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SALIENT FEATURES AND BIBLIOGRAPHY OF BIHAR HAIRY CATERPILLAR, *SPILOSOMA OBLIQUA* WLK. (LEPIDOPTERA : ARCTIIDAE)

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An attempt has been made on the salient features of Bihar hairy caterpillar, *Spilosoma obliqua* Wlk., a serious pest of agricultural importance; incorporating important aspects like distribution, biology, morphology, artificial diet, bioenergetics, insect pest and host specificity, various systems and pest management strategies. The scattered information available in literature on the pest were also compiled and presented in the form of a bibliography.

Bihar hairy caterpillar, *Spilosoma obliqua* Wlk. is an important pest of great economic value. Since it is a foliage feeder polyphagous pest, abundantly found in fields almost through out the year and also easy to rear under laboratory conditions, suitably received a favour of the scientists to serve as a test insect for various biological and toxicological studies. As such a lot of work has been done on this pest and subsequently it has succeeded to find a place in most of the leading journals world over. Since the review of literature is prerequisite to plan and undertake meaningful studies and to formulate proper pest management strategies, it becomes difficult to the workers to assess the scattered information. The present attempt has therefore, been made on the salient features of *S. obliqua* coupled with exhaustive bibliography comprising various important aspects like rearing, biology, food plants, distribution, morphology, histology, physiology, ecology, damage and loss to crops, natural enemies, antifeedants and pest management. Thus it is hoped that this will not only benefit the students in general, but will also prove a handy tool to the research scholars to plan and undertake their research projects in a right way and also to the scientists working on identical fields.

- **Salient features**

Spilosoma obliqua Wlk. also described under the genus *Diacrisia* and *Spilarctia* belongs to order Lepidoptera, suborder Ditrysia, superfamily Noctuoidea and family Arctiidae. It is widely distributed in Oriental India, Bangladesh and Pakistan and also reported from Argentina, China, Germany, Japan, Nepal, Netherlands, Nigeria, Russia, United Kingdom and U.S.A. It is represented by 19 species namely *casignata, congrua, imparilis, inaequalis, investigatorum, lubricipeda, luteum, maculatus, maculosa, menthastri, obliqua, rattrayi, rhodophila, sannio, seriatopunctata, subcarnea, utricae, virginia and virginica* worldwide.

Bihar hairy caterpillar, *S. obliqua* commonly known as the tufted caterpillar is a sporadic polyphagous pest of great economic significance causing heavy losses to several cultivated and ornamental plants, which include cereals, pulses, oilseeds, vegetables, spices, fodders, orchards, fiber crops, timber plants etc. The farming community is very much familiar with this pest under the name '*kamla*' or '*balon wali sundi*'. It has been reported by Mathur (1962) feeding on 15 species of medicinal plants and as much as on 96 host plants belonging to 34 different families by Singh (1992a). According to Deshmukh *et al.* (1977b & 1979) out of 154 plant species, 75 herbaceous plants were of wide acceptance. Recently Singh & Varatharajan (1999) have provided a list of 126 host plants of the pest.

The seasonal incidence of the pest is observed from mid-July in *kharif,* which goes to severe infestation in October to mid-November in *rabi.* The detailed biology of the pest has been studied on a number of host plants and environmental regimes (Djou, 1938; Kabir & Khan, 1969; Kabir, 1971; Singh & Gangrade, 1974a & 1974b; Rizzo, 1979; Banerjee & Haque, 1983; Ali *et al.*, 1988; Paul *et al.*, 1990; Singh & Singh, 1995a). In addition to the biology Chaudhary & Bhattacharya (1986) and Ren (1987) made attempt to study the bioecology and loss of chlorophyll, respectively. Nagia *et al.* (1991) reported the population multiplication potential of the pest reared on three host plants.. Bhattacharya *et al.* (1995a) while writing a review on the economic importance, host range and breeding resistance also included the biology. A brief account of biology of the pest is presented herein.

The eggs of *S. obliqua* are indehiscent, bright greenish in colour at the time of oviposition. Later they change to pale yellow and finally turn greyish in colour a day before hatching. The chorion is dorsally thick whereas flat and slightly depressed ventrally. A mucilagenous substance at the time of deposition of eggs adhere them each other and with the substratum on which they are being deposited. No solitary eggs are observed. The eggs are spherical in shape, measuring about 0.77 ± 0.09 mm in diameter. The head of the neonate was visible through chorion, which cuts open the chorion and wriggles out slowly making a round hole, but with distinct micropyle (Goel, 2001).

The pest usually completes its development by passing through 5 to 6 instars under normal conditions but it may undergo up to 8 instars during adverse conditions as reported by Dahale *et al.* (1988) on groundnut. The larval period 23 to 27 days in summers may extend up to 38 days during winters. With each moult, the caterpillars became, restive and stopped feeding. From 8 to 12 hr after 1st moult, the larvae rapidly dispersed in search of food, and with the passage of time, their feeding activity increased considerably. They ate away the leaves in small patches, leaving mere network of veins. The older larvae ate up the entire leafy tissue in contrast, causing severe defoliation. In case of sunflower it has been recorded that consumption of foliage quantitatively increased dawn to dusk (Goel *et al.*, 1986) and average total leaf area consumed by a larva in its whole life span amounted to be 234.50 ± 20.92 cm^2 (Singh & Singh, 1993a). Sharma & Tara (1988) also reported that an individual larva consumed a maximum 1195.186 mg of mulberry food (25-40% leaf area) in about 34 days. It has been established that the decrease in minimum temperature increases the possibility of survival of life stages. The statistical test further shows that values of multiple correlation (R) revealing that the effect of the maximum temperature, minimum temperature and relative humidity are significant on the survival of the caterpillars. In a biological study the climatic factors thus play a vital role in the growth and development of the caterpillars. The metrical analysis on progression factor, subsequently, characterised the growth index by 1.71.

The presence of an inverted Y-shaped epicranial suture, a hypostomal bridge and relatively large occipital foramen has been the characteristics of *S. obliqua.* The sensory receptors on antenna, maxilla and labium responded to gustatory and olfactory stimuli that are produced by host plant. It is reported that apical sensillae have multiple innervations to respond for gustatory, mechanical and olfactory stimuli. The detailed morphology of larva of *S. obliqua* has been described by Ahmad & Ahmed (1977), Goel & Kumar (1981 & 1983a), Kumar (1983c) and Goel (2001). Internal morphology of mature larva has also been studied (Sarkar, 1973).

The last instar larvae stopped feeding before entering the prepupal stage and started raising their head, became sluggish, having started spinning loose cocoon mixed with setae from their body. The prepupae were dull, constricted larvae without long setae, dorsolaterally yellowish and blackish ventrally. The prepupal stage lasted for 4 to 5 days. The pupae had been cylindrical, adectius, obtect type and usually spindle-shaped, and consisting of head, thorax and abdomen. The male pupae lighter in weight measured 17.00 ± 0.46 mm in length and 5.50 ± 0.22 mm in width whereas heavier female pupae measured 21.60 ± 0.60 mm in length and 6.50 ± 0.22 mm in width. The absence of scars of verrucae and prolegs, the number and arrangement of the cremastral setae and the irregularly arranged setae on the body segments of the pupa of *S. obliqua* are considered to be specific or generic features. The higher food consumption of the female larvae is correlated with the larger size of the female adults. The loss of weight during the pupal stage was positively due to the breaking down of the larval tissues and utilization of such cells for reorganizing the body organs. But the greater loss at emergence than at the beginning of the pupal stage certainly resulted in the former being followed by tremendous reorganizing activities inside the pupae. Moreover, greater consumption resulted in greater initial and final weights in the female pupae, while the lower percentage loss in the males further signified that the females reserve more of the energy which is to be utilized during oviposition after emergence. It is estimated that 1 g of food consumed increased the weight of pupa by 17 mg in males and 23 mg in females. The detailed morphology of *S. obliqua* pupa has been described by Ahmad & Ahmed (1977) and Goel & Kumar (1983b)

The adult moths having dusky brown forewings and light brown hindwings are dull yellow on the head, thorax and underneath the body. The abdomen is pinkish having paired segmental black spots on the abdomen dorsolaterally and lie hidden beneath the wings. The adult males could be recognised by the bipectinate antennae. The males are also smaller in size than females, both measuring about 16.27 ± 0.12 mm and 19.40 ± 0.40 mm in length, 2.50 ± 0.29 mm and 3.00 ± 0.0 mm in head width, 40.0 ± 1.15 mm and 47.6 ± 2.01 mm across the wings, respectively. The developmental period of the pest ranged from 59 to 76 days on soybean during the period of October–February (Singh & Gangrade, 1974a) 38 to 47 days in summers and 79 to 93 days in winters on castor (Goel, 2001). Alam (1972), Islam & Alam (1979 & 1980), Das & Bhuyan (1984) and Hussain (1993) discussed several aspects of the mating behaviour and sex pheromones of the pest. Average fecundity was reported up to the tune of 1287 eggs/female on soybean. Ahmad & Ahmed (1976) and Mastafa (1973) have studied the adult morphology in detail.

The life and age specific fecundity shows that the insect reproduced (Ro) 6.00 times in a generation time (T) of 68.93 days. The intrinsic rate of increase in number (rm) calculated graphically came to 0.026 female/female/day with a finite rate of increase in numbers (λ) being 1.0263 females/female/day on castor. The life expectancy (ex) of newly laid eggs was calculated as 9.30 days and 13.52 days during winters and summers, respectively (Goel, 2001). On the leaves of wingedbean, *Psophocarpus tetragonolobus* (L.) DeCandoele, age specific life table resulted in to a net reproductive rate (Ro) as 142.72 and an intrinsic rate of natural increase (r) 0.124 with mean larval period 23.5 days (Chaudhary & Bhattacharya, 1986). Life table to assess the key mortality and survival probability factors have also been constructed by Goel (2001) on castor. The presence of dipteran maggots constituted a major mortality factor in the field and the high value of trend index 1.84 referred to the population increase in the next generation.

The artificial diet in rearing the insects is of great importance to develop the insect colonies. The composition and preparation of such diet has been discussed for the maintenance of the mass laboratory rearing of *S. obliqua* larvae mainly required in the biological and toxicological studies. The major nutrients of an artificial diet are proteins, carbohydrates, vegetable oils and fatty acids, sterols, vitamins, salts and unrefined plant products. The survival of the larvae on semi-synthetic diet prepared from maize, rice, soybean, gram, ether extract of soybean, boiled soybean or wheat as basic ingredients helped a large number of individuals to complete their larval and pupal development. Normal adults emerged only when soybean was present in the diet. The flour of boiled soybean was found to be more suitable for the growth and development of *S. obliqua* as compared to raw soybean flour. Dry matter utilization and nutritional efficiencies of the semi synthetic diet also revealed enhanced consumption index (C.I.), growth rate (G.R.), approximate digestibility (A.D.), efficiency of ingested (E.C.I.) and digested (E.C.D.) food when *S. obliqua* larvae reared on a diet containing green gram, black gram, rice or red gram (Tiwari & Bhattacharya, 1987). For the quicker larval and pupal development of the pest various semi-synthetic diets have also been suggested (Islam & Usmani, 1972; Dass & Prasad, 1984; Narayanan, 1985a; Ahmed & Bhattacharya, 1994) but the granulosis disease remained the only constraint in the continuous maintenance of the pest on the artificial diet (Battu & Ramakrishnan, 1994). Minor alterations in the nutrients of the semi-synthetic diet would alter the larval and pupal development and emergence of deformed adults.

The alimentary canal of the larval *S. obliqua* is a straight tube and differentiating in three main regions, the stomodaeum (foregut), mesenteron (midgut) and proctodaeum (hindgut). The fore- and hindgut are slightly transparent on looking the greenish food inside whereas the midgut is the longest part of the digestive tract. The alimentary canal shows some structural and functional peculiarities. The foregut is characterised by the presence of oesophageal valve that appears crescent-shaped in cross section and the epithelium of the crop has longitudinal folds at its posterior region. The inner foldings of the crop epithelium seem peculiar to Bihar hairy caterpillar. The midgut constitutes the major part of the alimentary canal. The midgut epithelium is complex, composed of the columnar, goblet and regenerative cells. The anterior end of larval hindgut at its junction with the midgut is marked by posterior interestitial ring. The cells of this ring, like those of anterior interestitial ring, replace the larval hindgut epithelium through their reproductive process (Kabir, 1989). Such imaginal rings have been described from many insects including Lepidoptera.

The qualitative analysis of different enzymes in the alimentary canal of *S. obliqua* was done by Goel (2001) through colour development by using Fehling's, Fluckiger's, Barfoed's, Benedict's, Biuret's and Feigl's tests and several other specific chemicals. The following enzymes have shown their presence namely, α-amylase, maltase, lactase, invertase, cellulase, chitinase, inulase, polyglacturonase as carbohydrases; protease-A, polypeptidase, pepsin, trypsin as proteinases; lipase, carboxylesterase and triacylglycerolipase as esterases and urease as amidases. The meso- and metamesenteron are the most active part of the midgut to secrete the maximum number of enzymes, making these an active secretory zone. Singh & Pandey (1987b) undertook a detailed study of acid phosphatases and found that the role of this enzyme is in the development and metamorphosis in *S. obliqua* and its activity was higher in females than males. They also studied the characteristics and nature of alkaline phosphatase (Singh & Pandey, 1987a). In the gut contents of the larva the presence of phosphatases and non-specific esterases (Palanischamy *et al.*, 1989) and, high proteolytic, amylolytic and lipolytic activities (Anwar & Saleemuddin, 1997) have also been reported. Wax and gelatin cut histology sections of different regions of the gut of *S. obliqua* were processed for the localization of carbohydrates, proteins, lipids and DNA and by intense, moderate and poor staining techniques, their localization have been confirmed in different regions of the gut.

The excretory system of immature larvae is cryptonepheridial type and based on usual lepidopteran plan. The malpighian tubules are in three pairs, delicate, yellowish in colour and convoluted from the anterior proximity of the midgut. During metamorphosis, the cryptonepheridial malpighian tubules degenerate completely, leaving a few nuclei, which undergo endomitosis to become the nucleus of the adult tubule epithelium. Absorbed microvilli at prepupal stage reappear again to form the brush boarder at the pupal stage. The tubule enlarges in diameter and length in the adult.

The respiratory system comprises of the spiracles, tracheae and tracheoles in the terrestrial larvae. The spiracles are of peripneustic type under a polypneustic spiracular system in *S. obliqua*. An ultra structure of the larval and pupal spiracles has been described with the help of a scan electron microscope by Goel (2001) incorporating details of the unbranched and branched spiracular fringes which clearly differentiate the two. The record of tracheation of the body has also been made to show the tracheation of the head, thorax and abdominal regions.

The haemolymph is extracellular fluid plasma having numerous suspended nucleated haemocytes. In larvae of *S. obliqua*, they are of five types namely, the prohaemocytes, plasmocytes, podocytes, oenocytes and adipohaemocytes (Ahmad & Khan, 1992). The blood is slightly acidic in reaction and phagocystosis in function. About 90% of the insect blood is water, which carries inorganic constituents, organic constituents and pigments. The blood is commonly green in colour due to the presence of insectoverdin. The haemolymph proteins regulate the developmental stages of the insects, which are mainly in the form of amino acids. However, there exists a relationship of amino acids with the excretion, malpighian tubules, haemolymph and food of the Bihar hairy caterpillar. Shahjahan *et al.* (1978) have made qualitative studies of the amino acids in the different developmental stages of the pest. Mall & Pal (1980) experimented on bean leaves to check the amino acids both in the food and haemolymph of full grown 5th instar caterpillar. They have concluded that there exists a relationship of amino acids of excretion, malpighian tubules and haemolymph and food of *S. obliqua* larva.

The central nervous system is comprised of the supra-oesophageal (brain), sub-oesophageal, three thoracic and seven abdominal ganglia in *Sphida (Diacrisia) obliqua* Wlk. (DuPorte, 1915). The brain is characterised by three paired nerves and a connective and commissure, whereas sub-oesophageal gives out five pairs of nerves and a median, a paired connectives and commissures. The prothoracic ganglion gives rise to three pairs of nerves and a median. Identical conditions are observed in the mesothorax and metathorax. The nerves arising from 1st to 6th abdominal ganglion are in two pairs and a median, a commissure and a sympathetic plexus. The 7th abdominal ganglion, a composite structure made by the fusion of 7th and 8th abdominal ganglia also gives out two pairs of nerves and a median nerve. The sympathetic system (vagus or unpaired nerves) of the head region and paired sympathetic system consist of only two small ganglia and four nerves. The histochemical analysis of the central nervous system of the insect during metamorphosis with reference to the breakdown and reformation of neural lamella has been done by Chandra & Singh (1982).

The endocrine organs of insects are of two types namely, the neurosecretory cells and the endocrine glands. The neurosecretory cells occur normally in the ganglia of the central nervous system and function in the secretion of large protein molecules which act as carrier for a small hormone bound molecule. The neurosecretory cells act as intermediatries between the nervous system and the endocrine glands. In the neurosecretory cells of brain of larvae, pupae and adults of *S. obliqua* four types of neurosecretory phases are recognized *i.e.* synthesis, coalescence, release and resting (Arif & Singh, 1991). Corpora cardiaca, corpora allata and prothoracic glands are of three types of endocrine glands. The neurosecretory cells stimulate the glands for the release of hormones. Corpora cardiaca help to store and release hormones from the neurosecretory cells of the brain. Corpora allata produce juvenile hormone, which regulate the metamorphosis and yolk deposition in eggs. The prothoracic glands produce the moulting hormone, the ecdysone. Insect hormones play a vital role in proper growth and moulting, metamorphosis, diapause, polymorphism and maturation of oocytes.

The lepidopteran larvae feed over the green foliage and retain a part of the food and utilize the same in different metabolic activities. Hence the studies on consumption of food are of fundamental importance for proper understanding of the host plant relationship and nutritional physiology of the insect. Kumar (1983a) elaborated the study of energy transformations in living organisms, called bioenergetics. The data recorded on the consumption and utilization of sunflower leaves by *S. obliqua* gravimetrically on live, dry and energy basis revealed that the neonate caterpillar possessed the lowest body weight and energy values compared to be the highest at the last instar larvae. The successive gain in average biomass and calories in both the sexes at each moult compensated the energy requirement at each ecdysis and further to support an internal preparedness for the pupation. The females on daily basis observed to attain higher body weight, consumption and longer stadial period than males, perhaps to cope with an extra energy required for egg laying in adult females. The females have better assimilation over the males. In spite of higher consumption, the egestion is less in the females than the males. This emphasized a higher storage of energy in the former. The A.D. also results into suitability of the food and suggests the proportion of ingested food available to be passed on to the next trophic level. The E.C.I. increased with the development of the caterpillar and had poor values at the last larvae, perhaps an approach to the pupation. The E.C.D. follows the trend of E.C.I. even for the two sexes. The C.I. is mostly used to establish the host specificity and is with decreasing tendency in all the lepidopteran species. The females are superior over the males in C.I. In *S. obliqua* the G.R. declines towards the last instar stage and be regarded as one of the useful indices for the preferential feeding amongst different diets.

The food plants play an important role in the larval and post larval development. Such food, subsequently, helps to buildup the pest population. Host pest relation is thus significant in formulating the strategies for managing the natural population of the insect pest. Bihar hairy caterpillar is a key pest of major importance for oilseed crops like sunflower, sesamum, castor, soybean, groundnut, mustard and *toria*. Amongst pulses bean, blackgram, greengram, wingedbean, pigeonpea and cowpea, and amongst vegetables cabbage, cauliflower, knol khol, chillies, radish, brinjal, tomato, carrot and spinach formed the highly rated and most favourable food plants. Jute, an important fiber crop is always got defoliate by this pest. Fodder crops like shaftal (*Trifolium resupinatum*), berseem (*T. alexandrinum*), senji white (*Melilotus indica*) and senji yellow (*M. alba*) are no exception with heavy outbreak together with Japanese mint as another important food plant. Certain medicinal and weed plants are also added to the list of preferred foods. As such Singh & Varatharajan (1999) have provided a classified list of 126 host plants belonging to 24 plant families. A detailed account of growth and developmental behaviour of *S. obliqua* on major food plants including the impact of temperature in population buildup has been given by Goel (2001).

Natural parasites and predators have proved highly efficient biocontrol agents to check the field population of *S. obliqua* and the young stage larvae are highly susceptible for the infestation. Egg parasites *Trichogrammid perkinsi, T. australicum* and *Telenomus (Aholeus) molorchus* Nixon (Joshi *et al.*, 1983; Somchoudhury & Dutt, 1988); larval parasites *Apanteles obliquae* Wilk., *Apanteles* sp. (*glomeratus* group), *A.* (*Cotesia*) *flavipes*, *A. creatonoti*, *A. vitripennis* Hal, *A. ruidus*, *A. bosei* Bhatnagar, *A. ater* (Retz.), *Sarcophaga misera* W lk., *Sarcophaga* sp. nr., *kankauensis* Baranov., *Goniophthalmus halli* Mensil, *Carcelia corvinoides* Wulp., *Metarous* *spilosomae*, *Metarous* nr. *arctiicida* Vireck, *Drino (Prosturmia)* sp., *Charops* sp., *Bracon brevicornis* and *Campoplex collinus* (Singh & Gangrade, 1975; Poonia *et al.*, 1981; You *et al.*, 1983; Kumar & Yadav, 1987a; Muthukrishnan & Senthamizhselvan, 1987a & 1987b; Kakar & Dogra, 1989; Shetgar *et al.*, 1990; Narendran & Rema, 1996; Sathe & Bhosale, 1996) and pupal parasite *Blepharella lateralis* Macquart (Kumar & Yadav, 1987b) have been reported associated with *S. obliqua*. In field *Rhinocoris fuscipes* F., *Scadara annulipes* Reuben, *Cantheconidea furcellata* Wolff. and *Andrallus spinidens* F. were also found predating on larvae (Singh & Gangrade, 1975; Chand & Prasad, 1978).

The use of pathogens namely viruses, bacteria, fungi, protozoans and nematodes is gaining acceptance in Integrated Pest Management (IPM). The viruses (NPV, CPV & GV) are endopathogenic to regulate the insect population and are safe to biosphere. *S. obliqua* larvae infested with NPV at the level of 15.8×10^6 POB/ml consumed 35.97% less food as compared to healthy ones (Chaudhari, 1985) and diseased larvae also show a drastic reduction in glycogen and lipid contents (Gujar & Chaudhari, 1983). It has also been reported that the virus in combination with protozoan, pesticides and fertilizers reduces the pest larval population up to 100% (Narayanan, 1985b; Chaudhari, 1987). Entomocidal bacteria are also used for the control of crop pests. *Bacillus thuringiensis* commonly called *B.t.* producing α, β-exotoxins and δ-endotoxins, has proved more pathogenic to insects. Various formulations of *B.t.* have been evaluated against 3rd instar larvae of *S. obliqua* (Taluker *et al.*, 1989; Biswas *et al.*, 1994; Varatharajan *et al.*, 1996). Entomopathogenic fungi with several potential advantages like safety to users and non-target organisms are helpful to check the pest population. Various species of the genus *Entomophthora* are known to infect different insect pests of crops including *S. obliqua* in the fields of jowar, ragi, soybean, groundnut, maize, cowpea and sunflower. The level of infection by the fungus was estimated 45-75% recording 100% mortality (Thontadarya *et al.*, 1973). Like wise *Spicaria rileyi* (Farlow), *Beauveria bassiana* and *Metarhizium anisopliae* have also been reported causing 74-91% larval mortality (Singh & Gangrade, 1975; Pandit & Samanta, 1995).

Various organochlorine, organophosphate, carbamate and synthetic pyrethroid insecticides have been widely evaluated for the management of *S. obliqua* on different host plants. Amongst them endosulfan, quinalphos, chlorpyrifos, carbaryl, methyl parathion, dichlorvos, acephate, cypermethrin, deltamethrin, malathion and monocrotophos have been reported effective for its control (Sidhu & Dhawan, 1980; Singh & Grewal, 1982; Yadav, *et al.*, 1978a; Singh *et al.*, 1985; Bakhetia, 1987; Nagia *et al.*, 1990a & 1990b; Senapati & Ghosh, 1992; Goel & Kumar, 1991a; Nath & Singh, 1996).

The plant extracts having antifeedant activities proved to be a safe, biodegradable alternative to decrease the use of synthetic insecticides. They possessed diversified chemicals exerting growth inhibitory, toxic and hormonal effects on insects, which are basically non-nutrients called allelochemicals. *S. obliqua* fail to develop on plants like *neem*, fern, bougainvillia, parthenium and *tulsi* due to the antexenotic nature of the plant extracts (Ahmed & Bhattacharya, 1991) whereas, Compositae plants namely *Calandula officinalis* L., *Chrysanthemum indicum* L., *C. frutescens* L., *Tagetes erecta* L. and *Zinnia elegans* Jacqr. caused 63.33 to 70% larval mortality due to antibiosis compounds (Srivastava & Pandey, 1987). The use of *neem* based insecticides for insect control is being emphasized for environmental protection. Various formulations based on *neem* seed extract, *neem* seed oil and Azadirachtin have been evaluated to control the pest larvae by contact and oral applications (Parmar & Srivastava, 1987; Agrawal & Mall, 1988; Goel, 2001). Various plant extracts have been tested for the possible antifeedant effect against *S. obliqua* (Tripathi & Rizvi, 1985; Tripathi *et al.*, 1987; Tripathi & Singh, 1994). The other plant extracts which have proved good antifeedant against the pest include *Piper nigrum*, *Enrythrima indica*, *Annona squamosa*, *Alianthus excelsa, Psoralea corylifolia, Balanites roxburghii, Lindenbergia grandiflora, Passiflora mollissima, Eupatorium ayapana, Lantana camara, Euphorbia royleana, Nyctanthes arbortrytis, Swertia chirata, Stellaria média, Tithonia diversifolia, Inula racemosa, Tricholepis glaberrina, Oscimum basilicum, O. sanctum, Mentha viridis, Duboisia myoporoides, Astilbe rivularis, Convolvulus microphyllus, Echinops echinatus* and *Cantella asciatica.*

A number of chemicals are also known to have antifeedant activity. Amongst them triphenyltin acetate, Du-Ter, oxime ethers and synthetic pyrethroid insecticides like cypermethrin, fenvalerate and deltamethrin have exhibited significant insect growth inhibition and antifeedant activity against *S. obliqua* (Chand, 1975a; Siddaramaiah & Prasad, 1977; Nagia *et al.*, 1989; Walia *et al.*, 1997).

Host plant resistance is another ecofriendly approach in Insect Pest Management. As a result, the insect pests got attacked by natural enemies and require low doses of insecticides for their kill under the concept. Genetic engineering has recently revolutionized the field and developed about 500 insect resistant cultivars. Hybridization and interspecific crosses during different generations resulted to develop moderate resistance because of one incompletely dominant gene in soybean and cauliflower against *S. obliqua* in particular (Ram *et al.*, 1989; Lal *et al.*, 1994; Bhattacharya & Ram, 1995).

Endocrine glands in the larvae of *S. obliqua* secrete juvenile (JH) and moulting (MH) hormones, which control the formation of the larval-pupal intermediates. Hence neurosecretory changes by the hormones secreted by corpora allata are responsible for these deformities. The topical application of a chemosterilant, bisazir to larvae caused deformities in prepupae, pupae and adults with 100% sterility in both the sexes (Prasad & Srivastava, 1989). Similarly, a chitin inhibitor, penfluron caused a weight loss up to 73.77% in 3rd instar caterpillars (Srivastava & Srivastava, 1990) and larval-pupal intermediates developed when treated at low doses (Chawdhury & Srivastava, 1990). Using a JHA, methoprene caused larval-pupal and adult mortality with affected malformation in pupal physiology (Qamar *et al.*, 1994). Diflubenzuron initially described as a stomach poison has ovicidal activity and inhibits a number of enzyme systems in addition to those involved in chitin synthesis. The effect of diflubenzuron has been studied against eggs and larvae of the pest (Jaipal, 1985; Tiwari, 1989; Gupta *et al.*, 1994).

The microclimate of the agroecosystem is affected by intercropping, which ultimately produce an unfavourable environment for insect pests. It has been observed that the incidence of the pest increased when groundnut intercropped with sesamum than pure crop (Singh *et al.*, 1991) whereas incidence decreased, when crops of blackgram, castor and sesamum intercropped with pigeonpea as compared to pure crops (Yadav *et al.*, 1992a). The plant density influences the incidence of insect pests associated with the crops. In an early stage of the crop growth, the damage of *S. obliqua* was more in fields having 0.6 and 0.8 million plants per ha, however in the late stage of the crop growth no definite relationship between plant population and insect population was observed (Kumar & Bhattacharya, 1988). Moreover, the row to row spacing created much difference in the ecoclimate of the test plots because of the foliage canopy. The incidence and fluctuation of *S. obliqua* was higher in plots having 30 cm row to row distance than 45, 60 and 75 cm in early stage of soybean crop; however, a different trend was observed thereafter (Kumar & Bhattacharya, 1989). Similarly the trend of larval population under irrigated and unirrigated soil conditions in jute was different (Sagar *et al.*, 1990).

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