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Stage-Specific Life Table Studies of Legume Pod Borer, *Maruca vitrata* Fabricius (Lepidoptera: Crambidae) on Different Pulses

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ABSTRACT

The legume pod borer, Marca vitrata Fabricius, is one of the major stress factors affecting the production of many grain legumes. Their webbing nature of flowers and pods can cause severe infestation, leading to significant yield loss. Identifying the vulnerable stage in the life cycle of an insect pest is critical for sustainable pest management. Hence, stage-specific life table studies of this pest was conducted in response to feeding on pulses viz., pigeon pea (cv. CO-RG-6), green gram (cv. CO-GG-7), black gram (cv. CO-BG-6), cowpea (cv. CO-7), and lablab (cv. Rohini) under laboratory conditions (27.9 ± 2.2 °C, 76.6 ± 9.1% RH). The results revealed the highest egg mortality of M. vitrata (14.0%) on black gram and the lowest (6.0%) in lablab. Among five larval instars, maximum larval mortality was recorded at the first instar stage of black gram (13.95%), followed by green gram (7.61%) as against 3.13% on lablab. The highest survival rate of 1.00 was recorded in the third and fifth instar larvae on pigeon peas and the third instar larvae on black gram. The maximum trend index of 0.91 on pigeon peas showed the highest larval survival, and the highest generation survival on lablab (0.44) and pigeon pea (0.43) indicating the emergence of a higher number of female moths. In perusal of different parameters, lablab was found to be a comparatively more suitable host for the ideal growth and development of M. vitrata.

Keywords: *Pulses, Legume pod borer, Maruca vitrata, Life table, Mortality, Pigeon pea, Lablab, Survival rate, Trend Index*

INTRODUCTION

The legume pod borer *Maruca vitrata* Fabricius is one of the major stress factors that hamper the production of many grain legumes. It causes severe infestation by webbing of flowers and pods together and results in decaying and severe yield reduction. Hence, the indirect damage is found to be very severe, with economic losses estimated at around 20%–60% under field conditions [1]. Identifying a vulnerable stage in any insect life cycle is very important, to have sound and sustainable pest management. A life table study is one such technique to get an idea about the mortality and natality of different life stages of an insect species. It is a concise summary of certain vital statistics and provides a format for recording and accounting for all population changes in the life cycle of species [2].

Life table study offers knowledge on the dynamics of insect populations. It is also used to record the biotic potential and summarize every change that occurs in the existing population during the entire life cycle. In general, classical life tables help to understand the age dynamics of laboratory-cultured adult populations under controlled conditions [3]. They are the backbone for enumerating mortality and natality data, which provide clear information on the actual properties of the cohorts. In stage-specific life table studies, the life cycle is partitioned into unique stages, and survival and reproduction data of each stage are recorded. Importantly, the mortality rate of many insects varies in their subsequent life stages, making it a vital characteristic for drawing further insights from life tables. As very little work has been carried out on *M. vitrata*, the life table studies on different host plants will give an idea about host suitability. Hence, this study was undertaken to explore the stage-specific life table of *M. vitrata* on different pulse hosts such as pigeon pea, green gram, black gram, cowpea, and lablab.

MATERIALS AND METHODS

This study on stage-specific life table for *M. vitrata* was conducted on different pulses such as pigeon pea (cv. CO-RG-6), green gram (cv. CO-GG-7), black gram (cv. CO-BG-6), cowpea (cv. CO-7), and lablab (cv. Rohini) as host plants under laboratory conditions (27.9 ± 2.2 °C, 76.6 ± 9.1% RH) at Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India, during 2012–13. The methodology followed for the life table studies of *M. vitrata* larvae on black gram was adopted [4].

Filed populations of *M. vitrata* larvae were collected from different host crops in large numbers and mass-cultured in the laboratory. The emerged adult moths were allowed for mating and egg laying. Flowers and pods of the above host crops were kept individually as substrates for oviposition. Ten pairs of adult moths from stock culture were released in plastic buckets for oviposition on flowers of individual hosts lying at the bottom of the cage. Absorbent cotton swabbed with 10% honey solution and a drop of vitamin E placed on a sterile glass vial kept inside the cage for adult moths as the food source. The top of the plastic bucket was secured with a black sterile muslin cloth, which also served as a substrate for oviposition. One hundred eggs were collected from each host and transferred to glass bottles using a wet camel hair brush and kept for further studies. Fresh flowers from respective hosts were provided daily.

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From each host, 100 eggs were collected and kept separately in glass bottles. These bottles were covered with muslin cloth and fastened with a rubber band. Likewise, three replications were maintained on each host plant. After the emergence of neonates, fresh flowers of respective pulse hosts were provided and replaced periodically. Observations on the number of individuals who survived in each life stage such as eggs, different larval instars, prepupa, pupa, and adults of both male and female were recorded daily until their natural death.

Standard egg numbers (F) were set at 100, and hatching rate of eggs (S_E), survival rate of successive larval instars S_S (S_1, 1st instar; S_2, 2nd instar; S_3, 3rd instar; S_4, 4th instar; and S_5, 5th instar), survival rate of prepupa (S_{PP}) and pupa (S_P), survival rate of adults (S_A), and female proportion in adults ($P_♀$) were recorded for each host. These empirical data were collected individually from different host plants and a stage-specific life table was computed as per previous methodologies developed [5, 6, 7, 8]. The various parameters recorded to analyze and interpret the research findings are given below:

d_x = number dying in age interval (100 individuals)

l_x = number surviving at the beginning of the age interval (out of 100 born)

$100\ q_x$ = mortality rate (per hundred) at the beginning of age interval or d_x as a percentage of l_x

S_x = survival rate within the age interval x

Mortality Survivor Ratio (MSR) = $\frac{\text{Number dying in the current stage}}{\text{Numbers alive at the next stage}}$

Cumulative surviving (%) = numbers alive – d as a per cent of l_x

Survival rate at x = $\frac{\text{Numbers alive at the next stage}}{\text{Numbers alive at the current stage}}$

k value = Difference between Log_{10} values of numbers of individuals alive at the current stage and numbers alive at successive life stage

Trend index = $\frac{\text{Number of fifth instar larvae}}{\text{Number of neonate larvae}}$

Generation survival = $\frac{\text{Number of female moths}}{\text{Number of neonate larvae}}$

Trend index (I) = $N_1/N_0 = S_E S_S S_{PP} S_P S_A P_♀$

S_E - survival rates of eggs

S_S - survival rates of different larval instars

S_{pp} - survival rates of prepupae

S_p - survival rates of pupae

S_A - survival rate of adults

$P_♀$ - female proportion in adults

Population trend index (I) was worked out from population growth potential between current (N_0) and next generations (N_1).

Analysis of variance was done and mean values concerning mortality and survival were separated by Tukey's HSD [9] at a 5 percent significance level [10]. The statistical analysis was conducted using the SPSS 16.0 version and the critical p- value of 0.05 was set and interpreted.

RESULTS

Apparent mortality

The perusal of tables 1–5 about mortality of *M. vitrata* at different life stages revealed pronounced variations in the trend of mortality. At the egg stage, the highest percent mortality was recorded as 14.0 in black gram followed by 10.0% and 8.0% on pigeon pea and green gram whereas cowpea and lablab recorded the least mortality of 6.0%. Among larval instars, the mortality was maximum at the first instar stage on the black gram (13.95 %), followed by 7.61% on the green gram as against 3.13% on the lablab. In the second instar, *Maruca* larvae showed the least mortality of 2.33% in pigeon peas followed by 3.53% in green gram when compared to 6.38% and 6.59% in lablab and cowpea, respectively. In the third instar, *Maruca* larvae showed a minimum mortality of 2.82% in black gram and a maximum of 8.24% on cowpea, and no mortality was observed among the third instar larvae on pigeon pea. The morality in the fourth instar larvae ranged from 2.38% to 6.49% on pigeon peas and green gram, respectively. The fifth instar larvae of *M. vitrata* reared on pigeon pea and black gram successfully transformed to prepupal stage and showed no mortality whereas mortality rates ranged from 2.50% to 2.78% on lablab and green gram, respectively. The prepupal stage showed a mortality ranging from 2.44% on pigeon peas to 8.33% on cowpeas. The pupal stage of *M. vitrata* showed 4.41% mortality in green gram followed by 6.25%, 6.67%, and 7.58% in pigeon pea, cowpea, and lablab respectively. Black gram showed the highest mortality of 11.29%.

Survival rate

Variation in the survival rate (fraction) of *M. vitrata* eggs was of low order: 0.86, 0.90, 0.92, 0.94, and 0.96 on black gram, pigeon pea, green gram, cowpea, and lablab, respectively (Tables 1–5). In the case of first instar larvae, the lowest survival rate of 0.86 was recorded on black gram, and other hosts showed higher survival rates, ranging from 0.92 on green gram to 0.98 in lablab. Second instar larvae showed the lowest survival rate of 0.93 in lablab and cowpea compared to 0.98 in pigeon pea flowers. Third instar *M. vitrata* larvae showed the highest survival rate in pigeon pea (1.00), followed by 0.97 in lablab and black gram compared to 0.92 in cowpea.

However, there was no significant difference in survival rates among different pulses in four instar larvae, with rates varying from 0.94 to 0.98 on the green gram and pigeon pea, respectively. The five instar *M. vitrata* larvae showed the highest survival rate of 1.00 in pigeon pea and black gram, whereas it was 0.98 in lablab and 0.97 in green gram and cowpea. In the prepupal stage, the values were found to be insignificant, ranging from 0.92 on cowpea to 0.98 on pigeon peas. *M. vitrata* pupa showed the highest survival rate in green gram (0.96), followed by pigeon pea (0.94), lablab (0.93), and cowpea (0.92). The lowest survival rate of 0.89 was recorded on black gram.

Mortality survivor ratio

Of all the stages of *M. vitrata*, mortality survivor ratio (MSR) was highest at egg stages of pigeon pea (0.11), green gram (0.09), and black gram (0.16), and third instar larvae and prepupal stages of cowpea (0.09) and lablab (0.08). The ratio, however, remained zero for the third and fourth larval instars of pigeon pea and the fifth instar of black gram, resulting in complete transformation to subsequent stages without any mortality. First, larval instar had the lowest MSR value of 0.03 in cowpea and lablab as against 0.15 in black gram. The minimum MSR value in the second larval instar was recorded as 0.02 in pigeon pea, followed by 0.04 in green gram and black gram when compared to 0.07 in cowpea and lablab. In the third instar of *M. vitrata* it varied from 0.03 on black gram to 0.09 on cowpea. In the fifth instar *Maruca* larvae, the MSR value was 0.02 in pigeon peas compared to 0.07 in green gram. The fifth instar larvae showed MSR of 0.03 on the green gram, cowpea, and lablab. The prepupa recorded an MSR of 0.03 in pigeon pea and cowpea and 0.09 in cowpea. When pupal stages were examined, the lowest MSR was registered in green gram (0.05), followed by 0.07 in pigeon pea and lablab. The highest MSR of 0.13 was observed in black gram populations of *M. vitrata* (Tables 1–5).

k values

The *k* values of different life stages of *M. vitrata* varied according to the stages in different pulse hosts and there was no steady increase or decrease in *k* values in all hosts (Tables 1–5). In pigeon peas, the maximum *k* value was observed during the egg stage (0.0458), and the minimum value was recorded during the third and fifth larval instars (0.0000). In green gram and black gram, the highest *k* values were recorded in the egg stage (0.0362 and 0.0655) compared to 0.0000 (black gram) and 0.0122 (green gram) in the fifth instar larvae. In cowpea, *k* values ranged from 0.0119 in prepupa to 0.0378 in the fifth instar larvae. The maximum and minimum *k* values of 0.0336 and 0.0152 were obtained from lablab-reared populations of *M. vitrata.* Overall, the total generation mortality *K* was lowest on *M. vitrata* reared on pigeon pea (0.0156), followed by lablab (0.0194), green gram (0.0234), and black gram (0.0325) compared to the maximum mortality recorded on cowpea (0.0407) populations.

Trend Index

The trend index showed its highest value in *M. vitrata* populations from pigeon pea (0.91), followed by lablab (0.83) and cowpea (0.79) when compared to slightly lower values of 0.78 for green gram and black gram populations. But the maximum generation survival of *M. vitrata* was recorded on lablab (0.44), followed by pigeon pea (0.43), black gram (0.39), and green gram (0.38) whereas cowpea registered the lowest value of 0.18 (Tables 1–5).

DISCUSSION

Among different life stages the maximum mortality was observed in the egg stage followed by the first instar, prepupa, and pupal stages irrespective of different hosts when compared to the least dying in the fifth instar stage (Fig. 1). This might be due to the development of resistance against ill effects of host nutrition if any and good adaptability to the growing environment. Being continuously exposed to the host and environment and the ingested nutrition in their corresponding previous life stage might be attributed to the relatively higher mortality in the immobile stages such as prepupa, pupa, and eggs. Earlier life studies on *M. vitrata* are lacking, however, the results of the present study align with the findings in *Helicoverpa armigera* Hubner [11]. When comparing the five pulse crops, on black gram, the finite rate of mortality (0.14) of egg and first instar larvae was more. Among the five hosts studied, cowpea and lablab showed the least mortality at different stages, followed by pigeon peas and green gram. Comparatively, across life stages, rearing on black gram showed the highest finite rate of mortality (Fig. 1) irrespective of different life stages. Additionally, lablab relatively contributed to better nourishment and production of a greater number of individuals. Similarly, it was found that lablab could support 4–6 generations of *M. vitrata* with higher survival at different life stages under laboratory conditions [12]. Earlier reports showed that the mean fecundity of *M. vitrata* was lower than its net reproductive rate when reared at 20 C on cowpea, indicating a considerably higher survival rate [13]. The egg [6], larva, and adult [14] stages are reported to be ideal for finding out the proper trend index of an insect population.

The survival curves of *M. vitrata* on different pulses showed higher survival in lablab for early larval stages, while later stages received greater support from pigeon pea (Fig. 2). During the late instar stages, the death rate decreases on each host plant. This may be because of well-developed mouth parts, which could contribute easy feeding and host plant suitability. Similarly, Sambathkumar *et al.* (2017) [15] recorded a relatively good assimilation rate of lablab and pigeon pea by *M. vitrata* during mass culturing. A minor mortality of larvae was also found at later stages of development, possibly due to the variation in nutritional value of host plants. Among different hosts tested, on flowers of black gram, the rate of survival was found to be low irrespective of life stages. On the contrary, some studies showed a higher rate of survival, reproduction, and other related parameters on black gram [4]. This variation might be due to the variety of the crops selected for the life table studies, laboratory conditions, and the extent of host preference. Similarly, the maximum survival of *Pieris brassicae* Linnaeus was recorded at matured stages of development on all cole crops, with cabbage as the ideal host [16].

It is also clearly evident from the finite rate of mortality and pattern of survivorship curve that egg and larval stages of *M. vitrata* contribute to the highest population growth irrespective of host crop compared to pupa and adult stages (Figs 1 and 2). This is in line with the earlier findings on *M. vitrata* populations grown in black gram [4], green gram, and azukibean [17]. On chickpeas, it was earlier reported that eggs and larval stages of *H. armigera* contributed the maximum to their stable age [18]. Similarly, there were records for a major role of egg and larvae in the stable age distribution of *Spodoptera litura* Fabricius when cultured on castor and Lucerne [19]. Life expectancy of *M. vitrata* from egg to adult stages declines gradually irrespective of all pulse hosts evaluated (Figs 1 and 2). Similar observations were also recorded in *S. litura* [19] and *Plutella xylostella*

Linnaeus on lucerne and cabbage [20]. The survivorship curve (Fig. 2) indicated a modest rate of mortality during the early life stages and a gradual decrease as it approached adulthood irrespective of the host crop. The curve resembles a near-type III survivorship curve, which is common in many insects. This is in line with the findings on rice BPH, *Nilaparvatha lugens* Stal [21]. The survivorship pattern of *M. vitrata* indicated that larval stages were influenced by food and nutrition quality and they may be susceptible to the density-dependent factors such as food or host crop. Similar effects of different food sources on population parameters were observed in *Earias vitella* Fabricius [20] and *Diaphorina citri* Kuwayama [22]. These are mainly due to the influence of food sources and environmental factors on insect growth and development.

In practice, the *k* value is a valid measure of mortality of life stages compared to percent mortality. As *k* values are additive in nature, showing a combination of independent mortality processes. They provide a comprehensive idea of the mortality of insects by considering different life stages. Across different hosts, the maximum and minimum *k* values were associated with different stages. Notably in the current study, eggs, prepupa, and pupal stages had maximum *k* values, which showed a higher mortality during these stages. Similar results were recorded in *H. armigera* on chickpeas [11]. Among different hosts studied, the highest *k* value was recorded in black gram for the egg stage (0.0655) and second instar (0.0653) larval stage.

The highest trend index was recorded on pigeon peas followed by lablab, which showed that the host plants are highly suitable for larval feeding. Similarly, the generation survival was also maximum on pigeon pea and lablab compared to 0.18 on cowpea, aligns with the sex ratio studies of field populations of *M. vitrata.* These studies revealed that pigeon peas and lablab supported the emergence of the maximum number of female moths whereas in cowpea, the ratio was biased toward males. Comparatively, the higher trend index values from pigeon peas, followed by lablab and cowpea, indicated a higher rate of successful larval development from early instars to pupa. Moreover, good generation survival on pigeon peas and lablab showed a higher production of female moths from initially laid eggs. These parameters are good indices for higher-generation sustainability and population growth in the subsequent generations [8]. Hence, it is clear that the above hosts are highly suitable for culturing of *M. vitrata.* Shorter development time and higher rates of reproduction with a low mortality rate of any insects on a particular host reveal a greater adoption and suitability of a host plant [23]. It is also very clear that the mortality rate of *M. vitrata* declined gradually with the increase in the age of development. This is in line with similar studies conducted on green gram [24].

The present study showed the maximum survival was on lablab whereas, cowpea and lablab showed the lowest mortality at different stages. In the biology studies, Sambathkumar *et al.* (2023) [25] recorded the maximum host preference of *M. vitrata* was in the order of cowpea followed by lablab, green gram, pigeon pea, and black gram. Further, field studies have reported the highest infestation rates of *M. vitrata* on lablab, cowpea [26], and redgram [27], irrespective of the seasons and varieties of the crop. Hence, it is evident that lablab, followed by cowpea and pigeon pea, provide optimum conditions for the growth and development of *M. vitrata.*

Generally, in holometamorphic insects, the larval food is decided by the egg-laying female, and oviposition is based on cues that relate to the extent of larval survival. The selection of an oviposition site is a critical factor as slow-moving neonates must locate their suitable host plant [28] and may severely suffer until they find their ideal host food [29]. In general, it is very difficult to understand the influence of life table parameters on an insect under laboratory conditions compared to field conditions due to continuous exposure of insects to ever-changing environmental conditions [30]. However, previous laboratory studies have shown that different room temperatures can help to gain knowledge on insect growth and development, and also help to design effective and sustainable Integrated Pest Management (IPM) Programs [31]. Hence, pesticide treatments under the IPM program are an important component for managing sycamore lace bug, *Corythucha ciliate* Say [32]. The ideal time for the application of pesticides can further be fine-tuned by conducting various laboratory experiments on different vulnerable growth stages to get the status of considerable reduction of pesticide application against *M. vitrata.* Moreover, the mortality rates of early and late stages are often higher than those of the intermediate stages, which are in agreement with the previous findings [33]. Also, to improve the effectiveness of pest management, it is necessary to calculate the survival rate, stage differentiation, and fecundity [34].

Conclusion

The present life table study showed a clear picture of the survival and mortality pattern of *M. vitrata* from egg to adult stages. It may help in pest management by identifying the most vulnerable stages, offering the potential to increase the mortality rates sustainably through the demographic characteristics of *M. vitrata* populations. These studies are also essential for ecological management programs. However, from the present study, it can be concluded that lablab is a comparatively ideal food source for the population development of *M. vitrata*, followed by cowpea and pigeon pea. Further research is also needed to expand the process of building a sustainable generation and mass culturing, through promissive artificial diets that will be useful for many scientific studies. Similarly, this kind of stage specific or vertical life table studies in hidden feeders like *M. vitrata* would be helpful to identify the susceptible stages for release of biocontrol agents and also the ideal time for pesticide application without harm the environment.

CONFLICTS OF INTEREST

All authors declare no conflict of interest regarding the publication of this article.

AUTHORS CONTRIBUTION

SSK conceived the original idea. SSK and CD initiated and designed the work. SMK and NG guided the lab experiments. SSK conducted all experiments and collected and analyzed the data. SSK wrote the manuscript with support from CD, and NG.

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Table 1. Stage specific life table of M. vitrata on pigeon pea

Age interval	Number alive	Proportion of alive [B/100]	Factors responsible *dx*	Number dying during *x*	Finite rate of mortality *(d/lx)*	Apparent mortality	Mortality survivor ratio	Cumulative surviving (%)	Survival rate	Log no/ stage	*k* value
(x)	***(I_x)***	***(lx)***	-	***d_x***	***q_x***	***100qx***	***MSR***	-	-	-	-
Egg (S_E)	100	1.00	Unknown	10	0.1	10.00	0.11	90.00	0.90	2.0000	0.0458
First Instar (S_1)	90	0.90	Unknown	4	0.044	4.44	0.05	85.56	0.96	1.9542	0.0197
Second Instar (S_2)	86	0.86	Unknown	2	0.023	2.33	0.02	83.67	0.98	1.9345	0.0102
Third Instar (S_3)	84	0.84	Unknown	0	0.000	0.00	0.00	84.00	1.00	1.9243	0.0000
Fourth Instar (S_4)	84	0.84	Unknown	2	0.024	2.38	0.02	81.62	0.98	1.9243	0.0105
Fifth Instar (S_5)	82	0.82	Unknown	0	0.000	0.00	0.00	82.00	1.00	1.9138	0.0000
Prepupa (S_{PP})	82	0.82	Unknown	2	0.024	2.44	0.03	79.56	0.98	1.9138	0.0107
Pupa (S_P)	80	0.80	Unknown	5	0.063	6.25	0.07	73.75	0.94	1.9031	0.0280
Adult moths (S_A)	75	0.75	-	-	-	-	-	-	-	-	-
Adult male ($P_♂$)	32	0.32	♂	-	-	-	-	-	-	-	-
Adult female ($P_♀$)	43	0.43	♀	-	-	-	-	-	-	-	-
Trend index	**0.91**									***k* = 0.0156**	
Generation survival	**0.43**										

x- Insect life stage; Ix- Number of survivors at the beginning of each stage; lx- Survival rate from egg stage to the beginning of egg stage; dx- Number of deaths during each stage; qx- Rate of mortality of life stage to the proportion alive

Table 2. Stage specific life table of M. vitrata on green gram

Age interval	Number alive	Proportion of alive [B/100]	Factors responsible *dx*	Number dying during *x*	Finite rate of mortality *(d/lx)*	Apparent mortality	Mortality survivor ratio	Cumulative surviving (%)	Survival rate	Log no/ stage	*k* value
(x)	***(I_x)***	***(lx)***	-	***d_x***	***q_x***	**100qx**	**MSR**	-	-	-	-
Egg (S_E)	100	1.00	Unknown	8	0.08	8.00	0.09	92.00	0.92	2.0000	0.0362
First Instar (S_1)	92	0.92	Unknown	7	0.076	7.61	0.08	84.39	0.92	1.9638	0.0344
Second Instar (S_2)	85	0.85	Unknown	3	0.035	3.53	0.04	81.47	0.96	1.9294	0.0156
Third Instar (S_3)	82	0.82	Unknown	5	0.061	6.10	0.06	75.90	0.94	1.9138	0.0273
Fourth Instar (S_4)	77	0.77	Unknown	5	0.065	6.49	0.07	70.51	0.94	1.8865	0.0292
Fifth Instar (S_5)	72	0.72	Unknown	2	0.028	2.78	0.03	69.22	0.97	1.8573	0.0122
Prepupa (S_{PP})	70	0.70	Unknown	2	0.029	2.86	0.03	67.14	0.97	1.8451	0.0126
Pupa (S_P)	68	0.68	Unknown	3	0.044	4.41	0.05	63.59	0.96	1.8325	0.0196
Adult moths (S_A)	65	0.65	-	-	-	-	-	-	-	-	-
Adult male ($P_♂$)	27	0.27	♂	-	-	-	-	-	-	-	-
Adult female ($P_♀$)	38	0.38	♀	-	-	-	-	-	-	-	-
Trend index	**0.78**									***k* = 0.0234**	
Generation survival	**0.38**										

x- Insect life stage; Ix- Number of survivors at the beginning of each stage; lx- Survival rate from egg stage to the beginning of egg stage; dx- Number of deaths during each stage; qx- Rate of mortality of life stage to the proportion alive

Table 3. Stage specific life table of M. vitrata on black gram

Age interval	Number alive	Proportion of alive [B/100]	Factors responsible *dx*	Number dying during *x*	Finite rate of mortality *(d/lx)*	Apparent mortality	Mortality survivor ratio	Cumulative surviving (%)	Survival rate	Log no/ stage	*k* value
(x)	*(I_x)*	*(lx)*	-	d_x	q_x	**100qx**	**MSR**	-	-	-	-
Egg (S_E)	100	1.00	Unknown	14	0.14	14.00	0.16	86.00	0.86	2.0000	0.0655
First Instar (S_1)	86	0.86	Unknown	12	0.140	13.95	0.15	72.05	0.86	1.9345	0.0653
Second Instar (S_2)	74	0.74	Unknown	3	0.041	4.05	0.04	69.95	0.96	1.8692	0.0180
Third Instar (S_3)	71	0.71	Unknown	2	0.028	2.82	0.03	68.18	0.97	1.8513	0.0124
Fourth Instar (S_4)	69	0.69	Unknown	2	0.029	2.90	0.03	66.10	0.97	1.8388	0.0128
Fifth Instar (S_5)	67	0.67	Unknown	0	0.000	0.00	0.00	67.00	1.00	1.8261	0.0000
Prepupa (S_{PP})	67	0.67	Unknown	5	0.075	7.46	0.08	59.54	0.93	1.8261	0.0337
Pupa (S_P)	62	0.62	Unknown	7	0.113	11.29	0.13	50.71	0.89	1.7924	0.0520
Adult moths (S_A)	55	0.55	-	-	-	-	-	-	-	-	-
Adult male ($P_♂$)	16	0.16	♂	-	-	-	-	-	-	-	-
Adult female ($P_♀$)	39	0.39	♀	-	-	-	-	-	-	-	-
Trend index	**0.78**									***k* = 0.0325**	
Generation survival	**0.39**										

x- Insect life stage; Ix- Number of survivors at the beginning of each stage; lx- Survival rate from egg stage to the beginning of egg stage; dx- Number of deaths during each stage; qx- Rate of mortality of life stage to the proportion alive

Table 4. Stage specific life table of M. vitrata on cowpea

Age interval	Number alive	Proportion of alive [B/100]	Factors responsible *dx*	Number dying during *x*	Finite rate of mortality *(d/lx)*	Apparent mortality	Mortality survivor ratio	Cumulative surviving (%)	Survival rate	Log no/ stage	*k* value
(x)	*(I_x)*	*(lx)*	-	d_x	q_x	**100qx**	**MSR**	-	-	-	-
Egg (S_E)	100	1.00	Unknown	6	0.06	6.00	0.06	94.00	0.94	2.0000	0.0269
First Instar (S_1)	94	0.94	Unknown	3	0.032	3.19	0.03	90.81	0.97	1.9731	0.0141
Second Instar (S_2)	91	0.91	Unknown	6	0.066	6.59	0.07	84.41	0.93	1.9590	0.0296
Third Instar (S_3)	85	0.85	Unknown	7	0.082	8.24	0.09	76.76	0.92	1.9294	0.0373
Fourth Instar (S_4)	78	0.78	Unknown	4	0.051	5.13	0.05	72.87	0.95	1.8921	0.0229
Fifth Instar (S_5)	74	0.74	Unknown	2	0.027	2.70	0.03	71.30	0.97	1.8692	0.0119
Prepupa (S_{PP})	72	0.72	Unknown	6	0.083	8.33	0.09	63.67	0.92	1.8573	0.0378
Pupa (S_P)	66	0.66	Unknown	5	0.076	7.58	0.08	58.42	0.92	1.8195	0.0342
Adult moths (S_A)	61	0.61	-	-	-	-	-	-	-	-	-
Adult male ($P_♂$)	43	0.43	♂	-	-	-	-	-	-	-	-
Adult female ($P_♀$)	18	0.18	♀	-	-	-	-	-	-	-	-
Trend index	**0.79**									***k* = 0.0268**	
Generation survival	**0.18**										

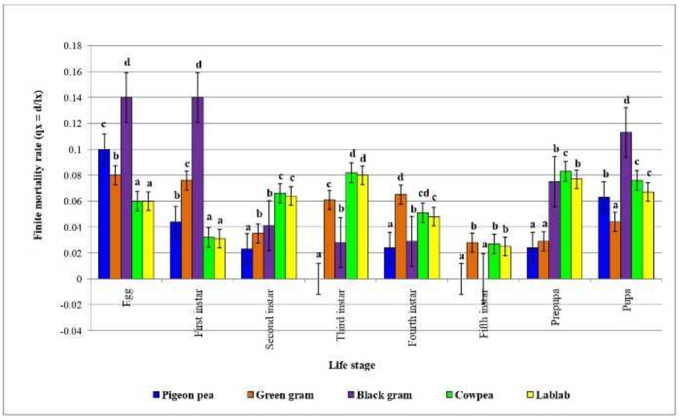
x- Insect life stage; Ix- Number of survivors at the beginning of each stage; lx- Survival rate from egg stage to the beginning of egg stage; dx- Number of deaths during each stage; qx- Rate of mortality of life stage to the proportion alive

Table 5. Stage specific life table of M. vitrata on lablab

Age interval	Number alive	Proportion of alive [B/100]	Factors responsible *dx*	Number dying during *x*	Finite rate of mortality *(d/lx)*	Apparent mortality	Mortality survivor ratio	Cumulative surviving (%)	Survival rate	Log no/ stage	*k* value
(x)	*(I_x)*	*(lx)*	-	d_x	q_x	100qx	MSR	-	-	-	-
Egg (S_E)	100	1.00	Unknown	6	0.06	6.00	0.06	94.00	0.96	2.0000	0.0177
First Instar (S_1)	96	0.96	Unknown	3	0.031	3.13	0.03	92.88	0.98	1.9823	0.0091
Second Instar (S_2)	94	0.94	Unknown	6	0.064	6.38	0.07	87.62	0.93	1.9731	0.0336
Third Instar (S_3)	87	0.87	Unknown	7	0.080	8.05	0.08	78.95	0.97	1.9395	0.0152
Fourth Instar (S_4)	84	0.84	Unknown	4	0.048	4.76	0.05	79.24	0.95	1.9243	0.0212
Fifth Instar (S_5)	80	0.8	Unknown	2	0.025	2.50	0.03	77.50	0.98	1.9031	0.0110
Prepupa (S_{PP})	78	0.78	Unknown	6	0.077	7.69	0.08	70.31	0.96	1.8921	0.0170
Pupa (S_P)	75	0.75	Unknown	5	0.067	6.67	0.07	68.33	0.93	1.8751	0.0300
Adult moths (S_A)	70	0.70	-	-	-	-	-	-	-	-	-
Adult male ($P_♂$)	26	0.26	♂	-	-	-	-	-	-	-	-
Adult female ($P_♀$)	44	0.44	♀	-	-	-	-	-	-	-	-
Trend index	**0.83**									***k* = 0.0194**	
Generation survival	**0.44**										

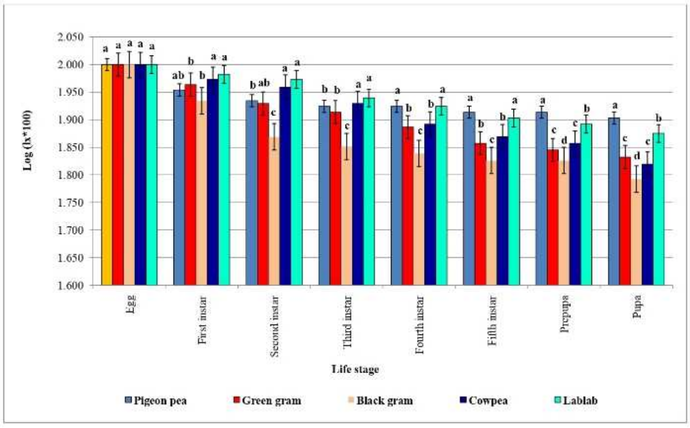
x- Insect life stage; Ix- Number of survivors at the beginning of each stage; lx- Survival rate from egg stage to the beginning of egg stage; dx- Number of deaths during each stage; qx- Rate of mortality of life stage to the proportion alive

Fig. 1 Finite rate of mortality of M. vitrata on different pulses under in vitro



**One-way ANOVA; P < 0.05, Tukey's HSD; Mortality values each parameter are out of three replications and 100 individuals per replication; The error bars indicate the Standard Error; Different alphabets on the error bar for the host crop are statistically significant @ P < 0.05*

Fig. 2 Survivorship curve of M. vitrata on different pulses under in vitro



**One-way ANOVA; P < 0.05, Tukey's HSD; Mortality values for each parameter are out of three replications and 100 individuals per replication; The error bars indicate the Standard Error; Different alphabets on the error bar for the host crop are statistically significant @ P < 0.05*

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