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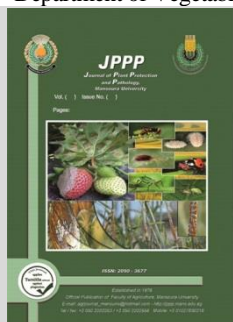
Effect of Potato Varieties on the Biology and Life Table Parameters of Potato Tuber Moth *Phthorimaea operculella* under Laboratory Conditions

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ABSTRACT

Effects of different varieties of potato tubers as a food source, Cara, Spunta and Rosetta on food ability, developing, fecundity and life table parameters of *Phthorimaea operculella* were studied under laboratory conditions. Egg incubation period was longest in time when *Ph. operculella* reared as larvae on Rosetta variety and spent 5.5 days. The natural mortality data for larvae reared on Cara variety were 23.14, 19.67 and 2.4%, respectively. Pupal duration which reared on the potato varieties Cara, Spunta and Rosetta were 9.22, 10.68 and 12.23 days, respectively. Duration of the generation was 40.90 and 35.9 days, on Cara and Spunta varieties, respectively. The obtained results indicate that potato variety Cara demonstrated the highest net reproductive rate (37.7 eggs/female) followed by Spunta variety (22.7 eggs/female) and Rosetta variety (16 eggs/female).

Keywords: Potato varieties, *Phthorimaea operculella*, biology, fecundity and life table parameters.

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). In terms of global production, potato ranks fourth after corn, rice and wheat as a food crop. The potato plays a strong role in developing countries with its ability to provide nutritious food for the poor and hungry people. The demand for potato is growing as both fresh and processed food (Flanders *et al.*, 1999; Omar *et al.*, 2011 and Abdallah *et al.*, 2012. Dillard *et al.* (1993) surveyed the major diseases, insect and other invertebrate pests of potatoes and evaluated the chemicals used to control them. Green peach aphid (*Myzus persicae*), potato aphid (*Macrosiphum euphorbiae*), potato moth (*Phthorimaea operculella*), and jassids and leafhoppers (Jassidae, Cicadellidae) were found to be the pests of greatest concern to the growers. Developmental stages, fecundity, and life table parameters of *Ph. operculella* were differed when various kinds of potato variety were used (El-Saadany *et al.*, 1998 and Debnath *et al.*, 2000). 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). Larvae cause defoliation by mining mesophyll layers in the leaves or by tunneling through tubers. Damage occurs principally in storerooms, where previously-infested tubers engender

continuous generations of *Ph. operculella* and damage uninfested potatoes in storage. In the field, larvae feed on both the potato foliage and the tuber, reducing the quality of production and increasing the risk of pathogen infection (Sporleder *et al.*, 2008; Rondon, 2010; Rivera 2011; Al saoud *et al.*, 2017). In applied entomology, life tables are most commonly used and the estimated parameters are crucial for studying population dynamics and for establishing management tactics for pest control. Life tables synthesize data on reproduction and mortality of a population thus may be used to evaluate the food suitability for insects (Peterson *et al.*, 2009; Golizadeh and Razmjou, 2010; Abdallah *et al.*, 2012; Ibrahim *et al.*, 2013). The present work aims to study the effect of different varieties of potato tubers as a food source, Cara, Spunta and Rosetta at 25 ± 2° C and 65% R.H. on food ability, developing, fecundity and life table parameters of *ph. operculella*.

MATERIALS AND METHODS

Rearing Technique:

Infested tubers of three potato varieties were collected from potato fields at harvesting time and kept in the laboratory as a stock culture. The infested tubers of every variety were placed in large woody cage and provided with fresh and uninfested tubers. The cage dimensions were 40 x 40 x 40 cm.

The cages were furnished with paper and sand. The newly emerged moths were collected, sexed then divided into groups (♀: ♂) of 10 pairs in oviposition glass jar in the same day of adult emergence to each variety of potato. These glass jars were coated inside with white cylindrical paper as an oviposition site. These jars were investigated

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daily to replace the cylindrical papers with another to count and record the number of eggs.

Evaluating the effect of potato varieties host:

Laboratory experiments were conducted under control conditions (25±2 C & 65±2 % RH) in an incubator. The newly deposited eggs were collected daily and divided into ten groups in plastic cups, (20 eggs/replicate) for each variety of potato and kept under the above mentioned controlled conditions.

The eggs were investigated daily until hatching. Percent of the hatched egg hatching and incubation periods of eggs were recorded. Newly hatched larvae were picked up from cups by using fine brush then transferred to four plastic jars, which were furnished with paper and freshly slices of the potato variety for feeding larvae. Then the plastic jars were covered with pieces of cloth and kept under laboratory conditions. Potatoes slices were replaced daily by fresh ones until pupation time.

Newly formed pupae were collected on the same day of pupation and placed in glass test tubes. Daily examination was carried out until adult emergence. The following biological parameters were investigated: larval duration, number of mutant virgins, percent of pupation, pupal duration, number of moths emergence from pupae and percent of adult emergence. The newly emerged moths were collected, sexed and confined in groups of couples (♀ and ♂) at 1st day of emergence in glass jars, supplied with cylindrical white paper as an oviposition site. Eggs were collected daily, counted and placed in plastic cups under controlled conditions until hatching. The adults of both sexes were left for mating and to deposit their eggs until death. Data of adult stage included adult longevity; pre-oviposition period, oviposition period, post-oviposition period of female, female fecundity [total number of eggs / female] and time of egg incubation, number of egg hatching, egg fertility (hatchability percentage of eggs) were recorded.

Life table studies:

The newly deposited eggs were collected daily. 300 newly deposited eggs were divided into three equal replicates set in each of 100 larvae/ replicate was tested from the three potato varieties. Tested potato tubers of the three varieties with the same weight and size were offered

to the larvae for feeding during the whole larval stage duration.

Newly formed pupae were transferred to a glass test tube covered with cotton till moth emerged. The newly emerged adults were sexed and transferred on the same day of emergence to an ovipositor glass chimney cage (♂+♀) in each cage which was covered with muslin and provided with piece of cotton soaked in 10% honey solution for feeding of moths.

Life table parameters:

Life tables parameters were estimated according to Anderwartha and Birch (1984). From this method, it could be possible to calculate generation time (Gt), fecundity (Mx), survival rate (Lx), net reproductive rate (R₀), intrinsic rate of increase (R_m), finite rate of increase (λ), and population doubling time (Dt). This method based on the date obtained from the effect of different tested potato varieties.

The mortality data figures were estimated through the following:

$$\text{Apparent mortality (AM \%)} = (\text{dx}_1/\text{lx}_1) \times 100, (\text{dx}_2/\text{lx}_2) \times 100 \dots \text{etc}$$

$$\text{Real mortality (RM \%)} = (\text{dx}_1/\text{lx}_1) \times 100, (\text{dx}_2/\text{lx}_2) \times 100 \dots \text{etc}$$

Log population: the natural logarithm of the population.

$$k\text{- Value} = \text{Log } N_t - \text{Log } N_{t+1}$$

RESULTS AND DISCUSSION

The study was conducted under laboratory conditions to evaluate the different biological developmental stages, life table parameters, some biological features and biological parameter of adult females of potato tuber moth, *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae) fed on three potato varieties namely (Cara, Spunta, and Rosetta).

1- Biological Features:

Table (1) showed that there were significant different between the average of the incubation period of egg obtained from adults reared on potato variety, Rosetta and those reared on the potato varieties Cara and Spunta. The averages were 5.50, 4.02 and 4.72 for Rosetta, Cara and Spunta respectively, whereas no significant difference were observed in the incubation period of egg between the two varieties Cara and Spunta.

Table 1. Mean of developmental time of immature stages of potato tuber moth (*phthorimaea operculella*) on potato, Cara, Spunta. Rosetta varieties under laboratory conditions.

parameter	Potato variety, Mean ±SE					
	Cara	Spunta	Rosetta	General mean	LSD5%	
Incubation period	4.02 b ±0.17	4.72 b ±0.37	5.50 a ±0.29	4.8 ±0.3	0.96	
Number of eggs hatching	17.00 b ±0.33	17.00 b ±0.3	17.20 a ±0.32	17.1 ±0.3	0.08	
Hatch percentage	85.00 b ±1.67	85.00 b ±1.49	86.00a ±1.63	85.3 ±1.6	0.34	
duration of the larval stage	14.04b ±0.32	14.02b ±0.47	18.07a ±0.56	15.4 ±0.45	1.49	
Number of mutant virgins	7.70b ±0.37	7.50c ±0.34	8.00a ±0.26	7.7 ±0.3	0.15	
Pupating percentage %	77.00b ±3.67	75.00b 3.42	80.00a ±2.58	77.3 ±3.3	2.8	
Duration of pupae	9.22c ±0.31	10.68b ±0.43	12.23a ±0.44	10.7 ±0.4	1.21	
Number of emerged moths	8.10a ±0.31	7.80b ±0.34	8.00ab ±0.26	7.9 ±0.3	0.21	
Adult number emergence	♂	4.2 ±0.32	4.3 ±0.3	4.2 ±0.29	4.2 ±0.3	1.04 (ns)
	♀	3.80 a ±0.25	3.50 b ±0.27	3.80 a ±0.42	3.7 ±0.3	0.17
Sex ratio (♂/♀)	1.11 b ±0.03	1.23 a ±0.06	1.11b ±0.04	1.2 ±0.04	0.09	
Adult emergence (%)	81.00 a ±3.14	78.00c ±2.27	80.00b ±2.58	79.6 ±2.7	0.89	

The obtained data in Table (1) revealed that the highest value hatchability percentage was 85% which

obtained when larvae fed on Kara and Spunta varieties followed by Rosetta variety with a value of 86%.

The careful examination of the data reveals that host plant had a strong effect on the larval and pupal longevity in addition to the potential fecundity of adult females. Table (1) showed that feeding on both Cara and Spunta significantly reduced larval duration with averages of (14.04 and 14.02) comparing with feeding on Rosetta variety which recorded an average of (18.07). Table (1) showed that there were significant different in pupal duration which reared on the potato varieties Cara, Spunta and Rosetta with averages of 9.22, 10.68 and 12.23 respectively.

There were significant different in the averages of emergence percentage of adults which reared as larvae on the potato varieties Cara, Spunta and Rosetta with an averages of 81, 78 and 80%, respectively. There are no significant difference in the number of males (♂) between

three varieties of potato Cara, Spunta and Rosetta, while there are significant different in the number of females (♀) obtained from larvae reared on potato variety, Spunta and those reared on the potato varieties Cara and Rosetta with averages of 3.50, 3.80 and 3.80, respectively.

Sex ratio

Data in Table (2) showed that female fecundity of female was affected by the different potato varieties, thus, female fecundity decreased from 113.30 eggs on Cara variety to 94.40 eggs on Spunta variety, and to 82.95 eggs on Rosetta varieties, respectively. The obtained results showed that feeding on Cara variety prolonged the longevity period of mated female (22.30 days) as shown in Table (2) comparing with Spunta and Rosetta varieties with an averages of 18.10 and 18.40 days respectively.

Table 2. Mean of developmental time of mature stage of potato tuber moth (*Ph. operculella*) on potato var. Cara, Spunta, Rosetta under laboratory conditions

Potato variety	♀ + ♂ per each replicate			One pupae per each replicate		
	Pre-oviposition period	oviposition period	Post-oviposition period	Number of eggs per female	Life span of adult female	Life span of adult male
	Mean±SE	Mean±SE	Mean±SE	Mean±SE	Mean±SE	Mean±SE
Cara	1.65 a±0.15	9.8 b±0.21	7.00 a±0.39	113.30 a±5.07	22.30 a±0.44	12.05 b±0.25
Spunta	1.55 b±0.14	10.35 a±0.42	6.10 c±0.34	94.40 b±3.89	18.10 b±0.74	14.25 a±0.26
Rosetta	1.45 c±0.12	9.75 b±0.51	6.55 b±0.31	82.95 c±1.49	18.40 b±0.35	12.40 b±0.28
General mean	1.6±0.14	9.96±0.38	6.6±1.04	96.9±3.5	19.6±0.51	12.9±0.26
LSD 5%	0.06	0.19	0.26	10.83	1.43	0.75

2 - Life table parameters:

Data presented in Table (3) show the changes in the estimated life table parameters of potato tuber moth when larvae were fed on potato tubers, Cara, Spunta and Rosetta varieties.

The obtained results indicate that the potato variety Cara demonstrated the highest net reproductive rate (R0) (37.7 eggs/female) followed by Spunta variety (22.7 eggs/female) and Rosetta variety (16 eggs/female) (Table3).

Data in Table (3) show also that the average generation duration (Gt) was obviously the longest (40.9 days) for the larvae of PTM fed on Spunta variety. The shortest generation duration (35.9 days) was obtained when larvae were fed on Cara variety. Meanwhile, generation duration was (37.8 days) when larvae were fed on Rosetta variety.

Data in Table (3) show the changes in the intrinsic rate of increase (rm) for PTM reared as larvae on three varieties of potato. It can be noticed from obtained results that population intrinsic rates decreased from 0.46, to 0.18 individuals/female/day when larvae were fed on Cara, and Rosetta varieties, while a moderate value of intrinsic rate of

increase (0.24 individuals/ female/day) was obtained when the larvae were reared on Spunta variety. The aforementioned results confirmed that Cara variety demonstrated the highest degree of variety suitability and was verified by R0, Gt and rm values.

Among the population doubling time (Dt), it is observed that the population of potato tuber moth had to double once every 1.90, 3.62 and 4.83 days when feeding the larvae of PTM on Cara, Spunta and Rosetta varieties, respectively. It appears from the data in Table (3) that Cara variety is the most preferred variety for PTM when population– doubling time was considered.

Feeding larvae of PTM on Spunta and Cara demonstrated the longest life span duration thus completing one generation duration in 60 and 55 days for the two varieties, respectively. Female fecundity (Mx) recorded 7.8, 6.2 and 5.6 for Cara, Rosetta and Spunta, respectively Table (3). The net reproductive rate (R0) values were 37.7, 22, 7 and 16.0 for Cara, Spunta and Rosetta, respectively. The mean duration of the generation (Gt) was 40.90 and 35.9 days, on Cara and Spunta varieties, respectively.

Table 3. Life table parameters of *Ph operculella* larvae reared on potato tuber Cara, Spunta and Rosetta varieties under laboratory conditions.

Varieties	X (days)	Mx Fecundity	Net reproductive rate (R0)	Generation duration Gt	Intrinsic rate of increase Rm	Finite rate of increase λ	Population doubling time (Dt)
Cara	55	7.8	37.7	35.9	0.46	1.58	1.9
Spunta	60	5.6	22.7	40.9	0.24	1.27	3.62
Rosetta	53	6.2	16.0	37.8	0.18	1.21	4.83

When the finite rate of increase (λ) (Table3) values were calculated it yielded 1.58, 1.27 and 1.21 individuals/female/day when larvae were fed on Cara, Spunta and Rosetta varieties, respectively. It is obvious

from the obtained data that the highest finite rate of increase (λ) of PTM was obtained for Cara variety with a value of 1.58 individuals/ female/day and accordingly considered as the most preferred feeding source. The

lowest preferred host plant in this respect was Rosetta variety.

In general, the calculated biological parameters viz. R0, Gt, λ and Dt indicate that Cara variety appeared to be the quite favorable for achieving the highest developmental and multiplication rates of *Ph. operculella*, followed by Spunta and Rosetta which were the least favorable in this respect.

3-Natural mortality analysis:

When the values of different types of natural mortality namely; apparent mortality (AM), real mortality (RM), log population and *k* value were estimated, Cara variety proved to be the most preferred variety based on number of deposited eggs in one generation revealing its strong suitability for feeding. Cara variety tended to harbor the lowest percentages of natural mortality expressed as

number of deposited eggs throughout one generation thus revealing its strong suitability as a food source for feeding. The natural mortality data figures for larvae reared on Cara variety were 23.14, 19.67 and 2.4%, respectively (Table 4).

The natural mortality data figures for larvae reared on Spunta variety were 25, 21 and 2.39 (Table 4) for AM, RM and log population, respectively. The natural mortality data figures for larvae reared on Rosetta variety were 19.9, 16.33 and 2.39 (Table 4) for AM, RM and log population, respectively. For pupae similar natural mortality trends were observed when *Ph. operculella* larvae were fed on Cara, Spunta varieties with values of 17.35, 11.33 and 2.29, 10.6, 6.7 and 2.27%, respectively, while the corresponding values of 19.3, 12.66 and 2.29% were obtained for Rosetta variety (Table 4).

Table 4. Effect of tubers potato varieties in natural mortality of the developmental stages of PTM *Ph. operculella*.

Potato variety	Age class	<i>Phthorimaea operculella</i> instar				
		Egg	Larvae	Pupae	Adults	
Cara	X	(0 – 5)	(6 – 20)	(21 – 30)	(31 – 55)	
	Ix	300	255	196	162	
	d _x		45	59	34	
	A.M. %	15	23.14	17.35		
	R.M. %	15	19.67	11.33		
	Log population	2.47	2.4	2.29	2.2	
	K- Value		0.07	0.11	0.09	
Spunta	X	(0 – 5)	(6 – 24)	(25 – 35)	(36 – 60)	
	Ix	300	252	189	169	
	d _x		48	63	20	
	A.M. %	16	25	10.6		
	R.M. %	16	21	6.7		
	Log population	2.47	2.39	2.27	2.22	
	K- Value		0.08	0.12	0.05	
Rosetta	X	(0 – 6)	(7 – 20)	(21 – 32)	(33 – 53)	
	Ix	300	246	197	159	
	d _x		54	49	38	
	A.M. %	18	19.9	19.3		
	R.M. %	18	16.33	12.66		
	Log population	2.47	2.39	2.29	2.19	
	K- Value		0.08	0.1	0.1	

Numbers between parentheses the range of duration in days.

The potato tuber moth (PTM), *Ph. operculella* 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). In applied entomology, life tables are most commonly used and the estimated parameters are crucial for studying population dynamics and for establishing management tactics for pest control (Ibrahim et al., 2013). The effect of different varieties of potato tubers Cara, Spunta and Rosetta as larval food on food ability, developing, fecundity and life table parameters of *ph. opercullella* was studied in the present work. In general, the calculated biological parameters indicate that Cara variety appeared to be the quite favorable for achieving the highest developmental and multiplication rates of *Ph. operculella*, followed by Spunta and Rosetta which were the least favorable in this respect.

Our results are in agreement with Badegana and Nagameni (2000) who found that the life span of the *Ph. operculella* females was longer than that of the males. Meanwhile, Omar et al., 2013 found that developmental stages, fecundity and life table parameters of insect were affected by the tested different food types, whereas, total

immature stages lasted 28.38, 28.37 and 24.50 days for female obtained when insect fed on the potato varieties, Kara, Spunta and Diamond, respectively. Female oviposition period lasted 29, 31 and 31 days which deposited eggs reached maximum to 65.87, 55.18 and 68.44 eggs with daily average numbers of 3.06, 3.52, 3.75 eggs/female when insect fed on the three potato varieties Kara, Spunta and Diamond, respectively.

However, Youssef (2019a) 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 author reported also, 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.

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 and both rates were higher for the leaves than on potato tubers. In Egypt, El-Saadany *et al.* (2000), 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 ubergine. 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 *rm* are relatively more resistant than the plants with higher values of *rm*. Golizadeh *et al.* (2014), in Iran, found that the intrinsic rates of increase were significantly higher on potato leaves than on potato tubers.

Youssef (2019b), studied Life table for potato tuber moth, *Phthorimaea operculella* (Zeller) were carried out to compare an artificial medium to potato tubers, *Solanum tuberosum* L. for rearing *Ph. operculella* larvae. The obtained results indicated that potato tubers proved to be more favorable for achieving the highest developmental and multiplication rates of *Ph. operculella*, than artificial diet. Singh and Charles (1977) also reared potato tuber moth from egg to adult for 3 generations on an artificial diet, at 30±2°C with a 16-h photoperiod. They found that the total life cycle was completed in 23 days, compared with 18.5 days on potato tubers. Average life cycle data from the 3 generations reared on diet (with corresponding data from tubers in parentheses) are: larval period, 13.0 (11.8) days; pupal period, 5-6 (4-5) days; survival to adult, 76.1 (100)%; fecundity, 102 (169) eggs/; pupal wt- female 8.3(11.4) mg, male 7.7 (9.1) mg. The longest average life span of females and males was 10.20 and 6.46 days, respectively, with the 17% sugar solution. Females fed with 17% sugar solution laid the most eggs (208).

According to Kashyab *et al.* (2008) potato tuber moth completed its life cycle on artificial diet and produced a new generation. The percent survival of the larvae on exclusive artificial diet was less (51.2%) than on potato leaves (89.6%). Survival could be increased significantly on artificial diet (89.2%) when the neonates were initially reared on potato leaves up to first instar and then released on artificial diet for completion of rest of the larval stages. The mean durations of different life cycle stages were longer on artificial diet as compared to control reared on potato leaves.

Similar results to our finding were found by Abdallah *et al* (2012) who evaluated the preferred variety for feeding *Ph. operculella* larvae. The calculated biological parameters indicate that Atlas proved to be the quite favorable for achieving the highest developmental and multiplication rates of *Ph. operculella*, followed by Simone and Spunta, meanwhile Nicola was the least favorable data figure in this respect were obtained. It could be concluded that Nicola is the least susceptible variety for infestation; while Atlas is the most favorable variety for feeding *Ph. operculella*.

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تأثير أصناف البطاطس على بيولوجي ومقاييس جدول الحياة لفرشة درنات البطاطس *Phthorimaea operculella* تحت الظروف المعملية

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تأثير تغذية فراشة درنات البطاطس على أصناف مختلفة من البطاطس Cara و Spunta و Rosetta على القدرة الغذائية، والتطور، والخصوبة، ومعايير جدول الحياة لـ *Phthorimaea operculella* للحشرة. أجريت التجارب تحت ظروف تحكم (25 ± 2 درجة مئوية و 60 ± 5% رطوبة نسبية). كانت فترة حضانة البيض هي الأطول في الوقت الذي تربت فيه يرقات *Ph. operculella* على صنف Rosetta وقضى 5.5 ± 0.29. كانت بيانات النفوق الطبيعي لليرقات المرية على صنف كارا 23.14، 19.67 و 2.4% على التوالي. فترة العذراء التي تمت تربيتها على أصناف البطاطس Cara و Spunta و Rosetta وكانت النتيجة كالتالي 9.22 ± 0.31 و 10.68 ± 0.43 و 12.23 ± 0.44 على التوالي. كانت مدة الجيل 40.90 و 35.9 يوماً، على صنف Cara و Spunta على التوالي. تشير النتائج المتحصل عليها إلى أن صنف البطاطس Cara أظهر أعلى معدل تكاثر صافٍ (37.7 بيضة / أنثى) يليه صنف Spunta (22.7 بيضة / أنثى) وصنف Rosetta (16 بيضة / أنثى).