Online Journal of Biological Sciences 1 (7): 656-659, 2001

Studies on the Life Table of Mussel Scale *Lepidosaphes ulmi* L. (Diaspididae: Homoptera) on Apple in Northeast England

Khawaja Farooq-Ahmad
University College of Agriculture, 12750 Rawalakot, Kashmir, Pakistan

Abstract: The life table developed for one complete and the other partial generations demonstrate that coccinellid predator *Exochomus quadripustulatus* (L.), Chalcid parasitoid *Aphytis* spp. and 'other' factors (mainly overcrowding, desiccation, etc.), playing role in the four different age intervals: eggs, crawlers, second instar larvae and adults stages, were the main regulating factors for mussel scale *Lepidosaphes ulmi* (L.) on apple in northeast England. The predatory role of *E. quadripustulatus* was higher at egg stage than other in the previous generation (F1) when compared to the following generation (F2). The parasitoid *Aphytis* spp. contributed an important role in the over all parasitism but was less obvious in F2 generation at the egg stage. Unknown causative mortality factors, contributed major kill in the whole generations. Overall, mortality recorded in the first whole generation *of L. ulmi* was 94.48%. Whereas in the second generation the egg mortality was 45.59%. The reduction in fecundity and body size between previous (F1) and new (F2) generations was also noticed. Both predator and parasites complement each other in keeping the population in check.

Key words: Mussel scale, diaspididae, *Lepidosaphes ulmi*, Coccinellidae, *Exochomus quadripustulatus*, *Aphytis* spp., apple

Introduction

For the quantification of the mortality data caused by natural enemies and determination of its ecological role in a particular system, life table may be used. Morris (1957) observed that in order to understand population dynamics, it is necessary to understand frequent population sampling and life table development. To interpret and discuss the life table or mortality data, several authors (Kiritani and Hokyo, 1962; Solomon, 1969; Varley and Grawell, 1970; Varley *et al*., 1973; Dempster, 1975 and Southwood, 1978) described methods in detail. For example, Morris (1957) made an important contribution in the interpretation of mortality data in population dynamics. He describes that the variation in mortality is more important than the absolute level of mortality and may be variable or constant either due to intrinsic or extrinsic factors of the environment. Mortality, one of the four key parameters (natality, mortality, immigration and emigration) of population requires a technique to know the occurrence of mortality and stage (juvenile or old) of organisms, so the convenient way of describing the mortality factors is a life table (Krebs, 1985) and these have been used widely in insect population studies (Harcourt, 1962). The construction and types of life tables (time-specific and or age-specific) is described by many authors (Merrell, 1947; Deevey, 1947; Morris, 1957; Southwood, 1978 and Bellows *et al*., 1992).

The life tables for *L. ulmi*, on apple, was intensively studied by Samarasinghe and LeRoux (1966) who revealed that the mite predator *Hemisarcoptes malus* (Shimer) and the Chalcid parasite *Aphytis mytilaspidis* (LeBaron), acted mainly in the egg, first larval and adult stages, as 'key' regulating factors for this species at low to medium densities on apple. There is no information available about the role of coccinellid predator *Exochomus quadripustulatus* (L.), apart from the mite predator and Chalcid parasite, as regulating factors for *L. ulmi*.

The present single life table and related mortality factors applying to one complete and the other partial generations may not be sufficient to explain all the factors (Hassel, 1987) which regulate the *L. ulmi* population at Close House. Nonetheless one might get help in finding solutions of the pest problem through life tables as they are an excellent tool to explain existing situations (Vandenbosch and Messenger, 1973). This study determines, for the first time, predatory role of *E. quadripustulatus*, besides Chalcid parasitoid *Aphytis spp.*and other factors that contribute towards the regulation of mussel scale population on apple at Close House (university field station) in order to understand the basic mechanism of improving the pest management.

Materials and Methods

Field studies on *L. ulmi*: Four apple trees of 3 different varieties (viz; two Laxton's Equisite, one House of Orange and one James Grieve) were used. These apple trees predominantly infested with mussel scale *L. ulmi* were selected and sampled weekly throughout the active seasons. These trees were pruned during winter 1992 before the commencement of this experiment. At the early stage of sampling usually old shoots were sampled but as the season progressed, the new shoots were also included and examined. Experiment were carried out from early spring (4 April) to autumn (11 November) during 1993 at Close House (university field station).

Stratification of apple trees and sampling procedure: Trees were vertically stratified into three different heights (lower, middle and upper strata). Each tree branch from each stratum was divided into three sections (S1 = close to the trunk, S2 = middle of the branch, and S3 = tip of the branch). Stratum levels were marked with white plastic labels along the steel wires which had been fixed previously on the wall behind the planted trees. As the trees were more or less similar in height there was no significant overlap in stratum height between trees. Each tree was divided into nine sampling units; three levels and three sections per tree. One branch from each side of trees per stratum with three sections was systematically chosen for accurate sampling. The sampled branch was marked with a label in order to provide an equal chance for the other branches to be sampled so that the repetition could be avoided on the next sampling date. Therefore, the total sample size per date including three branches with nine sections per tree per sampling day was 36 (4 trees x 3 strata x 3 sections). From each section a sample of 2.5-14 cm (mean 6.72 ± 0.2cm) long spurs was randomly selected as a sampling unit for further studies. Smaller sizes of spurs were taken in the beginning while the larger sizes of spurs were also included during the summer growing time. The spurs were removed from the apple shoots and placed separately in the marked labeled polythene bags for future

reference in a refrigerator at 4°C. Although three leaves of varying sizes (small, medium and large) from leaf bearing spur were observed, due to small population, only woody spurs were used as the standard sampling unit for quantification of *L. ulmi*. All the samples were examined before the next sampling date (usually within 2-3 days). All the stages (overwintering gravid females (OGF), first instar larvae (crawlers), second instar larvae, virgin females (VF) and new generation gravid females (NGF)) of *L. ulmi* were examined in detail.

Observations of mortality factors on different age intervals of *L. ulmi* : Although method for estimating of population densities and mortalities of *L. ulmi* are described in detail by Samarasinghe and LeRoux (1966), the following additional procedure was adapted for different stages of mussel scale.

Eggs: Five scale coverings per spur were removed and placed under a stereomicroscope. These scales with varying sizes were randomly chosen from different parts of the sampling unit. If there was fewer than five scales, all the available scales were examined. Apparently healthy eggs or those killed by different mortality factors were carefully examined and recorded. This was done by the aid of an entomological needle by removing the eggs from the scale coverings.

First instar larvae (crawlers): These were usually recorded either moving on the substrate or by removing the scale coverings. Mortality factors termed as 'other' included mainly shriveling (killed by desiccation), overcrowding, starvation etc.

Second instar larvae: Populations and mortality factors of second instar larvae were carefully observed because sometimes scales were closely packed/grouped and difficult to count particularly at the early larval stage. Sometimes, it was difficult to distinguish between the old and current desiccated scale coverings. Mortality factors attacked by Chalcid ectoparasite (*Aphytis* spp.) described by Samarasinghe and LeRoux (1966) were also noticed in addition to coccinellid *E. quadripustulatus* predation.

Adults: Adults, VF and GF were sampled separately. Their mortality symptoms are more or less similar to those of second instar larvae except for the mortality caused by the coccinellid predator.

Feeding symptoms of *E. quadripustulatus*: The evidence of *E. quadripustulatus* predation is that the beetle may gnaw, partly eat, or completely devour either the soft body of scale or its eggs. The beetle may attack either from the dorsal or lateral side of the scale covering by rupturing or making slit on the scale coverings. It was difficult to recognize such symptoms of attack in overwintering generation (eggs) where old scale coverings were also present. But it was recognized in the new generation of scales by their shiny or greyish/dark brown appearance.

The fecundity of each scale was obtained from the samples of adult GF collected during the period of egg laying particularly in late summer or autumn seasons.

Statistical analysis: Population density and mortality factors of each stage were determined as per unit area (1cm^2) of woody spur. The mean fecundity per GF was calculated by examining and counting the eggs of each individual scale under binocular stereomicroscope. The length of each scale was also measured under the stereomicroscope fitted with graticule micrometer in order to estimate the density of eggs per female. Thus the estimation of egg mortality was determined by using a linear regression equation ($Y = -38 + 30.4X$; where Y = numbers of eggs per female, and X = length of scale) which was derived for determining the relationship between length and numbers of eggs per female for population dynamics (published elsewhere). For the construction and development of life table, procedure suggested by Morris & Miller (1954) and Samarasinghe & LeRoux (1966) with the following columns was adapted.

x =	Age interval
lx =	Number alive at beginning of x
dxF =	Factor responsible for mortality at age interval ***x***
dx =	Number dying during x
$100qx1$ =	dx as percentage of lx
$100qx2$ =	dx as percentage of $lx1$

Results

The life table (Table 1) constructed from four different age intervals [eggs, crawlers, second instar and adults (virgin female)] of *L. ulmi*, provides insight into the relationship between mortality factors and population density. A partial life table of new generation (F2) confined to the egg stage also provides some important information that may be related to the previous generation (F1).

Mortalities during the egg stage were attributed mainly to *E. quadripustulatus* predation, parasite *Aphytis* spp. and unknown causes especially overcrowding ('others') in the F1 generation while in the F2 generation the earlier mortality factors were also observed to continue their regulatory role. The predatory role of coccinellid beetle was higher at egg stage in the previous generation than in the following generation, when apparent mortality (100 qx) at overwintering stage as compared to new generation eggs. Similarly the role of parasites was less obvious in F2 generation at the egg stage. Mortality in crawlers (the only mobile stage) was mainly due to overcrowding and desiccation ('other') of larvae in search of feeding sites. It seems difficult to measure quantitatively the effect of predation on the first instar density by direct observation because the crawlers are mobile whilts the other stages are sessile in nature. Crawlers may be consumed by predators without trace. Both predator and parasite caused high mortality at second instar stage compared to the egg stage. The proportion killed by these two natural enemies was higher than as recorded in the eggs. Unknown factors ('other') mortality compared to natural enemies remained high in the second instar larvae but in proportion to egg mortality it decreased. Predation by *E. quadripustulatus* was low at adult (VF) stage when compared to parasite and unknown factors. Overall, mortality recorded in the first whole generation of *L. ulmi* was 94.48 %. In the second generation, the egg mortality was 45.59 %.

The fecundity of *L. ulmi* varied between the previous and new generations. A significant ($t = 7.64$, $P < 0.001$) difference, using two sample t-test, in mean fecundity 31.62 ± 1.07 ($n = 150$) per female of present generation (F1) appeared when compared to the following generation F2 in which mean numbers of eggs laid by each female was 22.69 ± 0.47 ($n = 599$). This reduction in fecundity from generation to generation will also affect population increase. Similarly, the reduction in mean body length of adult females from 2.32 ± 0.02 ($n = 150$) to 2.2 ± 0.01 mm ($n = 599$) in F1 and F2, respectively, was also highly significant (Fig. 1A) and F2

Discussion

The life table demonstrates that 3 major factors: Predator *E. quadripustulatus*, parasitoid *Aphytis* spp. and unknown mortality factors ('others') are playing role in the population regulation of *L. ulmi*. The apparent mortality (100 qx) caused by the predator to *L. ulmi* was 7.5 % in general. Of this, the

Table 1: Mean life table development of L. ulmi on apple trees at Close House during 1993.

x	*lx*	*dxF*	*dx*	*100 qx1* (Stage mortality	*100 qx2* (Generation mortality)
Age interval	Numnber alive at Beginning of *x**	Factor responsible for mortality at age Interval *x***	Number dying during *x*	*dx* as percentage of *lx*	*dx* as percentage of *lxl*
Eggs (*F1*) 3586.75		Predator	168.93	4.71	4.71
		parasite	275.41	7.68	7.68
		Others	1934.26	53.93	53.93
		Total eggs =	2376.60	66.32	66.32
Larvae					
First instar	1208.15	Others	186.66	15.45	5.20
		Total first instar larva =	186.66	15.45	5.20
Second instar	1021.49	Predator	100.21	9.81	2.79
		Parasite	192.04	18.80	5.35
		Others	343.73	33.65	9.58
		Total second instar =	635.98	62.26	17.73
Adults		Predator	2.74	0.71	0.08
Virgin female	385.51	Parasite	126.76	32.88	3.53
		Others	75.95	19.70	2.12
		Total virgin females =	205.44	53.29	5.73
Generation mortality: 94.98		Surviving adult female (Female only:			
				Normal females: 180.07	
Generation Survival: 5.02%		Mean number of eggs/female 31.62			
Expected eggs: 5693.00		Actual eggs: 22.69			
Eggs of second generation (*F2*)					
Eggs (*F2*) 1953.33		Predator	43.25	2.21	2.21
		Parasite	14.82	0.76	0.76
		Others	832.46	42.62	42.62

*These eggs were estimated/calculated on the basis of numbers of adult females present in a sample.
** Egg mortality caused by other factors in mainly due to intra specific competition which could result in either reduced fecundity or no egg laying.

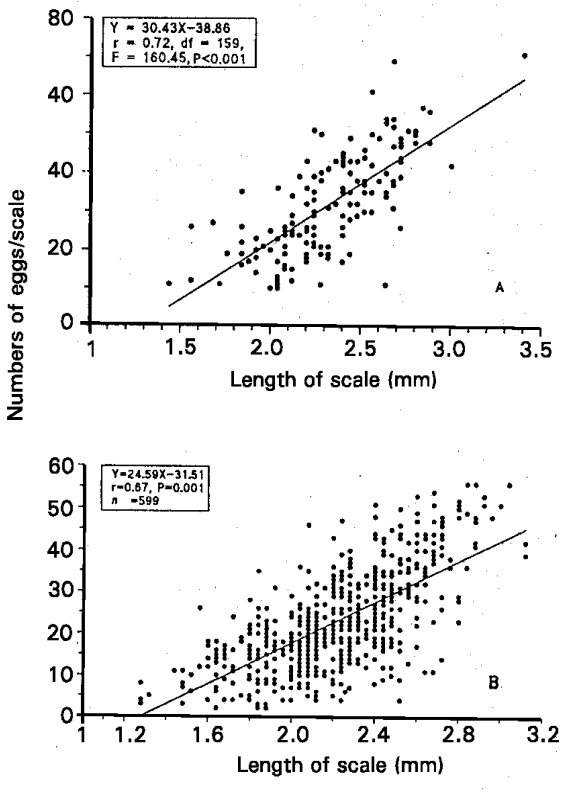

Fig. 1: Relationship between length of scale L. Ulmi and numbers of eggs per scale with fitted regression line. (A = F_1 and B = F_2 generations)

(Fig. 1B) show a linear relationship. A significant correlation between the scale length and the numbers of eggs per female appeared in both generations.

major contribution of predator was predation on the egg stage. This may be because the egg stage of *L. ulmi* lasts for a longer time than the other stages and hence the predator has greater opportunity to predate on GF than other stages in both late summer and early spring. It is apparent from the life table that parasite *Aphytis* spp. played an important role in the over all parasitism (16.56%). It may be inferred that both predator and parasite complement each other in keeping the population in check. Unknown causative mortality factors ('others'), mainly overcrowding, contributed 70% kill in the whole generation. This may result in intra specific competition, reduced fecundity or no reproduction. Percentage mortality due to other factors at the egg stage was extremely high in both F1 and F2 generations. Cook (1982) discussed in detail the overcrowding and competition within the scale *L. ulmi* and concluded that at high density intra specific competition was being experienced by the scales and was increasingly limiting their individual productivity. She further described that intensity of competition was apparently sufficient to prevent establishment and survival to reproduction of some scales. In the present study a similar situation occurred when reduced fecundity was noticed in the next generation which could be, apart from the other reasons, due to intensity of competition (Samarasinghe and LeRoux, 1966; Atkinson, 1983 and Lozano *et al.*, 1994). The present findings are in agreement with Cook (1982) that the attack had reached a seriously damaging level as most of the branches were enormously attacked by *L. ulmi* which obscured the surface of bark and branches. Despite the fact that there was intra specific competition damaging to the plant could not be prevented. The competition served to produce balance and so limit populations (Nicholson, 1933).

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