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ORIGINAL RESEARCH ARTICLE

Age specific life table of mulberry silkworm, *Bombyx mori*'Linn. race NB_4D_2 x SH_6 at two different temperatures ranges under laboratory conditions

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Abstract
The study on age specific life table of *Bombyx mori* Linn. race NB_4D_2 x SH_6 reared on leaves of mulberry (*Morus alba*) plant variety S-1 at two different temperatures viz. control temperature (25 ± 1 °C) with 75 ± 5% relative humidity and room temperature in the laboratory of Sericulture Research, Demonstration and Training Unit, Department of Entomology, College of Agriculture, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut-250110 (Uttar Pradesh), India. Data revealed that *Bombyx mori* Linn. race NB4D2 x SH6 required 37 and 40 days to complete its life cycle at control temperature (25 ± 1 °C) with 75 ± 5% relative humidity and room temperature, respectively. At control temperature, the highest mortality 85.19 per cent was exhibited at 36th day followed by 49.06 per cent at 35th day and the lowest mortality 1.12 per cent was recorded on 5th day followed by 1.14 per cent on 6th day. In case of room temperature, the highest mortality 88.89 per cent was recorded at 39th day followed by 66.67 per cent at 38th day and lowest mortality 1.20 per cent was recorded at 8th day followed by 1.35 per cent at 15th day. There an initial drop in survivorship (l_x) was seen followed by an intermittent steady decline with long pauses till the formation of adult and sharp decline was observed at adult stage in both the conditions viz., control temperature (25 ± 1 °C) with 75 ± 5% relative humidity as well as at room temperature till the end of generation.

Keywords Age specific life table · *Bombyx mori* Linn. race NB_4D_2 x SH_6 · Temperature ranges · Mulberry leaves

Introduction

The silk production was initially originated in China around 2000 years ago. When the art and technologies of silk production were evolved, it became capable to achieve silk production in different regions of the world. The mulberry silkworm, *Bombyx mori*'Linn. belongs to order Lepidoptera and family *Bombycidae,* which has been considered as a reference in several domain. It is the most studied lepidopteran model system with a wide range of well characterized mutations affecting virtually every aspect of the organism morphology, development and behaviour. Mulberry silkworm undergoes complete metamorphosis and life cycle takes approximately 39–41 days. (Singh et al. 2020).

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It has considerable economic importance especially for solving a large range of biological problems. At present about 4000 races of *Bombyx mori* Linn. were maintained by traditional sericulture countries like China, Japan, France, India, Italy and South Korea (Nagaraju 2004; Kumaresan et al. 2004).

India attains the 2nd position in silk production after China. In India, five known commercial varieties of silkworm viz.,mulberry silkworm (*Bombyx mori* Linn.), Eri silkworm (*Samia Cynthia* Drury), Muga silkworm (*Antheraea assamensis* Helfer), Tropical silkworm (*Antheraea mylitta* Drury) and Oak tasar silkworm (*Antheraea proylei* Jolly) are cultivated (Oomman 2004).

In India, the major mulberry silk producing states are Karnataka (8483 MT), Andhra Pradesh (5520 MT), Assam (5038 MT), Tamil Nadu (1206 MT), Meghalaya (999 MT), Jharkhand (800 MT), Manipur (313 MT), West Bengal (298 MT), Maharashtra (285 MT), Chhattisgarh (248 MT), Nagaland (230 MT), Uttar Pradesh (179 MT) and Telangana (166 MT) etc. (Central Silk Board 2021). Mulberry silk containing 75 per cent fibroin, 22.5 per cent sericin, 1.5 per cent

fat and wax, 0.5 per cent ash of silk fibroin and 0.5 per cent mineral salt (Elizabeth 2016).

The construction of life tables is an important tool for understanding the population dynamics of an insect. Age-specific life tables serve as a framework for organising data on mortality. Additionally, it provides a detailed transparent description of the actual properties of the cohorts (Carey 2001). The life table is a concise summary statement for every interval of age (X), the number of deaths (d_x), the number of survivors at the beginning of the age X (l_x), the rate of mortality (q_x) and the expectation of life (e_x) (Deevey 1947). Realizing the importance of the mulberry silkworm, *Bombyx mori* Linn. race NB_4D_2 x SH_6 as a beneficial insect an effort was made to construct the life table at different temperatures viz. control temperature (25 ± 1 °C) with 75 ± 5% relative humidity and room temperature.

Materials and methods

Eggs of mulberry silkworm were brought from Silkworm Egg Production Unit, State Sericulture Farm, Kanker Khara, Meerut, (U.P.). The culture of the silkworm was maintained in the Sericulture Research, Demostration and Training Unit, Department of Entomology, College of Agriculture, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut on mulberry leaves (Var. S-1).

Disinfection

Disinfection of the laboratory and all the rearing equipment's was done before rearing of mulberry silkworm with 4 per cent formaldehyde solution. The laboratory was closed for 24 h to destroy the pathogens causing infection like bacteria, virus, fungi, protozoa etc. The eggs sheet was dipped in 2 per cent formaldehyde solution for 5 min for disinfection. Thereafter, the egg sheet was thoroughly washed under tap water and dried in shade. After that the eggs were ready for incubation and placed in BOD at control temperature (25 ± 1 °C) 75 ± 5% relative humidity as well as at room temperature for uniform hatching.

The eggs sheet were kept in dark and cool condition and on the day of pin head or blue egg stage all eggs are covered with a black paper known as black boxing which facilitates faster development of embryo and uniform hatching.

The newly hatched larvae were collected with the help of fine hair brush from hatched eggs and reared in batches of hundred in plastic tray containing chopped mulberry leaves.

The larvae of mulberry silkworm were kept in plastic trays size (90 cm × 70 cm × 10 cm) for feeding. In order to maintained humidity a layer of wet filter paper was placed in the bottom of plastic tray. The trays were covered with muslin cloth. Fresh chopped mulberry leaves were provided 3 times in a day to the larvae till the maturity and proper hygienic conditions were maintained in the rearing room because mulberry silkworms are very prone to various microbial diseases like pebrine, flacherie, grassaerie and muscardine. When the larvae attained full growth and stop feeding, it was transferred to the montages fitted trays for the cocoon's formation at the rate of 40 to 45 larvae per fit^2. After all the mulberry silkworms have completed cocoon formation which took normally 5 to 7 days. The harvesting was done after 3 to 4 day of cocoon formation and the freshly harvested cocoons were kept in small boxes whose top was covered with muslin cloth for adult emergence.

Characteristics features of mulberry silkworm, *Bombyx mori* Linn. race NB_4D_2 x SH_6

- It is bivoltine race of mulberry silkworm.
- It is produced fine white colour silk by the mature worms.
- The weight of the cocoon ranges from 1.01 to 1.56 gm (with insect) and 0.01 to 0.1 gm (shell weight).
- It is mostly grown in tropical and subtropical climatic conditions.
- It is moderately tolerant to flacherie disease.
- It complete life cycle in 37 to 41 days depending on the temperature and relative humidity.

Observation

During entire period of experiment, observations are taken that the mortality was recorded daily till the adult stage at all the growth stages of mulberry silkworm for construction of age specific life table.

Observation on the number of live and dead insect out of hundred were recorded daily. The following assumption was used in the construction of age specific life table;

X = Age of insect in days.

l_x = Number of surviving insects at the beginning of each interval x out of 100.

d_x = Number of dead insects during the age interval x out of 100.

$100q_x$ = Mortality rate of the age interval X.

e_x = Life expectancy or mean life remaining for individuals of age x.

Life expectancy was calculated using the equations:

$$e_x = T_x/L_x$$

To obtain e_x two others parameters T_x and L_x were also computed as given 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 numbers of individuals of x age units beyond the age x and calculated by the equation.

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

where, l_w = The last age interval.

Results and discussion

Age specific life table of *Bombyx mori* Linn. race NB_4D_2 x SH_6 at control temperature (25 ± 1 °C) with 75 ± 5% relative humidity

It was evident from Table 1 that the mulberry silkworm, *Bombyx mori* Linn. race NB_4D_2 x SH_6 required 37 days to finish its generation at control temperature (25 ± 1 °C). It was observed that there was no drop in the survivorship (l_x)

Table 1 Age specific life table of *Bombyx Mori'* Linn. hybrid cross $NB_4D_2 \times SH_6$ at control temperature (25 ± 1 °C), 75 ± 5% RH

X	L_x	d_x	$100q_x$	L_x	T_x	e_x
0	100.00	0.00	0.00	100.00	2880.00	28.80
1	100.00	3.00	3.00	98.50	2780.00	27.80
2	97.00	2.00	2.06	96.00	2681.50	27.64
3	95.00	4.00	4.21	93.00	2585.50	27.22
4	91.00	2.00	2.20	90.00	2492.50	27.39
5	89.00	1.00	1.12	88.50	2402.50	26.99
6	88.00	1.00	1.14	87.50	2314.00	26.30
7	87.00	2.00	2.30	86.00	2226.50	25.59
8	85.00	2.00	2.35	84.00	2140.50	25.18
9	83.00	2.00	2.41	82.00	2056.50	24.78
10	81.00	1.00	1.23	80.50	1974.50	24.38
11	80.00	0.00	0.00	80.00	1894.00	23.68
12	80.00	0.00	0.00	80.00	1814.00	22.68
13	80.00	0.00	0.00	80.00	1734.00	21.68
14	80.00	0.00	0.00	80.00	1654.00	20.68
15	80.00	0.00	0.00	80.00	1574.00	19.68
16	80.00	1.00	1.25	79.50	1494.00	18.68
17	79.00	1.00	1.27	78.50	1414.50	17.91
18	78.00	1.00	1.28	77.50	1336.00	17.13
19	77.00	1.00	1.30	76.50	1258.50	16.34
20	76.00	0.00	0.00	76.00	1182.00	15.55
21	76.00	0.00	0.00	76.00	1106.00	14.55
22	76.00	0.00	0.00	76.00	1030.00	13.55
23	76.00	0.00	0.00	76.00	954.00	12.55
24	76.00	0.00	0.00	76.00	878.00	11.55
25	76.00	0.00	0.00	76.00	802.00	10.55
26	76.00	0.00	0.00	76.00	726.00	9.55
27	76.00	0.00	0.00	76.00	650.00	8.55
28	76.00	0.00	0.00	76.00	574.00	7.55
29	76.00	0.00	0.00	76.00	498.00	6.55
30	76.00	0.00	0.00	76.00	422.00	5.55
31	76.00	0.00	0.00	76.00	346.00	4.55
32	76.00	0.00	0.00	76.00	270.00	3.55
33	76.00	4.00	5.26	74.00	194.00	2.55
34	72.00	18.00	25.00	63.00	120.00	1.67
35	54.00	27.00	50.00	40.50	57.00	1.06
36	27.00	24.00	88.89	15.00	16.50	0.61
37	3.00	3.00	100.00	1.50	1.50	0.50

at the initial day. It again began falling from 1st day till 10th day. A slight pause where no survivorship reduction was recorded between 11th to 15th day. Thereafter, survivorship again dropped from 16 to 19th day. A long pause there no survivorship reduction was recorded from 20th to 32nd day. Thereafter, a sharp decline in the survivorship (l_x) was recorded till end of generation (Fig. 1).

In contrast to survivorship, mortality curve followed a pattern with few high and negative low peaks. The highest mortality was seen 88.89 per cent at 36th day followed by 50 per cent at 35th day and the lowest mortality 1.12 per cent was found at 5th day followed by 1.14 per cent at 6th day. While 27 and 24 number of deaths were experienced at 35th and 36th day respectively, followed by 18 deaths at 34th day.

Table 2 Age specific life table of *Bombyx mori'* Linn. race $NB_4D_2 \times SH_6$ at room temperature

X	L_x	d_x	$100q_x$	L_x	T_x	e_x
0	100.00	2.00	2.00	99.00	2729.00	27.29
1	98.00	3.00	3.06	96.50	2630.00	26.84
2	95.00	2.00	2.11	94.00	2533.50	26.67
3	93.00	4.00	4.30	91.00	2439.50	26.23
4	89.00	2.00	2.25	88.00	2348.50	26.39
5	87.00	2.00	2.30	86.00	2260.50	25.98
6	85.00	1.00	1.18	84.50	2174.50	25.58
7	84.00	1.00	1.19	83.50	2090.00	24.88
8	83.00	1.00	1.20	82.50	2006.50	24.17
9	82.00	2.00	2.44	81.00	1924.00	23.46
10	80.00	2.00	2.50	79.00	1843.00	23.04
11	78.00	0.00	0.00	78.00	1764.00	22.62
12	78.00	0.00	0.00	78.00	1686.00	21.62
13	78.00	2.00	2.56	77.00	1608.00	20.62
14	76.00	2.00	2.63	75.00	1531.00	20.14
15	74.00	1.00	1.35	73.50	1456.00	19.68
16	73.00	2.00	2.74	72.00	1382.50	18.94
17	71.00	1.00	1.41	70.50	1310.50	18.46
18	70.00	3.00	4.29	68.50	1240.00	17.71
19	67.00	1.00	1.49	66.50	1171.50	17.49
20	66.00	1.00	1.52	65.50	1105.00	16.74
21	65.00	2.00	3.08	64.00	1039.50	15.99
22	63.00	1.00	1.59	62.50	975.50	15.48
23	62.00	1.00	1.61	61.50	913.00	14.73
24	61.00	0.00	0.00	61.00	851.50	13.96
25	61.00	0.00	0.00	61.00	790.50	12.96
26	61.00	0.00	0.00	61.00	729.50	11.96
27	61.00	0.00	0.00	61.00	668.50	10.96
28	61.00	0.00	0.00	61.00	607.50	9.96
29	61.00	0.00	0.00	61.00	546.50	8.96
30	61.00	0.00	0.00	61.00	485.50	7.96
31	61.00	0.00	0.00	61.00	424.50	6.96
32	61.00	0.00	0.00	61.00	363.50	5.96
33	61.00	0.00	0.00	61.00	302.50	4.96
34	61.00	0.00	0.00	61.00	241.50	3.96
35	61.00	0.00	0.00	61.00	180.50	2.96
36	61.00	12.00	19.67	55.00	119.50	1.96
37	49.00	21.00	42.86	38.50	64.50	1.32
38	28.00	18.00	64.29	19.00	26.00	0.93
39	10.00	8.00	80.00	6.00	7.00	0.70
40	2.00	2.00	100.00	1.00	1.00	0.50

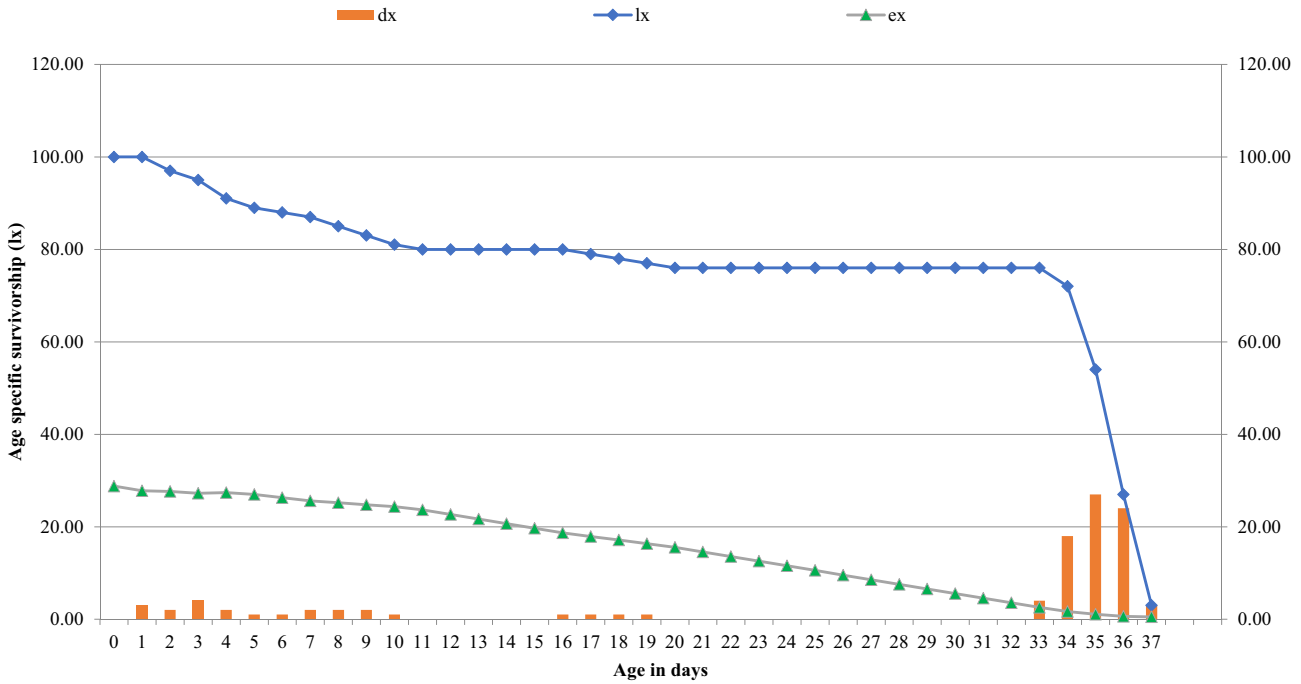

Fig. 1 Figure showing Age specific life table of *Bombyx Mori'* Linn. hybrid cross $NB_4D_2 \times SH_6$ at control temperature (25 ± 1 °C), 75 ± 5% RH

While deaths ranging from 1 to 4 were seen at 1st to 10th day, 16th to 19th day, 33rd day and 37th day. No mortality was exhibited in the remaining days like 11th to 15th day, 20th to 32nd day. The mortality of the silkworm was not observed at all remaining days.

As far as life expectancy (e_x) was concerned, it was marginally reduced till the end of generation because of greater number of deaths in preceding days. Then, own wards with the advancement of *Bombyx mori* Linn. there was gradual reduction in the life expectancy (e_x) till it finally reached 0.5 in 37th day. The curve was slightly linear.

Age specific life table of *Bombyx mori* Linn. race NB_4D_2 x SH_6 at room temperature

It was evident from Table 2 that the hybrid cross of *Bombyx mori* Linn. race NB_4D_2 x SH_6 required 40 days to complete its life cycle at room temperature. In this case, the survivorship gradually declined from initial day to 10th day. There was a slight pause at 11th to 12th day and again a steady decline in survivorship from 13th to 23rd day was observed. A long pause from 24 to 35th day with no mortality was observed and the survivorship again sharply decline from 36th day to end of generation (Fig. 2).

In contrast to survivorship, the mortality curve followed a pattern with few high and negative low peaks. The highest mortality 80 per cent was recorded at 39th day followed by 64.29 per cent at 38th day and lowest mortality 1.18 per cent was recorded at 6th day followed by 1.19 per cent at 7th day. The 21 and 18 numbers of deaths were recorded at 37th and 38th day, respectively. While 12 and 8 deaths were recorded in 36th and 39th day, respectively followed by 4 deaths at 3rd day and 3 deaths at 1st and 18th day. Only 2 deaths were recorded in following days, 2nd, 4th, 5th, 9th, 10th, 13th, 14th,16th, 21st and 40th day. While the one death was also recorded in 6th, 7th, 8th, 15th, 17th, 19th, 20th, 22nd and 23rd. No mortality was exhibited in all remaining days.

As far as life expectancy (e_x) is concerned, it was also reduced till end of generation because of greater number of deaths observed during preceding days. Then onwards with the growth of mulberry silkworm, gradual reduction in the life expectancy (ex) was observed till it finally reached 0.5 on 40th day. The curve was also slightly linear. These findings were found comparable with the findings of Balvasi et al. (2009) who recorded initial decline followed by an intermittent decline which continue for few days. The survivorship curve gave stair step like impression as earlier reported for holometabola insect, same curve was also observed by Ali and Rizvi (2010), Aziz et al. (2013) investigated on the life table of *Trilocha virescence* and *Coccinella septempunctata*, respectively. Similar trend was also observed by Golizadeh et al. (2009), Balvasi et al. (2009), Supriya et al. (2018) for study of following insects viz., *Plutella xylostella* Linn., *Bravicoryne brassicae* and *Spodoptera litura* Fab., respectively.

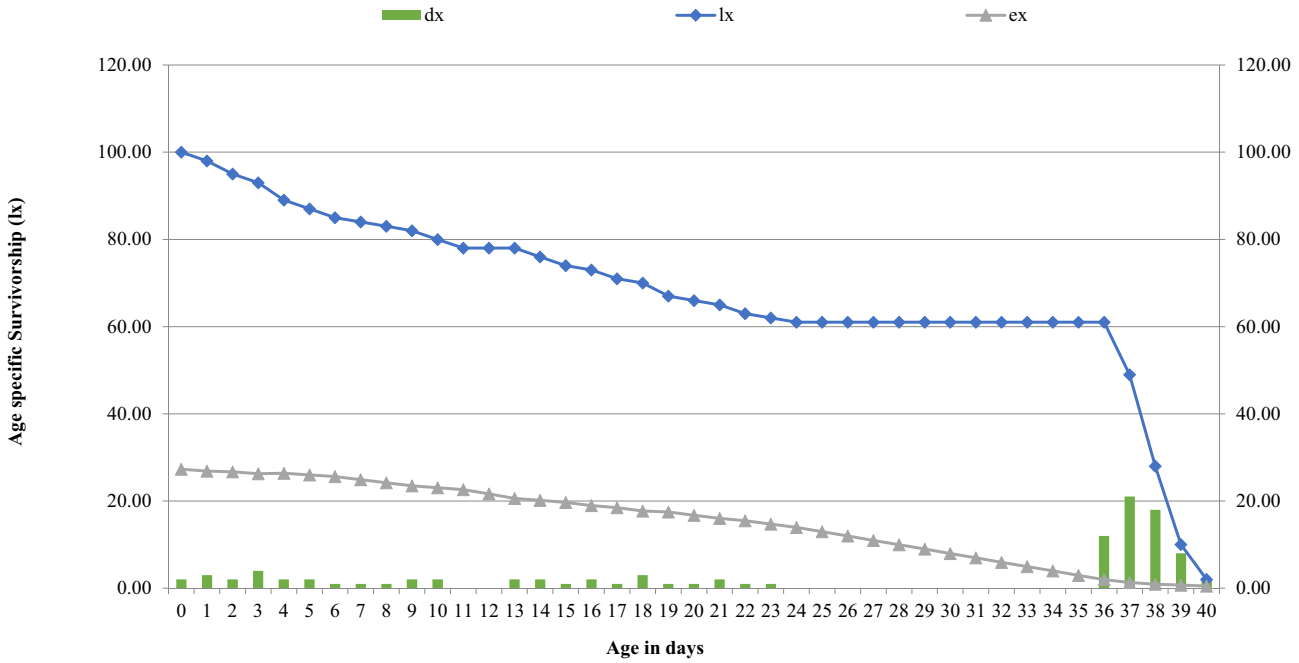

Fig. 2 Figure showing Age specific life table of *Bombyx mori'* Linn. race $NB_4D_2 \times SH_6$ at room temperature

Conclusion

Construction of age specific life table is an important tool for understanding the population dynamics of an insect. It provides a way to tabulate birth and death of insects. With the help of this, we can calculate the life expectancy of insects and therefore plan accordingly for the management of insect-pests at particular time. Quantifying age-specific birth and death rates enables us to discern patterns and make predictions about the growth or decline of insect populations in the future.

Abbreviations gm: Gram; X: Age of insect in days; l_x: Number of surviving insects at the beginning of each interval x out of 100.; d_x: Number of dead insects during the age interval x out of 100.; $100q_x$: Mortality rate of the age interval X.; e_x: Life expectancy or mean life remaining for individuals of age x.; L_x: The number of individuals alive between age x and x + 1; T_x: The total numbers of individuals of x age units beyond the age x; &: And; ^{o} C: Degree Celsius; RH: Relative humidity; BOD: Biological Oxygen Demand; *i.e.*: That is; viz.,: Namely; cm: Centimetres; MT: Metric tonne

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Declarations

Competing interests The authors have no financial or proprietary interests in any material discussed in this article.

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