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Field life tables and key mortality factors of *Pieris brassicae* (Linnaeus) (Lepidoptera, Pieridae) infesting cauliflower (*Brassica oleracea* var. *botrytis*) in Punjab, India

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ABSTRACT: To find out the key mortality factors of *Pieris brassicae* (Linnaeus) on cauliflower (*Brassica oleracea* var. *botrytis*), this study of field life table was conducted during 2021-22 at the research farm of the Punjab Agricultural University, Ludhiana, Punjab. Among biotic factors, *Cotesia glomerata*, *Beauveria bassiana* (Bals.), NPV, *Bacillus thuringiensis* (Berliner) were the main causes of mortality. Other unknown factors (temperature, rainfall, relative humidity) also contrived slight decline to all the immature stages of *P. brassicae.* Results revealed that the egg stage (17.46-28.35%) affected due to unknown factors, whereas, early larval instar stage (I-III) was the most sensitive, showing the highest loss (36.62-43.95%) followed by the late larval instar stage (25.77-29.43%) and pupal stage (16.19-22.41%). The trend index was positive during both seasons 16.91 (main season) and 19.17 (late season), indicating that population of *P. brassicae* increased in next season. Similar trend was observed in generation survival i.e. 0.39 (main season) and 0.32 (late season). © 2024 Association for Advancement of Entomology

KEY WORDS: Biotic factors, trend index, mortality, parasitisation, survivorship curves

INTRODUCTION

Cauliflower (*Brassica oleracea* var. *botrytis*) is one of the most crucial and widely grown vegetable crops in the world with maximum nutritive value. Many biotic and abiotic factors are responsible for low production and productivity of cauliflower crop in India. Being pest, *Pieris brassicae* (Linnaeus) (Lepidoptera, Pieridae) is the major biotic factor limiting the quality of cauliflower more than 40 per cent yield loss annually in India (Ali and Rizvi, 2007). This pest is largely managed by the use of toxic insecticidal chemicals which have their own adverse and ill-effects such as the development of insecticide resistance, pesticide residues and resurgence besides environmental pollution (Manyangarirwa, 2009). This entails the development of another possible control strategy that can be made a part of integrated pest management module. Life tables play a major role in pest management because it describes the growth, survival and fecundity (Nisar and Rizvi, 2021). It provides the format for recording all the population changes in the life cycle and quantifies the mortality in the population of the insect. These kind of ecological life tables provide a basis to

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quantify rates of death from various factors over generation (Naranjo and Ellsworth, 1999). The life table is of two types: cohort or generation life table and period life tables (Damanpreet *et al.,* 2022). The cohort or generation life table summarizes the age-specific mortality experience of a given birth cohort for its life and the period life table summarizes the age-specific mortality conditions pertaining to a given or short period of time. Through life table studies, determination of the most vulnerable stage for time-based application of insecticides for insect pest control can be known (Ning *et al.,* 2017). Various weather factors play a key role for the incidence and development of insect pests and understanding of these factors is vital to the population dynamics study, predicting pest outbreaks and in the development of pest management strategies (Chandi *et al.,* 2021). Therefore, it is vital to create life tables for *P. brassicae* under various circumstances in order to have a better knowledge of the diversity in the pest's demography. The published studies that focused on the ecology of this pest continuously over two crop seasons are not available in India, despite a significant amount of research on the influence of different abiotic and biotic factors on the development of *P. brassicae* population that has been used for constructing its life tables. The goal of the current work was to determine the key mortality factors of *P. brassicae* on cauliflower crop and develop an appropriate integrated management strategy for use in the field by analysing population variations through life tables.

MATERIALS AND METHODS

The experiment on life table studies of *P. brassicae* on cauliflower was carried out at Entomological Research Farm, Punjab Agricultural University, Ludhiana, Punjab during 2021-2022. Under Punjab conditions, cauliflower is grown in three season viz. early season (July-October), main season (September-December) and late season (December-March). But population of *P. brassicae* was observed during main season and late season crop. No incidence of *P. brassicae* was observed during early season crop. Life tables studies of *P. brassicae* were conducted on main season (September-December) and late season crop (December-March) of 2021-22.The mean temperature and RH on main season crop during the months of September, October, November, December was 28.1, 24.3, 18.7, 13.7°C and 71, 61, 61, 62 per cent, respectively. Similarly, on late season crop during January, February, March was 12.8, 14.8, 23.3°C and 83, 71, 63 per cent, respectively. The crop was grown in accordance with recommended package of practices (Anonymous, 2021). For the purpose of tracking the mortality of various pest life stages due to various parasitoids and other factors, several life stages of *P. brassicae* were taken from an unsprayed cauliflower crop and raised accordingly. Since there were overlapping generations, the life table was constructed for the entire season. *P. brassicae* was sampled from 20 quadrates of 2m x 2m of main season (September-December) and late season (December-March) crop during 2021-22 and then it was computed on hectare basis. Regular visits were made to examine the initial incidence of *P. brassicae* with respect to appearance of eggs on cauliflower crop and to determine mortality due to unviability and parasitisation. For efficient sampling of larval instars, they were grouped into two categories. The stage I-III was considered as early instars and IV-V as late instars. In each observation number of larvae was counted in randomly selected quadrates and the population was computed on hectare basis from the average obtained from the quadrates.

The different life stages were collected at weekly intervals and raised in Petri dishes with fresh leaves until pupation in order to determine mortality. The observations were recorded on mortality in different larval groups due to various biotic factors like parasitoids, bacteria, fungus and virus etc. and it was continued up to pupation. Based on the level of mortality at each developmental stage of the pest, a definite number of larvae of different larval groups were collected from cauliflower field for determination of the survival rate. To study the mortality factors during pupal stage, the pupae were collected from field and kept in cages for adult emergence and observations on number of deformed pupae, unsuccessful emergence and

unknown causes were recorded. To determine fecundity, the newly laid eggs were daily collected. For construction of life table, data was collected regarding the growth and survival of *P. brassicae* and its natural enemies. The observations recorded for pivotal age were (egg, larva, pupa, adult); number of individuals at beginning; number of individuals died; factors responsible for mortality; per cent apparent mortality; survival rate. The data on development and survival of *P. brassicae* and their natural enemies were observed for construction of life table. The different observations recorded as per given in (Table 1).

Table 1. Column heading and denotion of various parameters of life table

Heading	Denotion
x	Pivotal age
l_x	Number of individuals at beginning
d_x	Number of individuals died
d_{xf}	Factors responsible for mortality
100qx	Apparent mortality
S_x	Survival rate

The following standards and steps recommended by (Harcourt, 1963) and (Atwal and Bains, 1974) for creating the life table for various developmental stages: In order to determine egg survival (l_x) and mortality (d_x), eggs from the main and late season crops in 2021-22 were used. The first, second, and third larval instars were among the younger larvae. By directly sampling the quadrates, the l_x value for this group of larvae was determined and computed on a per-hectare basis. Fourth and fifth larval instars were among the older stages. Larval mortality owing to parasites, fungi, viruses, bacteria, and other unknown causes was subtracted from the population of younger larvae to determine the l_x value for older larvae. The mortality brought on by parasites, viruses, bacteria, fungi and other unknown factors from the older group of larvae was subtracted to determine the l_x value for pupa. Based on number of adults emerged from the pupa, the l_x for moths was determined. Mortality reported during pupal stage was subtracted from the l_x value of pupae. The Generation survival was determined by taking ratio of the number of females×2 (N3) by the number of younger larvae (N1) i.e. N3/N1. The trend index value "I" was calculated by taking population of the same developmental stage in two successive generations i.e.N2/N1 (Atwal and Singh, 1990).

Identification of key mortality factors: Determining the stage that has a significant impact on the index of population trend (I) or generation survival (SG) is the most important step in understanding population fluctuations. To determine the important variables that primarily impacted the population trend in both the main and late cauliflower crop, a separate budget was created. Richards (1961) created the key factors analysis method, and using this method, the killing power (K) of these mortality factors in each age group was calculated as the difference between the population density logarithms before and after its action. The overall killing power of "K" equals the sum of the killing powers of "k's" since a sequence of mortality factors operate in succession during the formation of a population. If,

K_0= log lx of egg stage - log lx of younger larval stage.
K_1 = log lx of younger larval stage -log lx of older larval stage
K_2 = log lx of older larval stage - log lx of pupal stage
K_n = log lx of pupal stage - log lx of adult stage
K thus equals $K_0 + K_1 + K_2 + K_n$.

Survivorship curve: The best way to display variations in *P. brassicae* population trend on the cauliflower crop was through survivorship curves, according to (Southwood, 1978). A survivorship curve is a graph in which the number (y axis) at a certain age (l_x) is plotted against age to demonstrate what percentage of a beginning group is still alive at each succeeding age (x). Typically, four different types of curves are obtained, each of which explains different mortality factor functions.

RESULTS AND DISCUSSION

During main season crop, the number of individuals at the beginning was 14850 (Table 2). The larval stages were divided into two different categorises *viz.,* early instar larvae (I-III instars), late instar

larvae (IV-V instars) and mortality factors (Figs. 1, 2) were categorised group-wise. Early instar larval stage (36.62%) had the highest mortality rate, followed by late instar larval stage (25.77%), egg stage (17.46%), and pupal stage (16.19%) (Fig. 3). The leading cause of egg mortality (17.46%) was unviability. The overall mortality recorded at this stage in early instar larvae, which originally had 12257 larvae, was 4489. *Cotesia glomerata*, a larval parasitoid, was the major factor of mortality among the numerous factors, accounting for 20.21% of all deaths, followed by Nucleopolyhedrovirus (7.88%) and unknown factors (1.39%). *Bacillus thuringiensis* (Berliner) and the fungus *Beauveria bassiana* (Bals.) were responsible for 4.70 and 2.41 per cent of the mortality, respectively. Fedosimov and Tsedev (1970) reported that *C. glomerata* killed 1 to 2 per cent of *P. brassicae* larvae and also observed numerous *Bacillus* species as well as one each of Diplococcus, Micrococcus and Vibrio shaped bacteria. *Bacillus* and *Pseudomonas* have been found in *P. brassicae* larvae, but no evidence of pathogenicity has been found.

At the end, 7768 early instar larvae were still alive. In the late instar larval stage; there was an overall mortality rate of 25.77 per cent, of which the

Table 2. Life table of *P. brassicae* for main season on cauliflower crop during 2021-22

Age interval	No. in the beginning	Factor for death	No. died	Mortality %	Survival rate
x	l_x	$d_{x\,F}$	d_x	100qx	S_x
Eggs	14850	Unviability	2593	17.46	0.82
Early instar larvae (I-III instar) (N1)	12257	*Cotesia glomerata*	2478	20.21	0.63
		NPV	967	7.88	
		Beauveria bassiana	577	4.70	
		Bacillus thuringiensis	296	2.41	
		Unknown factors	171	1.39	
		Total	4489	36.62	
Late instar larvae (IV-V)	7768	*Cotesia glomerata*	1038	13.36	0.74
		NPV	615	7.91	
		Beauveria bassiana	207	2.66	
		Unknown factors	142	1.82	
		Total	2002	25.77	
Pupa	5766	Pupal deformity	479	8.30	0.83
		Unsuccessful emergence	337	5.84	
		Unknown factors	118	2.44	
		Total	934	16.19	
Moths	4832	Sex 50 per cent			
Females x 2 (N3)	4832				
Reproducing female	2416				

Expected eggs = 289267; Number of dead/Sterile eggs = 82036; Expected viable eggs = 207231; Actual number of younger larvae in main season (N_2) = 207231; Trend index ($I=N_2/N_1$)= 16.91; Generation survival ($SG=N_3/N_1$)= 0.39

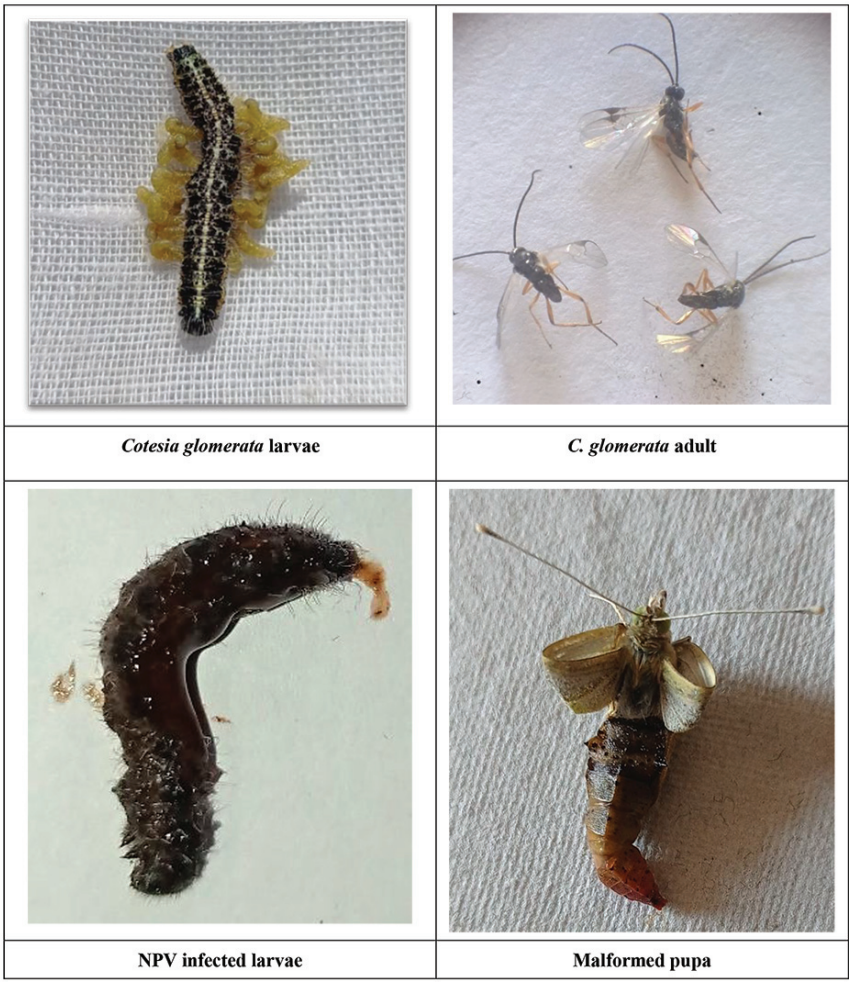

Fig. 1 Mortality factors recorded on *Pieris brassicae*

parasitoid *C. glomerata* alone was responsible for 13.36 per cent, while NPV, *B. bassiana* and unknown factors were responsible for 7.91, 2.66 and 1.82 percent of the mortality, respectively. Shapiro (1976) observed that the effect of dietary regime of the host on the growth of specific parasites, finding that *C. glomerata* parasitized 80-90 per cent of the larvae. Karnavar (1983) reported parasitism of 92.68-93.43 per cent in *P. brassicae* larvae by *C. glomerata*.

The results make it evident that *C. glomerata* caused parasitization in both early and late instar larvae. However, maximum parasitization was observed in early instar larvae which were due to the contribution of mortality of third instar larvae. Similarly, Razmi *et al*. (2011) observed the parasitism rate and parasitoid diversity of *P. brassicae* on cole crops and recorded *P. puparum* reducing pest number by 46.13-49.65 per cent, *C. glomerata* reducing pest number by 43.45-45.57 per cent in pupal stage and *B. femorata* by 2.43-4.89 per cent during different years in larval stage. Ahmad *et al*. (2007) observed that mortality of the larvae was greater during starting days due to high death rate of early instars.

There were 5766 late instar larvae alive at the end. The causes that contributed to pupal mortality in the pupal stage were pupal deformities (8.30%), unsuccessful emergence(5.84%) and unknown factors (2.44%). The main season cauliflower crop

Fig. 2 Mortality factors recorded on *Pieris brassicae*

had a positive trend index of 16.91, indicating that total mortality during this season was ineffective in causing pest population to decline and there will be more chances for population growth during the following season. The generation survival of 0.39 indicated that 39 per cent of the initial population could survive and successfully complete their generation (Table 2). The data analysis (Table 3) revealed that the highest mortality observed in early instar larval stage (K=0.1980) followed by late instar larval stage (K=0.1294), egg stage (K= 0.0833) and pupal stage (K=0.0767).

The initial population size for the late season crop was 289267 (Table 4). The early instar larval stage (43.95%) had the highest mortality rate, followed by the late instar larval stage (29.43%), egg stage (28.35%) and pupal stage (22.41%). Infertility was the leading cause of the egg mortality, which contributed about 28.35 per cent. Early instar larvae (I-III) mortality factors were primarily caused by *C. glomerata* (23.87%), NPV (9.98%), *B. bassiana* (5.63%), *B. thuringiensis* (3.66%) and unknown factors (0.80%). *C. glomerata*, NPV, *B. bassiana*, and unknown factors were the causes of larval mortality in the late larval instars (IV-V), accounting for 16.77, 7.37, 4.02 and 1.25 percent, respectively. The main causes of pupal mortality during the pupal stage were deformities (17.32%), unsuccessful emergence (4.12%), and unknown factors (1.18%). Third generation egg mortality was 35 as opposed to second generation's 28.35 per cent. Rizvi *et al.* (2009) documented that the mortality survival ratio and apparent mortality was found highest in pupal stage (0.19 and 15.91%) on Indian mustard and lowest at the pre-pupal stage

Table 4. Life table of *P. brassicae* for late season on cauliflower cropduring 2021-22

Age interval	No. of individuals in the beginning	Factor responsible for death	No. of individuals died	Mortality per cent	Survival rate
x	l_x	$d_{x\,F}$	d_x	100qx	S_x
Eggs	289267	Unviability	82036	28.35	0.71
Early instar larvae (I-III instar) (N_1)	207231	*Cotesia glomerata*	49467	23.87	0.56
		NPV	20697	9.98	
		Beauveria bassiana	11673	5.63	
		Bacillus thuringiensis	7587	3.66	
		Unknown factors	1674	0.80	
		Total	91098	43.95	
Late instar larvae (IV-V)	116133	C. glomerata	19484	16.77	0.70
		NPV	8566	7.37	
		Beauveria bassiana	4674	4.02	
		Unknown factors	1454	1.25	
		Total	34178	29.43	
Pupa	81955	Pupal deformity	14202	17.32	0.81
		Unsuccessful emergence	3377	4.12	
		Unknown factors	788	1.18	
		Total	18367	22.41	
Moths	66588	Sex 50 %			
Females x 2 (N_3)	66588				
Reproducing female	33294				

Expected eggs = 6112445; Number of dead/Sterile eggs = 2139356; Expected viable eggs= 3973089; Actual number of younger larvae in main-season (N_2)= 3973089; Trend index($I=N_2/N_1$)= 19.17; Generation survival ($SG=N_3/N_1$) = 0.32

(0.04 and 3.39 per cent) on cabbage and survival fraction was recorded highest (0.97) in the pre-pupal stage on cabbage and lowest (0.84) in pupal stage on Indian mustard.

Indicating that different mortality factors during this season were ineffective in causing the pest population to decline, the generation survival and positive trend index in the main season cauliflower crop was 0.32 and 19.17, respectively. This means that there will be a greater chance of increase in population during the following season (Table 4). The early instar larvae (K=0.2514), late larval instar stage (K=0.1513), egg stage (K=0.1448), and pupal stage (K=0.0901) contributed the most to the "K" value (Table 3). The findings are very similar to Ali

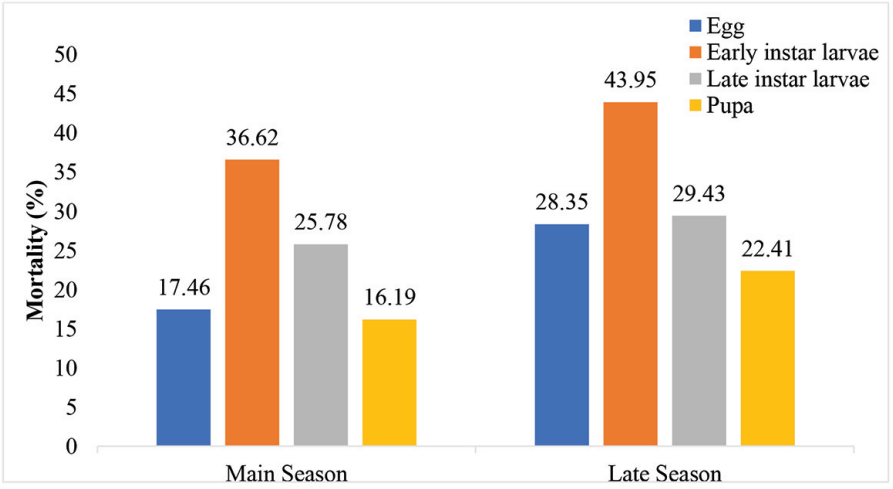

Fig. 3 Per cent mortality at different stages of *P.brassicae* for main season and late season crop during 2021-22

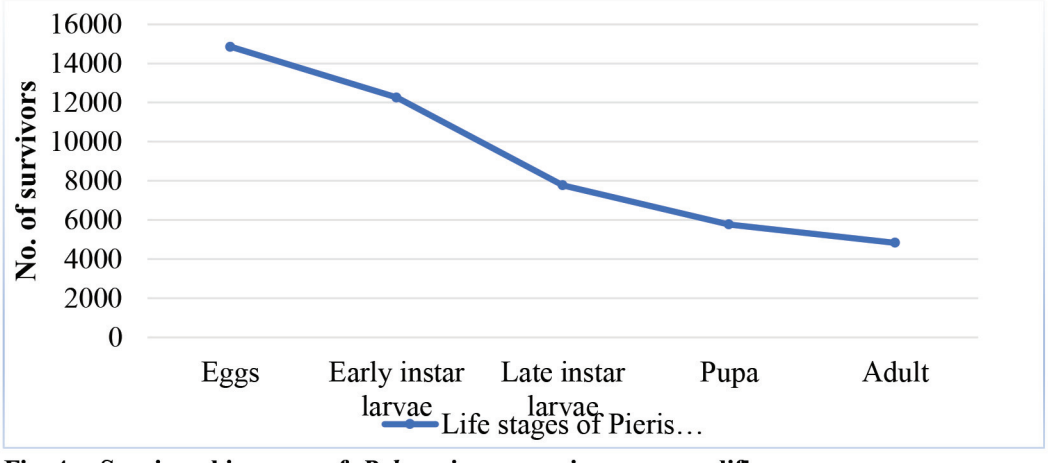

Fig. 4 Survivorship curve of *P. brassicae* on main season cauliflower crop

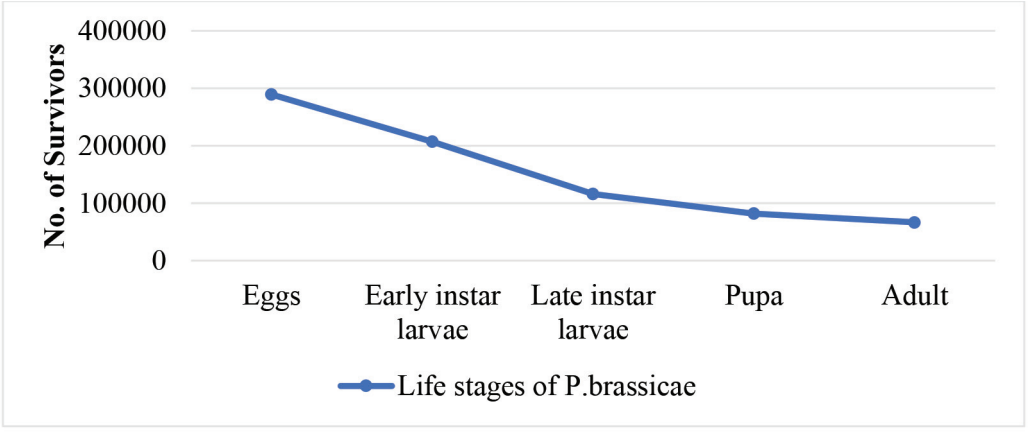

Fig. 5 Survivorship curve of *P. brassicae* on late season cauliflower crop

Table 3. Budget of *P. brassicae* on late season on cauliflower crop during 2021-22

Age interval	No's/ha		Log no's/ha		K' value	
	Main	Late	Main	Late	Main	Late
Expected eggs	14850	289267	4.1717	5.4612	0.0833	0.1448
Actual early instar larvae (I-III)	12257	207231	4.0883	5.3164	0.1980	0.2514
Actual late instar larvae after mortality	7768	116133	3.8903	5.0649	0.1294	0.1513
Actual pupae after mortality	5766	81955	3.7608	4.9135	0.0767	0.0901
Moth/ Adults	4832	66588	3.6841	4.8233	-	-
Reproducing females	2416	33294	-	-	-	
K Value					0.4042	0.4930

and Rizvi (2007) who found that the total K values of *P. brassicae* on cabbage, cauliflower, gobhi sarson, and yellow sarson, respectively, were 0.2486, 0.3042, 0.3216 and 0.3645, respectively.

***Survivorship curves*:** The most effective way to display differences of *P. brassicae* population trend on main and late season cauliflower crop. The highest mortality rate was seen in the early phases of the insect life cycle, and it was noted that the curve obtained in the current study was almost identical to type III curve. On main season as well as on late season crop, it appears that early instar larval death was more rapid (Fig. 4). Further, the survival was more in main season crop as compared to late season crop (Fig. 5). However, the combined outcome of the two curves indicated a continuous decline in *P. brassicae* survival by the pupal and adult stages. Therefore, the mortality at various developmental phases, such as the early instar larval stage, late instar larval stage, and egg stage, would have a stronger impact on population decrease of *P. brassicae* on cauliflower crop both during 2021-22. Similarly, (Rizvi *et al*., 2009) reported that the survivorship declined gradually from starting stage of development till the culmination of the generation on cauliflower. *P. brassicae* exhibited minimum mortality and maximum survival on cabbage leaves than other cole crops as it preferred cabbage for its fast and healthy development over other cole crops.

Overall, the results gave the impact that different variables play in population fluctuation in the field and for formulating prevention methods for *P. brassicae* on cauliflower. The potential of the ecosystem's natural enemies should be utilised since they are crucial in reducing the intrinsic rate of increase, which lowers the cost of insect control. By gathering the dead insects affected by the disease, the fungus attacking *P. brassicae* in natural environment should be identified and controlled. Local isolates are always a better option than commercial formulations and further research should be done to determine whether they have any potential as biopesticides. Researching field life tables of *P. brassicae* is an ongoing endeavour for identifying the main causes of mortality including biotic and abiotic factors. The identification of critical *P. brassicae* mortality factors through the study of field life tables should be emphasised for implementing an effective and long-term management programme for *P. brassicae* on cauliflower crop.

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