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The Role of Natural Enemies to Control Diamondback Moth, *Plutella xylostella* (L) Population in Various Seasons

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Abstract.- Three life table studies of *Plutella xylostella* (L.) (Lepidoptera: Plutellidae) were studied during 2008-2009 at Tando Allahyar, Sindh, Pakistan in the cauliflower plants under field conditions. First study was carried out during autumn season that is, October-November 2008, the second study during winter season (January-February 2009) and the third study during spring season (March 2009). To describe the mortality processes of immature stages of *P. xylostella*, the data on population census were recorded on alternate days from 50 randomly selected plants. All immature stages *i.e.*, eggs, larvae and pupae were recorded. Various predators and parasitoids were recorded feeding upon immature stages of *P. xylostella*. Predators included various species of ants and spiders, coccinellid beetles and *Chrysoperla* sp. *Cotesia plutellae* and *Oomyzus sokolowskii* were important larval and pupal parasitoids, respectively. There was relatively low parasitoid pressure during summer as compared to winter and spring.

Key words: *Plutella xylostella*, cauliflower, cabbage, *Cotesia plutellae.*

INTRODUCTION

The diamondback moth (DBM), *Plutella xylostella* (L.) (Lepidoptera: Plutellidae) is the most destructive insect pest of cruciferous plants throughout the world. It has been recorded since 1746 (Harcourt, 1962) and is believed to have originated in the Mediterranean region (Harcourt, 1954). Virtually *P. xylostella* occurs wherever crucifer crops are grown; it has now been recorded from at least 128 countries or territories of the world and is believed to be the most universally distributed of all Lepidoptera (CIE, 1968; Salinas, 1972; Lim, 1986; Talekar and Shelton, 1993).

P. xylostella feeds only on plants of cruciferae. Many of the plants of this family are cultivated as vegetables, and oilseed crops. There are numerous crucifer plants which are not consumed by man, are considered as weeds, but consumed by *P. xylostella* when its favoured hosts are absent thus providing a crucial link in maintaining *P. xylostella* populations (Talekar and Shelton, 1993; Begum *et al*., 1996; Kartosuwondo, 1991; Idris and Grafius, 1996).

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Plants continuously release volatile compounds into the surrounding environment. Some herbivores utilize these volatiles to locate their host plants (Visser, 1986), and natural enemies of the herbivores (predators and parasitoids) may utilize these plant info- chemicals to locate their prey or hosts (Elzen *et al*., 1983; Vet and Dicke, 1992). Feeding by phytophagous insects induces host plants to release a volatile blend of phytochemicals different from that released during the intact state (Turlings *et al*., 1990; Dicke *et al*., 1990) and natural enemies of herbivores may utilize the plant volatile phytochemicals released during feeding and produced from the frass of larval feeding, as source to locate their prey or hosts (Turlings *et al*., 1991; Dicke and Takabayashi, 1991; Dicke *et al*., 1990; Agelopoulos and Keller, 1994). Chand and Choudhary (1977) noted that *P. xylostella* attacked all the cruciferous plants; however, it exhibited a marked preference for cauliflower and cabbage. These two plant species possess fleshy succulent leaves that provide both olfactory and gustatory stimuli.

The life tables of *P. xylostella* have been studied by many entomologists such as Harcout (1963), Iga (1985), Sivapragasam *et al*. (1988), Wakisaka *et al*. (1992) and Keinmeesuke *et al*. (1992). They reported that most DBM larvae were killed in immature stages. However, the main mortality factors were different in each of the studies. Ooi (1979) noted that misuse of insecticides has exacerbated problems with DBM. Development of more ecologically based management strategies has been slow and difficult to implement on a large scale. Iga (1985) reported that seasonal fluctuation depended mainly on the action of natural enemies. However, microbial insecticides *Bacillus thuringiensis* Berlines (Bt) is highly toxic to certain pests, yet it has little or no adverse effects on most non target organisms, including humans. The insecticide usage becomes not only useless but also harmful when DBM develops into adult form.

MATERIALS AND METHODS

Three life table studies were carried out during 2008-2009 under field conditions, at Tando Allahyar cauliflower fields. First study was carried out during autumn season that is, October-November 2008, the second study during winter season (January-February 2009) and the third study during spring season (March 2009). The data for first life table study were taken from a cauliflower crop transplanted on July 30, 2008. While the data of second and third life table studies were recorded from a cauliflower crop transplanted on December 3, 2008. The cauliflower plants were planted on ridges; row to row distance was 0.6 meters and plant to plant distance 0.25 meters.

The population census data for life table studies were recorded on alternate days from 50 randomly selected plants. All immature stages *i.e.*, eggs, larvae and pupae were recorded. The eggs, larvae and pupae were also collected from neighbouring cauliflower fields and brought to the laboratory for recording the infertility and parasitization of eggs, larvae and pupae.

The life tables of *P. xylostella* (DBM) under laboratory and field conditions were constructed according to the methods described by Harcourt (1969), Southwood (1978), Dhandapani and Balasubramanian (1984) and Kreb (1985).

mx, Age specific fecundity; lamx, Multiplication of column lx and mx to give the total fecundity in each age interval.

The reproductive rate (Ro) = $\Sigma lxmx$ ....(1)

The mean length of generation, $T = \dfrac{\Sigma xlxmx}{Ro}$ ………..........(2)

The intrinsic rate of population increase $(rm) = \dfrac{\log_e Ro}{T}$ ….(3)

The finite rate of population increase = e^{rm} ……………......(4)

RESULTS AND DISCUSSION

To describe the mortality processes in the immature stages of *P. xylostella*, life tables were constructed as suggested by Morris and Miller (1954); one for late summer season 2008 cauliflower crop plot and one each for winter and spring season, 2009 cauliflower crop plots (Table I). There were some differences in mortality factors acting upon immature stages operating in various seasons. Numerical differences in mortality factors were also recorded within a generation.

Egg mortality

The important mortality factors were the parasitoid *Trichogramma* sp., infertility, predators and some unknown factors. The parasitism was relatively low during late summer season probably due to relatively high temperature in comparison to winter and spring seasons. Predators included various species of ants, coccinellid beetles, *Chrysoperla* sp. and spiders. The mortality due to predators and unknown factors varied from 11.20 to 20.30%. Egg mortality due to failure to hatch also varied from 6.40 to 18.30%.

Larval mortality

Diamondback moth larvae have four larval instars. Mortality for larval stages one and two were considered as larva 1, whereas for stages three and four were denoted as larva 2.

Larva 1

The mortality at this stage due to *C. plutella* ranged between 0.0 and 2.70%. Mortality due to other factors including predators, *Chrysoperla carnea*, *Coccinella* sp. beetles, ants and spiders and other unknown reasons such as dispersion after

Table I.- **Life table of *P. xylostella* on cauliflower in a naturally infested plot at Tando Allahyar. Values are number of *P. xylostella* life stage per 50 plants.**

Age-interval developmental stage	Mortality factors	No. of stages	Mortality	% mortality	Survival rate
Late summer-October-Nov., 2008					
Eggs		3829			
	Trichogramma sp.		333.12	8.7	
	Failure to hatch		237.40	6.2	
	Unknown and predators		585.84	15.3	
	Total		1156.36	30.2	0.698
Larva I		2672.64			
	Cotesia plutellae		0.0	0.0	
	Unknown & Predators		482.68	18.06	
	Total		482.68	18.06	0.819
Larvae II		2189.96			
	Cotesia plutellae		262.58	11.99	
	Unknown & Predators		1668.42	76.18	
	Total		1931.00	88.17	0.118
Pupa		258.96			
	Oomyzus sokolowskii		12.79	4.00	
	Failure to emerge		27.75	8.70	
	Unknown		70.71	25.30	
	Total		111.25	38.00	0570
Adult		147.71			
	General survival				0.038
Winter-January-February 2009					
Eggs		378			
	Trichogramma sp.		58.21	15.40	
	Failure to hatch		64.26	17.00	
	Unknown and predators		42.34	11.20	0.564
	Total		164.81	43.60	
Larva I		213.19			
	Cotesia plutellae		5.76	2.70	
	Unknown & Predators		50.10	23.50	
	Total		55.86	26.20	0.738
Larvae II		157.33			
	Cotesia plutellae		41.93	26.65	
	Cotesia sp.		12.55	7.98	
	Didegma sp.		4.18	2.66	
	Diadromus collaris		2.09	1.33	
	Unknown and Predators		29.37	17.71	0.440
	Total		88.09	56.00	
Pupa		69.24			
	Oomyzus sokolowskii		2.77	4.00	
	Diadromus collaris		0.92	1.33	
	Failure to emerge		3.46	5.00	
	Unknown		14.19	20.50	
	Total		21.34	30.83	0.692
Adult		47.90			
	General survival				0.1267
Spring-March 2009					
Eggs		33129			
	Trichogramma sp.		595.69	17.08	

Continued

Age-interval developmental stage	Mortality factors	No. of stages	Mortality	% mortality	Survival rate
	Failure to hatch		606.10	18.30	
	Unknown		672.34	20.30	0.443
	Total		1844.13	55.68	
Larva I		1467.87			
	Cotesia plutellae		39.63	2.70	
	Unknown		673.31	45.87	0.514
	Total		712.94	48.57	
Larvae II		754.93			
	Cotesia plutellae		392.34	51.97	
	Cotesia sp.		30.20	4.00	
	Didegma sp.		30.20	4.00	
	Unknown and Predators		247.16	32.74	
	Total		699.90	92.71	0.073
Pupa		55.03			
	Oomyzus sokolowskii		3.66	6.66	
	Failure to emerge		2.20	4.00	
	Unknown & Predators		14.19	25.80	0.635
	Total		20.05	34.45	
Adult		34.98			
	General survival				0.010

hatching, and failure to establish a feeding site and dew ranged between 11.2 to 20.3%.

Larva 2

The major mortality factors were parasitism by braconid parasitoids (*Cotesia (Apenteles) plutellae, Cotesia (Apenteles)* sp. and *Didegma* sp.) and some unknown factors. The braconid parasitoid *Cotesia plutellae* was major larval parasitoid; its parasitization increased from late summer to spring crops. In spring crop more than 50% fourth instar larval population was parasitized by this parasitoid. The unknown mortality factors also include predation by spiders, wasps and birds and dispersal of mature larvae from plants before pupation was also recorded. Some mature larvae pupated beneath fallen cauliflower leaves.

Pupal mortality

The parasitism by *Oomyzus (Tetrastichus) sokolowskii* and *Diadromus collaris* was observed. Parasitism was comparatively higher during spring season crop. Mortality due to unknown factors remained more or less same. Most of the unknown disappearance of pupae may be due to bird predation (Iga, 1985; Wakisaka *et al*. 1991) because pigeons and sparrows were found visiting the field and spiders were also seen in the crop. Many pupae were also found infected with diseases.

DBM feeds on a wide range of cruciferous host plants (Harcourt, 1957; Dube and Chand, 1977; Singh and Singh, 1982; Siemens and Mitchell-olds, 1996; Ramchandran *et al*., 1998). The effect of host plants on development and reproduction of *P. xylostella* vary (Wakisaka *et al*., 1992; Salas *et al*., 1993; Begum *et al*., 1996). Van Lenteren and Noldus (1990) have stated that shorter developmental times and greater total oviposition (fecundity) on a host reflected the suitability of the host plant. In the present study, DBM fed on cauliflower and cabbage showed higher intrinsic rates of increase (rm) resulting from faster development (shorter generation time), higher survivorship and higher fecundity rates. These two host plants are presumably more suitable hosts compared to other hosts. Wakisaka *et al*. (1992) studied the rm value of DBM on different host plants and found that 'rm' value ranged between 0.2778 and 0.1362 respectively on broccoli and a wild crucifer, *Capsella bursa-postoris*. Salas *et al*. (1993) investigated the life table parameters of DBMon different host plants and observed that the highest rm was on cauliflower. Also, there are many other studies where host plants have affected the biology and life table parameters of many insects/organisms (Root and Olson, 1969; Bessin and Reagan, 1990; Fouly *et al*., 1995; Tsai and Wang, 1996).

In the present study, mortality rate of eggs and young larvae was high and main mortality factor was the disappearance and unknown causes. Higher mortality may be due to desiccation of eggs during late summer generation and failure of freshly hatched first instar larvae to establish themselves at a suitable feeding site and predation by various predators such as *Chrysoperla carnea*, Coccinella beetles, ants and spiders.

All the authors mentioned above have shown rain as the most important mortality factor for eggs and young larvae, as the rain caused wash-off and mud splash mortality. Harcourt (1963) estimated 75% first instar larval mortality due to rain. Iga (1985) reported almost 100% mortality of first and second and from 14.3 to 71.4% mortality of third and fourth instar larvae due to rain. Rainfall normally does not occur during cauliflower growing season in Sindh, Pakistan hence this factor was not studied.

The role of natural enemies in determining the population trends of *P. xylostella* has been worked out by various workers (Lim, 1982; Iga, 1985; Sivapragasam *et al*. 1988; Wakisaka *et al* 1992). In the present study a steady rise in percent parasitism from late summer to spring generations was observed for almost all parasitoid species. This rise may be explained in terms of the intergenerational (delayed density) response of the parasitoid density to that of the host (Hassell, 1966). *Costesia (Apantelus) plutella* was found to be the most important parasitoid in the present study.

From the results presented, it was construed that population increase of *P. xylostella* on young cauliflower crop during late summer season was the result of favourable environmental conditions, especially temperature, which during this period remained in the range of 26±2°C to 28±2°C for development and enhancing fertility. There was also relatively low parasitoid pressure during this time. During winter the rate of development was slow, mortality was high and population density did not increase. As spring approached, the cauliflower plants matured and the nutritional quality of mature leaves deteriorated, pupal size became smaller resulting in small adults with reduced fecundity as it has been reported that reproductive rates of foliage feeding Lepidoptera declined with aging of host plants in peanuts, soybeans and corn (Barfield *et al*., 1980; Moscardi *et al*., 1981; Knutson and Gilstrap, 1990). Similarly Harcourt (1986) found highly significant correlation between fecundity and protein content of cabbage leaves and reported that *P. xylostella* reared on young leaves produced more eggs than those reared on old mature plants.

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