Effect of Host-Plant on Life Table Parameters of Potato Tuber Moth *Phthorimaea operculella* (Zeller)

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Abstract

Life table studies for potato tuber moth, *Phthorimaea operculella* (Zeller) were carried out on three host plants namely; potato tubers, *Solanum tuberosum* L. (Potato), eggplant fruits, *Solanum melongena* L. (Aubergine) and green tomatoes, *Solanum esculentum* Mill (Tomato), to evaluate the preferred host plant for feeding *Ph. operculella* larvae. The calculated biological parameters were: Net reproductive rate of increase (R_0), generation time (G_t), intrinsic rate of increase (r_m), finite rate of increase (λ) and population doubling time (D_t). Obtained results indicated that potato tubers proved to be the quite favorable for achieving the highest developmental and multiplication rates of *Ph. operculella*, followed by eggplant meanwhile tomato was the least favorable. The natural mortality figures; Apparent Mortality (AM), Real Mortality (RM) and Indispensable Mortality (IM) for larvae reared on potato tubers were 20.73, 17.00 and 13.34%, respectively. Meanwhile, the highest mortality rates were 32.58, 29.00 and 18.36% when larvae were fed on eggplant fruits. It is quite worth to mention out here that potato tubers are considered as the most attractive for feeding and rearing *Ph. operculella* for research purposes followed by egg-plant. Tomato seem to be the least acceptable host plant.

Key words: Host plants, Life tables, Potato tuber moth, *Phthorimaea operculella.*

Introduction:

Cultivated potato, *Solanum tuberosum* L. (Solanales-Solanaceae), is one of the most important vegetable crops for human nutrition worldwide (Flanders *et al*., 1999; Abdallah *et al*., 2012). The potato tuber moth (PTM), *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae), is one of the most damaging insect pests of potatoes in both field crops and also to the yielded tubers during storage (Min *et al.*, 2017). The moth larvae develop in the foliage and tubers of potatoes and cause direct losses of the product (Hashemi, 2015). Often, more than 10% of the harvested tubers are infested and unmarketable (Sileshi and Teriessa, 2001). It is a highly adaptable insect, found in locations with very different climatic conditions (Kroschel and Koch, 1994). The construction and analysis of age-specific life tables is an important and easy procedure based on biological parameters when the key factors governing the changes in the population dynamics is taken into consideration. In the meantime, forecasting growth rates; i.e. natality and mortality, provide a rational and predictive basis for pest control (Southwood and Henderson, 2000).

In this respect, many investigators studied the simultaneous effect of host plant and source of feeding on

mortality, distribution and population growth rates of the potato tuber moth, *Ph. operculella* such as Attalah *et al*., (1981); Sharaby and Saleh (1984); Abdel-Karim *et al*., (1985); Simchuk *et al*., (1986); Chi (1988), Vera-Graziano *et al*., (1988); Debnath *et al*., (2000); El-Saadany *et al.*, (2000); Ibrahim (2000); Ghazala (2005); Al- Taweel *et al*., (2006); Douches *et al*., (2010); Randon (2010); Abdallah *et al.*, (2012). In general, the present study aimed to evaluate the preferred potato variety for feeding and rearing *Ph. operculella* larvae.

Material and methods:

Rearing techniques:

At harvest of 2016 season potato yield, naturally infested potato tubers of Spunta variety were collected for the establishment of a laboratory insect stock culture to provide target insect in all developmental stages required for the laboratory studies. The infested potato tubers were medium sized and supplied with sound tubers, and a 5 cm layer of wood sawdust to help successful pupation. These tubers were placed in nine wire gauze wooden rearing cages measuring 40-40-40 cm. The culture was maintained at laboratory conditions at 27±2ºC and 60±5% R.H. and a light regime of approximately 12h daily light periodicity. The front of the rearing cage which served as a door for inserting selected tubers was provided with white cloth sleeves to facilitate daily examination; i.e. counting emerged moths and preventing their escape.

The newly emerged moths were collected by means of vacuum suction equipment, sexed and grouped, in 10 couples (5♂+5♀) each in an oviposition cage consisting of a glass chimney measuring 17 cm in depth and 7-8.5cm in diameter. The lower rim rested on the bottom of a Petri-dish lined with a disc of filter paper. The upper rim was covered with black muslin-upon which most of eggs were laid -fixed with a rubber band. Pieces of cotton stalks 6 cm in length soaked in 10% honey solution were supplied for moth feeding and were changed when needed. Deposited eggs were collected daily from the oviposition cages and kept in large test tubes covered with pieces of cotton. Newly hatched larvae were picked up by the aid of a moistened fine brush and transferred to potato tubers for feeding till pupation. Newly formed pupae were collected on the same day of pupation and placed in clean chimney glass cages. Daily examinations were carried out until adult emergence. Cages were cleaned and sterilized, saw dust was changed biweekly.

Life table studies:

A number of 300 newly hatched 1st instar larvae were set in three equal replicates each of 100 larvae/replicate was tested for each host plant. Three host plants with the same weight were offered to the larvae for feeding during the whole larval duration; namely; potato tubers: *Solanum tuberosum* L. (Potato), eggplant fruits: *Solanum melongena* L. (Aubergine) and green tomatoes: *Solanum esculentum* Mill. (Tomato)

The following biological parameters were measured i.e., egg and larval duration and mortality, percentage of pupation, duration of pupal stage, percentage of adult emergence, adult longevity, female relative fecundity and specific fertility rates.

Construction of life table data figures and estimating life table parameters:

Data obtained for evaluating the effect of the preferred host plants for *Ph. operculella* surviving were used for constructing life tables according to Anderwartha and Birch (1984) (Table 1). Where: (Lx) age specific survival rate, (Dx) number of dead individuals during the age interval (x)

The mortality data figures were estimated through the following:

*Apparent mortality (AM %) = (Dx_1/Lx_1) x 100, (Dx_2/Lx_1) x 100

*Real mortality (RM %) = (Dx_1/Lx_1) x 100, (Dx_2/Lx_2) x 100

*Indispensable mortality (IM %): this is that part of generation mortality that would not occur, should the mortality factor in question be removed from the life system .

Table 1. Age specific life table data figures expressed as definitions and corresponded formulae.

Symbol	Definitions	Formula
X	Age (in days)	----------
L_x	Probability of an individual surviving to age x.	----------
M_x	Reproductive expectation of a female at age x.	----------
R_0	Net reproductive rate, number of daughters that replace an average female in course of a generation.	$R_0 = \sum Lx\ Mx$
G_t	Mean generation time, mean of the period over which progeny are produced.	$G_t = (\sum x\ L_x\ M_x)/R_0$
r_m	Intrinsic rate of increase, number of progenies produced per unit time	$r_m = (\log e^{R_0})/G_t$
λ	Finite rate of increase, number of times a population double itself in unit time.	$\lambda = e^{rm}$
D_t	Generation doubling time.	$D_t = (\log e^2)/r_m$

Results and discussions:

The following parameters were recorded.

1 - Survival and fecundity rates:

Data presented in Tables (2, 3 and 4) show the changes in the estimated life table parameters of potato tuber moth when larvae were fed on potato tubers, eggplant fruits and tomato fruits. The careful examination of the data reveal that host plant had a strong effect on the larval and pupal longevity in addition to the potential fecundity of adult females. Data shown in Table (2) and Figs. (1 and 2) illustrate that the longevity of females resulted from larvae fed on potato tubers had the shortest longevity duration (21days) and obvious age-specific fecundity rate of 107.7 eggs/female; while immature stages completed 24 days. Oviposition started after 2 days from female emergence and lasted for 10 days while the post-oviposition period lasted for 9 days. Net reproductive rate was 20.86 eggs/female. Mean duration of generation was 29.31 days. The total generation time was 45 days. (Table 2).

Feeding larvae of PTM on eggplant and tomato fruits demonstrated the longest life span duration thus completing one generation duration in 63 and 60 days for the two host plants, respectively. The immature stages lasted for 37 days for both tested host plants. Female longevity lasted 25 and 22 days, respectively (Tables 3 and 4 and Figs. 1 and 2). A number of 57.3 and 64 eggs/female; 8.32 and 6.52 females/one female were recorded for female fecundity and net reproductive rate, while mean duration of the generation was 44.35 and 45.31 days, respectively (Tables 3 and 4).

Table 2. Life table parameters as number survivors (L_x) and fecundity rates (M_x) of *Ph. operculella* when larvae were fed on potato tubers.

Stage	Age (days) X	No. of observation	Survivorship L_x	Fecundity M_x	$L_x M_x$	$L_x M_x X$
Eggs	3	100	1			
Larvae	10	82	0.82			
Pupae	11	65	0.62			
Female	25	25	0.25	0	0	0
	26	25	0.25	0	0	0
	27	23	0.23	16.4	3.77	101.84
	28	22	0.22	20.5	4.51	126.28
	29	20	0.20	22.7	4.54	131.66
	30	18	0.18	15.2	2.74	82.08
	31	17	0.17	13.3	2.26	70.09
	32	17	0.17	11.1	1.89	60.38
	33	15	0.15	3.5	0.53	17.33
	34	13	0.13	2.9	0.38	12.82
	35	13	0.13	1	0.13	4.55
	36	11	0.11	1.1	0.12	4.36
	37	9	0.09	0	0	0
	38	8	0.08	0	0	0
	39	8	0.08	0	0	0
	40	7	0.07	0	0	0
	41	5	0.05	0	0	0
	42	3	0.03	0	0	0
	43	1	0.01	0	0	0
	44	1	0.01	0	0	0
	45	1	0.01	0	0	0
Total				107.7	**R_0=** 20.86	611.39

G_t = 611.39/20.86=29.31

Table 3. Life table parameters as number survivors (L_x) and fecundity rates (M_x) of *Ph. operculella* when larvae were fed on egg-plant fruits.

Stage	Age (days) X	No. of observation	Survivorship L_x	Fecundity M_x	$L_x M_x$	$L_x M_x X$
Egg	4	100	1			
Larvae	22	89	0.89			
Pupae	11	60	0.60			
Female	38	18	0.18	0	0	0
	39	18	0.18	0	0	0
	40	18	0.18	0	0	0
	41	18	0.18	0	0	0
	42	17	0.17	5.6	0.95	39.98
	43	17	0.17	11.3	1.92	82.60
	44	15	0.15	15.4	2.31	101.64
	45	14	0.14	10.6	1.48	66.78
	46	12	0.12	5.8	0.70	32.02
	47	13	0.13	3.5	0.46	21.39
	48	10	0.10	2.2	0.22	10.56
	49	10	0.10	1.7	0.17	8.33
	50	10	0.10	0.6	0.06	3
	51	9	0.09	0.3	0.03	1.38
	52	9	0.09	0.2	0.02	0.94
	53	8	0.08	0.1	0.01	0.42
	54	7	0.07	0	0	0
	55	6	0.06	0	0	0
	56	5	0.05	0	0	0
	57	4	0.04	0	0	0
	58	3	0.03	0	0	0
	59	3	0.03	0	0	0
	60	2	0.02	0	0	0
	61	2	0.02	0	0	0
	62	1	0.01	0	0	0
	63	1	0.01	0	0	0
Total				57.3	**R_0**=8.32	369.04

G_t= 369.04/8.32=44.35

Table 4. Life table parameters as number survivors (L_x) and fecundity rates (M_x) of *Ph. operculella* when larvae were fed on tomato fruits.

Stage	Age (days) X	No. of observation	Survivorship L_x	Fecundity M_x	$L_x M_x$	$L_x M_x X$
Egg	4	100	1			
Larvae	23	75	0.75			
Pupae	10	57	0.57			
Female	38	15	0.15	0	0	0
	39	15	0.14	0	0	0
	40	14	0.14	0	0	0
	41	14	0.14	0	0	0
	42	14	0.14	5.9	0.83	34.69
	43	13	0.13	7.6	0.98	42.48
	44	11	0.11	11.2	1.23	54.21
	45	10	0.10	9.3	0.93	41.85
	46	10	0.10	7.4	0.74	34.04
	47	9	0.09	6.5	0.56	27.50
	48	8	0.08	4.1	0.33	15.74
	49	8	0.08	3.7	0.27	14.50
	50	7	0.07	2.3	0.22	11.20
	51	7	0.07	2.5	0.18	8.93
	52	6	0.06	2.1	0.13	6.55
	53	5	0.05	1.4	0.07	3.71
	54	4	0.04	0	0	0
	55	3	0.03	0	0	0
	56	3	0.03	0	0	0
	57	2	0.02	0	0	0
	58	2	0.02	0	0	0
	59	1	0.01	0	0	0
	60	1	0.01	0	0	0
Total				64	R_0=6.52	295.40

G_t = 295.40/6.52=45.31

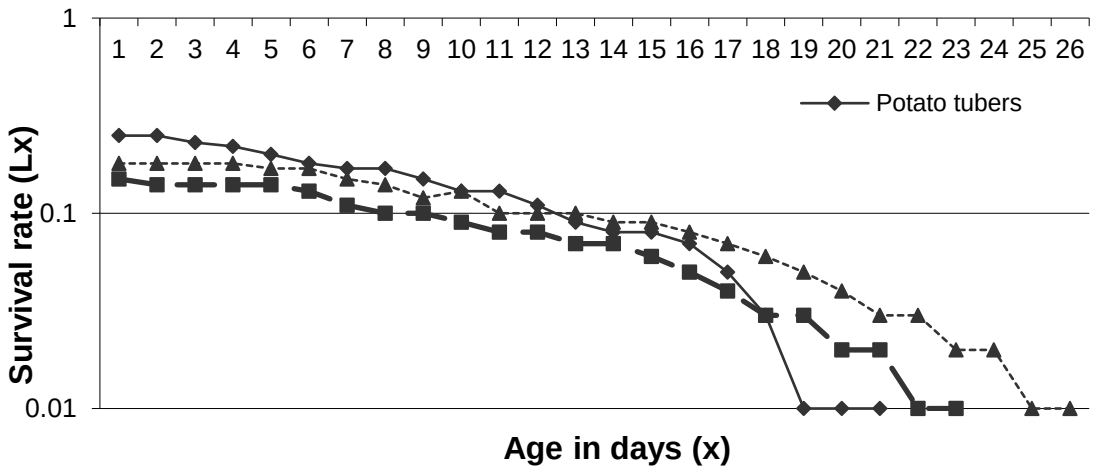

Fig. 1. The fluctuations in the age-specific survival rates (L_x) of *Ph. operculella* adult females obtained from larvae fed on three different host plants.

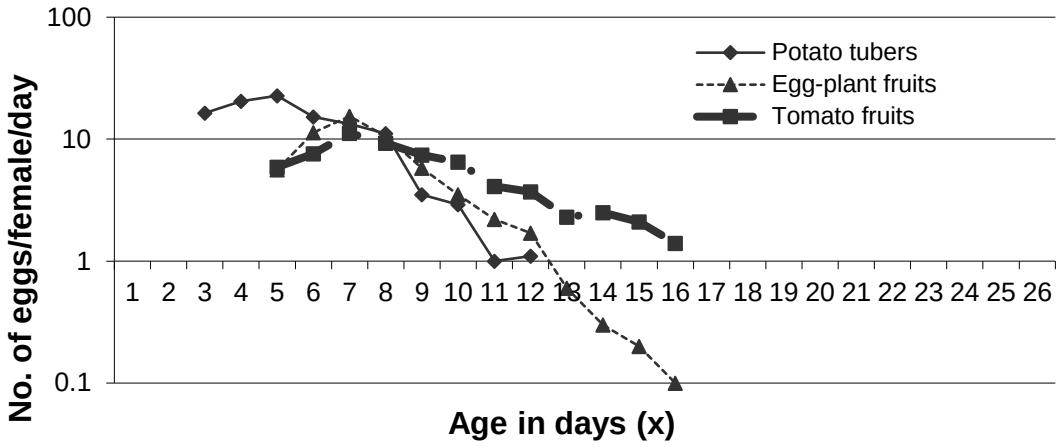

Fig. 2. Age-specific fecundity rate (M_x) of *Ph. operculella* adult females obtained from larvae fed on three different host plants.

2 - Life table parameters:

a- Net reproductive rate (R_0):

The obtained results indicate that potato tubers demonstrated the highest net reproductive rate (20.86 eggs/female) followed by eggplant fruits (8.32) and tomato fruits (6.52) (Table 5).

b- Generation duration (G_t):

Data in Table (5) show that the average generation duration was obviously the longest (45.31days) for the larvae fed on tomato fruits. The shortest generation duration (29.31days) was obtained when larvae were fed on potato tubers. Meanwhile, generation duration was (44.35 days) when larvae were fed on eggplant fruits.

c- Intrinsic rate of increase (r_m):

Data in Table (5) show the changes in the intrinsic rate of increase (r_m) for potato tuber moth reared on three host plant. It can be noticed from yielded results that population intrinsic rates decrease from 0.309, 0.081 to 0.063 individuals/female/day when larvae were fed on potato tubers, eggplant and tomato fruits, while the highest value of intrinsic rate of increase (0.309 individuals/ female/day) was obtained when the larvae were reared on potato tubers. The aforementioned results confirmed that potato tubers demonstrated the highest degree of host plant suitability and was verified by R_0, G_t and r_m values.

d- Finite rate of increase (λ):

When the finite rate of increase (λ) (Table 5) values were worked out, it yielded 1.362, 1.084 and 1.065 individuals/ female/day when larvae were fed on potato tubers, eggplant fruits and tomato fruits, respectively. It is obvious from the obtained data that the highest finite rate of increase (λ) of potato tuber moth was obtained for potato tubers 1.362 individuals/female/day and accordingly considered as the most preferred feeding source. The lowest preferred host plant in this respect was tomato fruits.

e- Population doubling time (D_t):

The population of potato tuber moth had to double once every 2.811, 10.723 and 13.897 days when feeding larvae on potato tubers, eggplant fruits and tomato fruits, respectively. It appears from the data in Table (5) that potato tubers is the most preferred host plant for potato tuber moth when population–doubling time was considered.

Table 5. Life table parameters of *Ph. operculella* larvae reared on three host plants.

Host	Net reproductive rate (R_0)	Generation time (days) (G_t)	Intrinsic rate of increase (r_m)	Finite rate of increase (λ)	Population doubling time (D_t)
Potato tubers	20.86	29.31	0.309	1.362	2.811
Eggplant fruits	8.32	44.35	0.081	1.084	10.723
Tomato fruits	6.52	45.31	0.063	1.065	13.897

In general, the calculated biological parameters viz. R_0, G_t, r_m, λ and D_t indicate that potato tubers appeared to be the quite favorable for achieving the highest developmental and multiplication rates of *Ph. operculella*, followed by eggplant fruits and tomato fruits were the least favorable in this respect.

3-Natural mortality analysis:

The types of natural mortality namely, apparent Mortality (AM), real Mortality (RM) and indispensable Mortality (IM) data figures were calculated. Potato tubers tended to be the highest referendum plant based on natural mortality figures expressed as number of deposited eggs through one generation revealing its strong suitability for feeding.

The other tested host plants, were the other way around feeding response i.e. 18, 18 and 11.2 (Table 6) for AM, RM and IM% figures, respectively. Similar trends were observed when the natural mortality for larvae and pupae expressed as mortality index, hence potato tubers again proved to be highly referendum as feeding host plant and accordingly harbored the lowest percentages of natural mortality figures Table (6).

Table 6. Changes in natural mortality parameters of potato tuber moth when larvae were fed on potato tubers.

Developmental stage							
Age lass	**Egg**		**Larvae**		**Pupae**		**Adults**
X	(0-3)		(4-14)		(14-24)		(25-45)
L_x	100		82		65		51
d_x		**18**		**17**		**14**	
A.M.%	18		20.73		21.54		
R.M.%	18		17		14		
I.M.%	11.2		13.34		14		

Numbers between parentheses represent the range of duration in days

The natural mortality figures for larvae reared on potato tubers was 20.73, 17 and 13.34, respectively (Table 6), the following values 32.58, 29 and 18.36 were obtained for eggplant fruits (Table 7) and 24, 18 and 10.74 for tomato fruits (Table 8) for AM, RM and IM, respectively.

For pupae similar natural mortality trends were observed when *Ph. operculella* larvae were fed on potato tubers, 21.54, 14 and 14 (Table 6), while these values were 36.67, 22.0 and 22.0 for eggplant fruits (Table 7). The corresponding values on tomato fruits were comparatively high; i.e. 40.35, 23.0 and 23.0 (Table 8).

Table 7. Changes in natural mortality parameters of potato tuber moth when larvae were fed on eggplant fruits.

Developmental stage							
Age class	**Egg**		**Larvae**		**Pupae**		**Adults**
X	(0-4)		(5-27)		(28-37)		(38-63)
L_x	100		89		60		38
d_x		**11**		**29**		**22**	
A.M.%	11		32.58		36.67		
R.M.%	11		29		22		
I.M.%	4.7		18.36		22		

Numbers between parentheses represent the range of duration in days.

Table 8. Changes in natural mortality parameters of potato tuber moth when larvae were fed on tomato fruits.

Developmental stage							
Age class	**Egg**		**Larvae**		**Pupae**		**Adults**
X	(0-4)		(5-28)		(29-37)		(38-60)
L_x	100		75		57		34
d_x		**25**		**18**		**23**	
A.M.%	25		24		40.35		
R.M.%	25		18		23		
I.M.%	11.33		10.74		23		

Numbers between parentheses represent the range of duration in days.

It is quite worth to mention out here that potato tubers are considered as the most attractive for *Ph. operculella* feeding followed by egg-plant fruits. Tomato fruits seem to be the least acceptable host plant. Many investigators studied the effect of host plant on natural mortality and age structure data figures from which Attalah *et al*., (1981) in Egypt, studied effect of feeding larvae of *Ph. operculella* on the tubers or fruits of 4 different solanaceous host plants. Larvae and pupal stages were shortest on potato tubers, followed by tomato, aubergine and pepper fruits. Similarly, adult life span and fecundity rate were greatest on potato, followed by tomato, pepper and aubergine. Abdel-Karim *et al*., (1985) found that potato tubers were the most suitable substrate for larval development of *Ph. operculella* with the shortest duration of the immature stages, the lowest mortality and the highest rate of adult emergence. Tomato and aubergine fruits were less suitable. Vera–Graziano *et al*., (1988), in Mexico, found that survival and reproduction rates of *Ph. operculella* were higher for adult females obtained from larvae developed on potato leaves. Both rates were higher for the leaves than on potato tubers. El-Saadany *et al.* (2000) in Egypt, studied the structure parameters concluding that potato leaves or tubers were the most attractive host plants for *Ph operculella*. Tomato fruits followed this, and the least acceptable was the aubergine. Debnath *et al*., (2000) found that *Ph. operculella* had the shortest larval and pupal periods (12.44 and 6.52, respectively), longest adult longevity periods (7.23 days for females and 4.88 days for males) and highest fecundity (105.6 eggs) when potato was the host plant, while larvae could not develop to maturity on *Solanum nigrum*. Larvae did not perform well on aubergine. Ibrahim (2000), in Egypt, found that potato leaves and tubers were considered the most attractive for *Ph. operculella* feeding followed by tomato fruits. Egg- plant leaves seem to be least acceptable host plant. Razmjou *et al* (2006), found that host plants with lower values of r_m are relatively more resistant than the plants with higher values of r_m. Golizadeh *et al*. (2014), in Iran, found that the intrinsic rates of increase were significantly higher on potato leaves than on potato tubers.

Conclusions:

From the afore mentioned results it could be concluded however that potato tubers were considered the most attractive for *Ph. operculella* feeding followed by eggplant fruits. Tomato fruits seem to be the least acceptable host plant.

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تأثير العائل النباتي على مؤشرات جداول الحياة لفراشة درنات البطاطا *Phthorimaea operculella* (Zeller)

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الملخص

أجريت تجربة مخبرية لحساب جداول الحياة لفراشة درنات البطاطا *Pthorimaea operculella* (Zeller) حيث ربيت على ثلاثة عوائل نباتية هي درنات البطاطا، وثمار الباذنجان، وثمار البندورة، لتقييم التفضيل الغذائي لأي منها عند تغذية يرقات الحشرة عليها. أظهرت النتائج عند دراسة معدل الزيادة الطبيعي (R_0)، ومعدلي الزيادة الأولي (r_m) ، والنهائي (λ)، ومدة الجيل (G_t)، ومعدل التضاعف (D_t) أن درنات البطاطا هي الأكثر تفضيلاً لتغذية يرقات فراشة درنات البطاطا عليها، يليها ثمار الباذنجان، بينما كانت ثمار البندورة الأقل تفضيلاً. عند حساب معدلات الموت الطبيعي كانت أقل قيم لنسب الموت الطبيعي 20.73، و17.00 و13.34% عند التربية على درنات البطاطا لكل من النسبة المئوية للموت الظاهري، والموت الحقيقي والموت الجوهري على التوالي. بينما كانت أعلى قيم لنسب الموت 32.58 و29.00 و18.36% لكل من النسبة المئوية للموت الظاهري، والموت الحقيقي، والموت الجوهري على التوالي عند التغذية على ثمار الباذنجان، مما يؤكد أن درنات البطاطا هي أنسب العوائل وأكثرها تفضيلاً لفراشة درنات البطاطا من أجل نموها وتطورها، يليها في ذلك ثمار الباذنجان، بينما تعتبر ثمار البندورة أقل العوائل جذباً لفراشة درنات البطاطا.

الكلمات المفتاحية: العائل النباتي، جداول الحياة، فراشة درنات البطاطا.