

Age-Specific Survival and Fecundity Dynamics of *Callosobruchus chinensis* on Green Gram Treated with Plant-Based Grain Protectants

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ABSTRACT

Green gram (*Vigna radiata* (L.)) is one of the most important pulse crops in India and is highly susceptible to infestation by the pulse beetle, *Callosobruchus chinensis*, a major pest of stored pulses in tropical and subtropical regions. The present study evaluated the life table parameters, growth, and developmental biology of *C. chinensis* on green gram seeds treated with different botanical grain protectants under laboratory conditions. An age-specific life table experiment was initiated with a cohort of freshly laid eggs and continued until the death of all adults to assess survivorship and female fecundity. The treatments included untreated control (T₁), neem leaf powder (T₂), chili powder (T₃), clove basil leaf powder (T₄), and talc powder (T₅). Significant differences were observed among treatments for all biological parameters. The net reproductive rate (R₀) was highest in the untreated control (32.3 females/female) and was significantly reduced in treated grains, with values of 10.347 (T₂), 18.73 (T₃), 19.77 (T₄), and 15.91 females/female (T₅). The mean generation time (T) ranged from 34.57 to 36.77 days across treatments. The doubling time (DT) was lowest in the control (6.89 days) and increased in treated grains, ranging from 8.0 to 10.55 days, indicating slower population growth under botanical treatments. Potential fecundity (P_f) was also markedly reduced in treated grains compared to controls. In all treatments, the approximate intrinsic rate of increase (r_{approx}) was slightly lower than the accurate intrinsic rate of increase (r_{accurate}). Overall, the life table parameters clearly demonstrate the suppressive effect of botanical grain protectants on the population growth of *C. chinensis*. The findings suggest that these botanicals can serve as effective, eco-friendly alternatives for the management of pulse beetle in stored green gram.

Keywords

Approximate rate of increase (r_{approx}), net reproductive rate (R₀), doubling time (DT), potential fecundity (P_f)

Article Info

Received:
22 February 2026
Accepted:
30 March 2026
Available Online:
10 April 2026

Introduction

Green gram (*Vigna radiata* (L.) Wilczek), commonly known as mung bean, is an important pulse crop widely cultivated in South Asia. In India, it ranks third after chickpea and pigeon pea and serves as a major source of protein, minerals, and vitamins, contributing significantly to nutritional security.

However, green gram is highly susceptible to insect pests both in the field and during storage. More than 150 insect species infest pulses, among which the pulse beetle, *Callosobruchus chinensis* L. (Coleoptera: Bruchidae), is one of the most destructive storage pests. It is widely distributed in tropical and subtropical regions and causes severe quantitative and qualitative losses, including reduction in seed weight, loss of viability, and deterioration of protein content (Menash, 1986). Due to the attack of this bruchid during post-harvest and storage, over 8.5% of the entire pulse crop produced in India is wasted (Agarwal *et al.*, 1988). It caused a 32.2 to 55.7% drop in seed weight and a 17.0 to 53.5% loss in protein content in green gram (Gujar and Yadav, 1978). Management of storage pests primarily relies on synthetic insecticides and fumigants because of their rapid action and effectiveness. However, indiscriminate use of these chemicals has resulted in resistance development, pest resurgence, environmental contamination, and accumulation of toxic residues in stored grains. In addition, fumigants may adversely affect seed germination under certain conditions. These concerns highlight the need for safer and sustainable alternatives.

Botanical grain protectants derived from plant materials offer a promising, eco-friendly option. Plant-based products are biodegradable, relatively safe to non-target organisms, cost-effective, and locally available. They exhibit insecticidal, repellent, and growth-regulating properties and may help preserve seed quality while reducing the risk of resistance development.

Life table analysis is an important ecological tool for assessing insect population dynamics. Age-specific life tables provide information on survival, fecundity, generation time, and intrinsic rate of increase, enabling evaluation of the impact of management strategies on pest populations.

Therefore, the present study was undertaken to assess the life table parameters and population growth of

Callosobruchus chinensis on green gram treated with selected botanical grain protectants under laboratory conditions, to evaluate their effectiveness in suppressing pulse beetle populations.

Materials and Methods

Experimental Setup

The experiment was conducted under laboratory conditions. Twenty grams of green gram seeds were placed in 200 g plastic containers. Five treatments were imposed:

- ✓ T₁: Untreated control
- ✓ T₂: Neem leaf powder
- ✓ T₃: Chilli powder
- ✓ T₄: Clove basil leaf powder
- ✓ T₅: Talc powder (standard)

Botanicals were mixed at a 1:100 (w/w) ratio. Each treatment was replicated three times.

Age-Specific Survivorship Study

Five pairs of newly emerged adults were released in each container. After three days, the adults were removed. Seeds bearing a single egg were selected, and 100 eggs were maintained per treatment as the initial cohort.

Daily observations were recorded for:

- Egg hatchability
- Adult emergence
- Adult mortality

Age-specific survivorship parameters (l_x , d_x , $100q_x$, L_x , e_x) were calculated. Data are presented in Tables 1–5.

Female Fertility Life Table

Five pairs of newly emerged adults were released in 10 g treated seeds. Daily fecundity and female survival were recorded.

Using l_x and m_x values, demographic parameters were calculated:

- Net reproductive rate (R_0)
- Mean length of generation (T)
- Approximate rate of increase (r_{approx})
- Intrinsic rate of increase (r_{accurate})
- Finite rate of increase (λ)

- Potential fecundity (P_f)
- Doubling time (DT)

Data are presented in Tables 6–10.

Results and Discussion

Age-Specific Survivorship and Life Expectancy

The age-specific survivorship (l_x) of *Callosobruchus chinensis* declined progressively with increasing age across all treatments (Tables 1–5). Survivorship remained relatively stable during the immature stages; however, a marked decline was observed during the adult phase, indicating increased mortality with advancing age. In untreated green gram (T_1), survivorship decreased sharply after the 46th day (Table 1; Fig. 1), and the highest initial life expectancy (e_x) of 39.01 days was recorded in this treatment. In neem leaf powder-treated seeds (T_2), a similar decline occurred after the 45th day (Table 2; Fig. 2), with an initial life expectancy of 38.42 days. Chilli powder-treated seeds (T_3) exhibited an earlier decline in survivorship after the 40th day (Table 3; Fig. 3), and life expectancy was reduced to 34.46 days. Likewise, in clove basil leaf powder-treated seeds (T_4), survivorship decline began after the 41st day (Table 4; Fig. 4), with life expectancy recorded at 33.70 days. The earliest and most pronounced decline was observed in talc powder-treated seeds (T_5), where survivorship dropped sharply after the 36th day (Table 5; Fig. 5), and the lowest initial life expectancy (31.09 days) was documented. The survivorship curves (Figs. 1–5) clearly demonstrate that botanical treatments reduced longevity compared to untreated seeds, indicating their suppressive effects on adult survival.

The age-specific female fertility schedules (l_x and m_x) are presented in Tables 6–10. In untreated seeds (T_1), peak fecundity was observed between 33.5 and 35.5 days (Table 6), resulting in the highest net reproductive rate (R_0) of 32.3 females per female.

Such a high reproductive rate indicates favorable conditions for rapid population buildup in untreated storage environments. Similar trends of elevated R_0 values under untreated conditions have been reported for bruchids infesting stored pulses (Borikar and Pawar, 1996; Joshi and Ghorpade, 2001).

In contrast, neem leaf powder treatment (T_2) significantly reduced fecundity (Table 7), leading to the lowest R_0

value of 10.347 females per female and an increased doubling time (10.55 days). The reduced reproductive performance and prolonged doubling time clearly demonstrate the strong suppressive effect of neem on population growth. Neem-based products are widely recognized for their oviposition deterrent, growth inhibitory, and toxic effects against stored grain pests. The reduction in fecundity observed in the present study corroborates the findings of Agarwal *et al.*, (1988), who reported effective protection of pulses using botanical materials.

Chilli powder (T_3) and clove basil leaf powder (T_4) showed moderate suppression of fecundity (Tables 8 and 9), while talc powder (T_5) also reduced reproductive potential compared to the control (Table 10). Although these treatments were less effective than neem, they significantly lowered population growth parameters relative to untreated seeds.

The increased mean generation time (T) observed in treated seeds suggests delayed development under botanical stress. Comparable developmental delays under botanical treatments have been documented in *Spodoptera litura* and other insect pests (Sundaram *et al.*, 2006; Gedda *et al.*, 2008a).

Furthermore, the intrinsic rate of increase (r) was lower in treated seeds than in untreated seeds, indicating slower population growth under botanical treatments. Reduced intrinsic growth rates under stress conditions have been similarly reported in other insect life table studies (Harcourt, 1969).

Life expectancy (e_x) also declined more rapidly in treated seeds, particularly in talc and clove basil treatments, reflecting increased adult mortality. Comparable reductions in survivorship under adverse conditions have been reported by Shah *et al.*, (2007) in aphids and by Hansen *et al.*, (2004) in stored grain moths.

Overall, neem leaf powder emerged as the most effective treatment, followed by talc powder. The lower reproductive potential, reduced survivorship, and increased doubling time observed in botanical treatments indicate their significant role in suppressing *C. chinensis* population buildup during storage. These findings support the integration of plant-based grain protectants into eco-friendly management strategies for pulse beetle control.

Table.1 Age-specific survivorship of *C. chinensis* on untreated green gram

x	lx	dx	100qx	Lx	Tx ($\sum Lx$)	ex
0	100.00	1.00	1.00	99.50	3901.00	39.01
1	99.00	1.00	1.01	98.50	3801.50	38.40
2	98.00	1.00	1.02	97.50	3703.00	37.79
3	97.00	1.00	1.03	96.50	3605.50	37.17
4	96.00	1.00	1.04	95.50	3509.00	36.55
5	95.00	1.00	1.05	94.50	3413.50	35.93
6	94.00	1.00	1.06	93.50	3319.00	35.31
7	93.00	1.00	1.08	92.50	3225.50	34.68
8	92.00	1.00	1.09	91.50	3133.00	34.05
9	91.00	1.00	1.10	90.50	3041.50	33.42
10	90.00	0.00	0.00	90.00	2951.00	32.79
11	90.00	0.00	0.00	90.00	2861.00	31.79
12	90.00	0.00	0.00	90.00	2771.00	30.79
13	90.00	0.00	0.00	90.00	2681.00	29.79
14	90.00	0.00	0.00	90.00	2591.00	28.79
15	90.00	1.00	1.11	89.50	2501.00	27.79
16	89.00	1.00	1.12	88.50	2411.50	27.10
17	88.00	1.00	1.14	87.50	2323.00	26.40
18	87.00	1.00	1.15	86.50	2235.50	25.70
19	86.00	1.00	1.16	85.50	2149.00	24.99
20	85.00	0.00	0.00	85.00	2063.50	24.28
21	85.00	0.00	0.00	85.00	1978.50	23.28
22	85.00	0.00	0.00	85.00	1893.50	22.28
23	85.00	0.00	0.00	85.00	1808.50	21.28
24	85.00	0.00	0.00	85.00	1723.50	20.28
25	85.00	1.00	1.18	84.50	1638.50	19.28
26	84.00	1.00	1.19	83.50	1554.00	18.50
27	83.00	1.00	1.20	82.50	1470.50	17.72
28	82.00	1.00	1.22	81.50	1388.00	16.93
29	81.00	1.00	1.23	80.50	1306.50	16.13
30	80.00	1.00	1.25	79.50	1226.00	15.32
31	79.00	1.00	1.27	78.50	1146.50	14.51
32	78.00	1.00	1.28	77.50	1068.00	13.69
33	77.00	1.00	1.30	76.50	990.50	12.86
34	76.00	0.00	0.00	76.00	914.00	12.03
35	76.00	0.00	0.00	76.00	838.00	11.03
36	76.00	0.00	0.00	76.00	762.00	10.03
37	76.00	3.00	3.95	74.50	686.00	9.03
38	73.00	2.00	2.74	72.00	611.50	8.38
39	71.00	3.00	4.23	69.50	539.50	7.60
40	68.00	2.00	2.94	67.00	470.00	6.91
41	66.00	1.00	1.52	65.50	403.00	6.11
42	65.00	5.00	7.69	62.50	337.50	5.19
43	60.00	3.00	5.00	58.50	275.00	4.58

44	57.00	5.00	8.77	54.50	216.50	3.80
45	52.00	5.00	9.62	49.50	162.00	3.12
46	47.00	7.00	14.89	43.50	112.50	2.39
47	40.00	9.00	22.50	35.50	69.00	1.73
48	31.00	14.00	45.16	24.00	33.50	1.08
49	17.00	16.00	94.12	9.00	9.50	0.56
50	1.00	1.00	100.00	0.50	0.50	0.50

x - age of insect in days; l_x -no of surviving at the beginning of age interval; d_x – the no of dying within age interval x to x+1; $100q_x$ -Mortality rate at the age interval x to x+1; L_x - average no of survival at age interval x to x+1; e_x - expectation of life at the beginning of age interval x.

Table.2 Age-specific survivorship of *C. chinensis* on neem leaf powder treated green gram

x	l_x	d_x	$100q_x$	L_x	$T_x (\sum L_x)$	e_x
0	100.00	1.00	1.00	99.50	3842.00	38.42
1	99.00	1.00	1.01	98.50	3742.50	37.80
2	98.00	1.00	1.02	97.50	3644.00	37.18
3	97.00	1.00	1.03	96.50	3546.50	36.56
4	96.00	1.00	1.04	95.50	3450.00	35.94
5	95.00	1.00	1.05	94.50	3354.50	35.31
6	94.00	1.00	1.06	93.50	3260.00	34.68
7	93.00	1.00	1.08	92.50	3166.50	34.05
8	92.00	1.00	1.09	91.50	3074.00	33.41
9	91.00	1.00	1.10	90.50	2982.50	32.77
10	90.00	1.00	1.11	89.50	2892.00	32.13
11	89.00	1.00	1.12	88.50	2802.50	31.49
12	88.00	1.00	1.14	87.50	2714.00	30.84
13	87.00	1.00	1.15	86.50	2626.50	30.19
14	86.00	1.00	1.16	85.50	2540.00	29.53
15	85.00	0.00	0.00	85.00	2454.50	28.88
16	85.00	0.00	0.00	85.00	2369.50	27.88
17	85.00	0.00	0.00	85.00	2284.50	26.88
18	85.00	0.00	0.00	85.00	2199.50	25.88
19	85.00	0.00	0.00	85.00	2114.50	24.88
20	85.00	0.00	0.00	85.00	2029.50	23.88
21	85.00	0.00	0.00	85.00	1944.50	22.88
22	85.00	1.00	1.18	84.50	1859.50	21.88
23	84.00	1.00	1.19	83.50	1775.00	21.13
24	83.00	1.00	1.20	82.50	1691.50	20.38
25	82.00	1.00	1.22	81.50	1609.00	19.62
26	81.00	1.00	1.23	80.50	1527.50	18.86
27	80.00	1.00	1.25	79.50	1447.00	18.09
28	79.00	1.00	1.27	78.50	1367.50	17.31
29	78.00	1.00	1.28	77.50	1289.00	16.53
30	77.00	1.00	1.30	76.50	1211.50	15.73
31	76.00	1.00	1.32	75.50	1135.00	14.93

32	75.00	1.00	1.33	74.50	1059.50	14.13
33	74.00	1.00	1.35	73.50	985.00	13.31
34	73.00	1.00	1.37	72.50	911.50	12.49
35	72.00	1.00	1.39	71.50	839.00	11.65
36	71.00	1.00	1.41	70.50	767.50	10.81
37	70.00	0.00	0.00	70.00	697.00	9.96
38	70.00	0.00	0.00	70.00	627.00	8.96
39	70.00	7.00	10.00	68.50	557.00	7.96
40	67.00	2.00	2.99	66.00	488.50	7.29
41	65.00	2.00	3.08	64.00	422.50	6.50
42	63.00	2.00	3.17	62.00	358.50	5.69
43	61.00	7.00	11.48	57.50	296.50	4.86
44	54.00	0.00	0.00	54.00	239.00	4.43
45	54.00	3.00	5.56	52.50	185.00	3.43
46	51.00	9.00	17.65	46.50	132.50	2.60
47	42.00	8.00	19.05	38.00	86.00	2.05
48	34.00	16.00	47.06	26.00	48.00	1.41
49	18.00	9.00	50.00	13.50	22.00	1.22
50	9.00	6.00	66.67	6.00	8.50	0.94
51	3.00	2.00	66.67	2.00	2.50	0.83
52	1.00	1.00	100.00	0.50	0.50	0.50

x - age of insect in days; x -no of surviving at the beginning of age interval; dx – the no of dying within age interval x to x+1; the 100qx-Mortality rate at the age interval x to x+1; Lx- average no of survival at age interval x to x+1; ex- expectation of life at the beginning of age interval x.

Table.3 Age-specific survivorship of *C. chinensis* on chilli powder treated green gram

x	lx	dx	100qx	Lx	Tx ($\sum Lx$)	ex
0	100.00	1.00	1.00	99.50	3446.00	34.46
1	99.00	1.00	1.01	98.50	3346.50	33.80
2	98.00	1.00	1.02	97.50	3248.00	33.14
3	97.00	1.00	1.03	96.50	3150.50	32.48
4	96.00	1.00	1.04	95.50	3054.00	31.81
5	95.00	1.00	1.05	94.50	2958.50	31.14
6	94.00	1.00	1.06	93.50	2864.00	30.47
7	93.00	1.00	1.08	92.50	2770.50	29.79
8	92.00	1.00	1.09	91.50	2678.00	29.11
9	91.00	1.00	1.10	90.50	2586.50	28.42
10	90.00	1.00	1.11	89.50	2496.00	27.73
11	89.00	1.00	1.12	88.50	2406.50	27.04
12	88.00	1.00	1.14	87.50	2318.00	26.34
13	87.00	1.00	1.15	86.50	2230.50	25.64
14	86.00	1.00	1.16	85.50	2144.00	24.93
15	85.00	1.00	1.18	84.50	2058.50	24.22
16	84.00	1.00	1.19	83.50	1974.00	23.50
17	83.00	1.00	1.20	82.50	1890.50	22.78
18	82.00	1.00	1.22	81.50	1808.00	22.05

19	81.00	1.00	1.23	80.50	1726.50	21.31
20	80.00	0.00	0.00	80.00	1646.00	20.58
21	80.00	1.00	1.25	79.50	1566.00	19.58
22	79.00	1.00	1.27	78.50	1486.50	18.82
23	78.00	1.00	1.28	77.50	1408.00	18.05
24	77.00	1.00	1.30	76.50	1330.50	17.28
25	76.00	1.00	1.32	75.50	1254.00	16.50
26	75.00	1.00	1.33	74.50	1178.50	15.71
27	74.00	1.00	1.35	73.50	1104.00	14.92
28	73.00	1.00	1.37	72.50	1030.50	14.12
29	72.00	1.00	1.39	71.50	958.00	13.31
30	71.00	1.00	1.41	70.50	886.50	12.49
31	70.00	1.00	1.43	69.50	816.00	11.66
32	69.00	1.00	1.45	68.50	746.50	10.82
33	68.00	1.00	1.47	67.50	678.00	9.97
34	67.00	1.00	1.49	66.50	610.50	9.11
35	66.00	1.00	1.52	65.50	544.00	8.24
36	65.00	1.00	1.54	64.50	478.50	7.36
37	64.00	0.00	0.00	64.00	414.00	6.47
38	64.00	4.00	6.25	62.00	350.00	5.47
39	60.00	3.00	5.00	58.50	288.00	4.80
40	57.00	3.00	5.26	55.50	229.50	4.03
41	54.00	8.00	14.81	50.00	174.00	3.22
42	46.00	9.00	19.57	41.50	124.00	2.70
43	37.00	4.00	10.81	35.00	82.50	2.23
44	33.00	11.00	33.33	27.50	47.50	1.44
45	22.00	16.00	72.73	14.00	20.00	0.91
46	6.00	4.00	66.67	4.00	6.00	1.00
47	2.00	1.00	50.00	1.50	2.00	1.00
48	1.00	1.00	100.00	0.50	0.50	0.50

x - age of insect in days; l_x -no of surviving at the beginning of age interval; d_x – the no of dying within age interval x to x+1; $100q_x$ -Mortality rate at the age interval x to x+1; L_x - average no of survival at age interval x to x+1; e_x - expectation of life at the beginning of age interval x.

Table.4 Age-specific survivorship of *C. chinensis* on clove basil leaf powder treated green gram

x	l_x	d_x	$100q_x$	L_x	$T_x (\sum L_x)$	e_x
0	100.00	2.00	2.00	99.00	3370.00	33.70
1	98.00	2.00	2.04	97.00	3271.00	33.38
2	96.00	1.00	1.04	95.50	3174.00	33.06
3	95.00	1.00	1.05	94.50	3078.50	32.41
4	94.00	1.00	1.06	93.50	2984.00	31.74
5	93.00	1.00	1.08	92.50	2890.50	31.08
6	92.00	1.00	1.09	91.50	2798.00	30.41
7	91.00	1.00	1.10	90.50	2706.50	29.74
8	90.00	1.00	1.11	89.50	2616.00	29.07

9	89.00	1.00	1.12	88.50	2526.50	28.39
10	88.00	1.00	1.14	87.50	2438.00	27.70
11	87.00	1.00	1.15	86.50	2350.50	27.02
12	86.00	1.00	1.16	85.50	2264.00	26.33
13	85.00	1.00	1.18	84.50	2178.50	25.63
14	84.00	1.00	1.19	83.50	2094.00	24.93
15	83.00	1.00	1.20	82.50	2010.50	24.22
16	82.00	1.00	1.22	81.50	1928.00	23.51
17	81.00	1.00	1.23	80.50	1846.50	22.80
18	80.00	1.00	1.25	79.50	1766.00	22.08
19	79.00	1.00	1.27	78.50	1686.50	21.35
20	78.00	1.00	1.28	77.50	1608.00	20.62
21	77.00	1.00	1.30	76.50	1530.50	19.88
22	76.00	1.00	1.32	75.50	1454.00	19.13
23	75.00	1.00	1.33	74.50	1378.50	18.38
24	74.00	1.00	1.35	73.50	1304.00	17.62
25	73.00	1.00	1.37	72.50	1230.50	16.86
26	72.00	1.00	1.39	71.50	1158.00	16.08
27	71.00	1.00	1.41	70.50	1086.50	15.30
28	70.00	1.00	1.43	69.50	1016.00	14.51
29	69.00	1.00	1.45	68.50	946.50	13.72
30	68.00	1.00	1.47	67.50	878.00	12.91
31	67.00	1.00	1.49	66.50	810.50	12.10
32	66.00	1.00	1.52	65.50	744.00	11.27
33	65.00	1.00	1.54	64.50	678.50	10.44
34	64.00	1.00	1.56	63.50	614.00	9.59
35	63.00	1.00	1.59	62.50	550.50	8.74
36	62.00	0.00	0.00	62.00	488.00	7.87
37	62.00	0.00	0.00	62.00	426.00	6.87
38	62.00	2.00	3.23	61.00	364.00	5.87
39	60.00	4.00	6.67	58.00	303.00	5.05
40	56.00	2.00	3.57	55.00	245.00	4.38
41	54.00	2.00	3.70	53.00	190.00	3.52
42	52.00	7.00	13.46	48.50	137.00	2.63
43	45.00	12.00	26.67	39.00	88.50	1.97
44	33.00	14.00	42.42	26.00	49.50	1.50
45	19.00	9.00	47.37	14.50	23.50	1.24
46	10.00	7.00	70.00	6.50	9.00	0.90
47	3.00	2.00	66.67	2.00	2.50	0.83
48	1.00	1.00	100.00	0.50	0.50	0.50

x - age of insect in days; x -no of surviving at the beginning of age interval; dx – the no of dying within age interval x to x+1; 100qx-Mortality rate at the age interval x to x+1; Lx- average no of survival at age interval x to x+1; ex- expectation of life at the beginning of age interval x.

Table.5 Age-specific survivorship of *C. chinensis* on talc powder treated green gram

x	lx	dx	100qx	Lx	Tx ($\sum Lx$)	ex
0	100.00	2.00	2.00	99.00	3109.00	31.09
1	98.00	2.00	2.04	97.00	3010.00	30.71
2	96.00	2.00	2.08	95.00	2913.00	30.34
3	94.00	2.00	2.13	93.00	2818.00	29.98
4	92.00	2.00	2.17	91.00	2725.00	29.62
5	90.00	1.00	1.11	89.50	2634.00	29.27
6	89.00	0.00	0.00	89.00	2544.50	28.59
7	89.00	1.00	1.12	88.50	2455.50	27.59
8	88.00	1.00	1.14	87.50	2367.00	26.90
9	87.00	1.00	1.15	86.50	2279.50	26.20
10	86.00	1.00	1.16	85.50	2193.00	25.50
11	85.00	1.00	1.18	84.50	2107.50	24.79
12	84.00	1.00	1.19	83.50	2023.00	24.08
13	83.00	1.00	1.20	82.50	1939.50	23.37
14	82.00	1.00	1.22	81.50	1857.00	22.65
15	81.00	1.00	1.23	80.50	1775.50	21.92
16	80.00	1.00	1.25	79.50	1695.00	21.19
17	79.00	1.00	1.27	78.50	1615.50	20.45
18	78.00	1.00	1.28	77.50	1537.00	19.71
19	77.00	1.00	1.30	76.50	1459.50	18.95
20	76.00	1.00	1.32	75.50	1383.00	18.20
21	75.00	1.00	1.33	74.50	1307.50	17.43
22	74.00	1.00	1.35	73.50	1233.00	16.66
23	73.00	1.00	1.37	72.50	1159.50	15.88
24	72.00	1.00	1.39	71.50	1087.00	15.10
25	71.00	1.00	1.41	70.50	1015.50	14.30
26	70.00	1.00	1.43	69.50	945.00	13.50
27	69.00	1.00	1.45	68.50	875.50	12.69
28	68.00	0.00	0.00	68.00	807.00	11.87
29	68.00	0.00	0.00	68.00	739.00	10.87
30	68.00	0.00	0.00	68.00	671.00	9.87
31	68.00	0.00	0.00	68.00	603.00	8.87
32	68.00	0.00	0.00	68.00	535.00	7.87
33	68.00	0.00	0.00	68.00	467.00	6.87
34	68.00	4.00	5.88	66.00	399.00	5.87
35	64.00	2.00	3.13	63.00	333.00	5.20
36	62.00	2.00	3.23	61.00	270.00	4.35
37	60.00	4.00	6.67	58.00	209.00	3.48
38	56.00	6.00	10.71	53.00	151.00	2.70
39	50.00	10.00	20.00	45.00	98.00	1.96
40	40.00	19.00	47.50	30.50	53.00	1.33
41	21.00	12.00	57.14	15.00	22.50	1.07
42	9.00	6.00	66.67	6.00	7.50	0.83
43	3.00	3.00	100.00	1.50	1.50	0.50

x - age of insect in days; lx -no of surviving at the beginning of age interval x to x+1; dx – the no of dying within age interval x to x+1; 100qx-Mortality rate at the age interval x to x+1; Lx- average no of survival at age interval x to x+1; ex- expectation of life at the beginning of age interval x.

Table.7 Age-specific female fertility life table of *C. chinensis* on untreated green gram

x	lx	mx	lx·mx	x·lx·mx	e-rx·lx·mx	% Contribution
31.5	0.79	3.3	2.60	82.120	0.10	10.49
32.5	0.78	4.0	3.12	101.400	0.11	11.89
33.5	0.77	5.7	4.38	147.031	0.15	15.13
34.5	0.76	16.3	12.38	427.386	0.38	38.63
35.5	0.76	4.4	3.34	118.712	0.94	9.43
36.5	0.76	3.0	2.28	83.220	0.58	5.81
37.5	0.76	1.8	1.36	51.300	0.31	3.15
38.5	0.73	1.2	0.87	33.726	0.18	1.82
39.5	0.71	0.8	0.56	22.436	0.10	1.07
40.5	0.68	0.7	0.47	19.278	0.81	0.81
41.5	0.66	0.5	0.33	13.695	0.50	0.50
42.5	0.65	0.5	0.32	13.812	0.45	0.45
43.5	0.60	0.2	0.12	5.220	0.15	0.15
44.5	0.57	0.1	0.57	2.536	0.64	0.65
45.5	0.52	0.1	0.52	2.366	0.53	0.53

$$\sum mx=42.60 \quad \sum lx.mx= 32.30 \quad \sum x.lx.mx =1124.240 \quad \sum e^{-rx.lx.mx}=5.93 \quad \sum \%contr=99.99$$

x: pivotal age in days; lx: survival fraction of females; mx: natality rate

Table.8 Age-specific female fertility life table of *C. chinensis* on neem leaf powder treated green gram

x	lx	mx	lx·mx	x·lx·mx	e-rx·lx·mx	% Contribution
33.5	0.74	2.2	1.62	54.538	0.18	18.05
34.5	0.73	3.4	2.48	85.629	0.25	25.77
35.5	0.72	4.3	3.09	109.908	0.30	30.14
36.5	0.71	1.8	1.27	46.647	0.11	11.63
37.5	0.70	0.8	0.56	21.000	0.47	4.77
38.5	0.70	0.6	0.42	16.170	0.33	3.35
39.5	0.70	0.6	0.42	16.590	0.31	3.14
40.5	0.67	0.5	0.33	13.567	0.23	2.34
41.5	0.65	0.1	0.65	2.697	0.42	0.42
42.5	0.63	0.1	0.63	2.677	0.38	0.38

$$\sum mx=14.40 \quad \sum lx.mx= 10.34 \quad \sum x.lx.mx =369.424 \quad \sum e^{-rx.lx.mx} =2.98 \quad \sum \%contr=99.99$$

x: pivotal age in days; lx: survival fraction of females; mx: natality rate

Table.9 Age-specific female fertility life table of *C. chinensis* on chilli powder treated green gram

x	lx	mx	lx·mx	x·lx·mx	e-rx·lx·mx	% Contribution
34.5	0.67	4.4	2.948	101.706	0.18	18.72
35.5	0.66	5.7	3.762	133.551	0.22	22.04
36.5	0.65	7.5	4.875	177.937	0.26	26.36
37.5	0.64	5.4	3.456	129.600	0.17	17.24
38.5	0.64	2.2	1.408	54.208	0.64	6.49
39.5	0.60	1.9	1.140	45.030	0.48	4.84
40.5	0.57	1.2	0.684	27.702	0.26	2.68
41.5	0.54	0.6	0.324	13.446	0.11	1.17
42.5	0.46	0.3	0.138	5.865	0.46	0.46

$$\sum mx=29.20 \quad \sum lx.mx= 18.73 \quad \sum x.lx.mx = 689.045 \quad \sum e^{-rx.lx.mx}=2.78 \quad \sum \%contr=100.00$$

x: pivotal age in days; lx: survival fraction of females; mx: natality rate

Table.10 Age-specific female fertility life table of *C. chinensis* on clove basil treated green gram

x	lx	mx	lx·mx	x·lx·mx	e-rx·lx·mx	% Contribution
32.5	0.66	4.3	2.838	92.235	0.17	17.04
33.5	0.65	6.4	4.160	139.360	0.22	22.94
34.5	0.64	10.2	6.528	225.216	0.32	32.96
35.5	0.63	5.1	3.213	114.061	0.14	14.87
36.5	0.62	2.5	1.550	56.575	0.65	6.58
37.5	0.62	1.8	1.116	41.850	0.43	4.34
38.5	0.62	0.4	0.248	9.548	0.88	0.88
39.5	0.60	0.2	0.120	4.740	0.39	0.39

$$\sum mx=30.9 \quad \sum lx.mx= 19.77 \quad \sum x.lx.mx = 683.583 \quad \sum e^{-rx.lx.mx}=3.2 \quad \sum \%contr=100.00$$

x: pivotal age in days; lx: survival fraction of females; mx: natality rate

Table.11 Age-specific female fertility life table of *C. chinensis* on talc powder treated green gram

x	lx	mx	lx·mx	x·lx·mx	e-rx·lx·mx	% Contribution
33.5	0.68	3.2	2.17	72.896	0.16	16.07
34.5	0.68	5.2	3.53	121.992	0.24	24.16
35.5	0.64	7.6	4.86	172.672	0.30	30.75
36.5	0.62	3.6	2.23	81.467	0.13	13.35
37.5	0.60	2.5	1.50	56.250	0.81	8.16
38.5	0.56	1.8	1.00	38.808	0.50	5.34
39.5	0.50	1.2	0.60	23.700	0.27	2.77

$$\sum mx=25.1 \quad \sum lx.mx= 15.91 \quad \sum x.lx.mx = 567.786 \quad \sum e^{-rx.lx.mx}=2.41 \quad \sum \%contr=100.00$$

X: pivotal age in days; lx: survival fraction of females; mx: natality rate

Fig.1 Age-specific survivorship (lx) and life expectancy (ex) of *C. chinensis* on untreated green gram during the life period

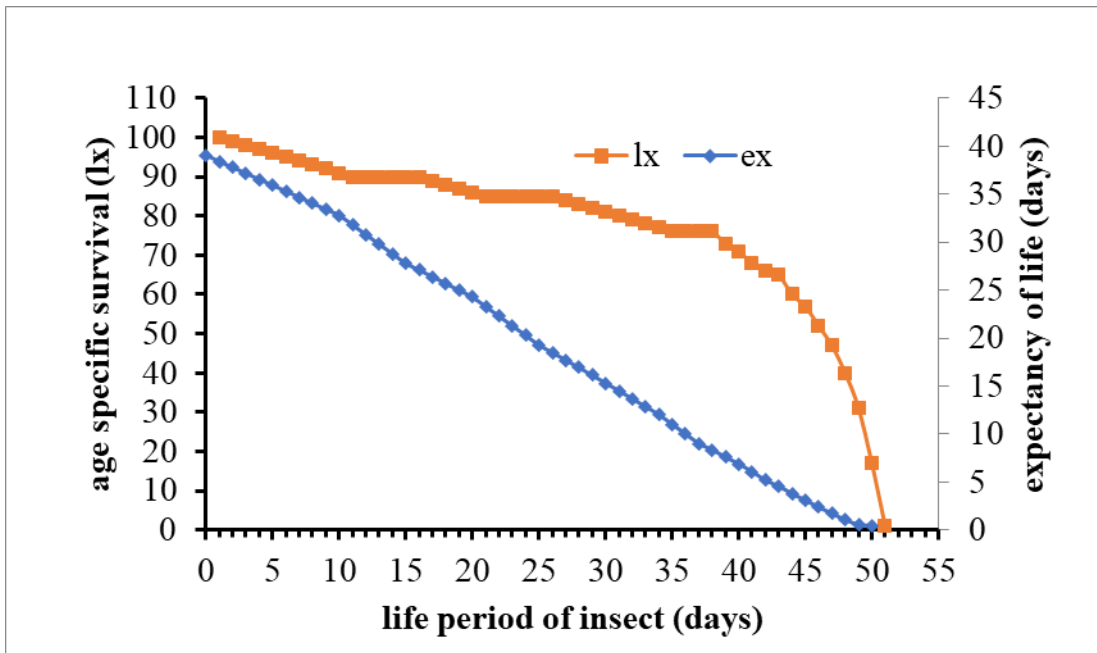


Fig.2 Age-specific survivorship (lx) and life expectancy (ex) of *C. chinensis* on neem leaf powder green gram during the life period

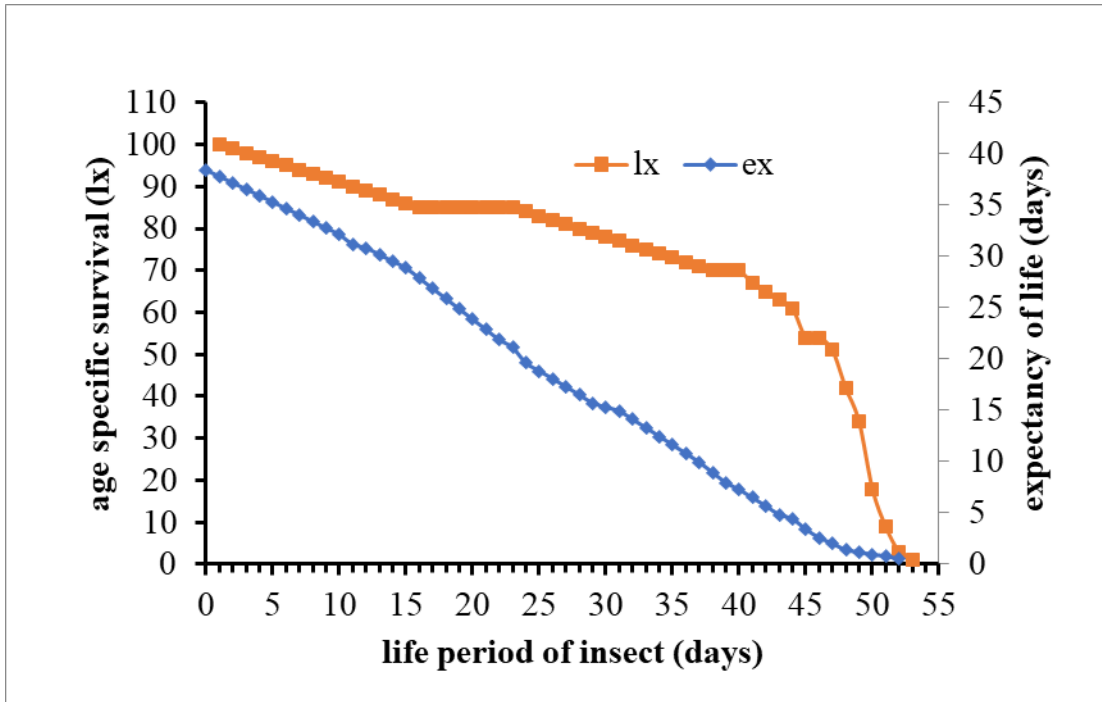


Fig.3 Age-specific survivorship (lx) and life expectancy (ex) of *C. chinensis* on chili powder treated green gram during the life period

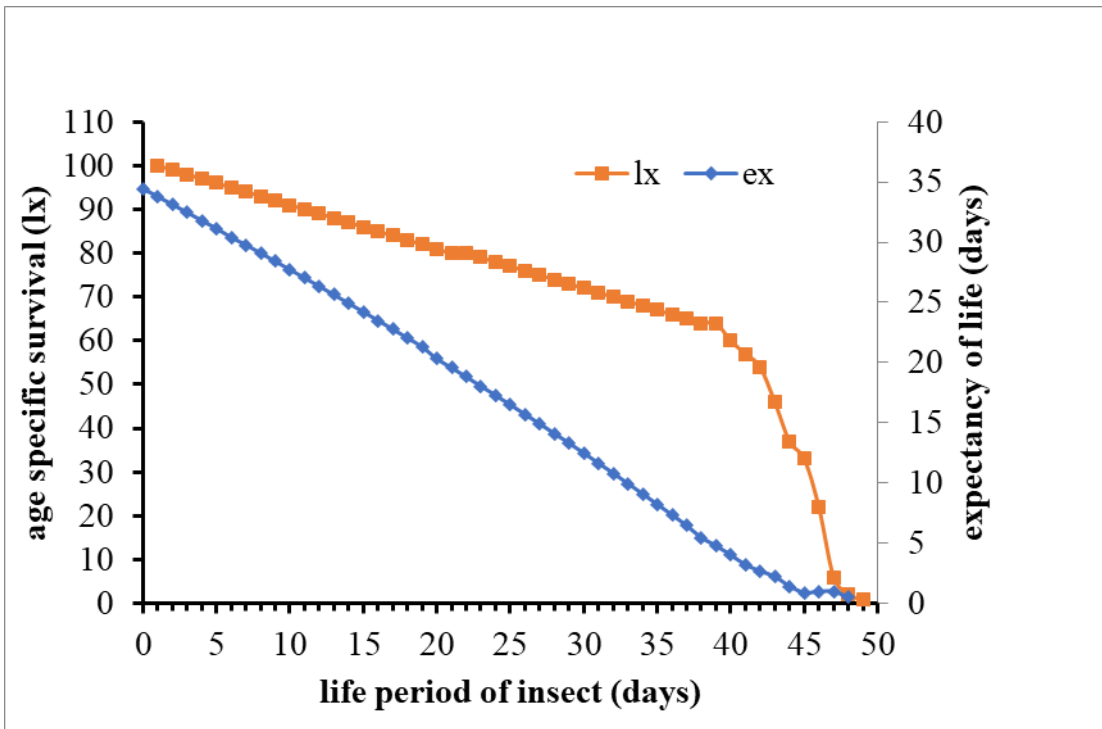


Fig.4 Age-specific survivorship (lx) and life expectancy (ex) of *C. chinensis* on clove basil leaf powder treated green gram during the life period

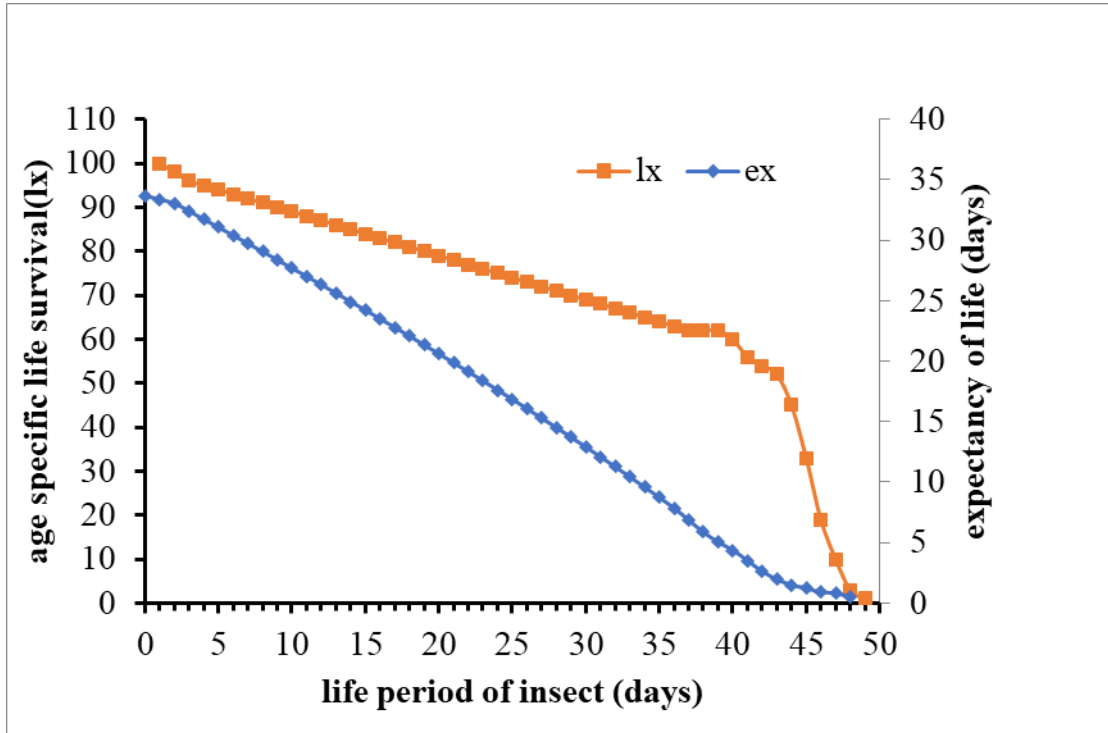


Fig.5 Age-specific survivorship (lx) and life expectancy (ex) of *C. chinensis* on talc powder treated green gram during the life period

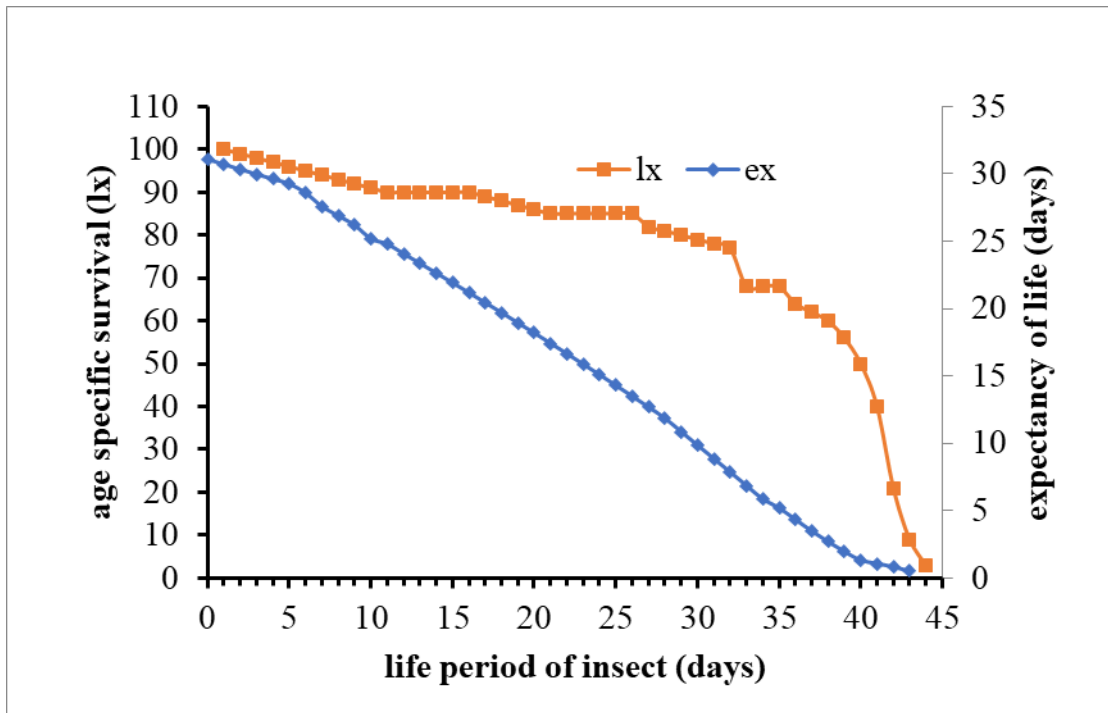


Table.11 Comparative Analysis of Life Table Parameters and Population Growth Metrics under Different Botanical Treatments (Neem, Chili, Clove Basil) and Talc Powder

Parameter	untreated (T ₁)	neem leaf powder (T ₂)	chili powder (T ₃)	clove basil leaf powder (T ₄)	talc powder (T ₅)
Net reproductive rate (R) = $\sum lx.mx$ females/female	32.3	10.34	18.73	19.77	15.91
Mean length of generation(T)= $\frac{\sum x.lx.mx}{\sum lx.mx}$ days	34.8	35.70	36.77	34.57	35.67
Approximate rate of increase(r_{approx}) = $\log_e R_0$ females/female/day	0.9984	0.6544	0.7967	0.8632	0.77572
Actual rate of increase ($r_{accurate}$) females/female/day	0.1005	0.6564	0.7991	0.8657	0.7780
Finite rate of increase (λ) = $e^{r(accurate)}$ females/female/day	0.105	1.067	1.083	1.0904	1.0904
Potential fecundity (Pf) = $\sum mx$ females/female	42.60	14.40	29.20	30.9	25.1
Doubling time (DT) = $\log_e 2 / \log_e \lambda$ days	6.89	10.55	8.67	8.0	8.90
Weekly rate of increase (WRI) = λ^7 females/female	2.02	1.58	1.74	1.82	1.71

In conclusion, Botanical grain protectants significantly affected survivorship, fecundity, and demographic parameters of *C. chinensis*. Neem leaf powder was most effective in reducing net reproductive rate and increasing doubling time. The findings support the use of plant-based grain protectants as eco-friendly alternatives for managing pulse beetle infestation during storage.

Author Contributions

Arupula Sudhakar: Investigation, formal analysis, writing—original draft. P. Mondal: Validation, methodology, writing—reviewing. H. Chatterjee:— Formal analysis, writing—review and editing. R. Nath: Investigation, writing—reviewing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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How to cite this article:

Arupula Sudhakar, Mondal P., Chatterjee H. and Nath R. 2026. Age-Specific Survival and Fecundity Dynamics of *Callosobruchus chinensis* on Green Gram Treated with Plant-Based Grain Protectants. *Int.J.Curr.Microbiol.App.Sci.* 15(4): 228-242. doi: <https://doi.org/10.20546/ijcmas.2026.1504.028>