* and chemical control have proved successful for control of pink bollworm, and *Bacillus thuringiensis* has also been found to be effective with chemical insecticides. Pheromone PB-Rope L should be used at 100-200 ropes/ acre and higher rates must be used if trap counts are consistently above economic threshold of 7 adults per day and ought to be replaced after about 3.5 months with fresh ones. Release of sterile insects, cultural controls, intensive monitoring with pheromone baited traps for males and adults mating disruption, boll sampling, very limited use of pesticides, widespread use of genetically engineered cotton, and use of nematodes as control agents are effective techniques in an integrated pest management program.

Keywords

Cotton Production, Pink Bollworm, *Pectinophora*, Pest Survey, Pesticides

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1. Introduction

The cotton ecosystem is very complex (Sarwar, 2016; 2017 a) and the gelechiid moth of genus *Pectinophora* in the family Gelechiidae of order Lepidoptera may be associated with cotton (Sarwar et al., 2013). The species of *Pectinophora* accompanying with cotton contain four species, *Pectinophora endema* Common 1958, *Pectinophora fusculella* (Pagenstecher, 1900), *Pectinophora gossypiella* (Saunders 1844) and *Pectinophora scutigera* (Holdaway,

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1926). Other host plants commonly used by *Pectinophora* bollworms are *Abutilon indicum*, *Hibiscus tiliaceus* and *Thespesia populnea*, which are widespread around the world (Karsholt and Razowski, 1996). The pink bollworm *P. gossypiella* is one of the world's most destructive insect pests that causes terrible damage to cotton bolls. Moths are dirty brown in colour, about 5 mm in length and measuring almost 12-20 mm across the wings. Adults are small, greyish brown and inconspicuous moths. When their wings are folded, they have an elongated slender appearance. The wing tips are conspicuously fringed with hairs. Forewings are much longer than wide, with a fringe of hair-like scales beginning from the middle of the posterior edge of the wing, continuing around the tip and terminating on the front edge about ¼ or $^1/_3$ the length of the wing from the tip. The forewing terminates in a pointed tip that may be obscured by the fringe scales which may give the appearance of a flat-tipped wing. The hind wing has broad fringe about as long as the width of the wing along the hind margin and curving around the anterior margin where it is no more than half the width of the wing in length. The distal end of the hind wing has a sigmoidal or s-shaped curve producing a sharp point on the anterior edge (Silvie and Goze, 1991).

Adults emerge as brownish or greyish moths with dark mottling and dark spots on their wings. The females take two or three days to mate and develop eggs within the body. After this brief period, it lays the majority of its eggs within ten days. Eggs are laid under the bracts of cotton bolls or the calyx of green bolls, elongate-oval, 0.4-0.6 mm in length and 0.2-0.3 mm wide. Early in the season, eggs are laid in any of the sheltered places of the plant axis of petioles or peduncles, the underside of young leaves and on buds or flowers. Once the bolls are 15 days old, these become favoured sites for oviposition. Pink bollworm eggs take about three to four days to hatch after they are laid. They are white at first and progress to an orange colour as development progresses (Kabissa, 1990).

Freshly-hatched larvae are white with a brown head. They do not turn pink until the fourth and last larval stage. Larvae bore into the cotton plant, but usually in the cotton boll in order to feed on the seeds. The larva moves from seed to seed within the boll, chewing through the cotton fibres as it grows. Larvae usually pass through four instars and after this they emerge from the top of the boll (in contrast to the behaviour of the noctuid cotton borers *Earias vittella* and *E. insulana*, which make exit holes in the lower half of the boll). Larvae take twelve to fifteen days to develop, after which they move to the soil to pupate. The brown pupa remains immobile in the top layer of the soil for seven to eight days. Pupation takes place in the ground, about 50 mm below the surface and adults emerge after about 9 days. Adults are nocturnal and females begin laying eggs a day or two after emergence, typically each laying 200-400 eggs. Under optimal conditions, the entire life cycle is completed in 25-31 days and there may be four to six generations per year. The mature larvae are either 'short-cycle' and will go on to pupate or 'long cycle' to enter a state of diapause. Short cycle larvae pupating may cut a round exit hole through carpel wall and fall to ground and pupation is inside a loose fitting cocoon. Under cool dry conditions, *P. gossypiella* larvae may undergo diapause in a small cocoon in partially opened bolls in cotton lint, stored seed, and plant debris or in the soil. Diapause larvae often spin up in the lint of an open boll and if still active in ginnery, can spin up on bales of lint, bags of seed or in cracks and crevices. The long cycle larvae entering diapause, spin a tough thick walled, closely woven, spherical cell 'hibernaculum' with no exit hole in mature bolls inside seeds during end of crop season. Hibernacula may occupy single seed or double seeds. Diapausing larvae normally emerge when conditions are more favourable (late March or early April), but may remain quiescent for up to 2.5 years. The effective population build-up starts after 100 to 110 days of crop emergence, while the peak infestations occur after 140 days. Moths emerging from the hibernating larvae are long lived with females and males living for 56 and 20 days, respectively (Metcalf and Metcalf, 1992; Sarwar, 2017 b).

The larva feeds on the blossoms, lint, and seeds of cotton and may also pupate in the buds. The larvae feed only on a few other crops such as okra, Hibiscus and jute. Eggs are laid on flowers, young bolls, axils of petioles and underside of young leaves. After hatching, the young larvae penetrate ovaries of flowers or young bolls within two days of hatching. Larvae turn into pink colour in 3-4 days after hatching. Larva when attacks the bud of less than 10 days old, shedding of bud occurs and larva dies. But with older bud, larva can complete development. The degree of pink colour depends on the food that the larvae eat. Dark pink colour results from eating of maturing seeds. 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. Further, the cotton lint in the insect infested bolls gets damaged by secondary fungal infection. Fibre qualities such as length and strength are also lowered. The seed cotton carried to market yards acts as a source for the pest to spread further. Young larvae are tiny, white caterpillars with dark brown heads. When mature, they have wide transverse pink bands on the back. To be able to see pink bollworm larvae, bolls have to be cracked open. The first and second instars are difficult to see against the white lint of the bolls. Larva in flower bud spins webbing that prevents proper flower opening referred as rosetted flower due to pink bollworm (improper opening of petals), which is typical of bollworm

attack. Small exit holes which is smaller than the feeding holes of *Earias* & *Helicoverpa* bollworms are seen on developing green bolls. Stained lint around feeding areas is seen in open bolls, but improper boll opening with damaged seeds are obvious (Khidr et al., 1990; Michel and Gomez, 1992).

2. Damage by Pink Bollworm

Pink bollworm generally arrives with the onset of winter and continues to survive on the cotton crop as long as flowers and bolls are available. Long duration cotton allows the pest to thrive for a longer continued period in multiple cycles, thereby affecting the subsequent cotton crop. In the absence of cotton, or as a genetically pre-disposed condition, the pink bollworm undergoes hibernation or diapause that allows it to be dormant for 6-8 months, until the next season. Pink bollworms 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. 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. Stained lint becomes visible in open bolls and this is a distinct symptom of damage. It occurs in the later stages of crop growth, once the damage is done. In case of rosette flowers, flowers do not open fully and they get twisted. In case of bolls, black spots on a green boll may often be indicative of pink bollworm's damage. Pink bollworm damaged bolls often predispose the occurrence of secondary bacterial infection that results in the blackening of boll rind on the outside. A small hole of 1.5 to 2 mm diameter clearly indicates the exit of the insect from the green boll (Henneberry and Naranjo, 1998; Hutchison, 1999).

3. Prevention and Control Options for Pink Bollworm

An account of summarizing the control methods most effective against *P. gossypiella* can be patterned in the following section. When high population levels of pink bollworm occur, the objectives of management are to keep infestations below damaging levels in the existing season without creating of secondary outbreaks of other pests and to reduce the overwintering population that can threaten the following season's crop. The main control tools are observance of host-free period, the judicious use of insecticides, timely crop termination and harvest, rapid crop destruction, properly timed winter and spring irrigations, and compliance with plough down requirements. When pink bollworms are found, a regional monitoring and sterile moth release program is implemented. Because of the danger of secondary outbreaks, especially it is wise to limit insecticide treatments to those periods when susceptible bolls are present and when sampling shows the percentage of infested bolls is above the treatment threshold. It is rarely necessary to apply insecticides against moths from the overwintered population of pink bollworm and often treatments are not needed against the first generation of moths that develop from larvae within squares. However, growers should be alert for high populations of pink bollworm moths when squares are developing, especially if other pests such as bugs and armyworms are also threatening. On the other hand, mating disruptants and sterile moth releases, are most effective when aimed at the overwintering generation, usually at the time when cotton plants have 6 to 8 leaves (Gao et al., 1992).

3.1. Monitoring and Treatment Decision

Normally, do not apply insecticides to control larvae as these are either inside the boll or in the ground and therefore insecticide contact is difficult. The simplest and most potent way to overcome the problem is to take up timely sowing and cultivate early maturing short duration varieties of about 150 days duration. All other management strategies such as avoidance of excess urea + insecticides, use of light traps, pheromone traps, biopesticides, biological control etc., can rally around to minimize the damage to zero levels. Regular monitoring of bollworm resistance to Bt cotton including use of the parasitoid *Trichogramma* in fields for bollworm management, and recommending planting of local cotton/ conventional non-Bt cotton and late planted okra as refugia crops should be taken. Timely termination of the crop latest by December and avoiding ratoon or extended crop, and utilization or destruction of crop residues and cotton stalks immediately after harvest must be taken, and crop rotation is strongly recommended to break the pest cycle. Short duration single-pick varieties (150 days) provide high yields in high density and escape the pink bollworm. Consider installation of light traps and pheromone traps in fields during the season, and also near go-downs, ginning mills and market yards to trap post season moths (Bagla, 2010; Ahmad and Sarwar, 2013).

3.2. Cultural Control

Late planting of crops has been used as a cultural control method where the end of diapause is triggered by day length. Larvae that emerge before the crop is ready then have no food supply. Certain methods have also been developed for reducing the number of overwintering larvae, including the chemical defoliation of crops and desiccation of the crop at the end of the season, removing immature late season bolls,

and the use of short-season varieties. Beasley and Adams (1995) have suggested eight cultural control methods following a field study of pink bollworm. In essence, they recommend the use of short-season cultivars appropriate to the seasonal climate of the area, not forcing regrowth and a second flowering cycle, rotating crops and specific recommendations for harvesting and dealing with crop debris. Other cultural control methods, including land preparation, irrigation, sowing date, weed control, fertilization, crop rotation, use of trap crops and resistant varieties, have been discussed by El-Amin and Ahmed (1991). It has been reported that gin trash is a carrier of pests and that cotton seed mills with adequate fans for the expellation of gin trash have fewer cotton pests than mills without this equipment. A three years break from cotton production has also been used successfully in areas not highly susceptible to constant re-infestation from other areas. Much recent research has centred on the use of genetically manipulated cotton which enables pest larvae to become infected with the *Bacillus thuringiensis* toxin. All transgenic varieties of cotton give a better yield than conventional strains, but a problem related to this is the resistance developed by the larvae. A strategy for overcoming this is the use of refuges in which non-transgenic plants are planted nearby, or else a strategy of inter-planting one non-transgenic row in five is used.

Eliminate the food supply for pink bollworm by cutting off irrigation early enough to stop production of green bolls by early September. Regardless of when the crop is terminated, immediately shred the cotton plants following harvest. Shredding destroys some larvae directly and promotes rapid drying of un-harvested bolls. If fall temperatures are high during September and much of October, leave crop debris on the soil surface for two or more weeks after the shredding operation to further destroy larvae. Be sure to comply with plough down requirements and cross disc or plough to a depth of at least 12-15 cm. Winter irrigations can reduce populations of overwintering pink bollworms, but flooding in December is more effective than flooding in November or January. Plan irrigations of the crop to prevent even slight moisture stress and to promote maximum emergence of moths in advance of susceptible squares. The use of *Bt* cotton can help to prevent damage by pink bollworm, but also offers suppression of cotton bollworm, along with beet armyworms, and tobacco budworm. It has been reported the survival of pink bollworm larvae to Cry1Ac and also developed resistance to two Cry toxins (Cry1Ac + Cry2Ab) in some regions. Thus, the seed breeders must ensure that Cry toxins are present in the hybrids in homozygous form, instead of the segregating heterozygous form as in the current hybrids (Simmons et al., 1998, Lin, 2000; Sarwar, 2013 a)).

3.3. Biological Control

Pest *P. gossypiella* has been a target for biological control, particularly parasitoid *Bracon kirkpatricki* from several countries can become easily established. Biological control agents such as nematodes have been used more recently as representative devices. There is a large number of records of other natural enemies on *P. gossypiella*, most of which can be of significance. Among list of Hymenopteran species released against *P. gossypiella*, only *Apanteles angaleti* is a major parasite. The genera *Apanteles*, *Bracon*, *Brachymeria*, *Chelonus* and *Elasmus* among the parasitic Hymenoptera contribute numerous species of potentially useful pink bollworm parasitoids, but *Apanteles oenone* and a *Dirhinnus* spp., are very active on *P. gossypiella*. All of the common predators in cotton fields are capable of feeding on pink bollworm eggs and first instar larvae including mites, predaceous Dermaptera, Hemiptera, Coleoptera and Neuroptera. The egg stage is most vulnerable to attack by predators because it is relatively more exposed when compared to larvae and pupae. The *Nabis*, *Geocoris* and *Orius* all have demonstrated effectiveness in field studies. Coleoptera are well represented with four species in four genera attacking pink bollworm and most of beetles focus on eggs and early instar larvae as prey. Predator *Chrysoperla carnea* (Stephens) is the only neuropteran reported attacking on pink bollworm and seems to prefer eggs and early instar larvae. Parasitoid *Trichogramma* is cosmopolitan in distribution and capable of parasitizing on pink bollworm eggs, so, use 10-15 cards of it per acre (Gouge et al., 1999; Ahmad et al., 2001; Ahmad et al., 2011; Sarwar, 2013 b; Khanzada et al., 2016).

3.4. Mating Disruption of the Pink Bollworm

As pink bollworm develops inside the boll, so, it is difficult to achieve an adequate control using chemicals. Pheromones are scents that are released generally by female moths to attract male insects. These scents are synthesized artificially and used in traps to observe the onset and levels of bollworms infestation. Pheromones at higher dosages or frequency of lures can also be used in mass trapping and to confuse mating. A good correlation has been obtained between the pheromone trap catches and larval incidence in the field. Pheromone has been found to enhance the efficacy of insecticides and the use of the sex pheromones gossyplure and virelure are more economically viable than the use of conventional insecticides. The PB-Rope L is a twisted tie which releases the same scent that female bollworms release to attract males. This scent confuses the male adults thus preventing them from finding and mating with the female adults. This reduces the number of eggs laid by females which decreases the population of the bollworms resulting in

less damage to the crop. The use of PB-Rope L in addition to the regular plant protection schedule has been found to be economically viable as a means of pest managing. The PB-Rope L should be used at 100-200 ropes/ acre, or higher rates should be used if the pheromone trap counts are consistently above the economic threshold of 7 adults per day. Ropes should be twisted securely around the main stem near the bottom of the plant or the stakes, avoiding contact with the soil and place uniformly within the treated field. Ropes twisted too tightly can constrict stem growth, so, apply these immediately prior to moths emergence in the field or when the cotton is at pin square stage. Ropes should be replaced after about 3.5 months with fresh ones as they may have run out of pheromone, but the pest can still be active. The active ingredients of this product are hazardous to humans and domestic animals and care should be taken in their handling by using of gloves. Moreover, early trials using gossyplure to saturate the cotton environment with pheromone in an attempt to disrupt the location of females by males have been proved inconclusive (Boguslawski and Basedow, 2001; Tamhankar et al., 2001).

3.5. Chemical Control

Insecticidal control is hindered by the pink bollworm larvae being internal feeders, moreover, resistance to insecticides develops making it often more expensive than other methods. Nonetheless, there is an extensive literature on chemical control, the efficacies of permethrin, asymethrin, chlorpyriphos, fenpropathrin, teflubenzuron, esfenvalerate, indoxacarb and organic insecticides with high contact toxicity (carbaryl, cyhalothrin, fluvalinate and fenvalerate) have been tested successfully. Application methods have also been assessed and Chlorantraniliprole @ 50 ml/ acre, Spinetoram @ 100-120 ml/ acre, Lambda-cyhalothrin @ 330 ml/ 100 l of water and Spinosad @ 80 ml/ 100 l of water should be sprayed. These insecticides must be reapplied every 7-10 days to provide protection, and when using chemicals, wear protective clothing such as masks, boots and gloves (Osman et al., 199; Walters et al., 1998; Sarwar and Sattar, 2016).

4. Conclusion

Pink bollworm *P. gossypiella* is a quarantine and an oligophagous pest, and it has been found to prefer okra over cotton towards the end of the season when the cotton boll surface is hard. Cultural controls, with the use of *Bt* cotton and the use of mating disruption and sprays of the important formulations are acceptable to use on organically grown cotton. Maintenance of host free period during crop off-season is an essential option to ensure a pink bollworm free next season. Therefore, effective measures of prevention of pink bollworm damage include post-harvest, off-season and pre-planting actions. Allowing cattle grazing of the left over green bolls on the plant at the end of crop season, timely crop termination to maintain closed season, clean up or destruction of cotton stubbles immediate to harvest, avoiding stacking of cotton stalks for fuel purpose over long periods and summer deep ploughing to expose the pupae of the surviving larvae constitute post-harvest and off season cultural measures. While planning for the next season, selection of varieties with early maturity, drying of seeds under sun for 6-8 hours and sowing of acid delinted seeds are effective and economical to prevent the carryover of pink bollworm to the next cotton season. One approach of pink bollworm suppression is to trap most of the male moths in the crop ecosystem by using large number of pheromone traps (@ 20 per ha. If the moth catches exceed eight per trap for three consecutive days, an insecticidal spray in the field is desired. Furthermore, mostly, small growers of cotton are more and they have less knowledge on modern pest control techniques, therefore trainings or seminars should be arranged for their awareness on pink bollworm control program.

References

[1] Ahmad, N. and Sarwar, M. 2013. The Cotton Bollworms: Their Survey, Detection and Management through Pheromones: A Review. Journal of Agriculture and Allied Sciences, 2 (3): 5-8.

[2] Ahmad, N., Ashraf, M. and Fatima, B. 2001. Integration of mating disruption technique and parasitoids for the management of cotton bollworms. Pakistan Journal of Zoology, 33 (1): 57-60.

[3] Ahmad, N., Sarwar, M., Wagan, M. S., Muhammad, R. and Tofique, M. 2011. Conservation of bio-control agents in cotton, *Gossypium hirsutum* L. Field by food supplements for insect pests management. The Nucleus, 48 (3): 255-260.

[4] Bagla, P. 2010. Hardy Cotton-Munching Pests Are Latest Blow to GM Crops. Science, 327 (5972): 1439-1439.

[5] Beasley, C. A. and Adams, C. J. 1995. Effects of irrigation, irrigation timing, and cotton boll burial on extent and patterns of pink bollworm spring emergence. Southwestern Entomologist, 20 (1): 73-106.

[6] Boguslawski, C. V. and Basedow, T. 2001. Studies in cotton fields in Egypt on the effects of pheromone mating disruption on *Pectinophora gossypiella* (Saund.) (Lep., Gelechiidae), on the occurrence of other arthropods, and on yields. Journal of Applied Entomology, 125 (6): 327-331.

[7] El-Amin, E. T. M. and Ahmed, M. A. 1991. Strategies for integrated cotton pest control in the Sudan. 1 - Cultural and legislative measures. Insect Science and its Application, 12 (5-6): 547-552.

[8] Gao, Z. R., Zhao, H. Y. and Jiang, Y. F. 1992. A study on the occurrence, damage and control of the pink bollworm in Henan Province. Plant Protection, 18 (4): 29-30.

[9] Gouge, D. H., Lee, L. L. and Henneberry, T. J. 1999. Parasitism of diapausing pink bollworm *Pectinophora gossypiella* (Lepidoptera: Gelechiidae) larvae by entomopathogenic nematodes (Nematoda: Steinernematidae, Heterorhabditidae). Crop Protection, 18 (8): 531-537.

[10] Henneberry, T. J. and Naranjo, S. E. 1998. Integrated management approaches for pink bollworm in the southwestern United States. Integrated Pest Management Reviews, 3 (1): 31-52.

[11] Hutchison, W. D. 1999. Review and analysis of damage functions and monitoring systems for pink bollworm (Lepidoptera: Gelechiidae) in southwestern United States cotton. Southwestern Entomologist, 24 (4): 339-362.

[12] Kabissa, J. C. B. 1990. Seasonal occurrence and damage by *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae) to cotton in eastern Tanzania. Tropical Pest Management, 36 (4): 356-358.

[13] Karsholt, O. and Razowski, J. 1996. The Lepidoptera of Europe: A distributional checklist. Stenstrup, Denmark: Apollo Books. 380 pp.

[14] Khanzada, M. S., Syed, T. S., Khanzada, S. R., Abro, G. H., Salman, M., Anwar, S., Sarwar, M., Perzada, A. A., Wang, S. and Abro, A. H. 2016. Occurrence and abundance of thrips, whitefly and their natural enemy, *Geocoris* spp. on cotton crop at various localities of Sindh, Pakistan. Journal of Entomology and Zoology Studies, 4 (1): 509-515.

[15] Khidr, A. A. Kostandy, S. N., Abbas, M. G., El-Kordy, M. W. and El-Gougary, O. A. 1990. Host plants, other than cotton, for the pink boll worm *Pectinophora gossypiella* and the spiny bollworm *Earias insulana*. Agricultural Research Review, 68 (1): 135-139.

[16] Lin, Y. 2000. Adaptation of transgenic strains of insect-resistant cotton to different ecological environments. Chinese Journal of Applied Ecology, 11: 246-248.

[17] Metcalf, R. L. and Metcalf, R. A. 1992. Destructive and useful insects. Their habits and control. McGraw-Hill Book Company (UK) Ltd. Ed. 5: 1104 pp.

[18] Michel, B. and Gomez, E. 1992. Diapause of *Pectinophora gossypiella* (Saunders) (Lep. Gelechiidae) in Paraguay. Coton et Fibres Tropicales, 47 (2): 95-100.

[19] Osman, A. A., Watson, T. F. and Sivasupramaniam, S. 1992. Inheritance of permethrin resistance in the pink bollworm (Lepidoptera: Gelechiidae). Journal of Economic Entomology, 85 (2): 335-339.

[20] Sarwar, M. 2013 a. Comparing abundance of predacious and phytophagous mites (Acarina) in conjunction with resistance identification between Bt and non-Bt cotton cultivars. African Entomology, 21 (1): 108-118.

[21] Sarwar, M. 2013 b. Management of Spider Mite *Tetranychus cinnabarinus* (Boisduval) (Tetranychidae) Infestation in Cotton by Releasing the Predatory Mite *Neoseiulus pseudolongispinosus* (Xin, Liang and Ke) (Phytoseiidae). Biological Control, 65 (1): 37-42.

[22] Sarwar, M. 2016. Bollworms *Earias vittella* (Fabricius) and *Earias insulana* (Lepidoptera: Noctuidae) Impairment in Cotton and Integrated Crop Management. Scholars Journal of Research in Agriculture and Biology, 1 (1): 1-7.

[23] Sarwar, M. 2017 a. Characteristics of Armyworm *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) Occurrence and Control on Cotton. Scholars Journal of Research in Agriculture and Biology, 2 (1): 33-38.

[24] Sarwar, M. 2017 b. Biological Parameters of Pink Bollworm *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae): A looming Threat for Cotton and its Eradication Opportunity. International Journal of Research in Agriculture and Forestry, 4 (7): 25-36.

[25] Sarwar, M. and Sattar, M. 2016. An Analysis of Comparative Efficacies of Various Insecticides on the Densities of Important Insect Pests and the Natural Enemies of Cotton, *Gossypium hirsutum* L. Pakistan Journal of Zoology, 48 (1): 131-136.

[26] Sarwar, M., Hamed, M., Yousaf, M. and Hussain, M. 2013. Identification of Resistance to Insect Pests Infestations in Cotton (*Gossypium hirsutum* L.) Varieties Evaluated in the Field Experiment. Journal of Scientific Research in Environmental Sciences, 1 (11): 317-323.

[27] Silvie, P. and Goze, E. 1991. Estimate of cotton production losses caused by pests in Chad. Coton et Fibres Tropicales, 46 (1): 15-32.

[28] Simmons, A. L. Dennehy, T. J., Tabashnik, B. E., Antilla, L., Bartlett, A., Gouge, D. and Staten, R. 1998. Evaluation of B. t. cotton deployment strategies and efficacy against pink bollworm in Arizona. 1998. Proceedings of Beltwide Cotton Conferences, San Diego, California, USA, 5-9 January 1998. 2: 1025-1030.

[29] Tamhankar, A. J., Rajendran, T. P. and Mamdapur, V. R. 2001. Evaluation of a pheromone trap for the cotton pink bollworm *Pectinophora gossypiella* Saunders. International Journal of Pest Management, 47 (1): 79-80.

[30] Walters, M., Staten, R. T. and Roberson, R. C. 1998. Pink bollworm integrated management technology under field trial conditions in the Imperial Valley, CA. 1998. Proceedings of Beltwide Cotton Conferences, San Diego, California, USA, 5-9 January 1998. 2: 1282-1285.