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Age-specific life table, fecundity table, life parameters, stable age distribution and life expectancy of *Spodoptera litura* (F.) on cotton hybrids during 90-120 DAS

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Abstract
To study the age specific survivorship of *S. litura*, on Bt cotton hybrids, life tables was constructed in controlled conditions (24±1°C, 70±5% R.H.). During 2012-13. From (December- June). At College of Agriculture, Department of Entomology. Bt-Lab. Professor Jayashankar Telangana State Agriculture University, Rajendranagar, Hyderabad. The age- specific life-table of *S. litura on* Bt-II hybrids showed maximum survivorship during fourth and fifth instar stages from third instar, mortality was more in the early stages and it gradually declined till culmination of the generation, it has shown type IV survivorship curve. The net reproductive rate (R_0) 101.34 females/ female/day, mean generation time (T_c), 40.93 days, intrinsic rate of increase (r_m) (0.1180), finite rate of increase (λ) (1.12) females/female/day, doubling time (DT) (5.81) days, weekly multiplication rate (WMR) (2.28) times per week, and annual rate of increase (ARI) (5.0929×10^{18}) indicating completion of 18 generations per year, recorded on different Bt-II hybrids revealed less values compared to Bt-I fed larvae. In Bt-II hybrids the life expectancy was less in early days ranged between (20.36-23.51days) and then it increased ranged from (18.19-26.00 days) and decreased gradually with the age. The protein estimation revealed that the amount of Cry 2Ab toxin in Bt-II hybrids was decreased in the leaves (126.20-210.71 ppm) and recorded more in squares (213.24-318.14 ppm) and bolls (343.50-767.08 ppm) during 90-120 DAS. The Bt-II hybrids have shown a profound impact on the growth and development of *S. litura* during early stages of crop, as the crop matured the Cry toxin content decreased, survival rate recorded was more in 4^{th} and 5^{th} instar larvae in later stages of crop.

Keywords: *S. litura*, Bt cotton hybrids, life-table, life parameters

1. Introduction

Insect-pests cause great hazard to the world's vegetation and significant reduction of crop's output. Many multiply hundredfold in a short period, feeding on leaves, stem and fruits to complete their development stages [1]. Tobacco caterpillar, *S. litura* is one among them, as it is a polyphagous noctuid with high reproductive potential and the ability to migrate long distances as adults [2], These factors contribute to the role of *S. litura* as a major pest of many agricultural crops throughout its geographical range [2] The caterpillar enjoys wide distribution and is a generalist herbivore infesting more than 290 species of plants belonging 80 to 99 families [3] It is pest on major crops like tobacco, ground nut, Cauliflower, Cotton etc. The polyphagous pest feed on foliage, flowers and bolls of Bt –cotton (Cry 1Ac), threatening Indian farmers in their quest for quality of fibre. There infestations can result in total crops failed. High population of these insect can cause economic loss in many plants by reducing product [4]

This situation leads to attempt to introduction of additional gene in the single gene cotton hybrids. The dual gene technology is being considered as an improvised pest management method not just for its enhanced efficacy but also as an efficient resistance management strategy. The addition of other Cry 1Ac has improved the efficacy against armyworms. [5-7].

Due to the wide adoption of Bt transgenic crops, the efficacy of this technology is threatened by the evolution of resistance by target pests. After more than a decade of commercialization, recent reports support field-evolved resistance to Bt crops in *Helicoverpa zea*, *Spodoptera frugiperda*, *Busseola fusca* and *Spodoptera litura* [8-11]

Keeping this in the view the present experiment was conducted on different Bt-I and Bt-II hybrids during 90-120 DAS in the laboratory.

The Bollgard –II genotypes with Cry1Ac+Cry2Ab background in terms of dynamics of *S. litura*, mortality rate, survival, reproduction, contribution of immature stages to the crop damage and life expectancy, which gives the information of at which stage of crop is vulnerable to test insect been considered in priority as IRM strategy. The information on exact advantage of these hybrids over Bt-I cultivars in terms of life expectancy, relative contribution of immature stages to the crop is scanty.

Morris and Miller [12] presented the first detailed example of a life table for natural population of spruce budworm. A complete picture of mortality in a population is illustrated systematically by the life table, a statistical device developed by students of human population [13]

Life tables constructed using laboratory data collected under controlled conditions and are useful in revealing the maximal growth potential of a population [14]. Life tables used can make quantitatively and qualitatively evaluation of various host plants [15].

Population parameters are important in the measurement of population growth capacity of species under specified conditions. These parameters are also used as indices of population growth rates responding to selected conditions and as bioclimatic indices in assessing the potential of a pest population growth in a new area [16]. The intrinsic rate of increase (r_m) is a functional ecological parameter and to predict the potential of population growth of an animal under a given environmental condition [17, 18].

So, there was necessity to generate the information on life and fertility table studies, to determine age specific survivals, fecundity, net reproductive rate, intrinsic rate of increase of these hybrids against potential pest *S. litura.* The present study was aimed to construct the life tables of *S. litura* feeding on different Bt cotton hybrids and study the effect of each hybrid on life table parameters.

2. Materials and Methods

Laboratory experiments were carried out during 2012-2013 to study the effect of transgenic Bt cotton hybrids consisting single and double toxin leaves against third instar larvae of *S. litura*.

2.1 Rearing of *Spodoptera litura*

A colony of *S. litura* was originally collected from Colocasia fields at ARI (Agriculture Research Institute) Rajendranagar and maintained in the Bt-Lab, Department of Entomology, Professor Jayashankar Telangana State Agriculture University, Rajendranagar, Hyderabad. The colony was periodically supplemented with larvae collected from the different fields of castor and tomato to reduce inbreeding depression. The egg mass after hatching were transferred to the leaves of castor. The newly emerged larvae settled on the leaves were taken and kept in the battery jars containing blotting paper at the bottom. The leaves were changed and the faecal pellets removed from the battery jar every 24 hrs. The grown up larvae were allowed to pupate in the soil. Moths were collected on emergence and released in battery jars for egg laying. During generation-II the larvae were reared on sorghum based artificial diet up to third instar and then released on to Bt-I and Bt-II hybrids leaves of 90-120 DAS. (Days after sowing).

2.2 Host Plants

Seeds of Bt cotton hybrids obtained from Monsanto seed company, Hyderabad. Seeds were dibbled with intra row spacing of 60 cm and inter row spacing of 90 cm. In each treatment plot, 100 plants were maintained at College farm, College of Agriculture Rajendranagar, PJTSAU. Leaves of 90-120 days old crop were used for present experiment.

Bt-I HYBRIDS		Bt-II HYBRIDS	
1.	NCS-145 Bt-I	7.	NCS-145 Bt-II
2.	NCS-207 Bt-I	8.	NCS-207 Bt-II
3.	NCS-950 Bt-I	9.	NCS-950 Bt-II
4.	NCS-954 Bt-I	10.	NCS-954 Bt-II
5.	RCH-2 Bt-I	11.	RCH-2 Bt-II
6.	RCH-134 Bt-I	12.	RCH-134 Bt-II

2.3 Experiments

The leaves of 90-120 DAS(Days after sowing) old cotton were collected from field were washed with distilled water and sandwiched between two blotting papers to remove excess moisture from the leaf, and maintained in Battery jars (10 cm in diameter and 15 cm in height) with round disc of blotting paper at bottom of the jar. Neonates hatched from the eggs of previous generation (reared initially on Bt-I and Bt-II hybrids) were reared up to third instar on sorghum based artificial diet [19] after reaching third instar, they were transferred to leaves of transgenic Bt-cotton hybrids of age 90-120 DAS and observation were recorded. Larvae were maintained in three replications till the death or pupation. The methods suggested by Morris and Miller [12] were used for constructing the life-tables.

After emergence of moths they are collected with the help of plastic tube and released into battery jar, which was closed at the top with a muslin cloth for ventilation and the internal walls were covered with the white paper as an oviposition substrate. A small cotton wick soaked in 10 per cent honey solution was placed in the small petriplates for adult feeding. The number of eggs laid by the female adults on each day was counted by using stage microscope till the death of the adults. The life-table for female was constructed from the column lx as described by Birch and Poole [20, 21]. Stable age distribution was worked out by observing the population schedule of birth rate and death rate (mx and lx) when grown in limited space. Life expectancy was computed by using the method suggested by Deevey and Atwal and Bains [22, 23].

Neonates hatched from the eggs of first generation-I were reared up to third instar on artificial diet later, they were transferred to leaves of transgenic Bt-cotton hybrids of age 90-120 DAS and observation were recorded as Generation-II (G-II).

2.4 Assessment of Cry protein expression and concentration in different parts of transgenic plants.

Quantification of Cry1Ac in Bt-I and Cry1Ac+Cry2Ab in Bt-II hybrids was undertaken by collecting separately top young leaves, squares and bolls collected from field in ice box and carried to laboratory. The samples were sent to M/S Monsanto Research Centre, Bengaluru.

2.5 Statistical analysis

The data collected was calculated in MS-EXCEL. For protein estimation based on absorption values of ELISA reader the quantification of Cry protein was assessed with the help of sigma plot version 8.01 programme [24].

3. Results and Discussion

3.1 Age specific survivorship

The age specific survivorship (lx) and mortality (dx) of *S. litura* on different Bt- II and Bt-I hybrids are presented in figures (1-12). Survival of third instar was low when reared on Bt-II hybrids which dropped sharply by 10th day. The survivorship curve indicated a modest rate of mortality during the third instar and a gradual decrease as it approached later stages and this curve assumed a near type IV survivorship curve. (mortality is more in early stages) Fig. (7-12) When the larva fed with the Bt-I hybrids the survivorship curve observed was type I as the mortality is more in adult stages. (Slobodkin, 1962) [25]. (Fig. 1-6). In general 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 [26] and larvae can tend to eat plant leaves easily and levels of Cry protein decreased gradually with the advancement of crop. A little mortality of larvae was also found at later stage of development, possibly, due to the variation in nutritional value of hybrids.

As the generation (Generation-II) (90-120 DAS) started with the third instar larvae due to the higher mortality in the early stages during G-I (Generation-I) (60-90 DAS) this can be supported with findings of authors, [27] who reported higher mortality of neonate larvae of *S. litura*, when fed with dual toxin Bt cultivars compared to single toxin Bt cultivars and non Bt cotton. Henneberry *et al*. [28] reported cent per cent mortality of neonate larvae of beet armyworm on leaves compared to 96 per cent mortality on squares of Bt-hybrids. Dhawan *et al*. [29] they have reported that even at 120 DAS of the crop the mortality of neonates of *S. litura* fed on different plant parts of BG-II hybrids was recorded (from pooled analysis) more than 56.67- 80.00 per cent in leaves, 65.56-90.00 per cent in squares and 75.56-83.33 per cent larval mortality on green bolls at ambient environmental condition. According to Kumar [30], using the neonates of *H.armigera*, there was 89.26, 80.00 and 86.30 per cent mortality observed after 10 DPT (Days post treatment) period when the leaves, squares and bolls of 120 DAS was given to *H.armigera*, respectively.

3.2 Age specific survivorship and fecundity

The age specific female survivorship (lx) and age specific fecundity (mx) was recorded more in *S. litura* fed on Bt-I hybrids, Figures (13-18) and it ranged between (948.00 - 1150.50) highest fecundity was recorded on adults as larvae fed on NCS-954 Bt-I and lowest was noticed in NCS-145 Bt-I. The potential fecundity on Bt-II hybrids, Figures (19-24) ranged from (711.50-865.50) the highest was recorded in RCH-2Bt-II and lowest in NCS-207 Bt-II fed larvae.

Host plant quality is a key determinant of the fecundity of herbivores insects, affecting insect reproductive strategies, egg size and quality, the allocation of resources to eggs, and the choice of oviposition sites may be influenced by plant quality, as may egg or embryo resorption on poor quality host [31]. Therefore, study of the influence of different host plants on the growth and development and fecundity of insects is very useful to understand host suitability of plant infesting insect species.

3.3 Life parameters

The different life parameters calculated for *S. litura* on Bt-I and Bt-II cotton hybrids of has been presented in Table 1. The lowest net reproductive rate (R_0) of *S. litura* was recorded on Bt-II hybrids compared to Bt-I. Similar trend was recorded with regard to other life parameters like potential fecundity, intrinsic rate of increase, finite rate of increase corrected generation time, hypothetical F_2 females, annual rate of increase and weekly multiplication rate.

The higher intrinsic rate of increase (r_m) of *S. litura* larvae which fed on Bt-I recorded more compared to Bt-II fed larvae, was due to the faster development of immature stages (shorter generation time), higher survivorship and higher fecundity rates and high value of r_m indicates the susceptibility of the host plant to insect feeding compared to Bt-II hybrids. While a low value indicates that the host plant species is resistant to the polyphytophagous prolific test insect *S. litura*. The increase in growth rate, shorter development time, and higher fecundity point out that increased feeding and or higher assimilation rate, both of which may be the result of an increased titer of digestive enzymes [32]. Mean generation time (T_c) was the longest on RCH-134 Bt-II (40.93 days). Lowest weekly multiplication rate of 2.28 times was recorded in RCH-134 Bt-II and highest rate of 3.21 times was recorded in RCH-134 Bt-I. Bagade *et al.* [33] reported that transgenic Bt cotton was found effective against three bollworms (*H. armigera*, *Earias spp*.and *P. gossypiella*) as well as Luttrell *et al.* [34] reported more tolerance in *S. frugiperda* against Cry 1 Ac than other bollworms. It was in agreement with the report of Arshad and Suhail [35] Cry1Ac was not effective against beet armyworm, *S. exigua* in the laboratory experiments Chakroun *et al* [36]. Cry toxin influences the toxicity to vary the species of *Spodoptera. S. exigua* was less susceptible than *S. frugiperda*.

3.4 Stable age distribution

The stable-age distribution of *S. litura* on Bt-I and Bt-II showed more than 90 per cent of immature stages contributed more than mature stages. (Table. 2). The studies on stable-age distribution of the insect pest by different authors concluded that more than 90 per cent immature stages formed in the stable-age distribution Bilapate and Pawar [37], Bilapate [38], Hemchandra and Singh [39], Acharya *et al*. [40], Shah *et al*. [41], Gedia *et al*. [42] and present results are in conformity with all of them. (Table. 2)

3.5 Life expectancy

Life expectancy of *S. litura* on Bt-I hybrids was more in early stages and declined gradually. (Table. 3)These results can be supported by findings of Dhabi *et al.* [43] who reported that the life expectancy of *P. xylostella* was more in early stages and declined with advancement of age. But in the Bt-II hybrids the life expectancy during 90-120 DAS was recorded as low during early days and increased in the later stages and then decline gradually, reflecting the clear-cut effect of Cry2Ab toxin in early instar stages and increased in the later stages of development indicating gaining resistance by late instar larvae. Banna *et al*. [44] reported that younger larvae are generally more susceptible than older larvae because of their peritrophic matrix bindings and the expected life decreased finally at the end.

3.6 Protein Estimation

The results of protein estimation of present research showed that the toxin expression in the leaves was low during 90-120DAS of the crop. The highest toxin was recorded in squares and bolls. (Table.4).

The reasons tagged for decline in expression of Cry toxins revolved around age factor of the crop, decline in total protein concentration and increased accumulation of pro-anthocyanin.

Climatic factors like temperature, soil moisture also found to play major role in toxin expression which has been related to damage. Surprisingly, Bt genotypes performed well in irrigated condition than in rain fed because of soil moisture [45-49] However, elevation and or maintenance of Cry toxins at fairly higher level throughout the season by any means have not been reported so far. Instead, the phenomenon of decline in toxin concentration has been convincingly accepted by the farming community and protection at later stage is being offered through chemical intervention.

The main causes for variation in performance of Bt transgenic could be either insect related (resistance), or crop performance (decline in expression) and even it could be environment related also. Hence, the decline or change in expression appear to be a significant factor which lead to survival of population at definite stages giving scope for development of resistance or platform for insect control failure, if not addressed properly. This phenomenon has been well predicted and documented in the early ages of Bt crop era. [50, 51, 48, 52].

Table 1: Life Parameters of *S. litura* fed on different Bt Cotton Hybrids. 90-120 DAS (Days after sowing)

Life Parameters	NCS-145 Bt-I	NCS-145 Bt-II	NCS-207 Bt-I	NCS-207 Bt-II	NCS-950 Bt-I	NCS-950 Bt-II	NCS-954 Bt-I	NCS-954 Bt-II	RCH-2 Bt-I	RCH-2 Bt-II	RCH-134 Bt-I	RCH-134 Bt-II
Net reproductive rate (R_0)	243.53	145.48	413.13	145.21	329.51	101.34	481.47	134.63	298.15	184.65	301.46	124.20
Mean duration of a generation (Tc) (days)	33.99	38.00	33.13	39.32	34.12	39.00	33.41	40.04	33.00	37.96	34.34	40.93
Arbitrary 'r_m' or 'r_c' value	0.1616	0.1310	0.1818	0.1265	0.1699	0.1184	0.1848	0.1224	0.1726	0.1401	0.1662	0.1178
Innate capacity for increase in number (r_m)	0.1621	0.1312	0.1824	0.1268	0.1704	0.1186	0.1854	0.1227	0.1732	0.1405	0.1667	0.1180
Potential fecundity	948.00	772.50	1087.00	711.50	960.50	777.00	1150.50	741.00	957.50	865.50	988.50	841.50
Finite rate of increase (λ) ♀'s/♀/day	1.17	1.14	1.20	1.13	1.18	1.12	1.20	1.13	1.18	1.15	1.18	1.12
Corrected generation time (T) (days)	33.89	37.94	33.03	39.24	34.01	38.92	33.29	39.95	32.90	37.91	34.24	40.87
Weekly multiplication rate $(e^{rm})^7$	3.11	2.50	3.58	2.43	3.29	2.29	3.66	2.36	3.36	2.67	3.21	2.28
Hypothetical F_2 females	59306.86	21164.43	170676.39	21085.94	108576.84	10269.79	231813.36	18125.23	88893.42	43793.93	90878.13	15425.64
Doubling time (DT)	4.27	5.28	3.79	5.46	4.06	5.84	3.73	5.64	4.00	4.93	4.15	5.87
Annual rate of increase (ARI)	5.0518×10^{25}	6.3771×10^{20}	8.3071×10^{28}	1.2915×10^{20}	1.0492×10^{27}	6.4049×10^{18}	2.5363×10^{29}	2.8200×10^{19}	2.8525×10^{27}	1.8769×10^{22}	2.7039×10^{26}	5.0929×10^{18}

Table 2: Stable age distribution of *S. litura* on different Bt-I and Bt-II hybrids

	Per Cent Contribution Of Immature Stages		
Hybrids	**Larval**	**Pupal**	**Adult**
NCS-145 Bt-I	94.65	4.80	0.55
NCS-145 Bt-II	96.56	3.04	0.40
NCS-207 Bt-I	95.93	3.69	0.37
NCS-207 Bt-II	96.50	3.05	0.45
NCS-950 Bt-I	96.28	3.35	0.36
NCS-950 Bt-II	96.41	3.25	0.32
NCS-954 Bt-I	96.36	3.18	0.45
NCS-954 Bt-II	97.25	2.67	0.50
RCH-2 Bt-I	96.18	3.14	0.28
RCH-2 Bt-II	96.68	2.95	0.36
RCH-134 Bt-I	96.26	3.37	0.35
RCH-134 Bt-II	97.29	2.37	0.34

Table 3: Life- expectancy of *S. litura* on different Bt-cotton hybrids

NCS-145 Bt-I		NCS-145 Bt-II		NCS-207 Bt-I		NCS-207 Bt-II		NCS-950 Bt-I		NCS-950 Bt-II	
x	e_x	x	e_x	x	e_x	x	e_x	x	e_x	x	e_x
1-3	30.80	1-3	21.41	1-3	30.92	1-3	22.10	1-3	30.50	1-3	21.35
4-6	28.39	4-6	21.57	4-6	30.10	4-6	22.93	4-6	28.69	4-6	20.99
7-9	26.51	7-9	22.05	7-9	28.03	7-9	24.48	7-9	26.26	7-9	19.63
10-12	23.77	10-12	23.00	10-12	25.33	10-12	25.74	10-12	23.52	10-12	18.56
13-15	21.25	13-15	24.62	13-15	22.33	13-15	26.00	13-15	22.00	13-15	17.89
16-18	18.69	16-18	22.56	16-18	19.33	16-18	24.50	16-18	19.23	16-18	18.19
19-21	15.88	19-21	20.46	19-21	16.33	19-21	21.50	19-21	16.64	19-21	17.65
22-24	13.20	22-24	17.46	22-24	13.49	22-24	18.50	22-24	14.00	22-24	16.14
25-27	10.33	25-27	15.16	25-27	10.76	25-27	16.22	25-27	11.78	25-27	14.63
28-30	7.53	28-30	12.16	28-30	7.86	28-30	13.53	28-30	9.18	28-30	12.33
31-33	4.88	31-33	9.40	31-33	4.86	31-33	10.80	31-33	6.27	31-33	9.33
34-36	3.17	34-36	6.57	34-36	2.86	34-36	8.00	34-36	3.59	34-36	7.00
37-39	2.00	37-39	3.57	37-39	2.00	37-39	5.00	37-39	2.00	37-39	4.16
-	-	40-42	2.67	-	-	40-42	2.31	-	-	40-42	2.83
-	-	43-45	2.00	-	-	43-45	2.00	-	-	43-45	2.00

x : Pivotal age in days e_x : Expectation of further life

Table 3

NCS-954 Bt-I		NCS-954 Bt-II		RCH-2 BT-1		RCH-2BT-II		RCH-134 Bt-I		RCH-134 Bt-II	
x	ex	x	ex	x	ex	x	ex	x	ex	x	ex
1-3	30.77	1-3	20.36	1-3	26.54	1-3	23.51	1-3	29.30	1-3	21.68
4-6	28.36	4-6	21.67	4-6	26.27	4-6	25.56	4-6	27.44	4-6	21.11
7-9	26.77	7-9	20.53	7-9	24.40	7-9	25.50	7-9	25.26	7-9	20.81
10-12	24.32	10-12	22.24	10-12	21.93	10-12	26.29	10-12	22.51	10-12	22.66
13-15	21.82	13-15	24.40	13-15	19.41	13-15	24.97	13-15	20.20	13-15	24.12
16-18	19.05	16-18	22.40	16-18	17.31	16-18	22.79	16-18	18.76	16-18	22.50
19-21	16.44	19-21	19.40	19-21	15.82	19-21	20.16	19-21	16.62	19-21	20.39
22-24	14.15	22-24	16.80	22-24	13.86	22-24	17.50	22-24	14.00	22-24	18.23
25-27	11.30	25-27	15.69	25-27	11.43	25-27	15.10	25-27	11.00	25-27	16.00
28-30	8.30	28-30	13.05	28-30	8.58	28-30	13.19	28-30	8.63	28-30	14.08
31-33	5.46	31-33	10.67	31-33	6.03	31-33	10.19	31-33	6.72	31-33	11.39
34-36	3.01	34-36	8.45	34-36	3.11	34-36	7.36	34-36	3.97	34-36	9.20
37-39	2.00	37-39	5.66	37-39	2.00	37-39	4.36	37-39	2.00	37-39	6.41
-	-	40-42	3.18	-	-	40-42	2.96	-	-	40-42	3.55
-	-	43-45	2.00	-	-	43-45	2.00	-	-	43-45	2.00

x : Pivotal age in days e_x : Expectation of further life

Table 4: Assessment of Cry1Ac + Cry2Ab (ppm) protein expression and concentration in different parts of transgenic plants. During 90-120 DAS (Days after Sowing)

Bt-I hybrids	**Leaf**		**Square**		**Boll**	
	Cry 1Ac		**Cry 1Ac**		**Cry 1Ac**	
NCS-145 Bt-I	3.02		2.59		1.61	
NCS-207 Bt-I	4.44		2.09		1.09	
NCS-950 Bt-I	1.86		2.00		1.47	
NCS-954 Bt-I	2.65		1.82		2.46	
RCH-2 Bt-I	2.47		1.80		2.68	
RCH-134 Bt-I	3.01		2.20		1.05	
Bt-II hybrids	Leaf		Square		Boll	
	Cry 1Ac	Cry 2Ab	Cry 1Ac	Cry 2Ab	Cry 1Ac	Cry 2Ab
NCS-145 Bt-II	2.63	162.81	2.10	228.24	1.89	602.42
NCS-207 Bt-II	2.20	126.20	1.68	213.24	1.04	456.36
NCS-950 Bt-II	1.63	138.31	1.92	251.43	1.64	343.50
NCS-954 Bt-II	2.65	122.78	2.46	300.51	2.46	769.56
RCH-2 Bt-II	1.62	207.23	1.62	311.06	1.86	643.82
RCH-134 Bt-II	1.59	210.71	1.59	318.14	1.89	767.08

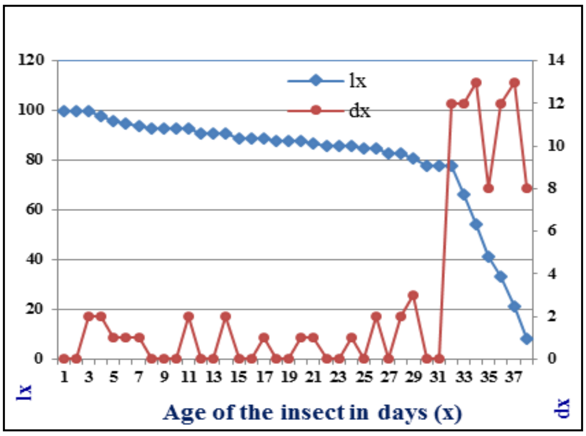

Fig 1: Age specific survivorship (lx) and mortality (dx) of *S. litura* on NCS-145 Bt-I

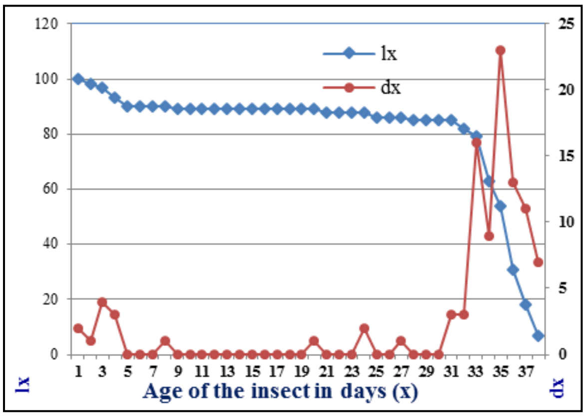

Fig 2: Age specific survivorship (lx) and mortality (dx) of *S. litura* on NCS-207 Bt-I

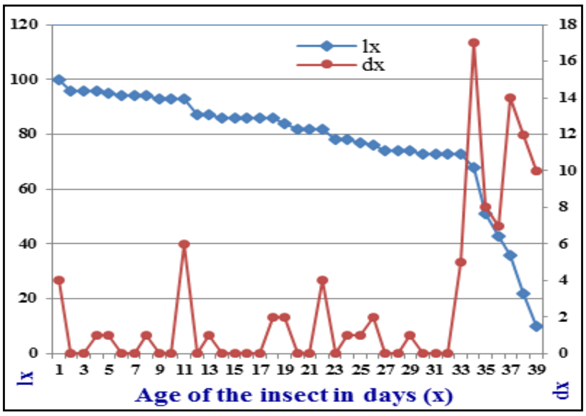

Fig 3. Age specific survivorship (lx) and mortality (dx) of *S. litura* on NCS-950 Bt-I

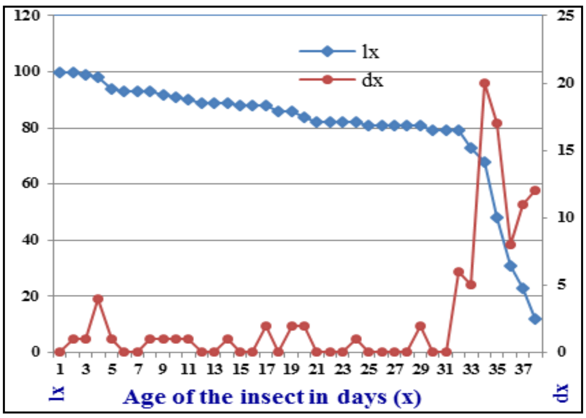

Fig 4: Age specific survivorship (lx) and mortality (dx) of *S. litura* on NCS-954 Bt-I

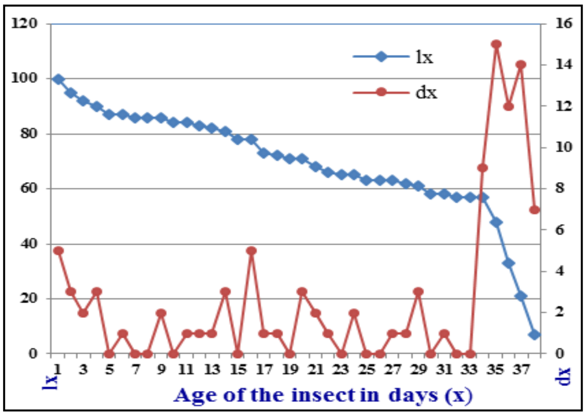

Fig 5: Age specific survivorship (lx) and mortality (dx) of *S. litura* on RCH-2 Bt-I

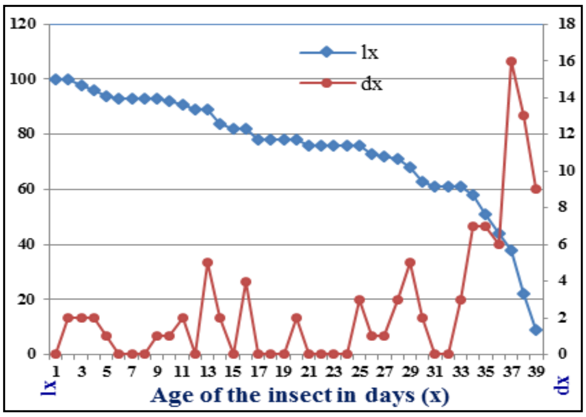

Fig 6: Age specific survivorship (lx) and mortality (dx) of *S. litura* on RCH-134 Bt-I

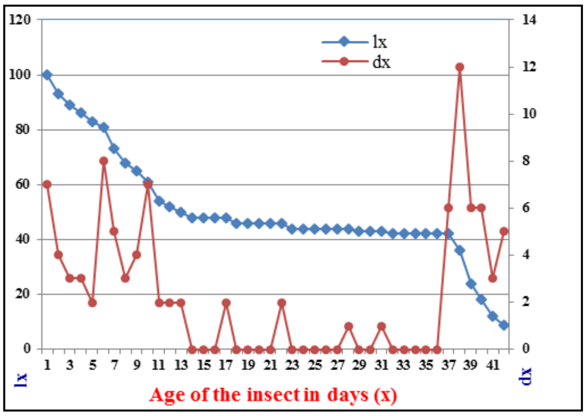

Fig 7: Age specific survivorship (lx) and mortality (dx) of *S. litura* on NCS-145 Bt-II

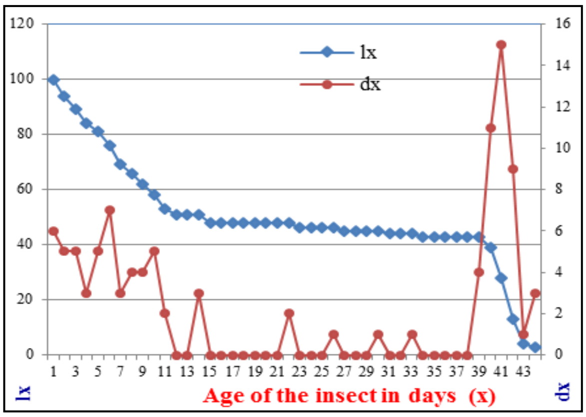

Fig 8: Age specific survivorship (lx) and mortality (dx) of *S. litura*

on NCS-207 Bt-II

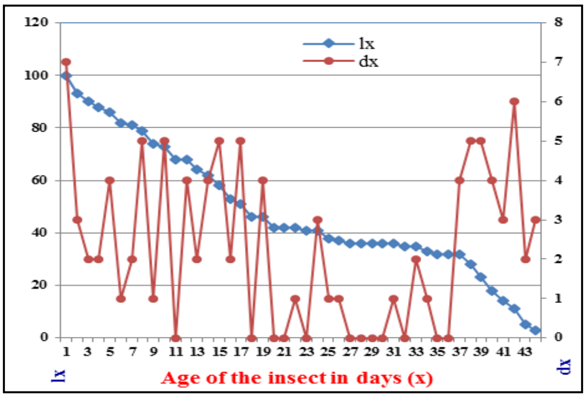

Fig 9: Age specific survivorship (lx) and mortality (dx) of *S. litura* on NCS-950 Bt-II

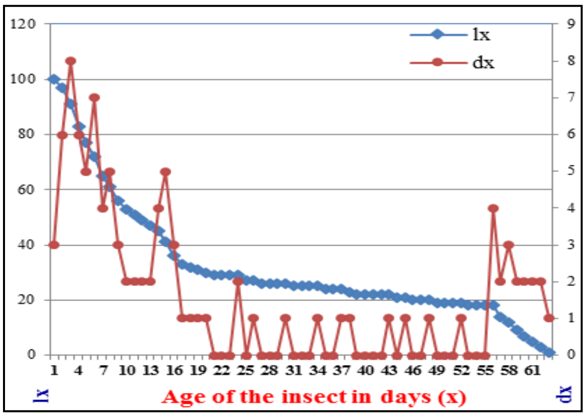

Fig 10: Age specific survivorship (lx) and mortality (dx) of *S. litura* on NCS-954 Bt-II

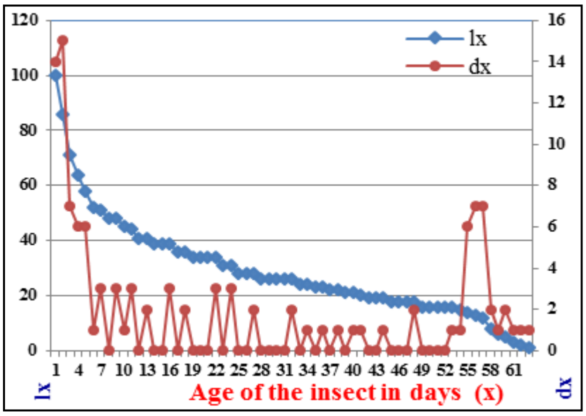

Fig 12: Age specific survivorship (lx) and mortality (dx) of *S. litura* on RCH-134 Bt-II

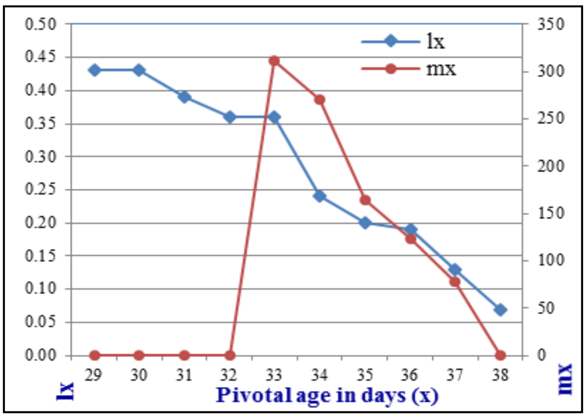

Fig 13: Age Specific survivorship of female (lx) and Fecundity (mx)

of *S. litura* on NCS-145 Bt-I

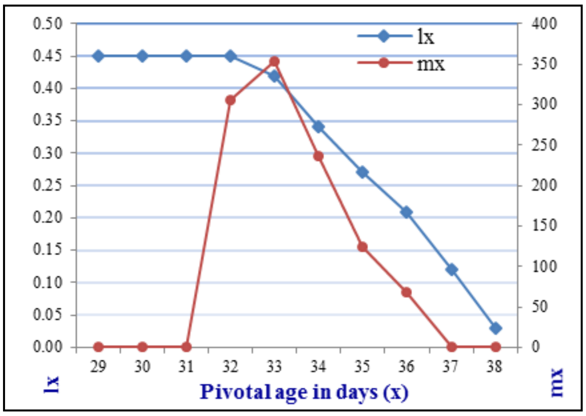

Fig 14: Age Specific survivorship of female (lx) and Fecundity (mx) of *S. litura* on.NCS-207 Bt-I

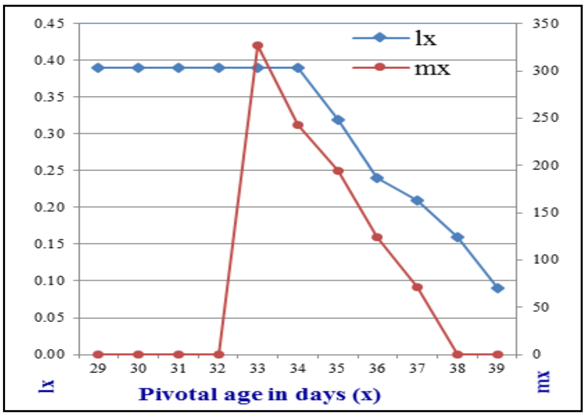

Fig 15: Age Specific survivorship of female (lx) and Fecundity (mx) of *S. litura* on..NCS- 950 Bt-I

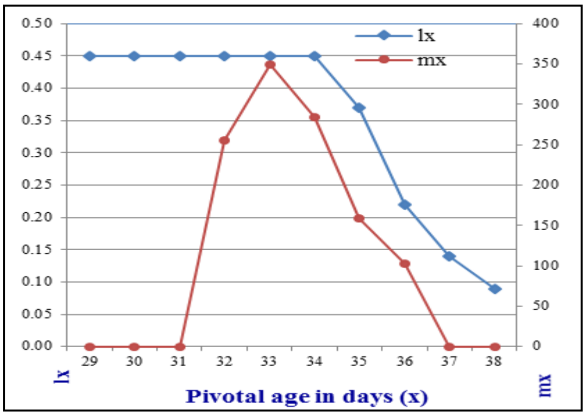

Fig 16: Age Specific survivorship of female (lx) and fecundity (mx) of *S. litura* on NCS-954-Bt-I

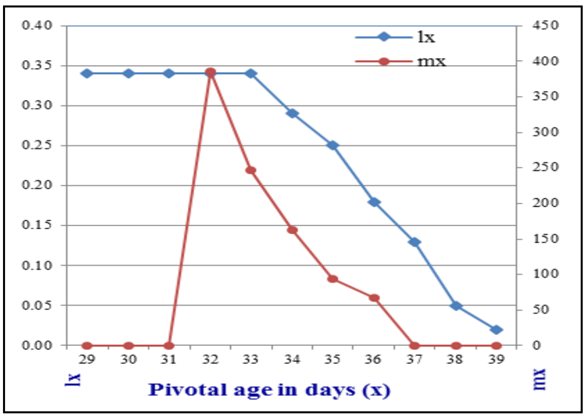

Fig 17: Age Specific survivorship of female (lx) and Fecundity (mx)

of *S. litura* on RCH-2 Bt-I

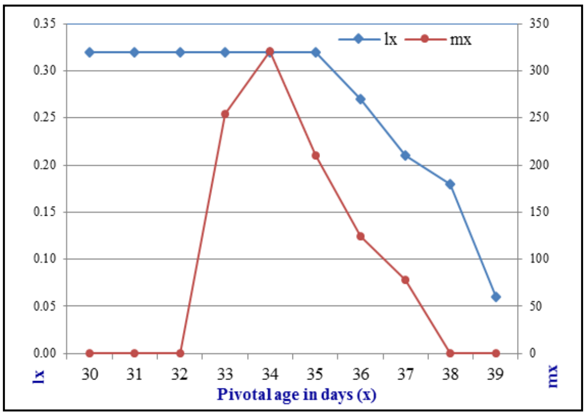

Fig 18: Age Specific survivorship of female (lx) and Fecundity (mx) of *S. litura* on RCH-134 Bt-I

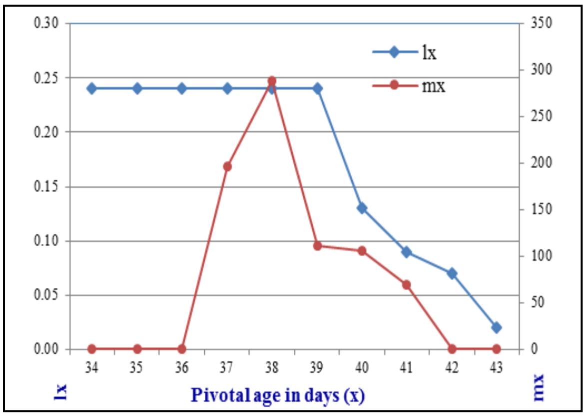

Fig 19: Age Specific survivorship of female (lx) and Fecundity (mx) of *S. litura* on NCS-145 Bt-II

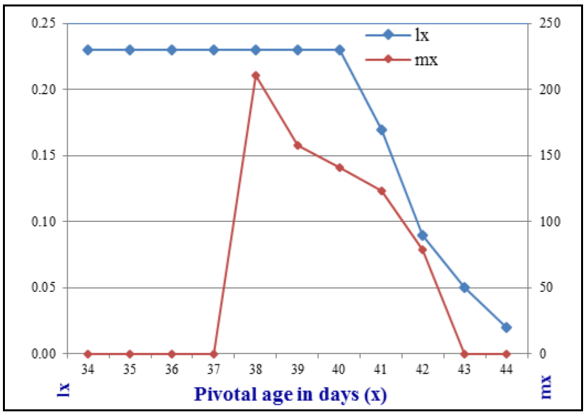

Fig 20: Age Specific survivorship of female (lx) and Fecundity (mx) of *S. litura* on NCS-207 Bt-II

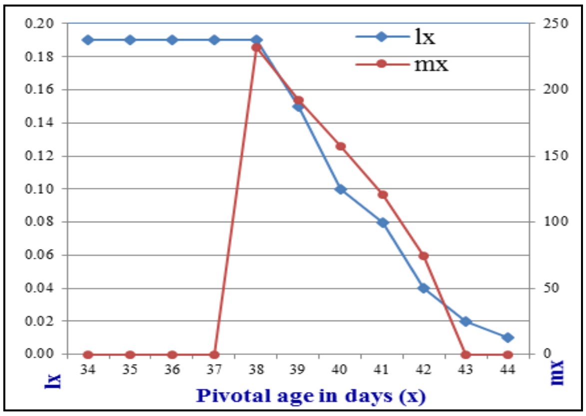

Fig 21: Age Specific survivorship of female (lx) and Fecundity (mx) of *S. litura* on NCS-950 Bt-II

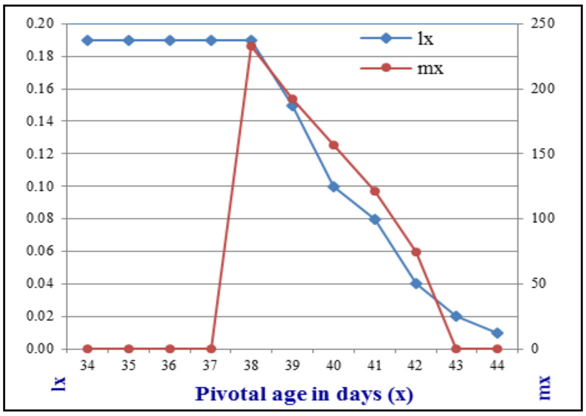

Fig 22: Age Specific survivorship of female (lx) and Fecundity (mx) of *S. litura on* NCS-954 Bt-II

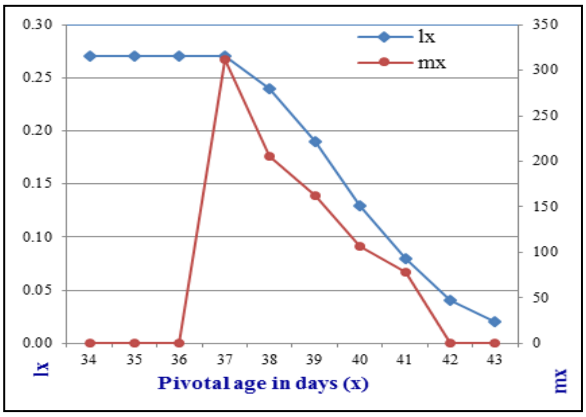

Fig 23: Age specific Survivorship (lx) and Fecundity (mx) of *S. litura* on RCH-2 Bt-II

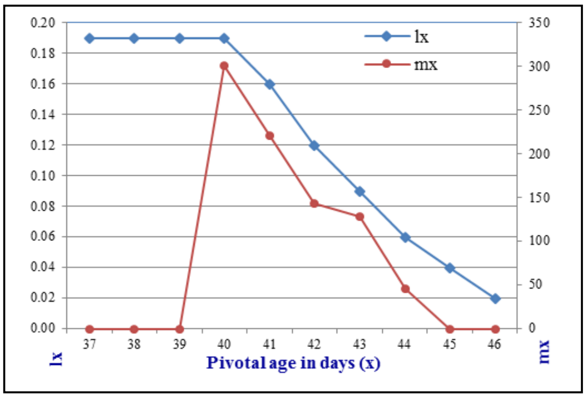

Fig 24: Age specific Survivorship (lx) and Fecundity (mx) of *S. litura* on RCH-134 Bt-II

4. Conclusion

The present study revealed that double gene hybrids had negative effect on the growth and development of *S. litura* during early stages of crop, as the crop matured the Cry toxin content decreased, the pest has developed resistance, hence the survival rate is more in fourth and fifth instar larvae in later stages of crop. Hence the future studies should elucidate on development of Bt cotton hybrids having Bt gene with higher and longer period of expression of Cry toxin, Plant-specific recommendations to reduce Bt-resistance development include increasing Bt expression levels (high-dose strategy), expressing multiple toxins (gene pyramiding), or expressing the protein only in tissues highly sensitive to damage (tissue-specific expression). For effective management of *S. litura infestation* and development of multigenerational pest management strategy to overcome the polyphytophagous prolific insects.

5. Acknowledgement
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