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AGE AND STAGE-SPECIFIC LIFE-TABLE OF CABBAGE BUTTERFLY, *PIERIS BRASSICAE* L. (*LEPIDOPTERA: PIERIDAE*) ON VARIOUS COLE CROPS

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Abstract: To study the response of cabbage butterfly, *Pieris brassicae* on cabbage, cauliflower, yellow sarson, gobhi sarson and Indian mustard, various life tables *i.e.*, age specific and stage specific life tables have been constructed in controlled conditions (25±1°C, 65±5% R.H. and 12 h L:12 h D). The age specific life-table revealed that *P. brassicae* required maximum period of 42 days on Indian mustard and minimum 36 days on cabbage to complete the generation. The survivorship decreased gradually from an initial stage of development till culmination of the generation on each host plant. However, mortality showed a significant variation at different development stages of *P. brassicae* on each host plant. The apparent mortality and mortality survival ratio was found highest at pupal stage (15.91 and 0.19%) on Indian mustard and lowest at pre-pupal stage (3.39 and 0.04%) on cabbage. Similarly, maximum k-value (0.0753) was recorded at pupal stage on Indian mustard and minimum (0.0150) at pre-pupal stage on cabbage. On the other hand, survival fraction was recorded highest (0.97) at pre-pupal stage on cabbage and lowest (0.84) at pupal stage on Indian mustard. The life-table parameters revealed that cabbage is the most preferred food of *P. brassicae* than other cole crops.

Key words: cabbage butterfly, life-table, survival, mortality, cole crops

INTRODUCTION

The term cole crop used to describe several vegetables and oilseeds growing in winter season and require 15.6–21.1°C temperature for proper growth. Due to a high nutritional value for human, these crops are extensively grown in various parts of the world. It provides much needed dietary fibers, essential minerals and vitamins. Certain insect-pests, mites and diseases reduce the yield of cole crops (Prasad 2006). Among them insect pest alone causes more than 40% of yield loss annually (Ali and Rizvi 2007). Pajmon (1999) listed about 38 insect pests fed on different vegetables, among them, cabbage butterfly, *Pieris brassicae* is one of the most destructive pest. It damages all the growing parts of the plant such as leaves, branches and pods (Lal and Ram 2004). During development single larva of *P. brassicae* consume 74–80 cm^2 leaf area (Younas *et al*. 2004).

The study of life table provides detailed information on survivorship, development, mortality and reproduction of target species. A lot of work has been done on utilization of food, population ecology and development response of cabbage butterfly, but there was no published report on the life-table of *P. brassicae*. Therefore, we use the age and stage specific life-table theory to analyze the impact of cabbage butterfly on cole crops under controlled conditions.

MATERIALS AND METHODS

The cole crops namely cabbage (*Brassica oleracea* var. capitata), cauliflower (*Brassica oleracea* var. botrytis), yellow sarson (*Brassica rapa* var. yellow sarson), gobhi sarson (*Brassica napus*) and Indian mustard (*Brassica juncea*) were raised in the winter season of year 2005–2006 at the experimental field of the Department of Plant Protection, Faculty of Agriculture Sciences, Aligarh Muslim University, Aligarh, India. All these crops were monitored regularly to assess oviposition of butterfly in field. The butterfly commence egg laying in the first week of November on cabbage and cauliflower, while on rapeseed-mustard (gobhi sarson, yellow sarson and Indian mustard) eggs were seen in the last week of November. The eggs laid by butterfly were found in clusters at under side of leaves. They were collected from respective crop and placed in BOD incubator calibrated at 25±1°C with 65±5% relative humidity and 12 L:12 D photoperiod. After hatching, the cluster of 5 caterpillars (zero day old) in 20 replications, making a cohort of 100, were reared in a plastic vial (6x10 cm) on leaves of respective host plant. When the caterpillars reached in to second larval instar, they were reared individually in separate vials till formation of adult and their subsequent death was also noticed. On adult emergence, the male and female reared in different sized nylon mesh cage on respective host plant. The cages were designed in accordance to the plant height.

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The height maintained 2 feet for cabbage and cauliflower; 3 feet for yellow sarson and 6 feet for Indian mustard and gobhi sarson. A sugar socked cotton swab along with flowers of respective host plant was also provided in the cage for feeding of the butterfly. The data obtained was analyzed for age and stage specific life-tables as per suggestions of Birch (1948) and Southwood (1978).

Age specific life-table

The number of alive and dead, out of hundred larvae was recorded daily and the following assumptions were used in the documentation of age specific life-table.

x = age of the insect in days

l_x = number of individuals survive at the beginning of each age interval x out of 100

d_x = number of individuals die during the age interval x out of 100

$100q_x$ = per cent mortality, computing through following equation:

$$100q_x = [d_x / l_x] \times 100$$

e_x = expectation of life or mean life remaining for individuals of age x

Life expectation was calculated by using the equation:

$$e_x = T_x / L_x$$

To obtain e_x two other parameters L_x and T_x were also computed as below

L_x = the number of individuals alive between age x and x+1 and calculated by the equation:

$$L_x = l_x + 1\ (x+1)/2$$

T_x = the total number of individuals of x age units beyond the age x and obtained by the equation:

$$T_x = l_x + (l_x + 1) + (l_x + 2) \ldots\ldots\ldots\ldots\ldots\ldots + l_w$$

where, l_w = the last age interval

Stage specific life-table

The data on stage specific survival for eggs, larvae, pupae and adults were recorded from the age specific survival and mortality life-table. The data obtained from such table were used for computing various life parameters as given below.

Apparent mortality

It gives the information on number dying as percentage of number entering that stage and was calculated by using formula:

$$\text{Apparent Mortality } (100\ q_x) = [d_x / l_x] \times 100$$

Survival fraction

Data obtained on apparent mortality were used for calculation of the stage specific survival fraction (S_x) of each stage by using equation:

$$S_x \text{ of particular stage} = [l_x \text{ of subsequent stage}] / [l_x \text{ of particular stage}]$$

Mortality survivor ratio

It is the increase in population that would have occurred if the mortality in the stage, in question had not occurred and was calculated as follows:

$$\text{MSR of particular stage} = [\text{Mortality at particular stage}] / [l_x \text{ of subsequent stage}]$$

Indispensable mortality

This type of mortality would not be there in case the factor(s) causing it is/are not allowed to operate. However, the subsequent mortality factors operate. The equation is:

IM = Number of adults emerged x M.S.R. of particular stage

k-values

It is the key factor, which is primarily responsible for increase or decrease in number from one generation to another and was computed as the difference between the successive values for "log l_x". The total generation mortality was calculated by adding the k-values of different developmental stages of the insect, which is indicated as "K" (Southwood 1978).

$$K = k_E + k_{L1} + k_{L2} + k_{L3} + k_{L4} + k_{L5} + k_{PP} + k_P$$

Where, k_E, k_{L1}, k_{L2}, k_{L3}, k_{L4}, k_{L5}, k_{PP} and k_P are the k-values at egg, first instar, second instar, third instar, fourth instar, fifth instar, pre-pupal and pupal stages.

RESULTS

Age specific life-table

Comparative study on age specific life table of cabbage butterfly on different host plant revealed that it required maximum of 42 days to complete generation on Indian mustard followed by 40 days on yellow sarson, 38 days on gobhi sarson, 37 days on cauliflower and 36 days on cabbage. The survival and mortality of *P. brassicae* was recorded maximum during first ten days on each host plant and remained stable for few days, thereafter, it decreased till the culmination of generation. The mortality at adult stage was recorded between 31 to 36 days on cabbage, 31 to 37 days on cauliflower, 34 to 38 days on gobhi sarson, 36 to 40 days on yellow sarson and 38 to 42 days on Indian mustard. When the life expectancy was computed, it plummeted sharply on Indian mustard as compared to other cole crops (Table 1).

Table 1. Age specific life table of cabbage butterfly, *P. brassicae* on different host plants

Age (in days) (x)	Individuals survive (l_x)	Individuals dying (d_x)	% mortality ($100q_x$)	Expectation of life (e_x)
Cabbage				
0	100.00	0.00	0.00	5.35
1–5	100.00	17.00	17.00	4.75
6–10	83.00	16.00	19.28	4.58
11–15	67.00	4.00	5.97	4.13
16–20	63.00	6.00	9.52	3.39
21–25	57.00	2.00	3.51	2.56
26–30	55.00	4.00	7.27	1.65
31–35	51.00	42.00	82.35	1.15
36	9.00	9.00	100.00	1.00
Cauliflower				
0	100.00	0.00	0.00	5.24
1–5	100.00	18.00	18.00	4.66
6–10	82.00	15.00	18.29	4.47
11–15	67.00	7.00	10.45	4.07
16–20	60.00	6.00	10.00	3.42
21–25	54.00	2.00	3.70	2.60
26–30	52.00	5.00	9.62	1.72
31–35	47.00	35.00	74.47	1.20
36–37	12.00	12.00	100.00	1.00
Gobhi sarson				
0	100.00	0.00	0.00	5.47
1–5	100.00	18.00	18.00	4.91
6–10	82.00	15.00	18.29	4.78
11–15	67.00	6.00	8.96	4.40
16–20	61.00	10.00	16.39	3.88
21–25	51.00	2.00	3.92	3.23
26–30	49.00	5.00	10.20	2.40
31–35	44.00	1.00	2.27	1.49
36–38	43.00	43.00	100.00	1.00
Yellow sarson				
0	100.00	0.00	0.00	5.37
1–5	100.00	19.00	19.00	4.83
6–10	81.00	15.00	18.52	4.71
11–15	66.00	6.00	9.09	4.33
16–20	60.00	10.00	16.67	3.82
21–25	50.00	4.00	8.00	3.23
26–30	46.00	2.00	4.35	2.38
31–35	44.00	4.00	9.09	1.48
36–40	40.00	40.00	100.00	1.00
Indian mustard				
0	100.00	0.00	0.00	5.37
1–5	100.00	19.00	19.00	4.83
6–10	81.00	15.00	18.52	4.71
11–15	66.00	6.00	9.09	4.33
16–20	60.00	11.00	18.33	3.85
21–25	49.00	5.00	10.20	3.34
26–30	44.00	1.00	2.27	2.51
31–35	43.00	2.00	4.65	1.56
36–40	41.00	38.00	92.68	1.07
41–42	3.00	3.00	100.00	1.00

Table 2. Stage specific life table of cabbage butterfly, *P. brassicae* on different host plants

Stages x	No. Surviving at the beginning of the stage l_x	No. Dying in each stage d_x	Apparent mortality $100q_x$	Survival fraction S_x	Mortality/survivor ratio of the stage MSR	Indispensable mortality IM	Log l_x	k-values
Cabbage								
Egg	100.00	11.00	11.00	0.89	0.12	6.43	2.00	0.0506
Larva 1	89.00	12.00	13.48	0.87	0.16	8.10	1.95	0.0629
Larva 2	77.00	7.00	9.09	0.91	0.10	5.20	1.89	0.0414
Larva 3	70.00	4.00	5.71	0.94	0.06	3.15	1.85	0.0256
Larva 4	66.00	3.00	4.55	0.95	0.05	2.48	1.82	0.0202
Larva 5	63.00	4.00	6.35	0.94	0.07	3.53	1.80	0.0285
Pre-pupal	59.00	2.00	3.39	0.97	0.04	1.82	1.77	0.0150
Pupal	57.00	5.00	8.77	0.91	0.10	5.00	1.76	0.0399
Adult	52.00	52.00	100.00	–	–	–	1.72	–
								K=0.2555
Cauliflower								
Egg	100.00	12.00	12.00	0.88	0.14	6.27	2.00	0.0555
Larva 1	88.00	13.00	14.77	0.85	0.17	7.97	1.94	0.0694
Larva 2	75.00	8.00	10.67	0.89	0.12	5.49	1.88	0.0490
Larva 3	67.00	5.00	7.46	0.93	0.08	3.71	1.83	0.0337
Larva 4	62.00	3.00	4.84	0.95	0.05	2.34	1.79	0.0215
Larva 5	59.00	5.00	8.47	0.92	0.09	4.26	1.77	0.0385
Pre-pupal	54.00	2.00	3.70	0.96	0.04	1.77	1.73	0.0164
Pupal	52.00	6.00	11.54	0.88	0.13	6.00	1.72	0.0532
Adult	46.00	46.00	100.00	–	–	–	1.66	–
								K=0.2988
Gobhi sarson								
Egg	100.00	13.00	13.00	0.87	0.15	6.43	2.00	0.0605
Larva 1	87.00	10.00	11.49	0.89	0.13	5.58	1.94	0.0530
Larva 2	77.00	10.00	12.99	0.87	0.15	6.42	1.89	0.0604
Larva 3	67.00	6.00	8.96	0.91	0.10	4.23	1.83	0.0407
Larva 4	61.00	6.00	9.84	0.90	0.11	4.69	1.79	0.0450
Larva 5	55.00	4.00	7.27	0.93	0.08	3.37	1.74	0.0328
Pre-pupal	51.00	2.00	3.92	0.96	0.04	1.76	1.71	0.0174
Pupal	49.00	6.00	12.24	0.88	0.14	6.00	1.69	0.0567
Adult	43.00	43.00	100.00	–	–	–	1.63	–
								K=0.3337
Yellow sarson								
Egg	100.00	14.00	14.00	0.86	0.16	6.51	2.00	0.0655
Larva 1	86.00	11.00	12.79	0.87	0.15	5.87	1.93	0.0594
Larva 2	75.00	9.00	12.00	0.88	0.14	5.45	1.88	0.0555
Larva 3	66.00	5.00	7.58	0.92	0.08	3.28	1.82	0.0342
Larva 4	61.00	6.00	9.84	0.90	0.11	4.36	1.79	0.0450
Larva 5	55.00	5.00	9.09	0.91	0.10	4.00	1.74	0.0414
Pre-pupal	50.00	3.00	6.00	0.94	0.06	2.55	1.70	0.0269
Pupal	47.00	7.00	14.89	0.85	0.18	7.00	1.67	0.0700
Adult	40.00	40.00	100.00	–	–	–	1.60	–
								K=0.3565
Indian mustard								
Egg	100.00	14.00	14.00	0.86	0.16	6.02	2.00	0.0655
Larva 1	86.00	10.00	11.63	0.88	0.13	4.87	1.93	0.0537
Larva 2	76.00	10.00	13.16	0.87	0.15	5.61	1.88	0.0613
Larva 3	66.00	6.00	9.09	0.91	0.10	3.70	1.82	0.0414
Larva 4	60.00	8.00	13.33	0.87	0.15	5.69	1.78	0.0621
Larva 5	52.00	5.00	9.62	0.90	0.11	3.94	1.72	0.0439
Pre-pupal	47.00	3.00	6.38	0.94	0.07	2.52	1.67	0.0286
Pupal	44.00	7.00	15.91	0.84	0.19	7.00	1.64	0.0753
Adult	37.00	37.00	100.00	–	–	–	1.57	–
								K=0.3879

Stage specific life-table

The various parameters on mortality and survival of *P. brassicae* were calculated in the form of apparent mortality, survival fraction, mortality survival ratio, indispensable mortality, k-value and reviewed in table 2.

Apparent mortality

At egg stage, the apparent mortality was recorded maximum (14.00%) on yellow sarson as well as Indian mustard and minimum (11.00%) on cabbage. At larval instars, the highest mortality (14.77%) was noticed at first instar on cauliflower and lowest (4.55%) at fourth instar on cabbage. Similarly, at pre-pupal and pupal stages, the maximum mortality (6.38 and 15.91%, respectively) was found on Indian mustard and minimum (3.39 and 8.77%, respectively) on cabbage (Table 2).

Survival fraction

The maximum survival fraction (0.89), at egg stage was recorded on cabbage and minimum (0.86) on yellow sarson as well as Indian mustard. At different larval instars, the highest fraction (S_x) was obtained (0.95) at fourth instar on cabbage and cauliflower, whereas, lowest (0.85) at first instar on cauliflower. On the other hand, at prepual stage maximum S_x (0.97) was found on cabbage in contrast to minimum (0.94) on yellow sarson and Indian mustard. Similarly, at pupal stage high S_x was recorded (0.91) on cabbage and low (0.84) on Indian mustard (Table 2).

Mortality survival ratio

At egg stage, highest ratio (0.16) was obtained on yellow sarson and Indian mustard as compared to lowest (0.12) on cabbage. While comparing larval instars, maximum mortality survival ratio (0.17) was found at first instar on cauliflower and minimum (0.05) at fourth instar on cabbage as well as cauliflower. At pre-pupal stage, it remained high (0.07) on Indian mustard and low (0.04) on cabbage, cauliflower and gobhi sarson. At pupal stage MSR ranged from 0.10 to 0.19 on different host plant (Table 2).

Indispensable mortality

The highest indispensable mortality (6.51) at egg stage was recorded on yellow sarson and lowest (6.02) on Indian mustard. At larval stages, indispensable mortality (IM) was noticed maximum (8.10) at first instar on cabbage and minimum (2.34) at fourth instar on cauliflower. At pre-pupal stage, it remained highest (2.55) on yellow sarson followed by lowest (1.76) on gobhi sarson. However, at pupal stage, maximum IM (7.00) was obtained on Indian mustard and minimum (5.00) on cabbage (Table 2).

k-value

At egg stage, the highest k-value was recorded (0.0655) on Indian mustard and lowest (0.0506) on cabbage. While comparing larval instars, the maximum 'k' (0.0694) was obtained at first instar on cauliflower and minimum (0.0202) at fourth instar on cabbage. At pre-pupal and pupal stage, the highest k-value (0.0286 and 0.0753, respectively) was found on Indian mustard and lowest (0.150 and 0.0399, respectively) on cabbage. Similarly, the total generation mortality, 'K' of *P. brassicae* was recorded maximum (0.3879) on Indian mustard followed by minimum (0.2555) on cabbage (Table 2).

DISCUSSION

With these experiments we have demonstrated the survival, mortality and life expectancy of life of cabbage butterfly on various cole crops. The survival of *P. brassicae* decreases continuously from day one, till the end of generations on each host plant. The death rate of the larvae was superior during initial days due to high mortality of early instars (Ahmad *et al.* 2007). However, the mortality was found relative low on cabbage than other cole crops, may be due to the soft tissue texture (Gupta 2002). Whereas, other cole crops have hard tissue texture and spine-like appendages (trichomes) on leaves that resulting high mortality at early larval instars (Ahmad *et al.* 2007). When larvae enter in third instar the death rate decrease automatically on each host plant, because the maxillae and mandibles of mouth parts get modified in these stages and larva can tend to eat plant leaves easily. A little mortality of larvae was also found at later stage of development, possibly, due to the variation in nutritional value of host plants. Several studies supported the nutritional value of these crops are Newkirk *et al.* (1997), Font *et al.* (2005), Padilla *et al.* (2007), Scalzo *et al.* (2008). On the other hand, the decline in survival and expectation of life was attributed to the continuous death of insect and a sharp decline was found at later stage of development coinciding with the death of adults (Sharma *et al.* 1999).

The findings on stage specific life-tables revealed that the mortality parameters *viz.*, apparent mortality, mortality survival ratio, indispensable mortality and k-value of cabbage butterfly were of the high magnitude at the first instar stage as compared to other development stages. Among different host plants, lowest mortality was found on cabbage may be due to choice of food. In contrast, the high mortality was recorded on Indian mustard followed by yellow sarson, gobhi sarson and cauliflower (Ali and Rizvi 2007). The survival fractions of *P. brassicae* exhibited reverse order that of mortality. The maximum survival was recorded at later stage of development on cabbage as compared to other cole crops (Thapa 1987; Melspalu *et al.* 2003; Ali and Rizvi 2007).

Despite the facts, cabbage butterfly exhibited minimum mortality and maximum survival on cabbage leaves than other host plants. Therefore, it could be accomplished that *Pieris brassicae* prefer cabbage for their fast and healthy development than other cole crops.

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POLISH SUMMARY

TABELE PARAMETRÓW ŻYCIA BIELINKA KAPUSTNIKA, *PIERIS BRASSICAE* L. (*LEPIDOPTERA: PIERIDAE*) NA RÓŻNYCH ROŚLINACH Z RODZINY KAPUSTOWATYCH

W celu zbadania reakcji bielinka kapustnika (*Pieris brassicae* L.) na kapustę, kalafiora, kapustę polną, rzepak i kapustę sitowatą (sarepską) sporządzono tabele parametrów życia motyla, a mianowicie odnośnie przeżywalności całego gatunku jak i poszczególnych faz rozwojowych owada. Tabele wykonano w oparciu o eksperymenty przeprowadzone w warunkach kontrolowanych (25±1°C, 65±5% RH i 12 h L:12 h D). Tabela przeżywalności wykazała, że *P. brassicae* do całkowitego zakończenia cyklu rozwojowego wymaga co najmniej 42 dni żerując na kapuście sitowatej, natomiast najmniej czasu, bo 36 dni potrzebuje zasiedlając zwykłą kapustę. Przeżywalność stopniowo malała poczynając od początkowego stadium rozwojowego aż do kulminacji generacji na każdej z roślin. Niemniej jednak, śmiertelność różniła się znacznie dla różnych stadiów rozwojowych *P. brassicae* na każdej roślinie. Śmiertelność i stosunek śmiertelności do przeżywalności były najwyższe dla stadium poczwarki (15,91 i 0,19%) na kapuście sitowatej, a najniższe dla stadium prepupalnego (3,39 i 0,04%) na kapuście. Podobnie maksymalną wartość k odnotowano dla stadium poczwarki (0,0753) na kapuście sitowatej a minimalną dla stadium prepupalnego (0,0150) na kapuście. Z drugiej strony, frakcja przeżywalności była najwyższa (0,97) dla stadium prepupalnego na kapuście, natomiast najniższa (0,84) dla stadium poczwarki na kapuście sitowatej. Tabele parametrów życia wykazały, że kapusta jest najbardziej preferowanym pożywieniem dla *P. brassicae* spośród wszystkich badanych kapust.