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Characteristics of Armyworm *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) Occurrence and Control on Cotton

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Abstract

In this paper, is examined the incidence of armyworm *Spodoptera litura* (Fabricius)(Lepidoptera: Noctuidae), which is a highly polyphagous pest and inflicts serious damage to a wide spectrum of crops. The ability of *S. litura*to thrive on diverse host plants is an adaptive advantage for its survival in the ecosystem, which is achieved by its high mobility, fecundity and capacity to develop resistance to wide spectrum of chemical insecticides. Hosts of *S. litura* include field crops grown for food and fiber, plantation and forestry crops, as well as certain weed species.On most crops, damage arises from extensive feeding by larvae, leading to complete stripping of the plants. On cotton, the leaves are heavily attacked, bolls have large holes in them from which yellowish-green to dark-green larval excrement protrudes and yield of the crop is severely affected. Freshly hatched *S. litura* scrape the leaves from ventral surface, and full grown larvae feed on the leaves voraciously and present an appearance to the field as if grazed by livestock.Marigold is identified as suitable intercrop/border crop for pest management apart from harboring activity of major parasitoids of *S. litura* such as Microplitis sp., Cotesiasp., Campoletischlorideae and a polyembryonic parasitoid Copidosoma sp. Also grow castor as a border or intercrop or trap crop and set up pheromone trap to monitor, attract and kill the male moths @ 12/ha.Collect egg masses and destroy, also collect the gregarious larvae as well and destroy them as soon as the early symptoms of lace-like leaves appear on crop. Avoid migration of larvae by digging a trench 30 cm deep and 25 cm wide with perpendicular sides around the infested fields.Use of synthetic pyrethroids and endosulfan alternatively is effective against *S. litura* at 10% visual damage threshold and for managing 1st to 3rd instars larvae spray Emamectin benzoate 5 SG @ 11gma.i./ha or Spinosad 45 SC @ 75gm. For control of the 4th to 6th instars larvae, use Indoxacarb 14.5 SC @ 75gm ha^{-1},Flubendiamide 480SC @ 48-60gma.i. ha^{-1} or Chlorantraniliprole 20 SC @30-40gm a.i. ha^{-1}. It is concluded that a combination of biological control agents, insect growth regulators, antifeedants, a trap crop and insecticides is an ecologically sound procedure for the control of *S. litura*.

Keywords: Armyworm; Caterpillar; Feeding damage; Spodoptera; Cotton.

Introduction

Armyworm *Spodoptera litura*, is a noctuid moth which is considered an important agricultural pest. It is also known as the cluster caterpillar, cotton leaf worm, tobacco cutworm, tropical armyworm and cotton worm. Moth is with grey-brown body, 15-20 mm long and wingspan 30-38 mm. The *S. litura* forewings are grey to reddish-brown with a strongly variegated pattern and paler lines along the veins.Adult moth is stout with wavy white markings on the brown forewings and white hind wings with a brown patch along its margin and lighter shaded lines and stripes. Hind wings are whitish with violet sheen, margin dark brown and venation brown. Thorax and abdomen orange to light brown with hair-like tufts on dorsal surface. Head clothed with tufts of light and dark brown scales. Females mate three or four times during their lifetime, while males mate up to 10 times.Two to five days after emergence, female moths lay 50 to 300 eggs in masses on the lower surface of leaves (preferred) or on the upper surface of the leaves. A single female can lay a total of 1,500 to 2,500 eggs in about six to eight days and the eggs hatch in three to four days. Castor bean is the most preferred host for ovipositing females and freshly irrigated fields are also very attractive to ovipositing females. Three peak periods of egg laying have been observed in the third weeks of June, July and in mid-August. The *S. litura* egg masses measure 4-7 mm in diameter in 3 to 4 clusters each of 80-150 eggs and appear golden brown because they are covered with body scales of females. Eggs are laid in groups usually

on ventral side of the tender leaves and covered with brown hair. The spherical egg are somewhat flattened, sculpted with approximately 40 longitudinal ribs, 0.4 to 0.7 mm in diameter, pearly green, turning black with time and laid with pale orange-brown or pink hair-like scales from the females body. The *S. Litura* adults are developed from first instar larvae in 23.4 days at 28°C (82°F). Mean female longevity is 8.3 days and mean fecundity varies from 2000 to 2600 eggs, and oviposition days vary from 6 to 8 days, while mean male longevity is 10.4 days. Male and female moths do not mate on the night of emergence, but maximum mating response occurs on the second night after emergence (Bae, 1999).

The *S. litura*larva is stout, cylindrical, pale brownish with dark markings or variable in color (young larvae light green, the later instars dark green to brown), hairless and sides of body with dark and light longitudinal bands. They are usually dull green but color can vary from pale to dark green with wavy, light-colored stripes running down the back and a broader pale stripe along each side. They usually have a dark spot on each side of the body above the second pair of true legs. Larval instars can be distinguished on the basis of head capsule width, ranging from 2.7 to 25 mm. Body length ranges from 2.3 to 32 mm and the body may have row of dark spots or transverse and longitudinal grey and yellow bands. When fully grown, measures about 35-40 mm in length. Newly hatched larvae are tiny, blackish green with a distinct black band on the first abdominal segment. Fully grown larvae are stout and smooth with scattered short setae. Head is shiny black, and conspicuous black tubercles each with a long hair on each segment. Color of fully grown larvae not constant, but varies from dark gray to dark brown, or black, sometimes marked with yellow dorsal and lateral stripes of unequal width. The lateral yellow stripe is bordered dorsally with series of semilunar black marks. The *S. litura* larvae generally pass through six instars and first to third instars generally remain on the underside surface of leaves. The fourth to sixth instars drop onto the ground, root around to loosen the surface of the soil and bite out soil particles to form a clay cell or cocoon in which to pupate. The final instars weigh up to 800 mg and larval period is 14-21 days. Groups of freshly hatched larvae feed on the epidermis of the leaf. If the population density is high or the host is not suitable, the young larvae can hang on silken threads and migrate to other leaves or preferred hosts (Selvaraj et al., 2010).

The pupa is 15-20 mm long, red-brown and tip of abdomen with two small spines.It pupates in rough earthen cells in soil for 15 days and last abdominal segment terminates in two hooks. The pre-pupal and pupal period of *S. litura* is spent in earthen cells or cocoons in the soil and lasts about 11 to 13 days at 25°C (77°F). The pupation is found maximal under fallen leaves, especially in wet sandy loam soil. Although the depth of pupation varies, no pupation is observed beyond 12 cm deep, but most larvae pupate at a 4 cm depth across soil types.Life cycle is completed in 30-40 days and *S. litura* completes 12 generations in a year each lasting slightly more than a month in winter and less than a month in the hot season (Bae et al., 1999).

Freshly hatched caterpillars feed gregariously, By scrapping the leaves from ventral surface. Greenish caterpillars feed on the leaves voraciously and present an appearance to the field as if grazed by cattle.Since this pest is nocturnal in habit it hides under the plants, cracks and crevices of soil and debris during the day time. Faecal pellets are seen on the leaves and on the ground which is the indicator of the pest incidence. On most crops, damage arises from extensive feeding by larvae, leading to complete stripping of the plants. Larvae are leaf eaters, but sometimes act as a cutworm with crop seedlings. If heavy feeding on a young plant occurs, it may lead to stunted development and fruit may be small or late to develop.On cotton, the pest may cause considerable damage by feeding on leaves and bolls, and damage is mainly to foliage, however, fruit can also be damaged. Leaves are heavily damaged and bolls have large holes and yellowish-green to dark green larval excrement may surround bore holes in bolls. A major constraint in cotton production is the damage caused by large number of insect pests, notably the *S. litura*. The pests cause direct marketable loss up to several percent cotton field. In this study, therefore is presented diversity and life stages for identification of the target species *S. litura*, its mode of damage and control in cotton (Chen et al., 1999).

Pest Importance

Armyworm *S. litura* is an extremely serious pest, the larvae of which can defoliate many economically important crops. This is a subtropical insect pest that is found largely and damages broad leaf plants like leguminous, cruciferous and other economically important crops. As the number of equipped greenhouse increases, it is found throughout the year and sometimes occurs in very large numbers under certain environmental conditions.The moths have a flight range of 1.5 km during a period of 4 h overnight, thus facilitating dispersion and oviposition on different hosts.Larvae of 4-5th instars have high tolerance to chemical pesticides. On most crops, damage arises from extensive feeding by larvae, leading to complete stripping of the plants. Larvae are leaf eaters, but sometimes act as a cutworm with crop seedlings. If heavy feeding on a young plant occurs, it may lead to stunted development and fruit may be small or late to develop. *S. litura* feeds on the underside of leaves causing feeding scars and skeletonization of leaves. Early larval stages remain together radiating out from the egg mass. However, later stages are solitary. Initially there are numerous small feeding points, which eventually spread

over the entire leaf. Because of this pest's feeding activities, holes and bare sections are later found on leaves, young stalks, bolls, and buds. Larvae mine into young shoots and in certain cases, whole shoot tips wilt above a hole and eventually die. Peak activity occurs in July and September and high concentrations of polyphenols in young leaves may reduce their attractiveness to *S. litura* larvae. Study has revealed the ecological factors on the incidence and development of *S. litura* on cotton. There is found a positive correlation with relative humidity, sunshine hours and dewfall, but a negative correlation with wind velocity. Determination of the effects of different weather factors on the population and incidence of *S. litura* in cotton is essential for effective pest management (Kim et al., 1998; Sarwar and Sattar, 2016).

Usually, armyworm destroys seedlings, terminals of young plants and squares and small bolls during early July. Early season infestations may develop on weeds and move to cotton when weeds are controlled, destroying seedling cotton or the terminals of older plants. As cotton plants grow, young larvae skeletonize leaves and bracts, often spinning loose webbing over the feeding site. Older larvae chew irregular holes in leaves and also feed on squares, flowers, and bolls. Square damage by the armyworm differs from bollworm damage in that the surrounding bracts and foliage are often damaged by the armyworm, but not by bollworm. The loss of a majority of squares and bolls during July or August may reduce yield or delay maturity by delaying fruit set. Severe defoliation may cause crop loss as well (Roychoudhury et al., 1995; 1997).

Control of *Spodoptera litura*

There is no set treatment threshold for armyworm (normally 8 egg masses/ 100 meter), it is up to the growers, based on past history and overall crop conditions, to determine if armyworm is causing significant economic losses to justify a treatment. When taking samples for armyworm egg masses, note the egg masses covered with grayish white, hairlike scales and are laid on upper leaf surfaces in the upper plant canopy, but below the terminal area. Also watch for clusters of small, greenish caterpillars that feed in groups in leaf folds that are webbed together (Ahmad and Sarwar, 2013).

Integrated Pest Management

In recent years, due to crop failures experienced despite the use of several combinations of chemicals, an integrated approach based on cultural and biocontrol with efficient monitoring using pheromones has been developed. The IPM technology that has been developed and implemented in irrigated areas where *S. litura* is endemic has the key components including clean cultivation to expose pupae to natural enemies and weather-related factors, practicing of castor plants (that attract Spodoptera) to be sown as trap crops both around and within fields, pheromone traps to predict Spodoptera egg laying,as well as mechanical collection of egg masses and larvae from trap plants on alternate days following the 'warning' from the pheromone traps.Application of neem kernel extract during the early stages of crop growth if necessary and application of nuclear polyhedrosis virus at 500 larval equivalents per hectare in the evening if needed can give significant reductions on the populations of *S. litura* with no adverse effects against its natural enemies (Zhou, 2009, Ahmad et al., 2011; Sarwar, 2013).

Monitoring

At present, pheromone technology has given high priority in pest monitoring for timing of plant protection measures within IPM programs. The studies have clearly indicated the migratory behavior of the *S. litura* in different areas. Developments in pheromone technology have made it possible to monitor *S. litura* in the field to improve inskill of plant protection actions. Due to monitoring the population of moths by the adoption of sex pheromone trapping, spraying times and costs of chemical pesticides against *S. litura* are significantly reduced. Population projections based on life tables and stage-specific consumption rates can reveal the stage structure and damage potential of the pest population of the moths. It is already established that minimum temperature is the predominant factor that influences pheromone traps whereas wind velocity is predominant in light traps. The overall influence of all the weather factors is high in case of pheromone traps compared to light traps. The identification of a male sex pheromone of *S. litura*, (ZE) 9,11-tetradecadienyl acetate and (ZE) 9,12-tetradecadienyl acetate has enabled effective monitoring of this species. Monitor the emergence of adult moths by setting up of light traps. Usually, set up pheromone trap (Spherodin SL) to monitor, attract and kill the male moths @ 12/ ha and change the septa once in 3 weeks(Song et al., 2001).

Host-Plant Resistance

The development of host plant resistance to *S. litura* in suitable cotton varieties has been regarded as a high priority without protecting it with insecticides.Amin et al., (2011) investigated the morphological and biochemical characteristics of three varieties of cotton and observed their effects on feeding and growth of *S. litura*. This suggests that the resistance factor which influences the neonates is associated with the leaf surface, because their feeding activity is restricted to scraping the leaf surface. The antixenosis is likely to increase the first-instar mortality that is characteristic of r-strategist noctuids and can therefore contribute to the determination of the level of damage caused by the older larvae among which mortality is

comparatively low. Bioassays carried out with larvae as preliminaries to detect the mechanism of resistance reveals no antibiosis effects on second to sixth-instar larvae when fed to mature leaves. The main mechanism of resistance is currently thought to be tolerance, which is manifested as the enhanced ability of vegetative tissue to regrow following defoliation (Xue et al., 2010; Sarwar et al., 2013).

Biological Control Using Natural Enemies

During the past the mass releases of egg and larval parasitoids for the control of *S. litura* in different crops in different geographical regions have achieved only partial success, In view of the development of insecticidal resistance and the destruction of the natural enemies, and the polyphagous nature of this species, there is a need to give more consideration to the role of natural enemies as a component of integrated approaches to manage *S. litura*. The *S. litura* is known to be attacked by several species of natural enemies at various life stages. Altogether, a total of 10 egg parasitoids reported from different parts of the world including four species of trichogrammatids, one scelionid and one braconid as egg parasitoids of *S. litura*, and Chelonus and species of Telenomus have also been reported as both egg and larval parasitoids. Among the trichogrammatids, *T. Chilonis* and *T. Dendrolimi* are the most common. Generally, the larval stage of *S. litura* is more prone to parasitism and fifty-eight parasitoid species have been reported to attack the larval stage of this species. Of these are Hymenoptera and Diptera like braconids, ichneumonids, tachinids (Peribaeaorbata), eulophids, chalcids (Chelonus formosanus), scelionids, encrytids, muscids, *Zelechloroph thalma* and *Campoletes chlorideae*. In general, among these, Apanteles (A. *Chelonus formosanus* and *A. prodeniae*) and species of Bracon (Enicospilus sp. and Echthromorpha sp.) are the most commonly reported. Eight parasitoid species have been reported from the pupal stage of *S. litura*, one of which is a larval-pupal parasitoid (Ichneumon sp.,) and one asprepupal parasitoid (species of Chelonus). Mass releases of *Telenomus remus* usually five weekly releases of 50,000 parasites per 0.2 ha results in parasitism. Altogether 36 predatory insects from 14 families and 12 species of spiders representing six families are reported to feed on *S. litura* eggs, larvae and pupae in different parts of the world. Of the total predators reported to feed on *S. litura*, the insect predatory and the spiders fauna are common (Rao et al., 1993; Khanzada et al., 2016)).

Protozoa Nosema carpocapsae is found to infect the larval stage of this species *S. litura*. So far, four fungi *Aspergillus flavus*, *Beauveria bassiana*, *Nomuraea rileyi* and *Metarhizium anisopliae* have been reported to infect *S. litura* and cause physiological disorders in larval growth and development.Among the viruses, nuclear polyhedrosis viruses and granulosis virus are the most common and potent on eggs and larvae. The *Bacillus thuringiensis*is found to be an effective microbial insecticide against *S. litura* larvae, and efficiency of *B. thuringiensis*is enhanced significantly though protoplast fusion with a strain of *Bacillus subtilis*. Studies have been undertaken to evaluate the bioefficacy of *B.bassiana* against third-instar larvae of *S. litura*, which are identified, isolated and maintained from field-collected cadavers of lepidopteran larvae. Trials with a nuclear polyhedrosis virus against *S. litura* damage found two sprays of virus suspension gave effective control similar to chemical insecticides tested.Four nematode species have been reported parasitizing to *S. litura* larvaeby the mermithid nematodes Ovomermisalbicans, Hexamermis sp., Pentatomermis sp., and Steinernema sp. The efficacies of several entomopathogenic nematodes of Steinernema and Heterorhabditis spp.,are examined against tobacco cutworm *S. litura*. The *H. bacteriophora* showed 100% mortality after 20 h against 2nd instar. Inthe case of 3-4thinstare, S. carpocapsae, *H. bacteriophora* and *S. monticola* showed 100% mortality after 47 h. In the case of 5-6thinstare, S. Carpocapsae proved more effectivethan the others. Generally, the number of nematodes harvested increased as their size decreased. Also, the highest number of nematodes are obtained in the 5-6th instar of *S. litura* by *H. Bacteriophora*, showing about 1.3×106 nematodes per larva. In vitrocultured *S. Carpocapsae* showed 100% mortality after 73 h against 5-6th instars tobacco cutworm, indicating that nematodes produced in vitrocan be potentially used for the biological control of *S.litura* instead of nematodes in vivo (Oikawa et al., 1999; Parket al., 2010).

Chemical Control

At one time, the control of arthropods depended mostly on inexpensive and efficient insecticides. But, in recent years populations of many pests including *S. litura* have developed resistance to many commercially available pesticides like cypermethrin, fenvalerate andquinalphos. The control of *S. litura* is therefore becoming increasingly difficult and it is vital that all biological alternatives to insecticides need to be given greater priority, both in research and application.New insecticides have been tested to deal with resistant strains of this moth and some promising results are coming forward. Some new molecules such as chlorantraniliprole, spinosad, flubendiamide, chlorfenapyr, emamectin benzoate,indoxacarb, methoxyfenozide, diflubenzuron, novaluron, bifenthrin, esfenvalerate, methomyl, chlorpyrifos and chlorantraniliprole have shown promising results against *S. litura*, and gave the highest cost: benefit ratio among pesticides tested.The effects of methoxyfenozide with its sterilizing properties, if used strategically on *S. litura*, might induce changes in the population

dynamics of this pest to be considered as a potent insecticidal compound for its controlling (Venkateswarlu et al., 2005; Shahout et al., 2011).

Plant oils and insecticides mixtures (synthetic pyrethroids) can give a higher mortality rate on 8-day-old larvae of *S. litura* than the synthetic pyrethroids alone. Neem oil microemulsion proved significantly superior tomacroemulsion. Studies on different bio-pesticides against *S. litura* showed that flavonoids could be used as an alternative to chemical pesticides in the plant ecosystem and as a component in organic pest management.For managing of insecticide resistance in armyworm, limit the total number of sprays of each insecticide. The best way to do this is to practice the basic principles of IPM, rotate chemicals with a different modeof action, and do not use products with the same mode of action more than twice per season to help in preventing the development of resistance (Suganthy and Sakthivel, 2013; Naeem et al., 2014).

Conclusion

Pest *Spodoptera litura* F., adversely affects a wide host range such as important cotton crop by feeding on various parts of the plant. Host selection may be associated with the presence of secondary metabolites found in these plants, but they also display variation in nutritional value for the insect. Adult armyworms are mottled gray and brown moths known by a number of different names like cotton, leafworm, tobacco cutworm, tomato caterpillar, as well as others. Eggs are laid in clusters and these clusters are covered with dirty white, hair like scales, forming a cottony covering. The larvae usually have a dark spot on each side of the body above the second pair of true legs. The pupa is the overwintering stage, but all stages may be present throughout the year and there are three to five generations in a year. Damage is primarily due to defoliation by the caterpillar, but cutworm-like damage also occurs on seedlings. The species feed on the undersides of leaves causing feeding scars and skeletonization of leaves. Larvae also mine into young shoots causing the tips to wilt. Monitor the insect by pheromone traps to detect presence of this pest and maximize the use of biological and cultural controls. Microbial control of the worm using *S. litura* nuclear polyhedrosis virus has been also reported. Spray the crop only when pest numbers warrant an application and use the most selective insecticides first to conserve natural enemy populations so they can help with the control of pests.Do not use insecticides with the same mode of action on successive armyworm generations to reduce economic damage.

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