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Research Article

Determination of key mortality factor of Mexican beetle, *Zygogramma bicolorata* Pallister

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ABSTRACT: Life tables were constructed under Delhi conditions for *Zygogramma bicolorata* in order to determine the key mortality factor acting on the species. The pupal stage was found to be the key mortality stage that contributed most to the overall mortality followed by egg stage. Pupal malformation, failure to lay eggs and infertility were prominent mortality factors. The main cause of mortality of older larvae was their inability to burrow into hard and dry soil for pupation. Besides, weather factors in general were found to have an effect on all developmental stages of *Z. bicolorata*. The sex ratio was biased towards females with their proportion being 0.6-0.7. The generation trend index was very high (272.21) during July followed by October (231.07) and August (199.40). The generation mortality was low during June-October while it was high during January, May and December.

KEY WORDS: Life table, *Zygogramma bicolorata, Parthenium hysterophorus*

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INTRODUCTION

The Neotropical weed, *Parthenium hysterophorus* L. (Asteraceae) is a native of West Indies and tropical South and North America. Though this weed was first noticed in India in Pune (Rao, 1956; Khosla and Sobti, 1976; Towers *et al.*, 1977), it now occurs in almost all the states of India (Krishnamurthy *et al.*, 1977) except Andaman and Nicobar islands (Gautam, 2005a, b) as a naturalized weed (Joshi, 1990). In a span of two decades, *Parthenium* has spread to five million hectares and attained the status of a noxious, problematic weed (Joshi, 1990) and is still spreading to new areas. The Mexican beetle, *Zygogramma bicolorata* Pallister (Coleoptera: Chrysomelidae), introduced in India during 1983 (Gautam, 2008), is a potential biocontrol agent of *P. hysterophorus* and was released for the first time in Delhi during 2002 (Gautam, 2002). It was further recommended for colonization in the areas of absence in the 3rd International Conference on Parthenium held at New Delhi during December 2010 (Gautam and Mahapatro, 2011). The beetle is so far reported safe to the non-target biodiversity due to its specific feeding on *P. hysterophorus* and *Xanthium strumarium* (Lokeshwari *et al.*, 2008). Besides, it is compatible with botanical agents like *Kochea indica* and *Cassia* spp. as well as other weed management strategies (Mahadevappa and Gautam, 2006; Gautam, 2010; Shrestha *et al.*, 2010).

Construction of life tables is an important component in the understanding the population dynamics of an insect and assessing the performance of exotic natural enemies introduced for biological control of weeds (Isaacson, 1973). A series of life tables for a species helps to unravel causes of mortality during various developmental stages, their density relationship and the most important cause of mortality, called key mortality factor. Knowledge of causes of mortality is helpful in manipulation of important mortality factors for population suppression in case of pests while in case of beneficial species like *Z. bicolorata*, this would be useful in conserving its population in Delhi and other places of release (Gautam *et al.*, 2005), which is often affected by climatic extremes (Bhoopathy and Gautam, 2006). With this background, the present studies were undertaken.

MATERIALS AND METHODS

The present study was carried out at Indian Agricultural Research institute, New Delhi, whereby 12 life tables, one each during January to December 2006, were constructed for *Z. bicolorata*. For generating life table census, 10 mated females from the laboratory culture which had already started laying eggs were released into a muslin-covered container of 75 cm diameter having 10 *P. hysterophorus* plants of about 30-40 cm height. The plants were enclosed within a muslin cage/container supported by a wire frame. The cages were properly sealed with soil from all the sides so as to avoid grub escape. The experiment had four replications. The release was made during evening hours and a muslin cloth used to prevent the adult beetles escaping from the container. After 24 hours, the cloth covering was removed and the beetles were collected back. The leaves were then observed for the number of eggs present. The eggs were observed daily until hatching. The first counting was made on the following day when all the eggs hatched. The number of eggs hatched was recorded as the initial numbers of first instar larvae. Subsequent counting was made at the end of each larval instar. A sub-sample population was maintained in the cage adequately protected to facilitate head capsule measurements to identify the exact duration of each instar. The total numbers of dead and live larvae were counted separately and the factors responsible for mortality during each stage were also studied. The final count was taken at the end of the fourth instar when the larvae neared pupation. The larvae were allowed to pupate in the same container and the emerging adult beetles were taken to the laboratory and sexed. The fecundity was determined in the laboratory. The data were summarized in a life table as described by Harcourt (1969), Elsiddig *et al.* (2006) and Babasaheb *et al.* (2010). The number of unfertilized eggs and dead larvae were tabulated.

For each life table, stage specific mortalities (k0, k1, k2......k6) and total generation mortality (K) were calculated and key mortality factor was determined. The number of unfertilized eggs, number of dead larvae and number of surviving individuals in different developmental stages of beetle were entered in the budget. Values in the budget were converted into logarithms and a series of age-specific moralities were calculated by subtracting each log population from the previous one. Total generation mortality (K) was given by summing up of all the stage specific mortalities (k) as

$$K = k_o + k_1 + k_2 + k_3 + \ldots\ldots + k_n$$

Values of sub-mortalities and total generation mortality over all the generations were plotted against respective generations. Likewise, each of the sub-mortalities over the generations was regressed upon total generation mortality to determine key mortality factor.

The generation trend index was calculated as: generation trend index = N_2/N_1, where, N_1 = actual number of eggs laid in previous generation; N_2 = expected eggs in succeeding generation. This was determined by multiplying the average fecundity of a female (744 eggs) (Antony, 1992) with the number of females at the end of the each generation.

RESULTS AND DISCUSSION

Twelve life tables of *Z. bicolorta* (Table 1) were analyzed for calculating stage specific mortalities and their causes. Survivorship curves depicting survival of *Z. bicolorata* in various developmental stages right from potential eggs onwards during 12 generations are presented in Fig. 1. Although *Z. bicolorata* was found to be active throughout the year during 2006 in Delhi, its population density fluctuated with the weather conditions. Egg laying was tremendously reduced during the winter and summer months due to harsh climatic conditions. Only during July, the number of actual eggs was similar to the potential eggs indicating occurrence of the most favourable weather for insect fecundity during this month.

Based on survival during successive development stages of the beetle, sub-mortalities (ks) and total generation mortality (K) for 12 continuous generations are shown in Table 2. Further, regression of each sub-mortality on total generation mortality revealed the following relationship:

$$k_0 = 0.2145K - 0.0216 \quad -1$$
$$k_1 = 0.1718K + 0.0069 \quad -2$$
$$k_2 = 0.1026K + 0.0972 \quad -3$$
$$k_3 = 0.0417K + 0.0665 \quad -4$$
$$k_4 = 0.0717K + 0.0018 \quad -5$$
$$k_5 = 0.1106K - 0.0327 \quad -6$$
$$k_6 = 0.2831K - 0.1148 \quad -7$$

The survivorship curves depicted higher mortality of the insect during pupal stage followed by egg and first instar larvae. Likewise regression equation (7), showed the highest regression coefficient (0.2831) between pupal mortality (k6) and total generation mortality (K). Therefore, pupal mortality was found to be the key mortality factor from insect dynamics view point. Likewise, in graphical representation (Fig. 2), pupal sub-mortality (k6) curve resembled total generation mortality curve (K). The heavy pupal mortality was ascribed to pupal malformation. However, this finding is contrary to the findings of Jayanth and Bali (1994) who reported infertility of eggs of *Z. bicolorata* as the most important mortality factor followed by pupal mortality under Bangalore conditions. This could be due to variations in climatic conditions, many generations in a year as well as adaptability of *Z. bicolorata* to adverse conditions besides several other factors (Gautam *et al.*, 2006, 2007, 2008).

Among the different factors responsible for egg mortality, failure to lay eggs and infertility, owing to high temperature conditions, were found to be important ones.

Table 1. Life table of *Z. bicolorata* on *P. hysterophorus* during January 2006

Age interval (x)	No. living at beginning of X (lx)	Factors responsible for dx	No. of dying during x (dx)	dx as a % of lx (100qx)	log (lx)	*k value
Potential eggs	7450	-	-	-	3.87	0.28
Eggs (N_1)	3900	Infertility	1350	34.61	3.59	0.31
	Unknown	650	16.67			
			2000	51.28		
Larval stage						
I	1900	Diseased	415	21.84	3.28	0.18
		Unknown	225	11.84		
		640	33.68			
II	1260	Diseased	121	9.60	3.10	0.13
		Unknown	207	16.43		
		328	26.03			
III	932	Diseased	98	10.52	2.97	0.13
		Unknown	142	15.24		
		240	25.75			
IV	692	Diseased	61	8.82	2.84	0.18
		Unknown	177	25.58		
		238	34.39			
Pupa	454	Malformed	115	25.33	2.66	0.44
		Unknown	173	38.11		
		288	63.44			
Adult	166				2.22	-
Male	54					
Female	112					
						K = 1.65

* k = log (lx)-log (lx-dx); generation mortality (K) = 1.65; generation trend index = 21.39

Regression of difference between log potential eggs and log actual eggs (k0) and total generation mortality (k) had second highest value (0.2145) followed by relation between actual egg mortality (k1) and total generation mortality (K) with 0.1718 value of regression coefficient. This finding is similar to the results of Jayanth and Bali (1994).

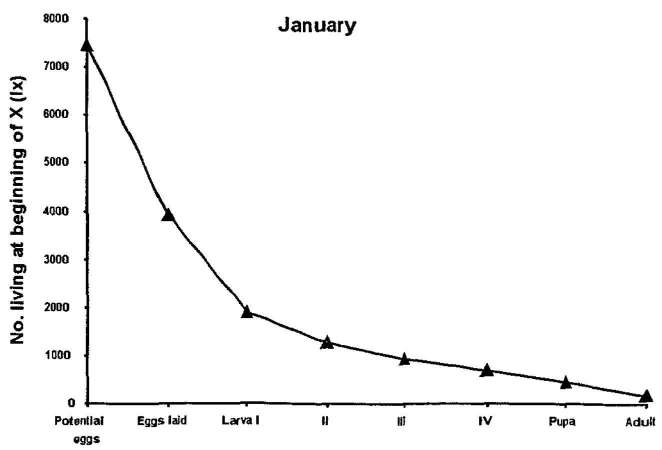
Mortality at 4th (last) larval instar (k5) was another important cause of mortality, its regression coefficient with total generation mortality being 0.1106. The main cause of this mortality was inability of the larvae to burrow into hard and dry ..oil for pupation. Though neither parasitoids nor predators were recorded on any larval stage of *Z. bicolorata* during the present study, microbial disease was found to be a dominant factor for the mortality in the first instar larvae (k2). The regression coefficient between k2 and K was determined to be 0.1026. Other mortalities in descending order of their influence were that occurring during 2nd (k3) and 3rd (k4) larval instars. Among larval stages, neonates and full-fed were thus more prone to mortality than 2nd and 3rd instars.

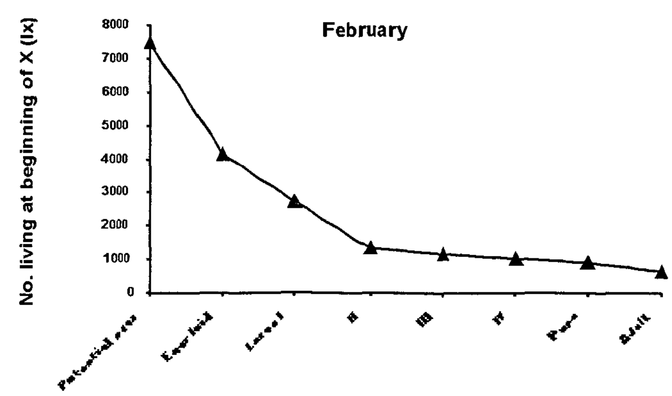
Generation trend index ranged from 21.39 in January to 272.21 in July. The total generation trend index of *Z. bicolorata* was fairly higher when compared to many other insects, which is mainly due to the very high fertility rate of *Z. bicolorata*. The present study revealed that though there are various mortality factors acting upon this insect under field conditions, *Z. bicolorata* is capable of overcoming such suppressing agents to its maximum benefits in the field. The result is similar to the findings of Jayanth and Bali (1994) who also observed high generation trend values indicating increasing biotic

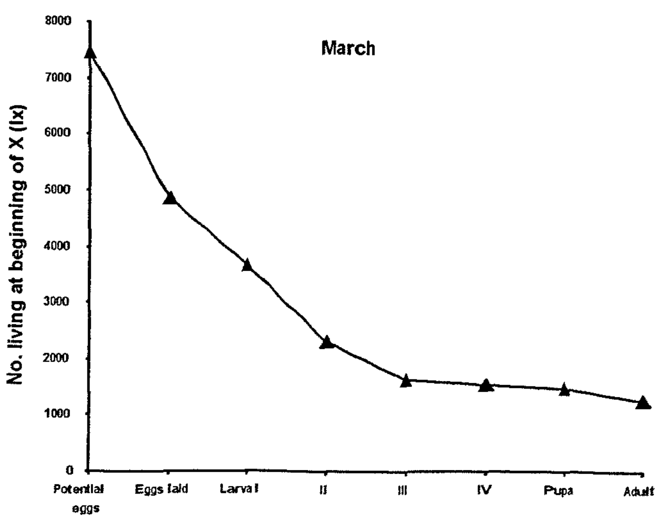
Table 2. Determination of key mortality factor for *Z. bicolorata* on *P. hysterophorus*

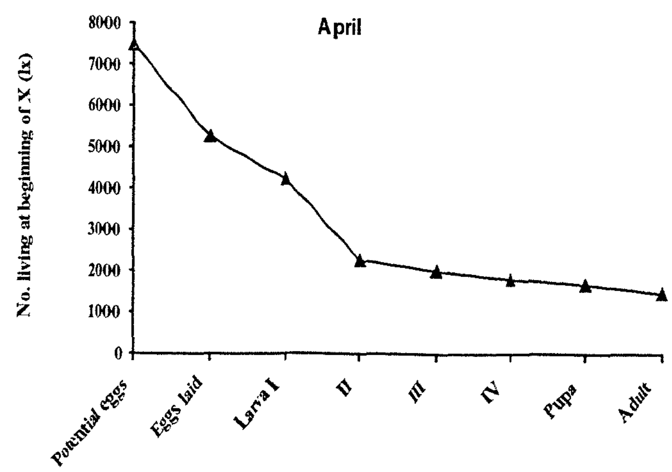
Generation	Sub-mortalities							Generation mortality (K value)
	k_0	k_1	k_2	k_3	k_4	k_5	k_6	
1	0.28	0.31	0.18	0.13	0.13	0.18	0.44	1.65
2	0.25	0.19	0.30	0.07	0.06	0.04	0.16	1.07
3	0.19	0.12	0.20	0.15	0.02	0.02	0.07	0.77
4	0.15	0.10	0.27	0.05	0.05	0.03	0.06	0.70
5	0.32	0.22	0.22	0.14	0.05	0.05	0.28	1.28
6	0.12	0.15	0.11	0.10	0.06	0.06	0.06	0.68
7	0.02	0.10	0.07	0.03	0.01	0.01	0.02	0.26
8	0.04	0.07	0.13	0.09	0.05	0.03	0.05	0.46
9	0.06	0.05	0.15	0.12	0.05	0.02	0.04	0.48
10	0.09	0.10	0.09	0.11	0.02	0.01	0.02	0.43
11	0.15	0.15	0.29	0.11	0.13	0.09	0.06	0.99
12	0.19	0.22	0.17	0.11	0.10	0.16	0.16	1.11

Regression equations between stage- specific mortalities and total generation mortality, $k_0 = 0.2145K - 0.0216$; $k_1 = 0.1718K + 0.0069$; $k_2 = 0.1026K + 0.0972$; $k_3 = 0.0417K + 0.0665$; $k_4 = 0.0717K + 0.0018$; $k_5 = 0.1106K - 0.0327$; $k_6 = 0.2831K - 0.1148$









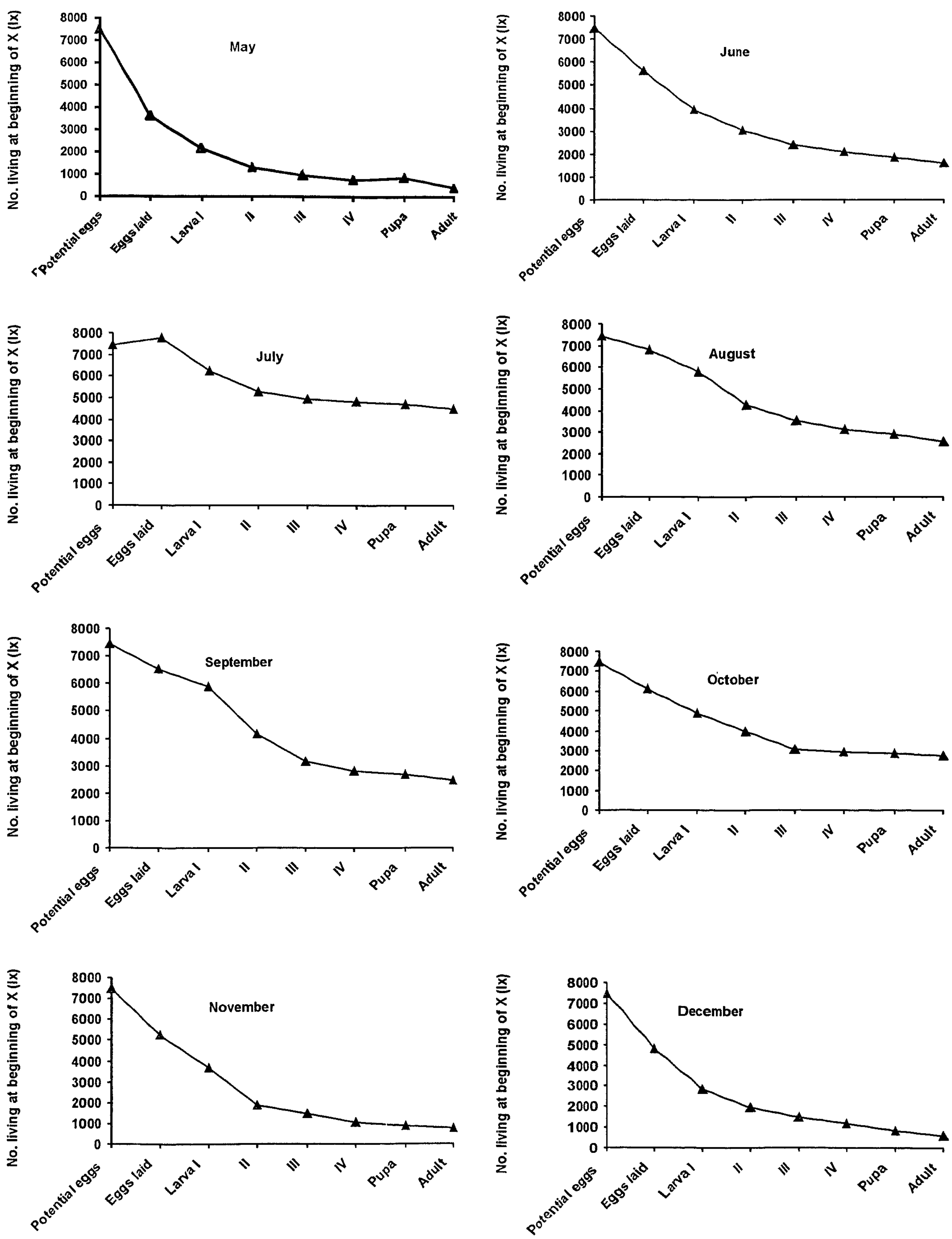


Fig. 1. Survivorship curve of *Z. bicolorata* during different months

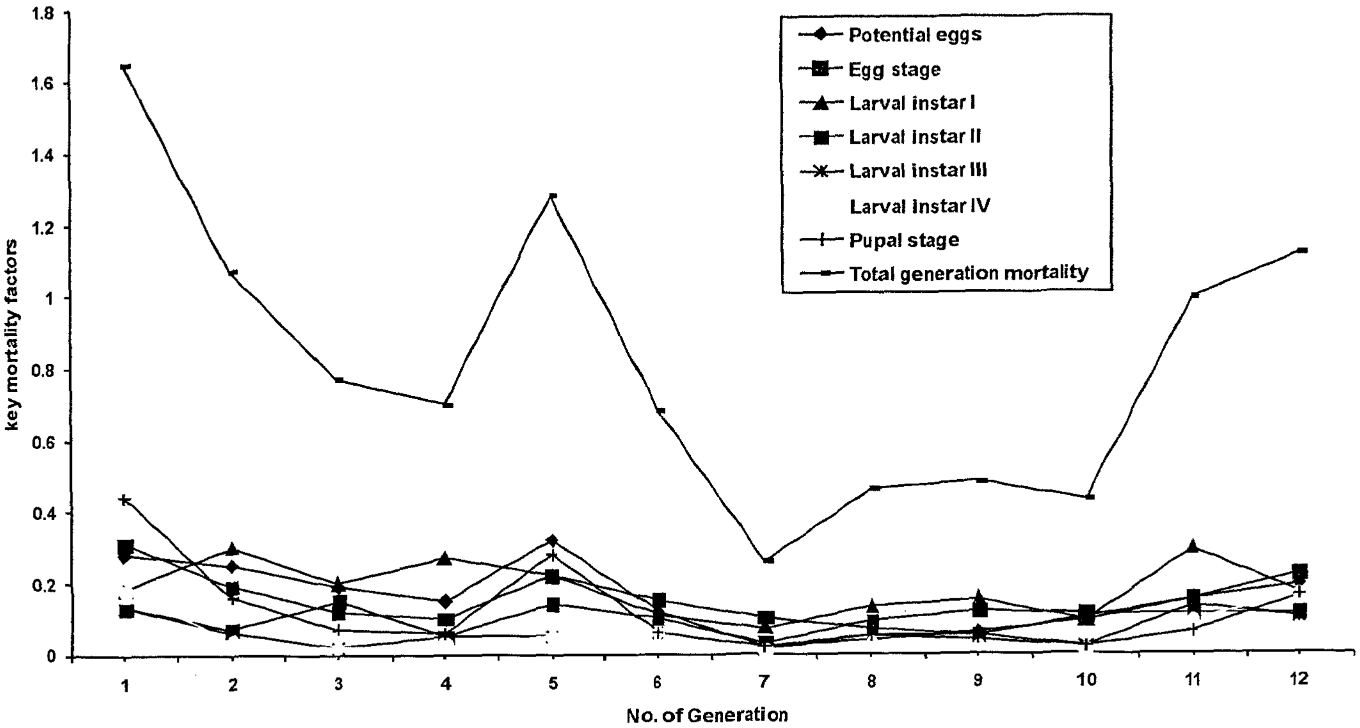


Fig. 2. Stage-specific mortality and total generation mortality of *Z. bicolorata* on *P. hysterophorus*

potential of this insect. The information on key mortality as well other important mortality factors would be helpful in devising strategies for its conservation through habitat management so as to mitigate the effect of various mortality factors on its growth and development.

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