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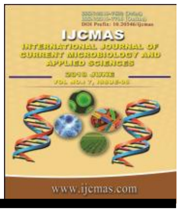

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Life Table Study of Tobacco Caterpillar *Spodoptera litura* (F.) (Noctuidae: Lepidoptera) on Different Bt Cotton Hybrids During 120-150 DAS (Days after Sowing)

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ABSTRACT

Survival and fertility characteristics of the third instar larvae of *Spodoptera litura* (Fabricius), on Bt-I and Bt-II cotton hybrids during 120-150 DAS were assessed in the laboratory. Life tables and population parameters of the *S.litura* were constructed in an environment with unlimited food supply and that was free of natural enemies. The results revealed that the modest rate of mortality occurred in the immature stage, especially in the third instar. The population parameters calculated are recorded as low in Bt-II hybrids compared to Bt-I hybrids. The net reproductive rate (R_0) recorded highest 447.24 on NCS-954 Bt-I whereas lowest on RCH-134 Bt-II as 169.35 with the mean generation time (Tc) 40.01 days. Intrinsic rate of increase (r_m) was ranged from 0.12- 0.18, the highest r_m was recorded on Bt-I hybrids. The population doubling time (DT) was 5.39 days on RCH-134 Bt-II. 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 4th and 5th instar larvae in later stages of crop.`

Keywords

S. litura, Bt- cotton, Age—specific survivorship, Fecundity and life expectancy

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Introduction

Modern biotechnology is dramatically redefining pest management in global cotton production. After a decade of research, transgenic, insect-resistant cotton varieties were developed that enable growers to use an in-plant protection method as part of their integrated pest management programs (Perlak *et al.*, 1990). The use of transgenic crops expressing *Bacillus thuringiensis* (Bt) toxins has escalated in recent years because of their advantages over traditional chemical insecticides. Cotton hybrids expressing Cry proteins are grown worldwide for the management of Lepidopteran pests. However, in crops with several target pests with varying degrees of susceptibility to Bt (e.g., cotton), there is concern regarding the suboptimal production of toxin, resulting in reduced efficacy and increased risk of Bt resistance during later stages of crop.

The fall in expression with advancement of season or age of the plant has been well documented in genotypes expressing Cry1Ac in cotton and many other genes in other crops. The decline in expression has been reported in fruiting structure (Greenplate 1999, Adamczyk *et al.,* 2001, Horwitz *et al.*, 2003, Kranthi *et al.*, 2005, Wan *et al.*, 2005).

Dual toxins (Cry1Ac+Cry2Ab) provided substantially better control of *H. zea*, *S. frugiperda* and *S. exigua* than single toxin Cry1Ac (Stewart *et al.*, 2001). Quite a few reports are also available for BG-II events stating decline in expression, however the dual genes have been able to contain the pest significantly (Udikeri, 2006 and Somashekar, 2009).

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* (Tabashnik *et al* 2008), *Spodoptera frugiperda* (Storer *et al* 2010), *Busseolafusca* (Van Rensburg, 2007), and *Spodoptera litura* (Jeya Kumar *et al.*, 2007).

Spodoptera litura (Fabricius) is the cosmopolitan insect species. It is belongs to Phylum -Arthropoda, Subphylum -Uniramia, Order -Lepidoptera, Family- Noctuidae and Subfamily- Amphipyrinae. It is an extremely serious pest, the larvae can defoliate many economically important crops. It is seasonally common in annual and perennial agricultural systems in tropical and temperate Asia. This noctuid is often found as part of a complex of Lepidopteran and non-Lepidopteran foliar feeders but may also injure tubers and roots. Hosts include field crops grown for food and fibre, plantation and forestry crops, as well as certain weed species (CABI, 2010).

The main objective of the experiment was to know the survivorship, fecundity, intrinsic rate stable age distribution and life expectancy of third instar larvae of *S.litura* on different Bt cotton hybrids during 120-150DAS (Days after sowing). For this life table was constructed on each hybrid. Life table studies are fundamental to population ecology.

The cohort life table gives the most comprehensive description of the survivorship, development and reproduction of a population that are fundamental factors in both theoretical and applied population ecology (Taghizadeh *et al.*, 2008). Life tables are of a great value in understanding the population dynamics of a species because they provide an integrated view of the biological characteristics of a given population under certain environmental conditions (Coppel and Mertins 1977). Although the present study was conducted under controlled conditions, insects in nature experience adverse biotic and abiotic factors that affect their fitness, so that life table studies are useful in evaluating these eco-logical factors (Nava *et al* 2008).

The life table parameters, particularly the intrinsic rate of natural increase (r_m), are the most important parameters that can be used to evaluate the level of plant resistance to insects (Razmjou*et al.*, 2006). Host plants displaying lower values of r_m are relatively more resistant than the plants with higher values of r_m. In the present study, the life table parameters, especially the r_m, are used to compare the potential population growth of *S.litura* on single and dual gene Bt cotton hybrids.

The present study is an effort to fulfil the deficiency of data on survival of third instar larvae of *S.litura* on Bt-I and Bt-II hybrids. Therefore, the present experiment provides novel information on the life table parameters of third instar larvae of *S.litura* on single and dual gene Bt cotton hybrids.

Materials and Methods

Laboratory experiments were carried out during 2012-2013 to study the effect of transgenic Bt cotton hybrids consisting single and double toxins leaves against of*S.litura*. The seeds of different Bt cotton hybrids as mentioned below were 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. Leaves of 60 days old crop were used in present experimentation.

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

Insect colony

A colony of *S.litura* was originally collected from a 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 on to sorghum leaf based artificial diet (Kranthi, 2005). The grown up larvae were allowed to pupate in the soil. Moths were collected on emergence and released in battery jars for egg laying.

Life table study

The leaves of 120-150 DAS 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 x15 cm) with round disc of blotting paper at bottom of the jar. Larvae hatched from one cohort of eggs reared initially on artificial diet up to third instar were transferred to leaves of different Bt-I and Bt-II cotton hybrids of 90-120 DAS. The battery jars were closed at the top with a muslin cloth for ventilation and larvae were maintained in three replications till the death or pupation. The methods suggested by Morris and Miller (1954) were used for constructing the life-tables.

Adult moths that emerged from the larvae reared on different Bt-I and Bt-II cotton hybrids, collected with the help of plastic tube were 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 (1948) and Poole (1974). 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 (1947) and Atwal and Bains (1974).

Data analysis

A computer software package MS-EXCEL was used for analysis.

Results and Discussion

At global scenario, life table statistics and intrinsic rates of increase have been studied by sizable workers in Lepidopteran insect pests.

The contribution of Morris and Miller (1954) on *Choristoneurafumiferana*, Stark (1959) on *Recurvastarki* and LeRoux*et al.*, (1963) on *Spilonotaocellana* are prominent.

Age specific survivorship

The age specific survivorship (lx) and mortality (dx) of *S. litura* on different Bt- I and Bt-II hybrids are presented in figures (1-12). When the larva fed with the Bt-I hybrids the survivorship curve observed was type I as the mortality is more in adult stages. Fig (1-6) (Slobodkin, 1962). Survival of third instar was low when reared on Bt-II hybrids. The pattern of survivorship that we observed indicated that the young and immature stage was more susceptible to physical disruptions caused by the suitability of the food quality. The survivorship curve indicated a modest rate of mortality during the early life stages and a gradual decrease as it approached later stages and this curve assumed a near type IV survivorship curve, (Slobodkin, 1962) it means most of the mortality is happening at the beginning of life cycle, i.e. mortality of third instar. Fig (7-12).

Age specific fecundity

The age specific female survivorship (lx) recorded highest in Bt-I hybrids compared to Bt-II hybrids. The lowest female survivorship was recorded in RCH-134 Bt-II as 0.19 whereas highest was recorded in 0.32 in RCH-134 Bt-I (Fig.13-24). Potential fecundity (m_x) was recorded more in larvae fed on Bt-I hybrids compared to Bt-II hybrids. Fecundity is defined as the number of offspring produced by an individual insect, whereas fertility is the number of viable offspring produced. Highest fecundity was recorded on NCS-207 Bt-I (1212.00) the lowest fecundity was observed on NCS-207 Bt-II (774.50).

Population growth 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 (RCH-134 Bt-II) hybrids compared to Bt-I. Similar trend was recorded with regard to other life parameters like potential fecundity (PF), intrinsic rate of increase (r_m), finite rate of increase (λ) corrected generation time (T), hypothetical F_2 females, annual rate of increase (ARI) and weekly multiplication rate (WMR). The higher intrinsic rate of increase was recorded on Bt-I hybrids, It is due to the faster development of immature stages shorter generation time, higher survivorship and higher fecundity rates. High value of r_m indicates the susceptibility of a host plant to insect feeding, while a low value of r_m indicates that the host plant species is resistant to the pest.

Stable age distribution and life expectancy

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) Life expectancy of *S.litura* on Bt-I hybrids was more in early stages and declined gradually, Whereas the larvae fed on Bt-II hybrid leaves the life expectancy was more in early days but less compared to Bt-I hybrid fed larvae and declined gradually.(Table.3)

Table.1 Life parameters of *S. litura* fed on different Bt Cotton Hybrids. 120-150 DAS (Days after sowing)

	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)	364.72	233.79	478.73	192.71	383.30	233.69	447.24	210.09	349.37	268.40	285.63	169.35
Mean duration of a generation (Tc) (days)	33.05	39.01	33.21	39.07	34.12	38.90	33.10	38.00	32.01	38.10	34.00	40.01
Arbitrary ‘r_m’ or ‘r_c’ value	0.1784	0.1398	0.1858	0.1346	0.1743	0.1402	0.1844	0.1407	0.1829	0.1467	0.1662	0.1282
Innate capacity for increase in number (r_m)	0.1791	0.1401	0.1864	0.1349	0.1748	0.1404	0.1849	0.1410	0.1835	0.1471	0.1667	0.1284
Potential fecundity	1039.50	880.00	1212.00	774.50	1018.00	888.00	1175.00	819.00	1045.50	931.00	1117.00	885.50
Finite rate of increase (λ) ♀’s/♀/day	1.19	1.15	1.20	1.14	1.19	1.15	1.20	1.15	1.20	1.15	1.18	1.13
Corrected generation time (T) (days)	32.92	38.93	33.10	39.00	34.02	38.83	32.99	37.09	31.91	38.00	33.90	39.94
Weekly multiplication rate $(e^{rm})^7$	3.50	2.66	3.68	2.57	3.40	2.67	3.65	2.68	3.61	2.80	3.21	2.45
Hypothetical F_2 females	133020.67	54657.76	229182.41	37137.14	146918.89	54611.01	200023.61	44137.80	122059.39	72038.56	81584.49	28679.42
Doubling time (DT)	3.86	4.94	3.71	5.13	3.96	4.93	3.74	4.91	3.77	4.71	4.15	5.39
Annual rate of increase (ARI)	2.5302 x 10^{28}	1.6154 x 10^{22}	3.5718 x 10^{29}	2.4210 x 10^{21}	5.2150 x 10^{27}	1.8376 x 10^{22}	2.0947 x 10^{29}	2.2850 x 10^{22}	1.2289 x 10^{29}	2.1253 x 10^{23}	2.7477 x 10^{26}	2.3278 x 10^{20}

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

	PER CENT CONTRIBUTION OF IMMATURE STAGES		
HYBRIDS	**Larval**	**Pupal**	**Adult**
NCS-145 Bt-I	96.08	3.53	0.37
NCS-145 Bt-II	96.38	3.24	0.36
NCS-207 Bt-I	96.26	3.39	0.33
NCS-207 Bt-II	96.57	3.05	0.36
NCS-950 Bt-I	96.21	3.42	0.35
NCS-950 Bt-II	97.19	2.58	0.22
NCS-954 Bt-I	96.35	3.35	0.30
NCS-954 Bt-II	96.70	2.96	0.32
RCH-2 Bt-I	96.85	2.81	0.32
RCH-2 Bt-II	97.51	2.14	0.34
RCH-134 Bt-I	95.95	3.66	0.38
RCH-134 Bt-II	97.25	2.46	0.28

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

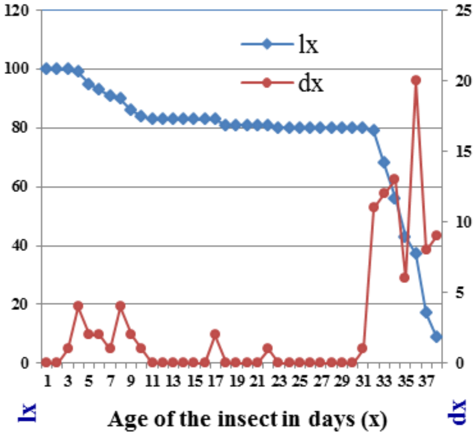
NCS-145 Bt-I		NCS-145 Bt-II		NCS-207 Bt-I		NCS-207 Bt-II		NCS-950 Bt-I		NCS-950 Bt-II	
x	**e_x**	**x**	**e_x**	**x**	**e_x**	**x**	**e_x**	**x**	**e_x**	**x**	**e_x**
1-3	29.45	1-3	28.19	1-3	32.03	1-3	28.79	1-3	32.66	1-3	28.64
4-6	26.73	4-6	28.43	4-6	29.96	4-6	27.81	4-6	30.94	4-6	26.75
7-9	25.90	7-9	26.35	7-9	27.85	7-9	26.59	7-9	28.24	7-9	24.55
10-12	24.89	10-12	25.85	10-12	24.85	10-12	25.74	10-12	25.24	10-12	23.10
13-15	22.17	13-15	23.47	13-15	22.35	13-15	24.66	13-15	22.24	13-15	20.86
16-18	19.17	16-18	21.36	16-18	19.57	16-18	21.97	16-18	19.90	16-18	19.05
19-21	16.59	19-21	19.78	19-21	16.77	19-21	19.83	19-21	16.90	19-21	18.24
22-24	13.59	22-24	17.32	22-24	13.93	22-24	18.20	22-24	14.23	22-24	16.23
25-27	10.74	25-27	14.80	25-27	11.07	25-27	15.45	25-27	11.51	25-27	13.90
28-30	7.74	28-30	11.80	28-30	8.17	28-30	12.45	28-30	8.96	28-30	11.10
31-33	4.74	31-33	9.11	31-33	5.24	31-33	9.79	31-33	6.05	31-33	8.25
34-36	2.91	34-36	6.23	34-36	3.36	34-36	7.19	34-36	3.54	34-36	5.57
37-39	2.00	37-39	3.96	37-39	2.00	37-39	4.19	37-39	2.00	37-39	3.50
-	40-42	2.64	-	-	40-42	2.58	-	-	40-42	2.29	-
-	43-45	2.00	-	-	43-45	2.00	-	-	43-45	2.00	-

Table.3 Cont..

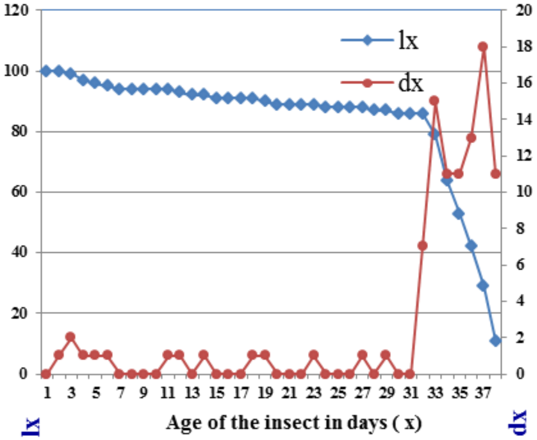
NCS-954 Bt-I		**NCS-954 Bt-II**		**RCH-2 BT-1**		**RCH-2BT-II**		**RCH-134 Bt-I**		**RCH-134 Bt-II**	
x	**ex**	**x**	**ex**	**x**	**ex**	**x**	**ex**	x	ex	x	ex
1-3	30.77	1-3	26.06	1-3	26.54	1-3	26.48	1-3	29.93	1-3	25.22
4-6	28.36	4-6	25.44	4-6	24.83	4-6	26.82	4-6	28.71	4-6	24.52
7-9	25.91	7-9	24.39	7-9	22.58	7-9	25.00	7-9	26.29	7-9	23.11
10-12	23.41	10-12	25.13	10-12	20.51	10-12	25.85	10-12	23.83	10-12	22.00
13-15	20.41	13-15	23.49	13-15	18.39	13-15	26.68	13-15	21.59	13-15	20.97
16-18	17.41	16-18	21.14	16-18	16.43	16-18	24.08	16-18	19.29	16-18	20.73
19-21	15.47	19-21	19.05	19-21	14.83	19-21	21.45	19-21	16.49	19-21	19.02
22-24	12.78	22-24	16.61	22-24	12.20	22-24	19.12	22-24	13.67	22-24	17.28
25-27	10.04	25-27	14.36	25-27	9.50	25-27	16.42	25-27	10.81	25-27	14.57
28-30	7.13	28-30	11.58	28-30	6.61	28-30	13.95	28-30	8.04	28-30	12.06
31-33	4.26	31-33	9.11	31-33	3.83	31-33	11.17	31-33	5.53	31-33	10.66
34-36	2.52	34-36	6.38	34-36	2.66	34-36	8.34	34-36	3.45	34-36	8.77
37-39	2.00	37-39	3.96	37-39	2.00	37-39	5.34	37-39	2.00	37-39	6.33
	40-42	2.75			40-42	2.93			40-42	3.59	
	43-45	2.00			43-45	2.00			43-45	2.00	

X: Pivotal age in days

e_x: Expectation of further life



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



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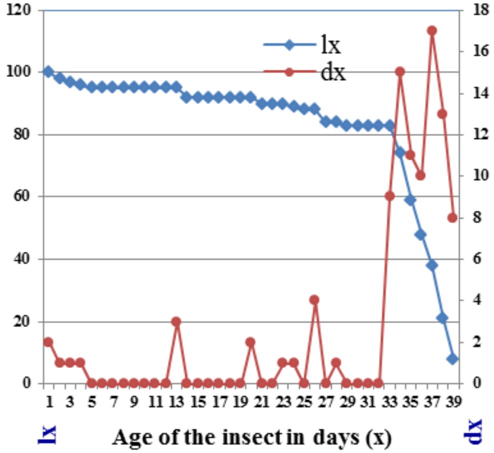

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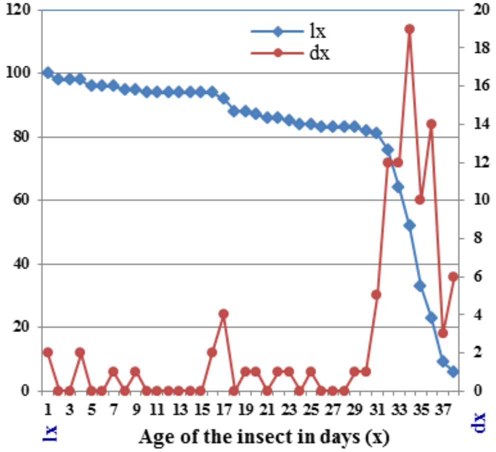

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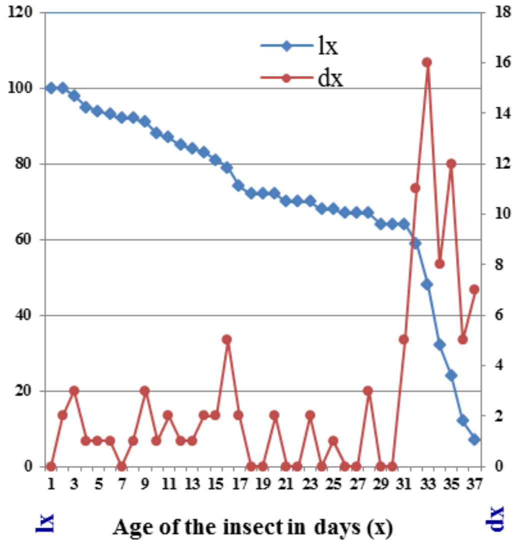
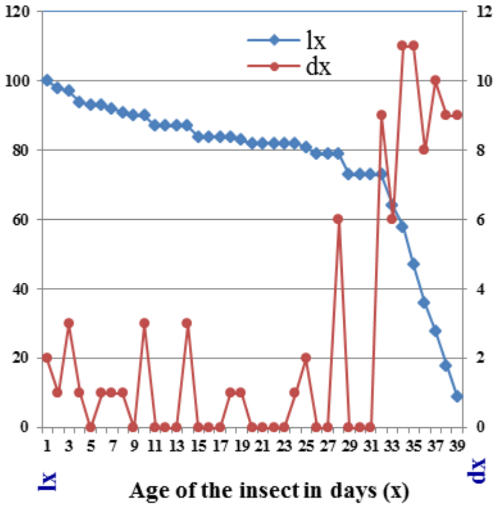


5.Age specific survivorship (lx) and mortality (dx) of *S.litura* on RCH-2Bt-I



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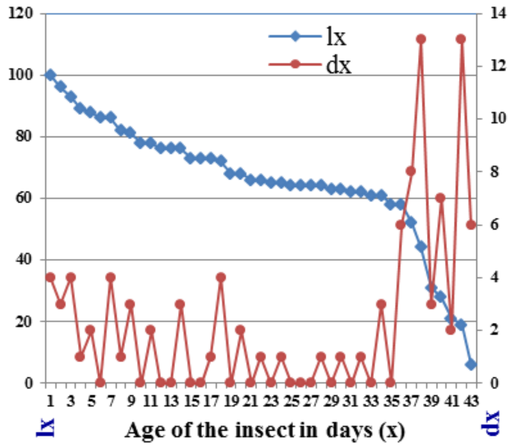

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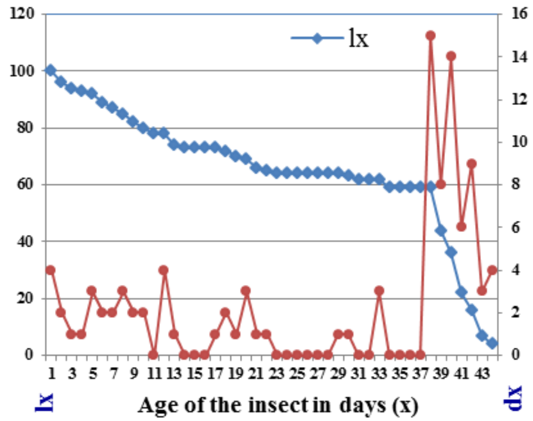
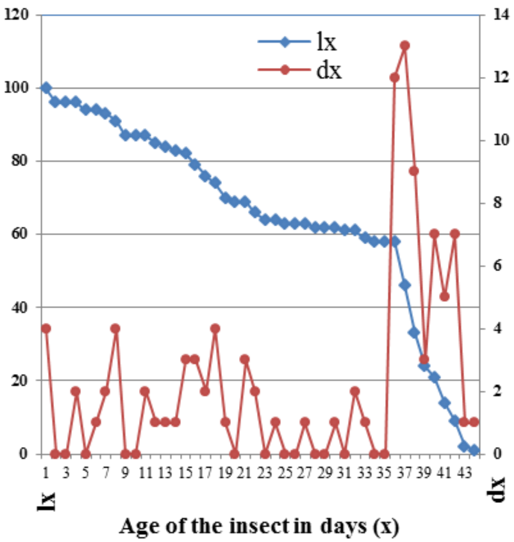


8.Age specific survivorship (lx) and mortality (dx) of *S.litura* on NCS-207 Bt-II



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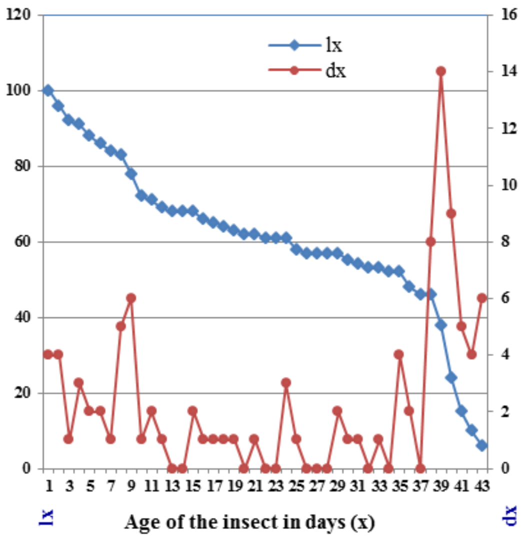
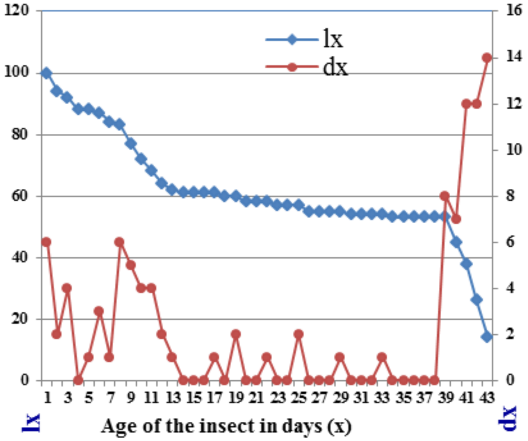
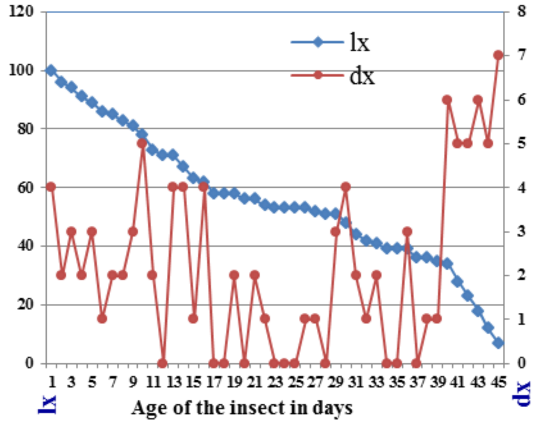


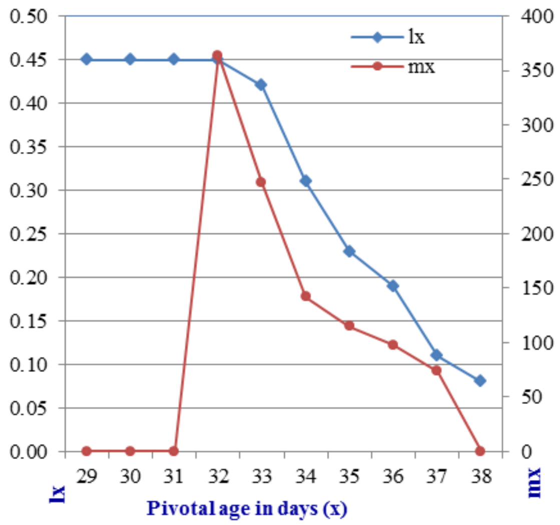
10. Age specific survivorship (lx) and mortality (dx) of S.litura on NCS-954 Bt-II



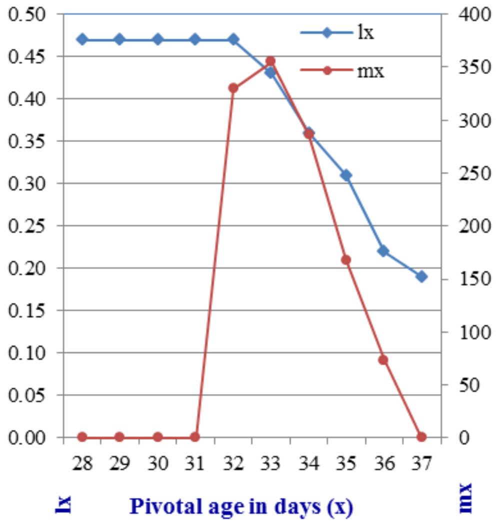
11.Age specific survivorship (lx) and mortality (dx) of *S.litura* on RCH-2 Bt-II



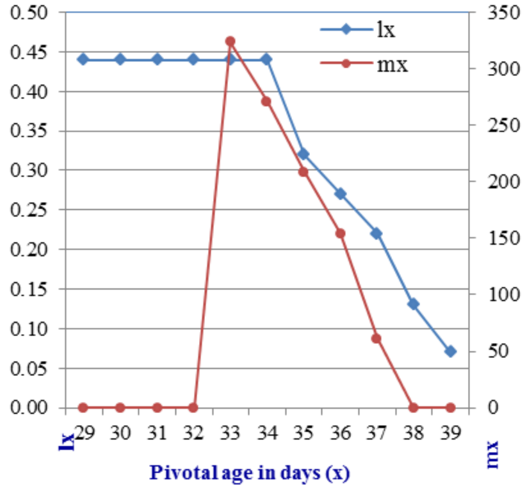
12. Age specific survivorship (lx) and mortality (dx) of *S.litura* RCH-134 Bt-II



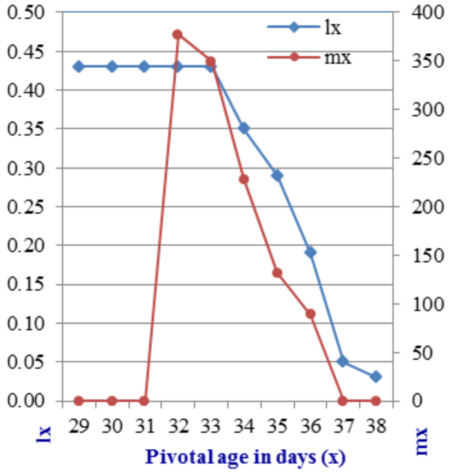
13. Age specific survivorship (lx) and fecundity (lx) of *S.litura* on NCS-145 Bt-I



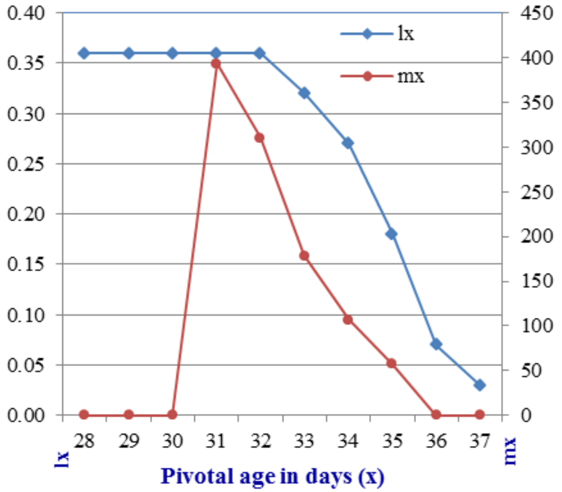
14. Age specific survivorship (lx) and fecundity (lx) of *S.litura* on NCS-207 Bt-I



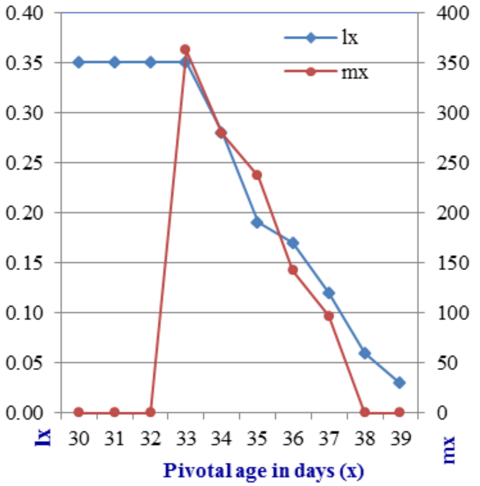
15. Age specific survivorship (lx) and fecundity (mx) of *S.litura* on NCS-950 Bt-I



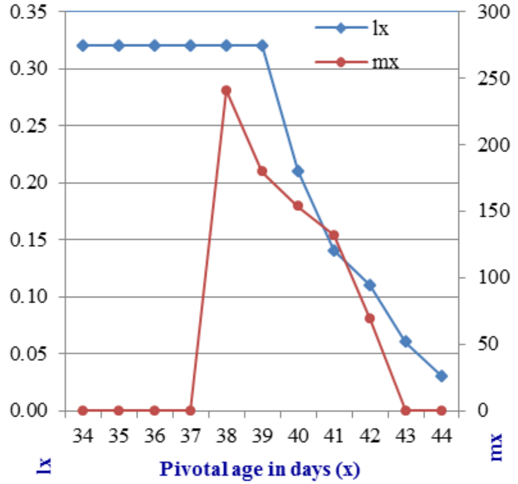
16.Age specific survivorship (lx) and fecundity (mx) of *S.litura* on NCS-954 Bt-I



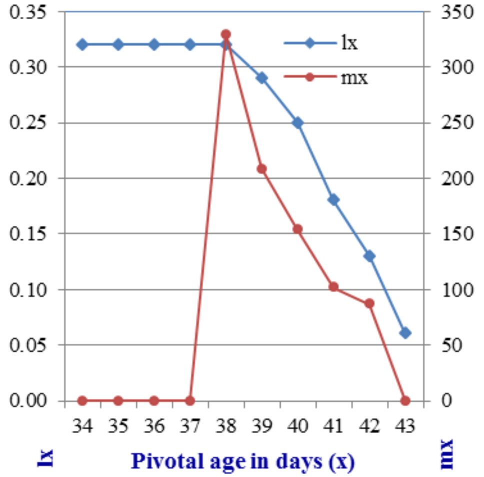
17. Age specific survivorship (lx) and fecundity (mx) of *S.litura* onRCH-2 Bt-I



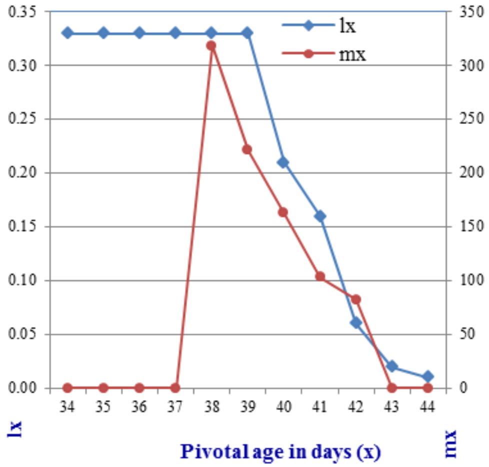
18.Age specific survivorship (lx) and fecundity (mx) of *S.litura* on RCH-134 Bt-I



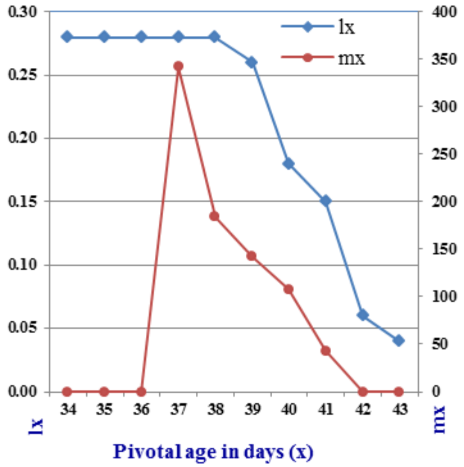
19. Age specific survivorship (lx) and fecundity (mx) of *S.litura* on NCS-145 Bt-II



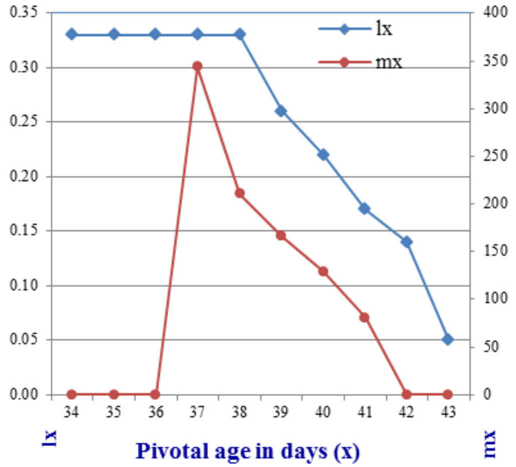
20. Age specific survivorship (lx) and fecundity (mx) of *S.litura* on NCS-207 Bt-II



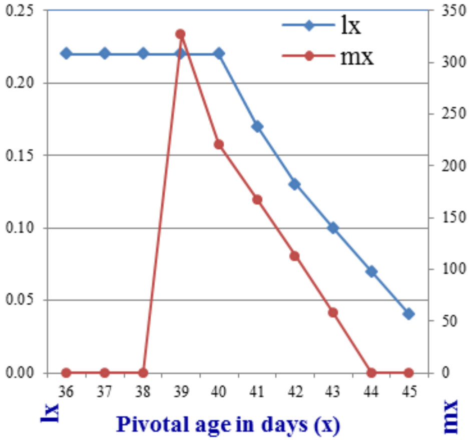
21. Age specific survivorship (lx) and fecundity (mx) of *S.litura* on NCS-950 Bt-II



22. Age specific survivorship (lx) and fecundity (mx) of *S.litura*on NCS-954 Bt-II



23. Age specific survivorship (lx) and fecundity (mx) of *S.litura* on RCH-2 Bt-II



24.Age specific survivorship (lx) and fecundity (mx) of *S.litura* on RCH-134 Bt-II

Age specific survivorship

The experiment (Generation-III) 120-150 DAS was started with the third instar larvae due to the higher mortality in the early stages during Generation –I (60-90 DAS) this can be supported with findings of authors Dhawan *et al.,* (2010) 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 (2005), 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. The results reported by Murugan *et al.*, (2003) observed that first instar larvae of *H. armigera* when reared on the squares of transgenic cultivars showed highest mortality at 72 hours.

Large host range is considered important for better chance to survive during evolutionary strategies (Simpson *et al.,* 2002; Raubenheimer and Simpson, 2003, Lee *et al.*, 2003). Host plant range of generalist insect pests like *S. litura* may vary due to their higher level of feeding on different plant species and almost all parts of these plants (Schoonhoven *et al.,* 1998; Suomela, 1996). Host selection may be associated with primary as well as secondary metabolites present in these plants which help them to choose preferred hosts due to nutritional variation (Ehrlich and Murphy, 1988; Rosenthal and Berenbaum, 1992, Simpson *et al.,* 2002, Lee *et al.*, 2003).

Insect herbivore relationship developed with respect to their feeding, survival and multiplication of generation. Such selection of different host plants helps in maintaining their numbers to multiply and maintain their diversity in nature (Raubenheimer and Simpson, 2003, Lee *et al.*, 2003). This insect pest, as important general leaf feeder, utilizes green matter and in severe food shortage feeds on almost all parts of the plants. Such observations were clear when the leaves were either eaten up and transfer of insects to plant fruiting parts like flowers, fruits in different crops (Rosenthal and Berenbaum, 1992; Simpson *et al.,* 2002). Host selection also depends on presence of plant metabolites which either attract or deter the pests (Ehrlich and Murphy, 1988, Hill, 1975). Cotton being the most suitable plant species is selected as a host by different sucking as well as chewing insect pests including *S. litura*. Presence of plant metabolites may also hinder their development but decrease deleterious effects due to gregarious feeding (Simpson *et al.*, 2002, Lee *et al.*, 2003).

Age specific fecundity

Potential fecundity may often be a good indicator of future reproductive output. In many Lepidopteran herbivore species all the eggs are present in the ovarioles at the adult moult, although they may not be all at the same stage of development, and host plant quality during larval growth and development is the key determinant of potential fecundity.

Adult insects need carbohydrate-rich food as their main source of energy for longevity, fecundity and mobility. The low number of eggs laid on a plant could have been affected by the more indirect route of reduced fecundity arising from larva feeding on nutritionally poor plants (Verkerk and Wright, 1996, Hamilton *et al.*, 2005).

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 (Awmack and Leather, 2002). 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.

The morphological characteristics such as leaf shape, hairiness, bract shape and the presence or absence of nectar producing glands on leaves or flowers, and physical or structural qualities of host plant interfere with insect feeding behaviour. Maternal diet is considered an important factor for optimal insect growth (McIntyre and Gooding, 2000, Agrawal, 2001) and duration of offspring development (Roff, 1992).

Population growth parameters

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 (Woods, 1999). Since intrinsic rate of increase (r_m) is a reflective of many factors survival and generation time and adequately summarizes the physiological qualities of an animal in relation to its capacity to increase, it would be a most appropriate index to evaluate the performance of an insect on different host plants as well as the host plant's resistance (Kocourek *et al.,* 1994; Southwood and Henderson, 2000). The intrinsic rate of increase (r_m) is a more useful statistic to compare the population growth potential of different species than is R_0 (Price, 1997). According to Southwood (1981) and Huffaker *et al.,* (1984), r-strategists are characterized by a high r_m, a large fecundity (large R_0) and short generation time (T).

Stable age distribution

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 (1980), Bilapate (1980), Hemchandra and Singh (2003), Acharya *et al.,* (2007), Gedia *et al.,* (2008), and present results are in conformity with all of them. (Table.2)

Life expectancy

These results can be supported by findings of Dabhi*et al.,* (2009) who reported that the life expectancy of *P. xylostella* was more in early stages and declined with advancement of age, similar results were reported by Patil *et al* (2014) of *S.litura* on tobacco.

In the Bt-II hybrids the life expectancy during 120-150 DAS was recorded as high during early days and decreased gradually, due to decline of Cry protein content in leaves during 120-150 DAS the third instar can able to feed on the leaves and Gilliland *et al.,* (2002) reported that larvae become less susceptible to δ-endotoxins as they age due to fewer binding sites in the older larvae.

The present results suggest 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. It would be better to switch to Bt cotton that produces Cry2Ab and one or more additional toxins unrelated to Cry1Ac, such as Vip3A (a vegetative insecticidal protein from Bt), so that the increased frequency of resistance to Cry1Ac already seen in some populations would not reduce efficacy of the new Bt cotton. The future studies should elucidate on development of Bt cotton hybrids by using of refuge strategy to increase the susceptible population in the field. 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).

In conclusion, knowledge of how Bthost plants influences the life table parameters of *S.litura* can help one to understand the population dynamics and select for the proper measures in management of this insect. After laboratory studies, more attention should bedevoted to field experiments to obtain moreapplicable results in field conditions.

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