Research Article
The J. Res. PJTSAU 50(1)23-32, 2022

AGE-SPECIFIC SURVIVORSHIP AND LIFE-FERTILITY TABLE STUDY OF INVASIVE ALIEN PEST FALL ARMYWORM ON CASTOR

SUPRIYA G.B[1], SRIDEVI. G[2], UMA MAHESWARI. T[3], BHARATI N. BHAT[4] and SRINIVASA CHARY. D[5]

[1] Department of Entomology, College of Agriculture, Rajendranagar
[2] AINP on Pesticide Residues, Rajendranagar, [3] Agricultural College, Sircilla-505 301
[4] Department of Plant Pathology, College of Agriculture, Rajendranagar
[5] Department of Statistics and Mathematics, College of Agriculture, Rajendranagar
Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad-500 030

Date of Receipt : 06-01-2022 Date of Acceptance : 28-01-2022

ABSTRACT

A laboratory experiment was carried out to study the demography of fall armyworm (FAW) in castor at Department of Entomology, College of Agriculture, Rajendranagar, Hyderabad, during 2020-21. Daily observations of FAW from neonates to death of adults was recorded where the age specific survivorship showed decrease in population of FAW on castor at transition of each stage representing the stair step survivorship curve. The net reproductive rate was 324.27, mean generation time (Tc) 30.07 and intrinsic rate of increase (r_m) 0.1922 indicating the susceptibility of the host plant. Finite rate of increase (or) female off-springs/female/day (ë) 1.556, doubling time (DT) 3.60 days, weekly multiplication rate (WMR) 3.83 times per week and annual rate of increase (ARI) 1.4223 x 10^{70}, indicated that castor is also a suitable host for FAW. The results on per cent contribution of larvae, pupae and adults were 97.48, 1.38 and 0.20, respectively at stable age distribution of *S. frugiperda* on castor. The life expectancy (ex) was high in early days *i.e.,* 10.32 (days) and decreased gradually with the age. The present results suggested that in the absence of maize, sorghum and other highly preferred crops, castor crop could become a potential host for FAW. Monitoring needs to be strengthened in order to determine the occurrence of FAW in castor and implement management tactics well in advance.

Keywords: Age-specific survivorship, castor, life expectancy, population parameters, *Spodoptera frugiperda*

The invasive pest fall armyworm, *Spodoptera frugiperda* (J.E. Smith, 1797) (Lepidoptera, Noctuidae) is native to two continents: South and North Americas (Casmuz *et al*., 2010 and Murua *et al*., 2015). The pest is highly polyphagous causing economic damage in various crops such as maize, sorghum, beans and cotton (Abrahams *et al.,* 2017; Day *et al.,* 2017). It made its first transcontinental migration to Africa in early 2016 (Georgen *et al*., 2016), and to India and Yemen in 2018. The pest came to Asia either through natural migration with the monsoon winds or through imported plant material. As in January 2019, it has been reported in Bangladesh, Myanmar, Sri Lanka, Thailand and China (FAO, 2019). In 2020, Australia, South Korea, Cambodia, Papua New Guinea, Timor Leste, New Caledonia, Jordan, Syria, and United Arab Emirates officially stated the occurrence of the pest (Prasanna *et al*., 2021).

Due to its perennial pest status, strategies for management of FAW are imperative. For an ecologically sound integrated pest management program, it is crucial to understand thoroughly ecology of the pest. The life table generates an integrated and comprehensive description of development, survival, fecundity and life expectancy of a population, and is often used to project the growth and populations (Chi, 1990). The background information provided by life and fertility table studies can be used for developing sustainable management strategies for FAW.

MATERIAL AND METHODS

Rearing of FAW in laboratory

S. frugiperda was reared in the laboratory of Department of Entomology, College of Agriculture, Rajendranagar after collecting the larvae from maize fields, during 2020-21, the larvae which were in various stages of development were put into multiwell trays containing artificial diet. After becoming pre-pupae, they were placed in plastic tubs containing soil and allowed to develop into pupae. As the adults emerged, they were collected using plastic vial and released for mating into jars (10x15 cm) that contained small petriplate with sterile absorbent cotton dipped in 10 per cent honey solution. The jars were lined with yellow paper acting

Email:supriyagangadhar18@yahoo.com

as substratum for egg laying as well as for providing darkness for moths. The top of the jars were covered with muslin cloth and secured with rubber band. After egg laying, the egg masses were collected for further experiments on life-fertility.

Age-specific survivorship experiment

Neonates that hatched from one cohort of egg mass were counted and transferred by brush on to fresh castor leaves. Primarily, the population was maintained in plastic jars (10 x15 cm) and later transferred to individual cups to prevent cannibalism. The plant parts were changed every 24 h to avoid microbial contamination. The larvae were maintained till adult emergence. Mortality data was recorded daily till all the adults died. Age-specific survivorship was used for constructing the life tables as suggested by Morris and Miller (1954). The survivorship curves were drawn by plotting the number living at a given age (lx) against the age (x). The shape of curve describes the distribution of mortality with age (Slobodkin, 1962).

Life- fertility experiment

The pupae that were developed from a cohort were segregated into males and females after examining the seventh, eighth and ninth sterno-abdominal segments for sex markings using a stage microscope. Sex ratio was calculated based on the emerged moths. Adult moths that emerged on a single day were collected using a plastic tube and released into a battery jar and covered with muslin cloth for ventilation. The internal wall was covered with yellow paper which acted as an oviposition substrate. A small cotton wick soaked in 10 per cent honey solution was placed in the small petriplate 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 age-specific fecundity was constructed as described by Birch (1948) and Poole (1974). In the fertility tables, x represents age interval in days, lx the number of females as a fraction of initial size of cohort and mx as age-specific fecundity. Also, the population parameters were calculated as given below.

1. Potential fecundity Σmx
2. Mean generation time $(T_C = \Sigma x.lxmx/R_0)$
3. Net reproductive rate $(R_0 = \Sigma lxmx)$
4. Corrected generation time $(T = \log_e R_0/r_m)$
5. Innate rate for increase in numbers (r_c) $(r_c = \log_e R_0/ Tc)$
6. Intrinsic rate of increase (r_m) $(\sum e^{-rm.x.mxmx} = 1)$
7. Finite rate of increase (λ) (antilog er_m)
8. Weekly multiplication rate (WMR) $(e/r_m)^7$
9. Doubling time (DT) (log2 e/r_m)
10. Annual rate of increase (ARI) (Antilog er_m 365)
11. Sex ratio (F:M)
12. Hypothetical female in F_2 generation $(R_0)^2$
13. Birth rate (β)
14. Instantaneous birth rate (b) $= (r_m.\beta/e^{rm} - 1)$
15. Instantaneous death rate (d)= $(b-r_m)$

Stable age distribution was worked out by observing the population schedule of birth rate and death rate when grown in limited space and life expectancy was computed by using the method suggested by Atwal and Bains (1974).

Data analysis

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

RESULTS AND DISCUSSION

Age specific life-table and survivorship of FAW

The total life cycle of the FAW was 36 days (Table1). The mortality rate during the age interval 1 to 18 days was less than 10 per cent while that between 19-25 days was 0 per cent. It increased to 35.71 per cent on 30^{th} day, thereafter decreased up till 34^{th} day before reaching 100 per cent on 36^{th} day. From the results, it can be inferred that during the larval instars, the mortality rate was maximum (8.65%) when 3^{rd} instar larvae moulted to 4^{th} instar. Mortality was also higher during pre-pupal (8.70%) and early pupal stages (8.47%) while in the adult stage mortality was highest at mid stage (35.71%).

The age specific survivorship curve (lx) and mortality (dx) of *S. frugiperda* on castor are presented in Figure 1. The survivorship curve was found to be similar to that of stair step type curves recorded for holometabolous insects and is in conformity to that reported by Odum (1971) and was intermediate to Type I and Type II survivorship curves described by Slobodkin (1962) and Deevey (1947). Choudhary and

Bhattacharya (1986) also recorded similar type of survival pattern in *Creatonotus gangis* (Linnaeus) and *Spodoptera litura* (F) on winged bean, while Chenchiah *et al*. (2007) recorded in *C. gangis* on artificial diet. Pramanik *et al.* (2012) reported stair step type of survivorship curve in *Leucinodes orbonalis* (Guenee) and Srivastava and Gupta (2015) in *Samia cynthia ricini* (Donovan) reared on castor. Also, Supriya *et al*. (2018) recorded stair step survivorship curve in *S. litura* when reared on castor for three generations.

Life-fertility of FAW in castor

The total number of surviving females that emerged were 24 out of 136 indicating lx to be 0.18 at the pivotal age of 26 days which remained so up to 30th day. Thereafter it gradually declined reaching 0.01 by 36 days, when all the adults died. The adult emergence was noticed for 9-10 days. (Table 2) (Fig 2). The potential fecundity was 2896.18 eggs with the highest egg laying being recorded on 29th day

Table 1. Age-specific survivorship of FAW on castor

Age of the insect in days(x)	Number surviving at the beginning of each age interval x out of 136(lx)	Number dying during the age interval x out of 136(dx)	Mortality rate at the ageInterval x(100qx)	Stage of the insect
1	136	2	1.47	I- INSTAR
2	134	6	4.48	
3	128	5	3.91	II-INSTAR
4	123	7	5.69	
5	116	4	3.45	III-INSTAR
6	112	8	7.14	
7	104	9	8.65	IV-INSTAR
8	95	6	6.32	
9	89	3	3.37	
10	86	5	5.81	V-INSTAR
11	81	4	4.94	
12	77	3	3.90	
13	74	5	6.76	VI-INSTAR
14	69	6	8.70	
15	63	4	6.35	
16	59	5	8.47	PRE-PUPAL
17	54	2	3.70	
18	52	1	1.92	PUPAL
19	51	0	0.00	
20	51	0	0.00	
21	51	0	0.00	
22	51	0	0.00	
23	51	0	0.00	
24	51	0	0.00	
25	51	0	0.00	
26	51	3	5.88	ADULTS
27	48	4	8.33	
28	44	4	9.09	
29	40	12	30.00	
30	28	10	35.71	
31	18	6	33.33	
32	12	2	16.67	
33	10	1	10.00	
34	9	2	22.22	
35	7	2	28.57	
36	5	5	100.00	

Table 2. Age-specific fertility of FAW on castor

Age interval in days	Number of females alive/ number of eggs at the initial stage of the cohort	Average number of eggs laid by female in each interval (x) / sex ratio			Innate rate for increase in numbers (r_c =loge R_0/ Tc) = (0.1923) r_c is 0.1923					
					Intrinsic rate of increase (r_m) by iteration When r_m value is 0.1934			Intrinsic rate of increase (r_m) " e-rm.x. lxmx=1) When r_m value is 0.1922l		
x	lx	mx	lxmx	x.lxmx	r_m.x	$e^{rm.x}$	$e^{-rmx.lxmx}$	r_m.x	e^{-rmx}	$e^{-rmx.lxmx}$
26	0.18									
27	0.18									
28	0.18									
29	0.18	880.50	158.49	4596.21	5.609	0.003666	0.5811	5.5738	0.00380	0.60163
30	0.18	227.86	41.02	1230.46	5.802	0.003022	0.1239	5.7660	0.00313	0.12847
31	0.13	641.91	83.45	2586.89	5.995	0.002490	0.2078	5.9582	0.00258	0.21568
32	0.04	694.09	27.76	888.44	6.189	0.002052	0.0570	6.1504	0.00213	0.05921
33	0.03	451.82	13.55	447.30	6.382	0.001691	0.0229	6.3426	0.00176	0.02385
34	0.02	0.00	0.00	0.0000	6.576	0.001394	0.0000	6.5348	0.00145	0.00000
35	0.02	0.00	0.00	0.0000	6.769	0.001149	0.0000	6.7270	0.00120	0.00000
36	0.01	0.00	0.00	0.0000	6.962	0.000947	0.0000	6.9192	0.00099	0.00000
		$\sum$mx = 2896.18	$\sum$lxmx = 324.47	$\sum$x.lxmx = 9749.30			$\sum e^{-rmx.lxmx}$ = 0.9927			$\sum e^{-rmx.lxmx}$ = 1.02884

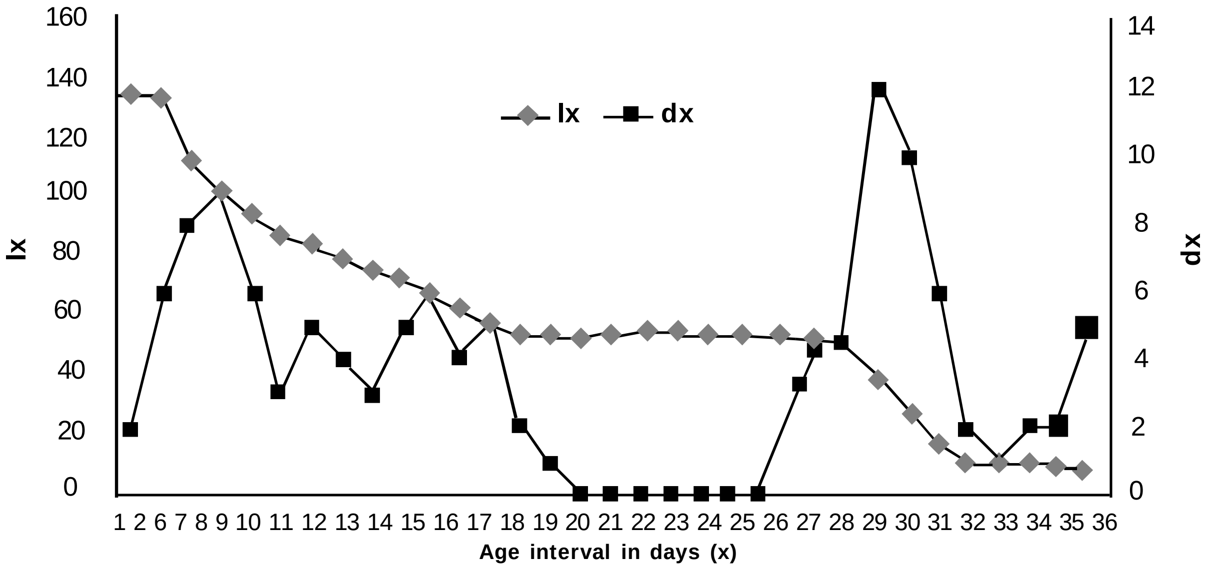

Figure 1. Age-specific survivorship (lx) and mortality (dx) of FAW on castor

(880.50 eggs). No eggs were laid from 34th day. From these observations, it can be inferred that the potential egg laying period was for 5 days. The present findings are in agreement with the results of Supriya *et al*. (2018) who reported potential fecundity of 1651.00 eggs in *S. litura* on castor during third generation. 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. 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).

The life parameters *viz*., net reproductive rate (R_0), mean generation time (Tc) and intrinsic rate of increase (r_m) were 324.27, 30.07 days and 0.1922 females/female/day, respectively (Table 2). The present findings were in agreement with the results of Sooravan *et al.* (2005) who reported that the intrinsic rate of natural increase (r_m) of *S. litura* population on the host plant ranged from 0.153 to 0.195 females / female/day. Similarly, the results of Tuan *et al.* (2013) indicated that the intrinsic rate of increase of *S. litura* reared on peanuts was 0.1828 females/female/day. The faster development of immature stages (shorter

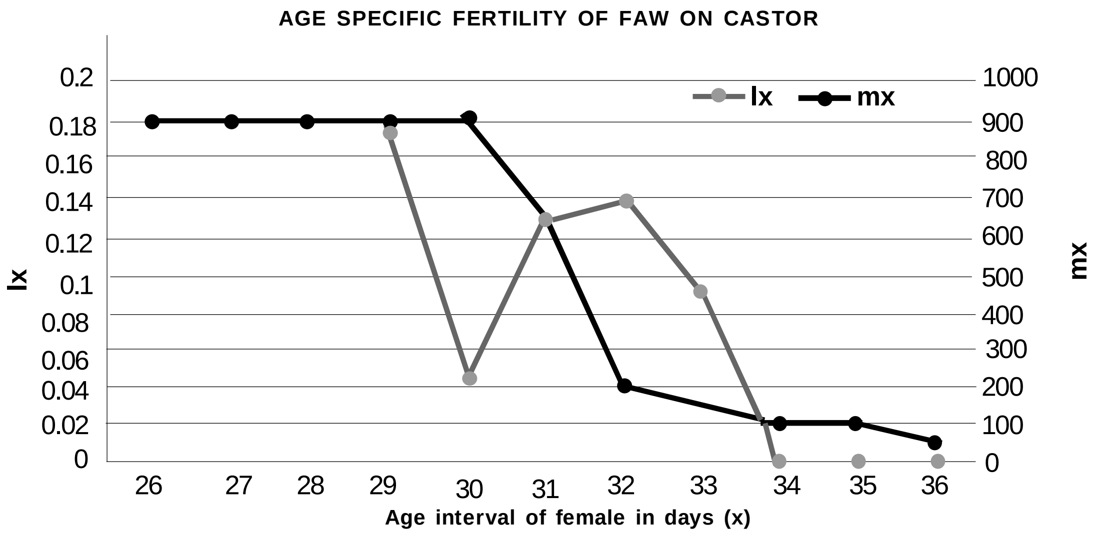

Figure 2. Age-specific survivorship (lx) and fecundity (mx) for female of FAW on castor

generation time), higher survivorship and higher fecundity rates and high value of r_m indicated the susceptibility of the host plant for insect feeding and also pointed out that increased feeding and or higher assimilation rate, both could result in an increased titre of digestive enzymes (Woods, 1999).

Life parameters of FAW on castor

Life parameters represented in (Table 3) *viz*., finite rate of increase (ë) *i.e.,* @&'s/@&/day (female off-springs/female/day) was 1.556 while other parameters like weekly multiplication rate (WMR), doubling time (DT) and annual rate of increase (ARI) were recorded as 3.83, 3.60 and 1.4223 x 10^{70}, respectively. Sunil *et al.* (2019) who reported that the *S. litura* on groundnut also recorded WMR and DT as 3.09 and 4.29 days, respectively, similar to present observations on FAW. Sex ratio (F:M) (1:1.13) indicated high male moth population compared to females.

Stable age distribution of FAW on castor

The study on the influence of each developmental stage of *S. frugiperda* on castor towards the stable age distribution was calculated by observing the age schedule of birth rate and death rate. In the present studies, the immature stages and pupae contributed to 99.74 per cent (Table 4) and indicated that immature stages contributed highest to the stable age distribution of the population. Similar pattern of distribution of stable age was observed with *S. litura* on castor (Supriya *et al*., 2018; Maghodia and Koshiya, 2008). Instantaneous birth rate and instantaneous death rate of FAW on castor were recorded as 0.501 and 0.309, respectively indicating lower death rate compared to birth rate.

Table 3. Life- parameters of FAW on castor

S.No	Life-Parameters	Formulae	Values obtained
1	Finite rate of increase @&'offsprings/@&/day	λ = antilog e^{rm}	1.556
2	Weekly multiplication rate	WMR= $(e^{rm})^7$	3.83
3	Doubling time	DT= (log2 e/r_m)	3.60
4	Annual rate of increase (ARI)	Antilog e^{rm} 365	1.4223 x 10^{70}
5	Sex ratio	F:M	1:1.13
6	Hypothetical F_2 females	$(R_0)^2$	105151.03

Table 4. Stable-age -distribution of FAW on castor

x	Lx	x+1	r_m(x+1)	e (-r_m(x+1)	e (-r_m(x+1) X Lx	Px. e(-r_m(x+1)	px.100	% Contribution
1	0.99	2	0.38440	0.68086	0.67585	0.21366	21.366	(38.46 %) I-Instar
2	0.96	3	0.57660	0.56181	0.54115	0.17108	17.108	
3	0.92	4	0.76880	0.46357	0.42778	0.13524	13.524	(24.14 %) II-Instar
4	0.88	5	0.96100	0.38251	0.33610	0.10625	10.625	
5	0.84	6	1.15320	0.31563	0.26457	0.08364	8.364	(14.90 %) III-Instar
6	0.79	7	1.34540	0.26044	0.20682	0.06538	6.538	
7	0.73	8	1.53760	0.21490	0.15722	0.04970	4.970	(11.73 %)
8	0.68	9	1.72980	0.17732	0.11995	0.03792	3.792	
9	0.64	10	1.92200	0.14631	0.09414	0.02976	2.976	IV-Instar
10	0.61	11	2.11420	0.12073	0.07412	0.02343	2.343	(5.61 %) V-Instar
11	0.58	12	2.30640	0.09962	0.05787	0.01829	1.829	

Table 4. (Contd.)

x	Lx	x+1	$r_m(x+1)$	e $(-r_m(x+1)$	e $(-r_m(x+1)$ X Lx	Px. e$(-r_m(x+1)$	px.100	% Contribution
12	0.56	13	2.49860	0.08220	0.04563	0.01443	1.443	
13	0.53	14	2.69080	0.06783	0.03566	0.01127	1.127	(2.641%) VI- Instar
14	0.49	15	2.88300	0.05597	0.02716	0.00859	0.859	
15	0.45	16	3.07520	0.04618	0.02071	0.00655	0.655	
16	0.42	17	3.26740	0.03811	0.01583	0.00500	0.500	(0.887 %) Pre-pupa
17	0.39	18	3.45960	0.03144	0.01225	0.00387	0.387	
18	0.38	19	3.65180	0.02594	0.00982	0.00311	0.311	(1.385%) Pupal
19	0.38	20	3.84400	0.02141	0.00803	0.00254	0.254	
20	0.38	21	4.03620	0.01766	0.00662	0.00209	0.209	
21	0.38	22	4.22840	0.01458	0.00547	0.00173	0.173	
22	0.38	23	4.42060	0.01203	0.00451	0.00143	0.143	
23	0.38	24	4.61280	0.00992	0.00372	0.00118	0.118	
24	0.38	25	4.80500	0.00819	0.00307	0.00097	0.097	
25	0.38	26	4.99720	0.00676	0.00253	0.00080	0.080	
26	0.36	27	5.18940	0.00558	0.00203	0.00064	0.064	(0.206 %) Adults
27	0.34	28	5.38160	0.00460	0.00156	0.00049	0.049	
28	0.31	29	5.57380	0.00380	0.00117	0.00037	0.037	
29	0.25	30	5.76600	0.00313	0.00078	0.00025	0.025	
30	0.17	31	5.95820	0.00258	0.00044	0.00014	0.014	
31	0.11	32	6.15040	0.00213	0.00024	0.00007	0.007	
32	0.08	33	6.34260	0.00176	0.00014	0.00004	0.004	
33	0.07	34	6.53480	0.00145	0.00010	0.00003	0.003	
34	0.06	35	6.72700	0.00120	0.00007	0.00002	0.002	
35	0.04	36	6.91920	0.00099	0.00004	0.00001	0.001	
36	0.02	37	7.11140	0.00082	0.00001	0.00000	0.000	
				3.16318		**100.00**		

Birth rate (β) = 3.163, px = 1/(β) = 0.316

Instantaneous birth rate (b) = $(r_m. \ \beta / e^{rm}-1)$ = 0.501

Instantaneous death rate (d) = $(b-r_m)$ = 0.309

Life expectancy of FAW on castor

The life expectancy (ex) of *S. frugiperda* on castor declined gradually with the advancement in development of the insect (Table 5). The life expectancy of newly hatched larvae was 10.32 days. The mortality rate (dx) increased gradually which was indicated by a decrease in the lx value, and mortality was comparatively high at 31-35 days of pivotal age. The expectation of further life was reduced to 2.00 days from 10.32 days in the beginning (Fig 3). These results are supported by Dhabi *et al.* (2009) who reported that the life expectancy of *P. xylostella* was more in early stages and declined with the advancement of age.

CONCLUSION

The present study signifies the first complete report on the life history data of *S. frugiperda* on castor. The higher survivorship of immature stages indicated the potential damage to crop by larval instars which needs to be managed by appropriate management strategies. The higher net reproductive rate, fecundity and shorter mean generation time explained the strong environmental adaptability of FAW, which is responsible for the serious damage to castor in near future. Our findings provide useful information in predicting population dynamics and understanding the potential damage that could be incurred by *S. frugiperda* infestation on castor.

Table 5. Life-expectancy of FAW on castor

Pivotal age (Days)	Number Surviving to the beginning of the age interval	Number dying during 'x'	Mortality rate per hundred alive at beginning of the age interval	Alive between age 'x' and 'x+1'	Number of the individuals life days beyond 'x'	Expectation of further life (e_x)
x	lx	dx	dx*100/lx	lx+(lx+1)/2	Tx	Tx/lx*2
1-5	136	24	17.65	192.00	701.50	10.32
6-10	112	31	27.68	152.50	509.50	9.10
11-15	81	22	27.16	110.50	357.00	8.81
16-20	59	8	13.56	84.50	246.50	8.36
21-25	51	0	0.00	76.50	162.00	6.35
26-30	51	33	64.71	60.00	85.50	3.35
31-35	18	13	72.22	20.50	25.50	2.83
36-40	5	5	100.00	5.00	5.00	2.00

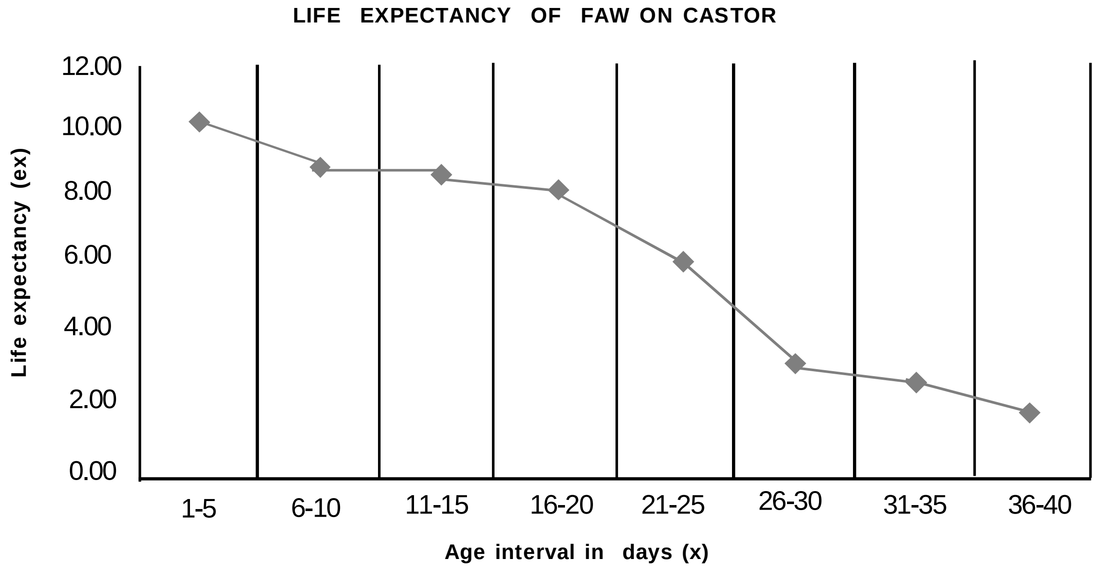

Figure 3. Life expectancy (ex) of FAW on castor

REFERENCES

Abrahams, P., Bateman, M., Beale, T., Clottey, V., Cock, M., Colmenarez, Y., Corniani, N., Day, R., Early, R., Godwin, J., Gomez, J., Gonzalez Moreno, P., Murphy, S.T., Oppong -Mensah, B., Phiri, N., Pratt, C., Silvestri, S and Witt, A. 2017. Evidence Note (2), CABI, Wallingford, UK.

Atwal, A.S and Bain, S.S. 1974. Applied Animal Ecology (Ludhiana: Kalyani Publishers), New Delhi.

Awmack, C.S and Leather, S.R. 2002. Host plant quality and fecundity in herbivorous insects. Annual Review of Entomology. 47: 817-844.

Birch, L.C. 1948. The intrinsic rate of natural increase of an insect population. Journal of Animal Ecology. 17: 15-26.

Casmuz, A., Juarez, M.L., Socias, M.G., Murúa, M.G., Prieto, S., Medina, S., Willink, E and Gastaminza, G. 2010. Review of the host plants of fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae). Journal of the Argentine Entomological Society. 69(3-4): 209-231.

Chaudhary, R.R.P and Bhattacharya, A.K. 1986. Bioecology of Lepidopterous Insects on Winged bean, *Psophocarpus tetragonolobus* (Linnaeus) DeCandole. Memoir No. 12, The Entomological Society of India, Division of Ento-mology, IARI, New Delhi, 110 012, India. 202.

Chenchaiah, K.C., Mondal, P and Bhattacharya, A.K. 2007. Life tables and stable age distribution of *Creatonotus gangis* (Lepidoptera: Arctiidae) on artificial diet. Journal of Ecofriendly Agriculture. 2: 26-32.

Chi, H. 1990. Timing of control based on the stage structure of pest population: A simulation approach. Journal of Economic Entomology. 83: 1143-1150.

Day, R., Abrahams, P., Bateman, M., Beale, T., Clottey, V., Cock, M., Colmenarez, Y., Corniani, N., Early, R., Godwin, J and Gomez, J. 2017. Fall armyworm: impacts and implications for Africa. Outlooks on Pest Management. 28: 196-201.

Deevey, Jr. E.S., 1947. Life tables of natural populations of animals. Quarterly Review of Biology. 22: 283-314.

Dhabi, M.R., Mehta, D.M, Patel C.C and Korat, D.M. 2009. Life table of diamondback moth, *Plutella xylostella* (Linnaeus) on cabbage (*Brassica oleraceae var. capitata* L.). Karnataka Journal of Agriculture Sciences. 22(2): 319-321.

FAO, 2019. http://www.fao.org/3/BS183E/bs183e.pdf

Goergen, G., Kumar, P.L., Sankung, S.B., Togola, A and Tamo, M. 2016. First report of outbreaks of the fall armyworm *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera, Noctuidae), a new alien invasive pest in West and Central Africa. PLoS ONE.11: 10.

Maghodia, A.B and Koshiya, D.J. 2008. Life fecundity studies (for female) of *Spodoptera litura* (Fabricius) on different hosts. Crop Research. 35(3): 277-284.

Morris, R.F and Miller, C.A. 1954. The development of life tables for the spruce bud worm. Canadian Journal of Zoology. 32: 283-301.

Murua, M.G., Nagoshi, R.N., Santos, D.A., Hay-Roe, M., Meagher, R.L and Vilardi, J.C. 2015. Demonstration using field collections that Argentina fall armyworm populations exhibit strain specific host plant preferences. Journal of Economic Entomology. 108: 2305-2315.

Odum, E.P. 1971. Fundamentals of Ecology. W B Saunders Co., Philadelphia. pp.37-85

Poole, P.W. 1974. An introduction to quantitative ecology. McGraw Hill, U.S.A. pp. 111.

Pramanik, P., Mondal, P and Chatterjee, M. 2012. Studies on Biology of Brinjal Fruit and Shoot Borer, *Leucinodes orbonalis* (Guenee) under Laboratory Condition. International Journal of Bio-resource and Stress Management. 3(3): 336-340.

Prasanna, B.M., Huesing, J.E., Peschke, V.M and Eddy, R. (Eds). 2021. Fall Armyworm in Asia: A Guide for Integrated Pest Management. Mexico, CDMX: CIMMYT.

Slobodkin, L.B. 1962. Growth and regulation in annual populations. Holt, Rinehart and Winston, New York. 184 pp.

Sooravan, T., Sankarperumal, G and Baskaran, S. 2005. Life-table of *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) reared on three different hosts. Entomon. 30(4): 337-341.

Srivastava, A and Gupta. D.K. 2015. A Study of *Philosamia Ricini* Life Cycle for ERI Culture in Northern Planes of India. The International Journal of Science and Technoledge. (ISSN 2321 – 919X). 3(4): 22-25.

Sunil, K., Pramod, K., Nadagouda, S and Hanchinal S.G. 2019. Life Table Evaluation of *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) on Groundnut. International Journal of Current Microbiology and Applied Sciences. 9: 1-12.

Supriya, G.B., Singh, T.V.K., Sunitha, V and Vinod, S.K. 2018. Demographic parameters of tobacco caterpillar *Spodoptera litura* (Fabricius) on castor (*Ricinus communis*) under lab conditions. Research Journal of Agricultural Sciences. 9(4): 775-779.

Tuan, S.J., Lee, C.C and Chi, H. 2013. Population and damage projection of *Spodoptera litura* (F.) on peanuts (*Arachis hypogaea* L.) under different conditions using the age-stage, two-sex life table. Pest Management. 70: 805-813.

Woods, H.A. 1999. Patterns and mechanisms of growth of fifth instar *Manduca sexta* caterpillar following exposure in low or high protein food during early instar. Physiological Zoology. 72: 445-454.