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Original Research Article

Life Table and Survivorship of a Short Horned Grasshopper Exposed to Arsenic Compound under Laboratory Conditions

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ABSTRACT

Spathosternum prasiniferum prasiniferum **(Walker, 1871), a common short horned grasshopper considered as pest of paddy, mungbean, urd bean, chick bean in India. They were acclimatized in bisexual pairs under laboratory conditions and exposed to various doses of sodium arsenate such as 0.0125mg.l^{-1}, 0.025 mg.l^{-1}, 0.050 mg.l^{-1}, 0.10 mg.l^{-1}, 0.20 mg.l^{-1} with the aim to find out survivorship, mortality and life expectancy. Sodium arsenate created the variation in their life cycle as well as life span of the insect compared to the control. A convex shaped survivorship curve of both male and female revealed a high mortality in older adult. A sizeable increment in the number of individual presented in the biplot of both male and female grasshopper advocated its ability to use the arsenic efficiently. After slight depression in 0.025 mg.l^{-1}, rapid recoveries signify the insect ability to overcome the initial stress situation and successfully maintained the life cycle with the advancement of doses.**

Keywords: Grasshopper, Sodium arsenate, Life table, Survivorship curve, Stress, Life expentancy

Arseniğe Maruz Bırakılan Çekirgelerin Laboratuvar Şartlarındaki Hayat Tablosu ve Hayatta Kalma Becerileri

ÖZ

Kısa antenli çekirge *Spathosternum prasiniferum prasiniferum* (Walker, 1871) Hindistan'da çeltik, maş fasulyesi, siyah mercimek ve nohutun önemli bir zararlısı olarak tanımlanmaktadır. Bireyler laboratuvar şartlarına adapte edildikten sonra değişik dozlarda sodyum arsenata (0.0125mg.l^{-1}, 0.025 mg.l^{-1}, 0.050 mg.l^{-1}, 0.10 mg.l^{-1}, 0.20 mg.l^{-1}) maruz bırakılmış ve bunun sonucunda hayatta kalma becerileri, ölüm oranları ve ortalama yaşam süresi üzerindeki etkileri incelenmiştir. Kontrole göre karşılaştırıldığında sodyum arsenat bireylerin yaşam döngülerinde ve yaşam sürelerinde varyasyonlara neden olmuştur. Erkek ve dişi bireylerde görülen konveks şekilli yaşam eğrisi, yaşlı bireylerde yüksek ölüm oranını ortaya çıkarmıştır. Erkek ve dişi bireylerin biplot tablolarında görülen birey sayılarındaki artışlar, çekirgelerin arseniği verimli biçimde kullanma yeteneklerini desteklemiştir. 0.025 mg.l^{-1} uygulamasında görülen depresyondan sonra meydana gelen iyileşmeler, böceklerin başlangıçta yaşanan stres koşullarından kurtulabildiği ve yaşam döngülerine devam edebildiğini göstermiştir.

Anahtar Kelimeler: Çekirge, Sodyum arsenat, Hayat tablosu, Hayatta kalma eğrisi, Stres, Ortalama yaşam süresi

INTRODUCTION

In most lifecycle, mortality varies greatly with age in insects as well as in higher organisms. Life tables provides a systematic and complete picture of mortality in a population and a tabular device to describe every particular age of interval (Aziz *et al.* 2013) and provides precise description of the survivorship, development pattern and life expectancy (Ali and Rizvi 2007; Yazdani and Samih 2012). Pearl and Parker (1921) first introduced the life table into general biology by applying it on *Drosophila* under the laboratory conditions. Neukirch (1982) has been reported that the life span of worker honeybees was found to be determined by the duration of the hive-period and of the foraging period. Togashi (1990) has been constructed the life table of *Monochamus alternatus* and analyzed for four consecutive generations within *Pinus thunbergii*. Grist and Gurney (1995) prepared the model related to the effect of periodic environmental variations on the synchronization of life cycle. A threshold model of outbreak bark beetle population dynamics involved resources assemble during low-density periods and depletion during out-breaks (Okland and Bjornstad 2006). Life table of the Olive leaf moth, *Palpita unionalis* revealed that the intrinsic rate of population increase depends upon the nature of host plants provided (Kumral *et al.* 2007). Momen (2011) studied the biology of *Proprioseiopsis cabonus* in relation to life table and predation

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rates of these predatory mites. Whereas, Kakde *et al*. (2014) reviewed the importance of life table in studying allocation, determination of age and mortality of an organism and individuals. *Spathosternum prasiniferum prasiniferum* (Walker 1871) a common short horned grasshopper available in India, was considered as a pest of paddy, mungbean and urdbean chickpea (Usmani *et al*. 2012). Analyses of the mortality are a very useful tool to determine key factors responsible for the highest mortality within population. By calculating the life expectancy of a pest insect we can predict and determine the particular instars within which we get maximum mortality and such idea may be utilized in the management of insect pest at particular time. So the studies were conducted with the aim to find out survivorship, mortality and life expectancy of *Spathosternum prasiniferum prasiniferum.*

MATERIALS AND METHODS

To study the life table and mortality rate under laboratory conditions, adults of *Spathosternum prasiniferum prasiniferum* were collected from a fallow land near Piyali, South 24 Parganas and were kept in bisexual pairs. They were acclimatized under laboratory conditions for 7 days in insectariums. Plastic jars of 10 liter capacity containing 4.0 cm thick sand at the bottom were taken as the rearing cage. The open portion of the cages was covered with nylon net in order to maintain the air supply properly. Conical flask of 50 ml capacity containing food plant was placed in the jar for providing food to the insects (Nath and Rai 2010). Leaves of *Cynodon dactylon* collected from the institute campus were considered as food plant due to the preference of this grass by this grasshopper.

For the control experiments, adults were fed on leaves grown in distilled water. For contamination, arsenic salt (sodium arsenate) was dissolved in distilled water along with food plant (Schmidt & Ibrahim 1994) and kept for twenty four hours. Concentration of 0.0125mg.l^{-1} (d1), 0.025 mg.l^{-1} (d2), 0.050 mg.l^{-1} (d3), 0.10 mg.l^{-1} (d4), 0.20 mg.l^{-1} (d5) arsenic salt water were tested respectively. Bisexual pairs were fed upon the contaminated food along with the untreated.

After copulation, the female laid eggs in the sand. After approximately 30days of oviposition the first instars hatched out from the eggs. A total number of 1000 newly hatched first instars were taken into consideration.

The first instars and their successive stages including the adult insects were also reared following the same procedure. The laboratory mortality data of *Spathosternum prasiniferum prasiniferum* were used to construct life tables and survivorship curves.

Explanation of symbols used in the life table (Ricklefs & Miller 1999; Dash 2005; Smith and Smith 2007):

x = age in days.

n_x = number of individuals from the original cohorts that are alive at the specified age x.

l_x = the probability at birth of surviving to any given age.

d_x = number of individuals out of l_x who die before completing age x+1.

s_x = survival rate (proportion of individuals of age x surviving to age x+1).

m_x = mortality rate (proportion of individuals of age x surviving to age x+1).

L_x = number of individuals alive between ages x and x+1.

T_x = total number of days lived by the cohort after age x days. In fact, this is the total future life time of the lx individual (until all of them die off).

q_x = mortality rate for an age interval.

e_x = expectation of further life of individuals of age x.

$k_x = -\log_e s_x$, the exponential mortality rate between age x and x+1.

RESULTS AND DISCUSSION

Spathosternum prasiniferum prasiniferum, a short horned grasshopper exposed to various doses of sodium arsenate results in disturbance in their life cycle, which results in the significant changes in the life span of the insect compare to the control. Percentage of mortality of first instar in control was 17.5 per cent (Table 1), which was maximum 25 percent in grasshopper exposed to 5d (Table 6). Second instars had 9.09 percent mortality, and showed a maximum of 14.40 per cent exposed to d2 (Table 3). The third instars had maximum mortality 23.12 percent at 4d (Table 5) and significant change in the mortality of the same instar at d2 (Table 3), d3 (Table 4) and d5 (Table 6) in compare to the untreated grasshoppers.

Table 1. Life tables of control **(**untreated) *S. prasiniferum prasiniferum.*

Stage	l_x	d_x	d_x ***as % of*** l_x
Ist instar	1000	175	17.5
IInd instar	825	75	9.09
IIIrd instar	750	75	10
IVth instar	675	175	25.92
Vth instar	500	0	0

Adult female 175
Adult male 125

Female

X(days)	n_x	l_x	d_x	S_x	m_x	L_x	T_x	q_x	$175q_x$	e_x	K_x
0	175	1	25	0.857	0.143	162.5	600.5	0.143	25	3.43	0.15
5	150	0.857	27	0.82	0.18	136.5	438	0.18	31.5	2.92	0.19
10	123	0.703	33	0.73	0.27	106.5	301.5	0.268	46.95	2.45	0.31
15	90	0.514	23	0.74	0.26	78.5	195	0.255	44.72	2.16	0.30
20	67	0.382	23	0.65	0.35	55.5	116.5	0.343	60.0	1.74	0.43
25	44	0.251	21	0.52	0.48	33.5	61	0.477	83.52	1.38	0.65
30	23	0.131	12	0.47	0.53	17	27.5	0.521	91.3	1.19	0.75
35	11	0.063	6	0.48	0.52	8	10.5	0.545	95.45	0.95	0.73
40	5	0.028	5	0	1	2.5	2.5	1.00	175	0.5	-

Male

X(days)	n_x	l_x	d_x	S_x	m_x	L_x	T_x	q_x	$125q_x$	e_x	K_x
0	125	1	25	0.96	0.04	122.5	422.5	0.2	25	3.38	0.04
5	120	0.96	5	0.95	0.05	117.5	300	0.04	5.2	2.5	0.05
10	115	0.92	30	0.73	0.27	100	182.5	0.26	32.6	1.58	0.31
15	85	0.68	53	0.37	0.63	58.5	82.5	0.62	77.9	0.97	0.99
20	32	0.25	24	0.25	0.75	20	24	0.75	93.75	0.75	1.38
25	8	0.06	8	0	1	4	4	1	125	0.5	-

Table 2. Life tables of 0.0125*mg*.L^{-1}treated *S. prasiniferum prasiniferum* .

Stage	l_x	d_x	d_x ***as % of*** l_x
Ist instar	1000	63	6.3
IInd instar	937	63	6.72
IIIrd instar	874	63	7.21
IVth instar	811	62	7.64
Vth instar	749	0	0

Adult female- 375
Adult male - 374

Female

X(days)	n_x	l_x	d_x	S_x	m_x	L_x	T_x	q_x	$375q_x$	e_x	K_x
0	375	1	0	1	0	375	1673.5	0	0	4.46	0
5	375	1	0	1	0	375	1298.5	0	0	3.46	0
10	375	1	63	0.832	0.168	343.5	923.5	0.17	63	2.46	0.18
15	312	0.83	112	0.641	0.359	256	580	0.29	134.6	1.85	0.44
20	200	0.53	63	0.685	0.315	168.5	324	0.31	118.1	1.62	0.37
25	137	0.36	62	0.668	0.332	106	155.5	0.45	169.7	1.13	0.40
30	75	0.2	63	0.16	0.84	43.5	49.5	0.84	315	0.66	1.83
35	12	0.03	12	0	1	6	6	1	375	0.5	-

Male

X(days)	n_x	l_x	d_x	S_x	m_x	L_x	T_x	q_x	$374q_x$	e_x	K_x
0	374	1	0	1	0	374	1674	0	0	4.47	0
5	374	1	0	1	0	374	1300	0	0	3.47	0
10	374	1	0	1	0	374	926	0	0	2.47	0
15	374	1	149	0.60	0.4	299.5	552	0.39	149	1.47	0.5
20	225	0.6	125	0.44	0.56	162.5	252.5	0.55	207.7	1.12	0.82
25	100	0.26	60	0.4	0.6	70	90	0.6	224.4	0.9	0.91
30	40	0.10	40	0	1	20	20	1	374	1	-

Table 3. Life tables of 0.025*mg*.L^{-1}treated *S. prasiniferum prasiniferum.*

Stage	l_x	d_x	d_x *as % of* l_x
Ist instar	1000	222	22.2
IInd instar	778	112	14.40
IIIrd instar	666	0	0
IVth instar	666	0	0
Vth instar	666	0	0

Adult female- 222
Adult male- 111

Female

X(days)	n_x	l_x	d_x	S_x	m_x	L_x	T_x	q_x	222q_x	e_x	K_x
0	222	1	0	1	0	222	1179	1	0	5.3	0
5	222	1	0	1	0	222	957	1	0	4.3	0
10	222	1	21	0.90	0.1	211.5	735	1	21	3.3	0.1
15	201	0.9	16	0.92	0.08	193	523.5	0.9	17.67	2.6	0.08
20	185	0.83	45	0.76	0.24	162.5	330.5	0.83	54	1.78	0.27
25	140	0.63	42	0.7	0.3	119	168	0.63	66.6	1.2	0.35
30	98	0.44	98	0	1	49	49	0.44	222	0.5	-

Male

X(days)	n_x	l_x	d_x	S_x	m_x	L_x	T_x	q_x	111q_x	e_x	K_x
0	111	1	0	1	0	111	394.5	0	0	3.5	0
5	111	1	12	0.89	0.11	105	283.5	0.108	12	2.5	0.1
10	99	0.89	19	0.8	0.2	89.5	178.5	0.19	21.3	1.8	0.2
15	80	0.72	31	0.61	0.39	64.5	89	0.38	43.0	1.1	0.49
20	49	0.44	49	0	1	24.5	24.5	1	111	0.5	-

Table 4. Life tables of 0.050*mg*.L^{-1}treated *S. prasiniferum prasiniferum.*

Stage	***l_x***	***d_x***	***d_x as % of l_x***
Ist instar	1000	167	16.7
IInd instar	833	0	0
IIIrd instar	833	0	0
IVth instar	833	168	20.04
Vth instar	665	0	0

Adult female- 333
Adule male- 332

Female

X(days)	**n_x**	**l_x**	**d_x**	**S_x**	**m_x**	**L_x**	**T_x**	**q_x**	**333q_x**	**e_x**	**K_x**
0	333	1	0	1	0	333	1904.5	0	0	5.7	0
5	333	1	3	0.9	0.1	331.5	1571.5	.009	3	4.7	0.1
10	330	0.99	15	0.95	0.05	322.5	1240	0.04	15.14	3.75	0.05
15	315	0.94	31	0.9	0.1	299.5	917.5	0.09	32.7	2.9	0.10
20	284	0.85	35	0.87	0.13	266.5	618	0.12	41.0	2.2	0.14
25	249	0.74	82	0.67	0.33	208	351.5	0.32	109.6	1.4	0.4
30	167	0.5	107	0.36	0.64	113.5	143.5	0.64	213.3	0.85	1.02
35	60	0.18	60	0	1	30	30	1	333	0.5	-

Male

X(days)	**n_x**	**l_x**	**d_x**	**S_x**	**m_x**	**L_x**	**T_x**	**q_x**	**332q_x**	**e_x**	**K_x**
0	332	1	0	1	0	332	1792	0	0	5.39	0
5	332	1	0	1	0	332	1460	0	0	4.39	0
10	332	1	5	0.98	0.02	329.5	1128	0.015	5	3.39	0.02
15	327	0.98	28	0.91	0.09	313	798.5	0.08	28.4	2.44	0.09
20	299	0.90	67	0.77	0.23	265.5	485.5	0.22	74.39	1.62	0.26
25	232	0.69	128	0.45	0.55	168	220	0.55	183.2	.95	0.79
30	104	0.31	104	0	1	52	52	1	332	0.5	-

Table 5. Life tables of 0.10*mg*.L^{-1}treated *S. prasiniferum prasiniferum.*

Stage	l_x	d_x	d_x ***as % of*** l_x
Ist instar	1000	125	12.5
IInd instar	875	62	7.08
IIIrd instar	813	188	23.12
IVth instar	625	62	9.92
Vth instar	563	0	0

Adult female- 375
Adult male- 188

Female

X(days)	n_x	l_x	d_x	S_x	m_x	L_x	T_x	q_x	$375q_x$	e_x	K_x
0	375	1	0	1	0	375	1874.5	0	0	4.99	0
5	375	1	0	1	0	375	1499.5	0	0	3.99	0
10	375	1	53	0.832	.168	348.5	1124.5	0.14	53	2.99	0.18
15	322	0.85	25	0.92	0.08	309.5	776	0.07	29.1	2.40	0.08
20	297	0.79	125	.599	0.401	242	466.5	0.42	157.8	1.57	0.51
25	187	0.49	85	0.54	0.46	144.5	224.5	0.45	170.4	1.20	0.61
30	102	0.27	73	0.28	0.72	65.5	80	0.71	268.4	0.78	1.27
35	29	0.07	29	0	1	14.5	14.5	1	375	0.5	-

Male

X(days)	n_x	l_x	d_x	S_x	m_x	L_x	T_x	q_x	$188q_x$	e_x	K_x
0	188	1	0	1	0	188	817.5	0	0	4.34	0
5	188	1	0	1	0	188	629.5	0	0	3.35	0
10	188	1	53	.72	0.28	161.5	441.5	0.28	53	2.35	0.33
15	135	0.71	35	0.74	0.26	117.5	280	0.25	48.7	2.07	0.30
20	100	0.53	25	0.75	0.25	87.5	162.5	0.25	47	1.62	0.28
25	75	0.39	75	0	1	75	75	1	188	1	-

Table 6. Life tables of 0.20*mg*.L^{-1}treated *S. prasiniferum prasiniferum.*

Stage	l_x	d_x	d_x ***as % of*** l_x
Ist instar	1000	250	25
IInd instar	750	0	0
IIIrd instar	750	0	0
IVth instar	750	0	0
Vth instar	750	0	0

Adult female- 500
Adult male-250

Female

X(days)	n_x	l_x	d_x	S_x	m_x	L_x	T_x	q_x	$500q_x$	e_x	K_x
0	500	1	0	1	0	500	2997	0	0	5.9	0
5	500	1	0	1	0	500	2497	0	0	4.9	0
10	500	1	0	1	0	500	1997	0	0	3.9	0
15	500	1	0	1	0	500	1497	0	0	2.9	0
20	500	1	75	0.85	.15	462.5	997	0.15	75	1.9	0.16
25	425	0.85	103	0.75	0.25	373.5	534.5	0.24	121.2	1.3	0.28
30	322	0.64	322	0	1	161	161	1	500	0.5	-

Male

X(days)	n_x	l_x	d_x	S_x	m_x	L_x	T_x	q_x	$250q_x$	e_x	K_x
0	250	1	0	1	0	250	1332	0	0	5.32	0
5	250	1	0	1	0	250	1082	0	0	4.32	0
10	250	1	0	1	0	250	832	0	0	3.32	0
15	250	1	0	1	0	250	582	0	0	2.32	0
20	250	1	43	0.83	0.17	228.5	332	0.17	43	1.32	0.18
25	207	0.83	207	0	1	103.5	103.5	1	250	0.5	-

Table 7. Rate of metamorphosis (%) in *S. prasiniferum prasiniferum.*

Grasshopper	**Control**	**0.0125mg.l^{-1} (dose1)**	**0.025mg.l^{-1} (dose2)**	**0.050mg.l^{-1} (dose3)**	**0.10mg.l^{-1} (dose4)**	**0.20mg.l^{-1} (dose5)**
Male	12.5	37.4	11.1	33.2	18.8	50
Female	17.5	37.5	22.2	33.3	37.5	25
Adult	30.0	74.9	33.3	66.5	56.3	75

Among the instars the fourth one of untreated grasshopper showed highest mortality 25.92% (Table 1) which was zero in d2 and d5, whereas fifth instars showed zero mortality in untreated grasshopper and maintained almost similar trend in all the treated insects. When treated grasshopper was concerned, first instars showed highest mortality at d5 and lowest at d1, second instar have highest mortality at d2, third instars highest at d4 and lowest in rest of the doses except d1. Fourth instars showed highest mortality in d3 and lowest in d2 and d5, whereas, treated 5th instars revealed a zero mortality rate in treated as well as untreated grasshopper studied.

Life table of adult female and male were found significant variation when treated with different doses of arsenic. The average life span of normal female was 40 days which reduced to 30 in d2 and d5 treated grasshopper, but in d4 the life span was 35 days. Whereas, male have normal 25 days life span which increased to 30 days in d1 and came down in 20 days in d2. Again an increase up to 30days was available when the grasshopper was treated with d3. Life expectancy (e_x) of treated grasshopper was observed significant difference from that of control male and female. Untreated female have e_x of 3.43 (Table 1) whereas it ranged between 4.46 and 5.9 in treated one. Untreated zero days old male have e_x of 3.38 which was ranged between 3.5and 5.39 in arsenic treated male grasshopper. When survival rate (s_x) was concern, it was found almost significantly high throughout the life span in grasshopper exposed to d5 (table-6). Whereas other treated grasshopper almost maintained a similar trend of s_x in comparison to untreated.

Survivorship curve of both male and female revealed a convex shape which indicates a high mortality in older adult. 30% of the untreated grasshopper were converted into adult, whereas, such metamorphosis was comparatively higher in treated grasshopper. Highest conversion was more than 70% in d1 and d5. 17.5% adult female and 25% adult male were metamorphosed in case of untreated grasshopper, whereas, this rate was ranged between 22.2 and 37.5 per cent and 11.1 to 50 per cent in arsenic treated female and male grasshopper respectively (Table 7).

The study of life table in *Spathosternum prasiniferum prasiniferum* indicated the impact of arsenic on nymph as well as adult mortality was different when their life span was concerned. The mortality rate was higher in the nymph of the studied grasshopper in comparison to the adult grasshopper.

Such nymphal mortality i.e. early death in the population more or less counter balances the effect of reproduction in most animal population. So pre reproductive death rate helps to hold a population in check which obviously depend on the reproductive capacity of the species (Nath and Rai 2010)

It is demonstrated in the present study that *Spathosternum prasiniferum prasiniferum* possessed a resistance when exposed to arsenic infection. Though the metamorphosis rate in male was come down in d2 but it recovered and went up to 50 present at 0.20mg.l^{-1} , which was also observed in female.

Adult male maintained a steady life span in various doses of arsenic. Life span of adult female slightly reduced than untreated but maintained distinct survival rate in younger adult. High metamorphosis rate in both the sexes also emphasized its ability to recover from the detrimental effect of arsenic at various doses. It was designated that organisms, those subject to different stresses of toxic substances in the ecosystems have their own mechanism to decontaminate various toxic substances (Migula 2000). In many cases arsenic have been acted as an essential trace element for the normal growth and development of experimental animals (Schwarz 1977; Anke *et al*. 1980). Present study advocated the ability to use the arsenic efficiently as presented in the biplot of both male and female grasshopper (Figure 1).

Cohort life table helps to estimate the parameters related to growth potential and suitable to study dynamics of insect population (Aziz *et al*. 2013). After slight depression in d2, rapid recoveries signify the insect ability to overcome the initial stress situation and successfully maintained the life cycle with the advancement of doses.

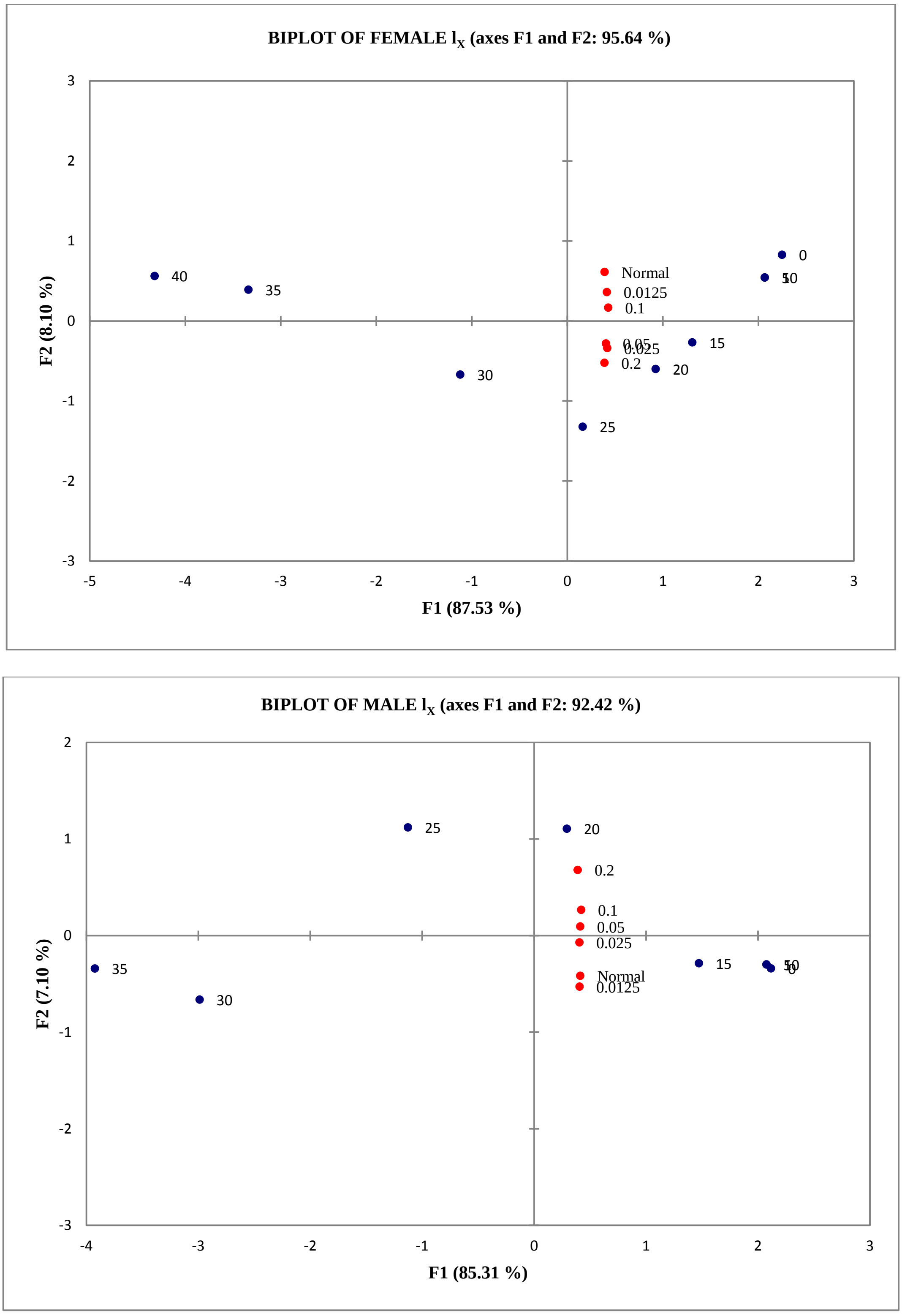

Figure 1. Biplot showing the effect of various doses of arsenic on *Spathosternum prasiniferum prasiniferum* female and male.

CONCLUSIONS

The studies were conducted with the aim to find out survivorship, mortality and life expectancy of *Spathosternum prasiniferum prasiniferum* exposed to arsenic compound. Result demonstrated a rapid recovery from initial effect of arsenic and able to maintain a steady rate of life cycle with further increase of doses. Authors are also grateful to Prof. Samiran Chakraborty, University of Kalyani, India, for help in preparing this manuscript.

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