ISSN: 2456-6527

sjrabeditor@scischolars.com Online Publication Date: October 29, 2016 Volume 1, No. 1

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Scholars Journal of Research in Agriculture and Biology

www.scischolars.com

Bollworms Eariasvittella (Fabricius) and Eariasinsulana (Lepidoptera: Noctuidae) Impairment in Cotton and Integrated Crop Management

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Abstract

This article focuses on bollworms Eariasvittella (Fabricius) and Earias insulana Boisduval (Noctuidae: Lepidoptera), which are primarily insect pests of cotton and can make cultivation of crop nearly impossible in some years. Initially, the caterpillars tunnel into buds by destroying of vessels and growing points, and they cause adjacent blooms, young leaves and eventually whole shoots to turn blackish-brown and die off, which can result in bunched growth of young plants. Examination of the affected plant parts reveals a number of small holes either on or near to leaf, or flower buds. On cotton, the damaged flower buds sometimes spread their bracteoles prematurely (flared squares). When fruiting starts, the larvae turn towards the bolls, which as a result then become brown and fall off. Older bolls may stay on the plant, but are often so damaged that they cannot be harvested. Secondary invasion by fungi and bacteria sometimes occurs, and ultimately damage and excrement-filled tunnels in surviving fruit result in a low market price. Management of Eariasbollworms is becoming increasingly difficult due to the development of their resistance to many chemical insecticides. In view of these facts, it is needed to develop eco-friendly tactics such as Integrated Pest Management (IPM) program wherein all practicable tactics are implemented. Setting of light trap or pheromone traps at 12 per ha effective for 40-45 days can commendably monitor adult's activity.Pheromone trapping data on bollworms give early warning of the infestation and also exhibit the density of the insect population.Biological control and botanical pesticides are economical and safe to the environment. The egg parasitoid Trichogramma chilonisis the most widely exploited hymenopteran parasitoid by releasing at 1, 25,000 perha three times in crop is effectiveto control the bollworms. The infested fruits and shoots should be removed regularly and buried deep in the soil. Spraying with quinalphos 25 EC (2 ml per liter of water) or carbaryl (4 g perliter of water) can effectively control the pest. Before spraying all the affected plant parts should be removed.After harvest, cotton plants which can sprout from the stump should be uprooted and destroyed in order to eliminate the food source for Earias spp., and thereby to interrupt population build-up.

Keywords: Cotton; Spotted and Spiny Bollworms; Eariasvittella and Eariasinsulana; Crop Management.

Introduction

The genus Eariasis a group of moths in the family Noctuidae of order Lepidoptera,which are insect pests that can cause extensive damage to field crops. Species studied include Eariasbipalaga Walker, E. chlorana (L.), E. cupreoviridis Walker, E. fabia Stoll, E. huegeli Rogenhofer, E. insulana Boisduval, E. vernana (Hubner) and E. vittella Fab.The larvae live in the fruits of their hosts, mostly in species of malvaceous plants,but also on otherHibiscus plants. Host plants species affectedby Earias pests are Abelmoschus esculentus (okra), Abutilon (Indian mallow), Gossypium (cotton), Gossypium arboreum (tree cotton), Gossypium hirsutum (Bourbon cotton), Hibiscus (rose mallows) and Solanum lycopersicum (tomato). Cotton G.hirsutum is attacked by a number of insect pests during different growth stages. Among these insects, Eariasvittella (Fabricius) and Eariasinsulana Boisduval (Lepidoptera:Noctuidae) are the most important and damaging pests.Their larvae bore into the growing shoots during early vegetative growth stage and during reproductive stage these divert to floral buds and fruits (Herms, 1998).

The impact of E. vittella varies considerably, but it can be the most important species within a pest complex on cotton. Often the literature does not distinguish the losses due to E. vittella from those caused by other Earias species or an entire pest complex.The adults of E. insulana are small; fore wings with uniform silvery green colored, whereas E. vittella has buff colored forewing with a green band on the middle of the forewings. The E. vittella larvae are brownish with longitudinal white stripes on dorsal side having orange dots on prothorax without finger shaped process on the cream colored body. But, E. insulana has finger shaped process on at least two thoracic segments and all abdominal segments. The larval instars of these pests cause severe loss in cotton production by damaging the cotton bolls.The entrance holes in bolls are neatly rounded about 1 mm in diameter, and mostly filled with frass. On okra, the symptoms are very similar, severely-affected flower buds become shed, and the pods are tunneled into in the same way as the cotton bolls and sometimes also hollowed out. The tendency for secondary invasion by fungi and bacteria may conceal the infestation. The Earias spp., can transmit bacteria Xanthomonas malvacearum, causing bacterial blight of cotton (Nietschkeet al., 2007).

Spotted Bollworm Eariasvittella Fabricius

The adult E. vittella moths measure about 2.5 cm across the wings and forewing is 9 mm in length. Forewings are pale yellow-orange with a light green longitudinal streak extending from the base of the wing to the termen (band in the middle of forewing). The green wedge dividing the forewing longitudinally distinguishes this species from several yellow noctuids, however they lack the green longitudinal streak and overall yellow-orange hue. The hindwings are white with pale brown wing margins. The distinction between the male and female , is that the male is smaller than the female in the size and the latter has V shape pattern at the end of the anal part, but the male has thick hairsat the end of anal part. The female moth lays 200-400 eggs at night, singly on flower buds and tender leaves of plant. Females also lay eggs singly on the young shoot, leaf bracts and squares, which are crown shaped and sculptured. Eggs are spherical, single and light bluish green in color or of sky blue color with longitudinal ridges. The eggs hatch in 3-4 days and the caterpillar passes through 6 stages for becoming full-grown in 10-16 days.The full grown dull-green caterpillars are 2 cm long having tiny stout bristles and a series of longitudinal black spots on the body. Caterpillar is brownish white with number of brown and milky white markings. The larva is cylindrical, stout, and stands up on the prolegs and claspers which are all present, but weak. The hair tubercles of segments T2 and T3 and of A7-10 are more prominent than on the rest of the segments. There is a broad dorsal whitish yellow band from T3 to A8, very irregular, consisting of patches, spots and lines, while, T1 has a glossy blackish collar. Tubercles of T2 are all orange, but only the dorsal ones of T3 and none on the other segments. The setae are prominent, long and fine,body is shining, the orange as spiracular patches and the venter is greenish (Hassan and El-Khidir, 2005; Mapuranga et al., 2015).

Caterpillars pupate either on the plants or outside the infested fruit or on the ground in a boat shaped cocoon among the fallen leaves and moths emerge within 8-14 days. The pupa is stout, roundly conical at the posterior end without cremastral ornamentation and it can be also formed in a cocoon on a leaf. The cocoon is asemiovoid, slightly peaked dorsally above the vertical emergence slit anteriorly.Pupa is covered in a boat shaped tough silken cocoon attached to plant parts or on the fallen leaves or fruiting bodies. The pupal period lasts for 10-12 and the entire life cycle is completed in 17-29 days.The pre-oviposition, oviposition and post-oviposition durations are 1.8±0.78, 2.8±0.79 and 4.5±0.53 days, while the adult male and female longevities observed are about 4.2±0.79 and 9.5±1.08 days, respectively. The longest life cycle (49 days) occurs during January, while the shortest (29 days) happens during July (Sewak, 2016).

The caterpillars of this species are a pest on cotton (Gossypium species)and okra (A.esculentus), and also feed on various other plants in the family Malvaceae, including Rosella(Abelmoschus ficulneus). During the fruiting stage, larvae bore into fruits and feed by contaminating the fruit with excreta. The incidence of fruit borers usually occurs during humid conditions after the rainfall. The adult female lays eggs individually on leaves, floral buds and on tender fruits. Small brown caterpillars bore into the top tender shoots and tunnel downwards to the main axis which wither, droop down, and growing points are killed and later on they bore into the fruits and feed inside. Affected shoots wither, growing point is killed and side shoots may arise. Damaged buds and flowers fall while affected fruits are distorted and affected fruit is unfit for consumption. Affected fruit show entry hole plugged with excreta andbored fruits lose their market value. The damage caused to cotton by E. vittella third-instar larvae is found to harm bolls up to 6 weeks old. All those attacked when 1 week old are shed, those damaged when 2-4 weeks old are not shed, but 33-57% are so badly damaged that they are un-harvestable. Some 57-80% of the seed cotton in the harvested bolls is damaged and stained. When bolls are attacked once 1, 2, 3, 4 or 6 weeks old, the total reduction in the weight of seed cotton is calculated to be 100, 98.7, 82.2, 67.5 and 35.3%, respectively. When third-instar larvae attack 3-week-old bolls formed in the first week of August, the third week of August, the first week of September or the third week of September, the loss in seed-cotton yield is calculated to be 91.1, 88.5, 70.5 and 66.2%, respectively. In addition, lint in 79-97% of the loculiis stained as a result of the bollworms infestation (Ahmad and Sarwar, 2013).

Spiny Bollworm Earias Insulana (Boisduval)

The spiny bollworm is an oligophagous pest on Malvaceae, including cotton and okra (H.esculentus). The adult moth has an overall wingspan of about 20-22 mm, is covered with a soft, dense coating of scales and has a variable, mostly green or yellow-brown color. The forewings of the adult moth are yellow-green or sometimes brown, with a diagonal green stripe. Apparently these color morphs are seasonal, representing local adaptations to ambient heat, humidity and foliage density. The hindwings are dull white with a brown subterminal line. The 3-7 day-old female lays up to 200 eggs on host plants, preferably on young bolls, shoot tips and buds. Some days later, the larvae emerge and after wandering about on the plant, they bore into the soft terminal shoots. The fully-grown larva is 13-18 mm long, initially grey, later grey-blue with yellow spots, and its dorsum is with small tubercles bearing short hairs. The head is dark and shiny and the final length is 15-18 mm. The larvae of the first generation bore into terminal cotton buds, those of later generations into flower buds, flowers and newly-set bolls. Towards the end of their development, they often move from boll to boll, thus increasing the amount of damage. The five instars of the larval stage normally last for 8-25 days. For pupation, the larvae spin a white cocoon, which they attach to dry leaves on the food plant or to plant debris on the ground. The pupal stage normally lasts about 9-15 days, but it may extend up to two months if development is delayed by low temperature. During winter it lives on cultivated shrubs like China rose Hibiscus spp. But, being a specialist, the size of its populations is restricted by the availability of various Malvaceae, especially cotton. There is no true diapause and in some areas, the insects move between crops with different growing seasons (okra and cotton), so there is no interruption to their food supply, and populations can build up over a long period (Kandil-Mervat, 2013).

TheE.insulana is a major pest of cottonand the damage is caused by the larvae, which cause bud and flower withering. The pest prefers the developed cotton bolls, especially the nutritious seeds. Infestations of maturing bolls injury to the developing filaments, concurrently introduce bacterial and fungal agents. After depleting the initial boll, the larvae move to other cotton plants, penetrating new bolls and heavy attack may destroy the entire crop.The symptoms of attack are similar for all Earias species and are often described in general terms rather than for individual species in much of the literature.Cotton infestation generally starts with shoot boring in the young crop, caterpillars enter the terminal bud of the vegetative shoot and channels downward from the growing point, or directly penetrate the internode. Only soft growing tissue is attacked, while extensive tunnelingcan result in the wilting of the top leaves and the collapse of the apex of the main stem. The whole apex turns blackish-brown and is generally killed. The result is bunched growth in young plants and killing of the growing point in the mature plant. If only the apical bud is attacked, damage may not be noticed until the mainstem divides (twinning) as the axillary buds take over. The larvae usually bore deeply, filling the tunnel opening with excrement. The tunnel often enters bolls from below, entering at a slight angle to the peduncle. Small bolls up to 1 week old turn brown, rot and drop, whereas bigger bolls of 2-4 weeks may not drop, but open prematurely and may be so badly damaged as to be un-harvestable. Bolls of up to 6 weeks age are vulnerable and the larvae tend to move from boll to boll and damage may be disproportionate to their numbers (Arif and Attique, 1990; Ahmad et al., 2011).

Prevention and Control

Bollworms cause loss to the cotton fruit that are frequently more destructive than those insects which damage leaves, stems and roots. Integrated pest management (IPM) involves a number of pest management practices that are both location and crop specific. Finally, it focuses on long term prevention or suppression of pest problems through a combination of techniques (Sarwar, 2013 a).

Monitoring

Two techniques are used for capturing of the adult moth, sex pheromone traps and light traps in order to determine the best dates for chemical control.Pheromone traps use specific sex lures for each species viz., (10E 12E)-10, 12 Hexadecadienal for E. insulanaandZ11- Hexadecenal Z11 octodecenal (10:2:2) for E. vittella. The Delta trap is most sensitive device to use for monitoring of these insects. However, Moth catcher trap may be used in dusty condition or in high moth's population density. Do not re-use the trap to monitor different insects as this may lead to mixed catches. Trap density may be two traps per hectare for small holdings in field of uneven topography and one trap for every two hectares of large scale fields of homogenous lands. Trap position may be near the highest point of the plant using supporting posts approximately 1 meter high or higher if the crop is higher. Collect data weekly from the start of the flight of the over wintering generation. The trap catches are collected weekly from all pheromone and light traps, sorted out, identified and counted for both species. During the peak period of the population more frequent reading may be needed. Decisions on pesticide application should not be taken solely on the trap catch data, but climatic and biological considerations should also be taken in account. Lures can be changed every 4-6 weeks to get the most accurate results. Pheromone lures are very sensitive tool and they can be affected by

exposure to elevated heat and direct sunshine. Direct touching by hand may cause cross contamination leading to mixed catches in the trap. Some contaminants such as Nicotine may have repellent effect in reducing of trap catch. Subsequent synthetic formulations have shown promise in Pakistan for disrupting mating and achieving season-long control (Qureshi and Ahmed, 1991; Nakache et al., 1992; Shah et al., 2011).

Cultural Control and Sanitary Methods

Growers may burn or ploughof cotton fields to a depth of 30 cm or more, in order to destroy all residual material and any pests remaining thereon after harvest. Moth of E. vittella requires a food source throughout the year. This may be provided by crops interspersed with other suitable hosts. Long duration cultivars of cotton alternated with okra supply food to E. vittella throughout the year. Irrigated cotton in summer also supports the Earias population.If cotton plants are not removed after the harvest, they sprout from the stump. Lower pest incidence is found in fields where stumps are removed after harvest. It is also claimed good control of Earias by completely removing of cotton stumps and yield of raw cotton is increased with such a practice. Legislation in some countries requires farmers to uproot and destroy harvested plants, but this is apparently poorly enforced.Removal of possible alternative host plants is recommended and this is now thought to be of dubious benefit as many are useful to man and removal may reduce the pool of natural enemies.The cotton should be inspected regularly and all wilted shoots removed, thus removing larvae. Some farmers allow livestock to graze cotton during the vegetative stage with much the same effect. The benefits of such 'topping' are apparently controversial, but inter-growing of cotton with crops such as rice and groundnuts helps to reduce damage.The timing of sowing may also help to reduce infestation. Ii is found that earlier sowings are beneficial, but this is observed that when two sowings of cotton are made per year instead of one, E. vittella increased to become the most dominant bollworm. Reduced damage by Earias spp., is observed when the crop is more closely spaced and after deep ploughing. It is found that with chemical control the increased yields of cotton after application of nitrogen fertilizers outweighed the disadvantages, but potassium uptake is negatively correlated with infestation (Pedigo, 2002; Sarwar et al., 2013; Khanzada et al., 2016).

Host-Plant Resistance

Considerable resistance to Eariasbollworms has been recorded in several wild species of Gossypium, butG. hirsutum has been reported to be more susceptible than either G. barbadense orG. aboreum. Numerous trials have tested the resistance of various cultivars and reduced susceptibility has been found in many of them. Those with high levels of tannin and gossypol, frego-bract and okra-leaf characters, and red pigmentation have been found to be less susceptible than many commercial cultivars. Hirsute varieties and glandless varieties have been found to be more susceptible. Tall plants having bigger top leaves and bolls in clusters have carried more bollworm attack. Conversely, dwarf varieties with early flowering habit have been found to escape the damage of spotted bollworm.Thirteen of the most common lepidopteran-specific Cry proteins of Bacillus thuringiensis(Berliner)have been tested for their efficacy against newly hatched larvae of two populations of the spiny bollworm E.insulana. At a concentration of 100 µg of toxin per milliliter of artificial diet, six Cry toxins (Cry1Ca, Cry1Ea, Cry1Fa, Cry1Ja, Cry2Aa, and Cry2Ab) are not toxic at all. Cry1Aa, Cry1Ja, and Cry2Aa do not cause mortality, but caused significant inhibition of growth. The other Cry toxins (Cry1Ab, Cry1Ac, Cry1Ba, Cry1Da, Cry1Ia, and Cry9Ca) are toxic to E. insulana larvae. The 50% lethal concentration values of these toxins ranged from 0.39 to 21.13 µg/ml (for Cry9Ca and Cry1Ia, respectively) for an E. insulana laboratory colony and from 0.20 to 4.25 µg/ml (for Cry9Ca and Cry1Da, respectively) for another laboratory colony. All Bt cotton hybrids recorded significantly reduced damage of Eariasspp., in shoots, squares, green bolls and freshly shed fruiting bodies as compared to the isogenic non-Bt genotypes (Ibargutxi et al., 2006; Dahi, 2012; Sarwar, 2013 b).

Biological Control

Maximum parasitism byparasitoids, predators and pathogens attacking Earias spp., naturally throughout their distribution range has been observed. Egg attacking parasitoids are Trichogrammatoidea spp., Trichogramma achaeae and T.chilonis; larval parasitoids Bracongreeni, Rogas sp., Elasmus johnstoni; and pupal parasitoid Brachymeria nephantidis. Other parasitoids reported include egg-attacking Chelonus heliopae, larva-attacking Rogas kampurensis, and Strobliomyianana, Actia aegyptia, Bracon brevicornis, Centrochalcis sp., Chelonusrufus, Rogastestaceus, Phanerotoma hendecasisella, and pupa-attacking Goryphusnursei, Brachymeria tachardiaeand B.responsator.In Pakistan, the pupal parasitoid Brachymeria bicolorata and the larval parasitoids Elasmus orientalis and E. dorsalisare are known. The parasitoids Apanteles diparopsidis, Agathis aciculata, Rogas sp., Netelia sp., and Trichogramma sp., have been reared on Earias. The Brachymeria obscurataishas been reared from Earias pupae. Parasitoid Bracon brevicornis is highly active, while Bracon lefroyiis most active. Predators Coccinellidae are the more important huntersin the earlycotton season (June-July), whereas, Hemipteran predators occur in large numbers during August and September. Important predators include Brumoides suturalis, Geocoris

sp., Cartheconidea furcellata), Eumenes petiolata, Menochilus sexmaculatus and Phanerotoma hendecasisella. Field releases of Chelonus blackburni and Rhogaslefroyiare found to reduce the pest population (Stam and Elmosa, 1990; Sarwar and Sattar, 2016). Fungi attacking Earias spp.,naturally are Fusarium moniliformae var. subglutinams, Serratia marcescens and Bacillus cereus. A laboratory strain of Beauveria bassianasensulato (Balsamo) Vuillemin (Hypocreales: Clavicipitaceae) and commercial formulation of B. thuringiensishave been assessed against three field populations of E. vittella in the laboratory. Three dose rates of B. bassiana (1.5×106, 1.5×107 and 1.5×108 conidia ml^{-1}) andone of B. thuringiensis(0.5 µg g^{-1}) are applied alone and in combination against 2^{nd} and 4^{th} larval instars, and the mortality isobserved until pupation. The highest larval mortality is observed with lowest pupation rate, adult emergence and egg eclosion treated with combined concentrationsof B. bassiana and B. thuringiensis. Overall results demonstrate that all the treatments gave significant control of E. vittellaand both microbialagents may become the integral part of the successful IPM program of E. vittella (Sarwar, 2013 c; Ali et al., 2015).

Chemical Control

The studies carried out determine the efficacy of different insecticides viz., dimethoate, profenofos, lamb-dacyhalothrin, monocrotophos, indoxacarb, endosulfan, chlorpyriphos andmultineem against the spotted bollworm E.vittella.All the insecticides provedsignificantly effective in controlling of E. vittella infestation andthe seed yield among treatments differed significantly (Navon et al., 1997; Hasan, 2010).

Conclusion

Cotton is attacked by severalinsect pests, spotted bollworms E.insulana and E.vittellaare major pests of cotton, among which shoot and fruit borer E.vittella is most serious as it takes upper hand by causingdirect damage to tender fruits. The larvae feed on and damage to growing vegetative parts, developing seed in the cotton bolls,shoots of the main axes, succulent internodes, tops of side branches, young leaves and flower buds.Adult moth ofE.vittellahas buff colored forewings with a green wedge down the forewing.InE.insulanamoth, the forewings are uniformly silvery green and the hind wings and body are silvery white. Theirlarvae are about 2 cm long with the color of larva of E.insulana ranges from light grey to grey, while the color of E.vittellalarva is brown having a dorsal milky streak. Both species have the same pupal obtect shape and the coloris either white or light brown. Their caterpillars enter young shoots before the flower bud formation.After the square and boll formation, the infestation is also noticed on these parts.Damage symptoms are drying and drooping of terminal shoots,and during pre-flowering stage, side shoots are given out.Shedding of squares, young bolls and flaring up of squares is common during square formation. Entrance hole on boll is plugged with excreta and affected bolls drop off in early stage and bad boll opening is seen.The use of chemical pesticides has adverse consequences such as development of resistance, resurgence, outbreak of secondary pests, toxicity to non-target fauna, disturbance in the natural balance between pests and natural enemies' populations, and environmental pollution. Moreover, the widespread development of these pest problems is one of the most serious indictments of our present day pest control technology. In view of the above facts, it is visualized a need to develop eco-friendly approaches i.e., Integrated Pest Management program, wherein all available practicable, economical and compatible techniques of pest control are implemented systemically in a single unified program that cause minimum or no adverse effect on environment including non-target fauna and flora.

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- Awarded Gold Medal-2010 by Zoological Society of Pakistan (International) in recognition of research contributions in the field of Insect Science.
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