

The impact of three mealybug species on life table parameters of vedalia beetle, *Rodolia cardinalis* (Mulsant) (Coleoptera: Coccinellidae).

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Abstract

This study aimed to measure survivorship and fecundity of the vedalia beetle, *Rodolia cardinalis* (Mulsant) reared on three mealybug species (*Icerya purchasi* Maskell, *Planococcus ficus* (Signoret) and *Pseudococcus longispinus* (Targioni-Tozzetti)). The experiment was conducted under laboratory conditions, life table and population parameters were established to evaluate survivorship in all stages of the vedalia beetle life cycle. Results obtained from this experiment showed that the highest rates of death were recorded in the immature stages (larval stages) for all prey was 42.86, 45, 44.11 % and the total mortality was 57.69, 62.11, and 50 % on *I. purchasi*, *P. ficus* and *P. longispinus* respectively. Fertility tables recorded that the reproductive rate R_0 of the population was 139.98, 81.10, 37.70 and mean generation time T was 35.85, 44.71, 44.03 and the intrinsic rate of increase r was 0.14, 0.09, 0.08 and the population doubling time D_T was within 4.95, 6.93, 8.66 day for three mealybug species respectively. Based on the mentioned results, it could be proved that the survivorship curve of *Rodolia cardinalis* (Mulsant) belongs to a diagonal model curve, which indicates a humble rate of death during life stages and piecemeal reduction when moving toward adulthood with a significant influence of nutrition preference for *I. purchasi* comparative with *P. ficus* and *P. longispinus*.

Keywords: vedalia beetle, *Rodolia cardinalis*, life table, fecundity parameters.

Introduction

Coccinellid predator considered an important predatory insect. It was registered in different regions of the world on many agricultural crops of economic value. Significant species of it play an important role in biological control of aphid species, whiteflies, and other soft scale insects. *R. cardinalis* (Coleoptera:

Coccinellidae) is the main Coccinellid predator devouring on mealybug species

(Awadalla 2010). It has been announced to be an extremely active naturalistic enemy of mealybug pests in view of the fact that both larvae and adults insects mainly depends on feeding on these pests (Ozgekce *et al.*, 2006). These species of predators have also been successfully reared and released on citrus trees and grape vineyards, in addition to glasshouses which mealybugs considered the main insect pest (Ozgekce *et al.*, 2006). In Egypt,

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mealybugs species considered one of the most serious pests that infested citrus, guava, grapes and many ornamental plants. *Icerya purchasi* Maskell, *Planococcus ficus* (Signoret) and *Pseudococcus longispinus* (Targioni-Tozzetti) are important pests in many parts of the world, especially in the tropical and subtropical regions. The great harm of these pests is attributed to the weak effect of natural enemies which could decrease their numbers (Abd Rabou, 2001; Abdel-Salam *et al.*, 2010; Mohamed, 2013).

Mealy bugs cause huge losses to farmers due to feeding these insects on the tissues of plants by absorbing their saps and injecting toxins, and more than that, these insects are a vector of many plant viruses. In addition, these insects excreted their excreta as honeydew, which is a sirup of sugar liquid that covered leaves them with a glossy, gummy layer. Honeydew considered a fertile nutritional environment for the reproduction of black mold fungi that negatively affects the process of photosynthesis that also destroys the plant's manifestation. Severe plant infestation by mealybugs may cause the leaves to fall off, and It may lead to the death of whole plants if they are not controlled at appropriate times (Esfandiari and Mossadegh, 2007).

In Egypt, little information was obtainable on the effectiveness of various prey species on the biological attributes and life table guidelines of the most substantial predators attacking mealybug species. However, few studies have been concerned with the developmental time, consuming rate, life span and fertility of this predator to evaluate these measurements for breeding methods and release (Ragab, 1995 and Saleh *et al.*, 2017). Therefore, the objective of this investigation aimed to highlight and clarify the importance of studying the effect of mealybug species on the biological attributes of vedalia beetle predator *R. cardinalis* under

laboratory stipulation to control the mealybug species because of its high propagation rate and fast growth. The results obtained were anticipated to supply beneficial recommendations about its futurity use as a biocontrol factor in mealybug management.

Materials and Methods

Insects

The colony of vedalia beetle, *R. cardinalis* was established in rearing jars by feeding on the long-tailed, *P. longispinus* under laboratory controlling (temperature of $26 \pm 2^\circ\text{C}$ and $60 \pm 5\%$ relative humidity) in the Plant Protection Department, Faculty of Agriculture, South Valley University. Australian mealybug *I. purchasi* was originally collected from *Pittosporum tobira* (Thunb.) plants; *P. longispinus* was originally collected on *Acalypha marginata* plants from the Agricultural Research Experiments Center, Faculty of Agriculture, Assiut University. Whereas the vine mealybugs, *P. ficus* was originally collected on grapevine plants from the Agricultural Research Experiments Center, Faculty of Agriculture, South Valley University. The populations of the mealybugs (*I. purchasi*, *P. ficus* and *P. longispinus*) were reared on potato sprouts at the laboratory conditions.

Development and survivorship of *R. cardinalis* immatures

R. cardinalis adults that were reared on the long-tailed, *P. longispinus* were confined in the petri dish (9x1.5 cm), accompanied by nymphs third age of mealybug as a prey feeding on it in Petri dishes lined with filter paper till the eggs of *R. cardinalis* were put. In a random way, one egg was captured, for development, while the *R. cardinalis* adults and the other remaining eggs were removed. Every 24 hours, the survival and development of eggs and larvae of the vedalia beetle are observed using a stereomicroscope

(7x-45x OPTO-EDU A23.1502-T1, Beijing, China) of 10-60 magnification power. On each type of mealybug, thirty eggs of *R. cardinalis* were breeding. Bearing in mind, the mealybugs change every three days to ensure they are supplied with fresh food.

Fecundity and longevity of *R. cardinalis* adults

One newlywed adult pair of *R. cardinalis* was bred in a Petri dish (9x1.5 cm) and each of them was fed with one of the three types of mealybugs, which are changed daily to make sure they are fresh. The eggs laid by the female of *R. cardinalis* were recorded and counted daily. Also, the fertility and life span of the *R. cardinalis* female adults were accounted for. Ten female adults of *R. cardinalis* raised on each separated species of mealybug were noticed.

Life table analysis

Based on the arithmetic methods used by Southwood (1966), life table coefficients were calculated for *R. cardinalis* fed on the three types of mealybugs (*I. purchasi*, *P. ficus* and *P. longispinus*). The results obtained for the survival and reproduction were used to calculate, x (the age category), l_x (The number of survivors at the beginning of each age group), L_x : The number of living individuals through age x and $x+1$, $L_x = (l_x + l_{x+1}) / 2$, d_x : The number of individuals who died during the age stage x , $100q_x$: The percentage of deaths visible in individuals, $100q_x = (d_x/l_x)100$, S_x : The rate of individuals who survive in the stage, T_x : The total number of individuals in each age x Units after the age x , e_x : Average life expectancy for individuals of age x , $e_x = T_x/l_x$ and m_x (The fertility rate for each female). Final reproduction value (R_0) = $\sum l_x m_x$, Generation length rate (T) = $\sum x l_x m_x / R_0$, The time needed to double the population (DT) = $\log_e 2 / r$, The fundamental

rate of increase (r) = $\log_e R_0 / T$, Limited rate of increase (λ) = e^r .

Results and Discussion

There is great difficulty in controlling adult insects of mealybugs species due to the heavy wax excretion that coating these bodies. Based on that result, most of the pesticides that were used to control and reduce the populations of these pests targeted the immature stages. (Townsend *et al.*, 2000). The modern direction to dominance the mealybug utilizing biological factors management. Insect predators are immediately applied as significant biotic elements to control many species of mealybug in numerous regions (Afifi *et al.*, 2010). In Egypt, the vedalia beetle, *R. cardinalis* is considered one of the vital biological control elements of many species of mealybugs (Ghanim *et al.* 2006; Awadalla, 2010).

As a matter of fact, scientists study life tables as a way to estimate population growth as well as to predict the size of the population increase. Life tables provide detailed information on the stages of development, survival rates for each age, fertility, and average life expectancy of the population. (Yang *et al.*, 2013). Laboratory studies provide important information and results on the dynamics and population of insects. However, these results may be completely incorrect in nature. Host mealybugs species are key factors for the growth and development of *R. cardinalis*; the development of *R. cardinalis* has also been considered a good indication of the viability of mealybugs as a host and benefit from it as a good source of food.

Age-Specific Survival Life Table:

The results obtained from tables (1, 2 and 3) showed that the high deaths from *R. cardinalis* were recorded in the larval stages, especially the early stages of them, then the deaths gradually decreased in the advanced stages of

predator life. The first age of the larvae recorded the highest mortality rate (22.34, 16.44 and 23.08) on three mealybug species *I.purchasi*, *P.ficus* and *P. longispinus* respectively.

Table (1): Life table of vedalia beetle, *Rodolia cardinalis* on *Icerya purchasi*

x	l_x	L_x	d_x	$100q_x$	s_x	T_x	e_x
Eggs	130	117.5	25	19.23	80.77	510	3.92
1 st larval instar	105	94.5	21	22.34	77.66	392.5	3.74
2 nd larval instar	84	78.5	11	10.48	89.52	298	3.55
3 rd larval instar	73	70.5	5	6.85	93.15	219.5	3.01
4 th larval instar	68	64	8	11.76	88.24	149	2.19
pupa	60	57.5	5	8.33	91.67	85	1.42
Adults	55	27.5					

It may be that one of the reasons for the high number of deaths in the first age of predator larvae is the intense crowding of these small larvae on their hosts from mealybugs to obtain food. Larvae exhibit offensive behavior as a result of competition for food, which of course reduces their population. On the other hand, larval death at an early age can be attributed to the phenomenon of overfeeding, which gradually decreases with the older ages of the larvae. The death of young larvae may also be due to their strong influence by the surrounding weather factors such as heat and humidity, and this is clearly shown in field studies.

The results obtained are identical to the results of (Ali and Rizvi, 2009) who mentioned that the first larval instars, presented a high death-rate in comparison with the second instar than the 3rd and 4th instars and this is maybe due to much delicate of the 1st instar than the later instars. While Kindlmann, *et al.* (2000) found that the larvae of two predatory, *Harmonia axyridis* and *Coccinella septempunctata* were demonstrated the highest mortality during the first and fourth instars.

Table (2): Life table of vedalia beetle, *Rodolia cardinalis* on *Planococcus ficus*

x	l_x	L_x	d_x	$100q_x$	s_x	T_x	e_x
Eggs	95	84	22	23.16	76.84	353.5	3.72
1 st larval instar	73	67	12	16.44	83.56	269.5	3.69
2 nd larval instar	61	56.5	9	14.75	85.25	202.5	3.32
3 rd larval instar	52	45	8	15.38	84.62	146	2.81
4 th larval instar	44	42	4	9.09	90.91	98	2.23
pupa	40	38	4	10	90	56	1.4
Adults	36	18					

Table (3): Life table of vedalia beetle, *Rodolia cardinalis* on *Pseudococcus longispinus*

x	l_x	L_x	d_x	$100q_x$	s_x	T_x	e_x
Eggs	90	84	12	13.33	86.67	384	4.27
1 st larval instar	78	69	18	23.08	76.92	300	3.85
2 nd larval instar	60	59	2	3.33	96.67	231	3.85
3 rd larval instar	58	54	8	13.79	86.21	172	2.97
4 th larval instar	50	49	2	4	96	118	2.36
pupa	48	46.5	3	6.25	93.75	69	1.44
Adults	48	22.5					

Generally, the highest mortality rate was recorded in the larval stage, taking into account the length of the larval life span compared to other age stages. The results showed that the death rate in the larval stage was 42.86, 45 and 44.11% on *I. purchasi*, *P. ficus* and *P. longispinus* in the mentioned order. Pretty much our results agree with Baskaran *et al.* (2002) in Indian, When they conducted their studies on life tables of the Australian ladybird beetle, *Cryptolaemus montrouzieri* when bred on mealybugs (*Maconellicoccus hirsutus* and *Dactylopius tomentosus*) under laboratory conditions. The percentage of death during the larval age was recorded 43, 17, and 40.18 on *Maconellicoccus hirsutus* and *Dactylopius tomentosus* respectively. Also, there are many reasons for the high death rate in the larval age of the predator being studied, *R. cardinalis* such as Cannibalism which may clarify a substantial survival technique for numerous insect types. The ecological theorem picks out many agents that can impact cannibalism, containing sustenance accessibility, nourishment goodness, size inconsistency, the grade of closeness, and population density. Cannibalism was monitored and studied for a long time in the Coleoptera. Cannibalism or self-predation considered the most significant mortality agent for larval coccinellids Schellhorn and Andow (1999). Michaud (2003) was, studied

a comparative of larval cannibalism in three species of ladybird, (*Cycloneda sanguinea* (Linnaeus), *Harmonia axyridis* (Pallas) and *Olla v-nigrum* (Mulsant) Coccinellidae (Coleoptera)). Obrycki and Hiring (1998) confirmed through their studies that cannibalism is the main problem they face when raising coccinellid species for the purpose of using them in biological control programs.

During the egg stage, the death rate was recorded 19.23, 23.16 and 13.33% on three mealybug species, *I. purchasi*, *P. ficus* and *P. longispinus* respectively, which also expresses the proportion of hatching on the three types of mealybug species under study, taking into account the genetic and physiological factors that influence infertility. On the same line of our consequence, Results of Baskaran *et al.* (1999) reported that the egg stage had a death rate of 20.66% and 18.25 when studying life tables for Australian ladybird beetle, *Cryptolaemus montrouzieri* on *Planococcus citri* and *Dactylopius tomentosus*.

The final exit indicated by tables (1, 2 and 3) indicates that the total final percentages death of vedalia beetle, *R. cardinalis* was 57.69, 62.11 and 50.00 % on three mealybug species, *I. purchasi*, *P. ficus* and *P. longispinus*, respectively. The results of our study were consistent with the results recorded by Kairo and Murphy (1995) which

showed that the total percentage of death of *Rodolia iceryae* on *Icerya pattersoni* was 56.00%.

Figure (1) shows the survival curves (lx) of *R. cardinalis* that were raised on three mealybug species. These curves demonstrated that mortality rates were relatively high in the early stages of the life of *R. cardinalis*, and then those rates began to decline when reaching the stage adult for all mealybug species that were studied.

The results confirmed that the diagonal model curve attributed to Schowalter (2011) applies to the survival curve of *R. cardinalis*. The results also showed the significant effect of food quality on mortality rates during different stages of the life cycle. Bearing in mind the significant effect of *I. purchasi* as food for *R. cardinalis* in compared to other types of mealybug used in breeding.

The effect of food was clearly demonstrated on the ability of *R. cardinalis* to survive during different ages as *R. cardinalis* recorded the higher survival rates when fed on *I. purchasi*

followed by *P. longispinus*, and *P. ficus*. According to the above, the *I. purchasi* considered is the preferred food or prey for *R. cardinalis*. In this direction, there are many studies that have been conducted to know the effect of mealybug species on the growth, development, and survival of predators that feed on them, such as *Cryptolaemus montrouzieri* on two mealybug species, *Planococcus citri* and *Dactylopius tomentosus* Baskaran *et al.* (1999), *Coccinella septempunctata* L. and *Harmonia axyridis* Pallas (Coleoptera: Coccinellidae) on *Aphis citricola* van der Goot (Homoptera: Aphididae), and on the twospotted spider mite, *Tetranychus urticae* Koch (Acarina: Tetranychidae) Lucas *et al.* (1997).

Age-Specific fecundity table: lx (The number of survivors at the beginning of each age group) and mx (The fertility rate for each female) of the vedalia beetle, *R. cardinalis* reared on three mealybug species *I. purchasi*, *P. ficus* and *P. longispinus* are shown on a comprehensive data in figure (2).

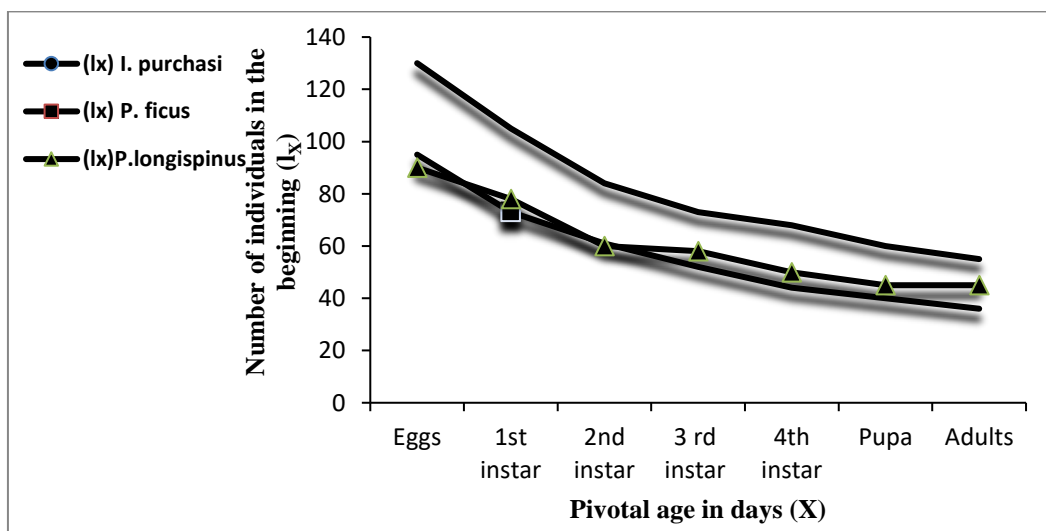


Fig. (1): The age-stage specific survival rates of *Rodolia cardinalis* on three different mealybugs.

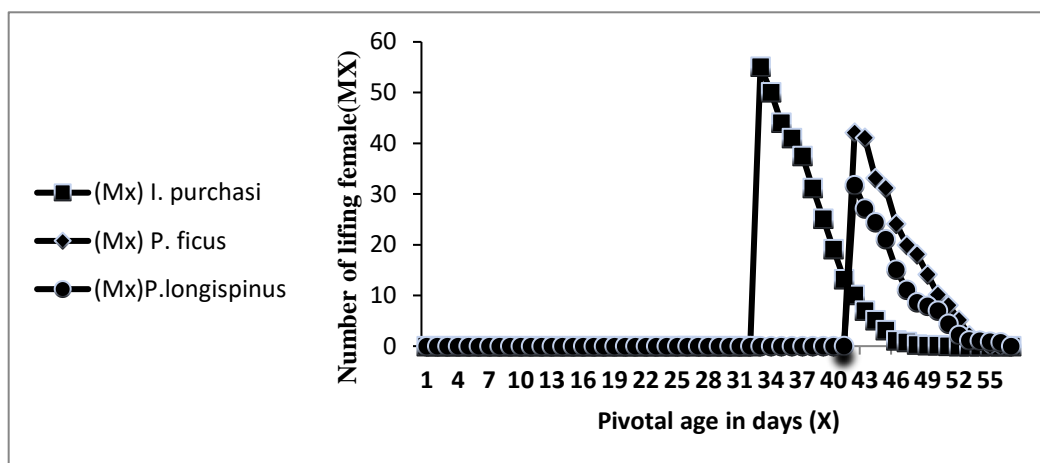


Fig. (2): The female fertility of *Rodolia cardinalis* on three different mealybugs.

According to the results obtained, the first adult female was recorded on the day (22, 30 and 38), and early egg-laying was also recorded after (11, 12 and 4) day after the emergence of adult females and the laying of eggs for those females continued almost until death. Concurrently, the results also recorded the first death of female adult predator in the day (53, 56, and 57) on the three species of mealybug *I. purchasi*, *P. ficus*, and *P. longispinus* on

respectively. The last female of *R. cardinalis* died on day (55, 61 and 64). Furthermore, results in Table (4) showed that the pre-ovipositional period of *R. cardinalis* continued about 10, 11.01, and 3.11 days; ovipositional period continued about 18, 12 and 13 days; and post-ovipositional period continued about 4, 8 and 10 days on three mealybug species *I. purchasi*, *P. ficus* and *P. longispinus* respectively.

Table (4): Reproduction and longevity of *Rodolia cardinalis* feeding on three different mealybugs

Parameter	<i>I.Purchasi</i>	<i>P.Ficus</i>	<i>P.Longispinus</i>
Pre.oviposition period	10 ± 0.21	11.01 ± 0.34	4 ± 0.15
Oviposition period	18 ± 0.11	12 ± 0.22	13 ± 0.17
Post- Oviposition period	4 ± 0.13	8 ± 0.52	10 ± 0.48
Fecundity	334.94 ± 0.55	250.94 ± 0.17	165 ± 0.03
Female longevity	55 ± 0.07	61 ± 0.13	64 ± 0.17

The results in Table (4) had also supported that the highest fecundity of *R. cardinalis* (334.94 eggs/female) of *R. cardinalis* were registered

when nutrition on *I. purchase*. The results obtained showed that he fully agreed with Ghanim et al. (2006) proved that the favorite

prey for *R. cardinalis* was *I. purchasi* compared with the other prey types of mealybug, such as *Planococcus citri* (Risso) and *Icerya seychellarum* (Westwood), this is due to the growth of the predator and the completion of its life cycle in a short period, in addition to increasing its predation capacity and reproductive efficiency when feeding on the *I. purchasi*, thus this predator can be used efficiently as a biological control agent for this mealybug specie.

Figure (2) shows that in general, in the first days of ovulation, the largest number of eggs laid by the adult females predator, while the least numbers of eggs were laid in the last days of the life of those females.

Numerous researchers have proven that the degree of fertility, pre-oviposition, oviposition, postoviposition time, and life span of many predatory insects (Coleoptera: Coccinellidae) is greatly affected by the types of mealybug that feed on them. Baskaran *et al.* (2002) demonstrated that the host mealybug species had the main impact on pre-oviposition, oviposition, postoviposition periods of *C. montrouzieri*, Zhen-Qiang Qin *et al.* (2014) registered the highest fecundity of *C.*

montrouzieri on *Ferrisia virgata* Cockerell. between 3 various hosts mealybug species.

The current study confirmed that many important biological characteristics such as growth rates, fertility, and life table factors for the vedalia beetle, *R. cardinalis* were greatly affected by the species of mealybug raised on them. The fundamental rate of increase (r) and Limited rate of increase (λ) of the *R. cardinalis* bred on three mealybug species were remarkably various.

Table (5) indicated that the population and venereal parameter of *R. cardinalis*. The fundamental rate of increase (r) was the highest in populations bred on *I. purchasi* (0.14). The varied (r) between the three mealybug species *I. purchasi*, *P. ficus* and *P. longispinus*, it is likely that due to the separate groupings of *R. cardinalis* that are spread in different regions of the world as well as to the differences between the types of mealybug that they prey on (Caltagirone and Doult (1989), Grafton (2005) and Ghanim *et al.*, 2006). As the same, the highest final reproduction value (R_0) was also noticed on *I. purchasi* (139.98).

Table (5): Life table parameters of vedalia beetle, *Rodolia cardinalis* feeding on three different mealybug

Parameters	<i>I. purchasi</i>	<i>P. ficus</i>	<i>P. longispinus</i>
R_0	139.98	81.10	37.70
T	35.85	44.71	44.03
r	0.14	0.09	0.08
λ	1.15	1.11	1.08
D_T	4.95	6.93	8.66
$\sum M_x$	334.94	250.94	165.00

Results in Table (5) also displayed that the time needed to double the population (D_T) was

registered (4.95, 6.93 and 8.70) on three mealybug species *I. purchasi*, *P. ficus* and *P.*

longispinus respectively, which proved the great influence of the food type. The results also determined that the vedalia beetle preferred feeding on *I. purchasi* compared with *P. ficus* and *P. longispinus*. Generation length rate (T) presented an obvious variation in vedalia beetles bred on the diverse steward mealybug species. The longest generation length rate (T) was established on vedalia beetles bred on *P. ficus* and *P. longispinus*, but the shortest generation length rate was noticed in vedalia beetles rearing on *I. purchasi*. Concerning the gross procreation rate of females, it has amounted to the highest (Σmx) around 334.94 on *I. purchasi* mealybug.

A lot of the studies carried out on life table transactions are used as important references when selecting the most effective biological control elements in integrated control programs for many pests (Lee, 2002). Usually, it is preferable to choose the biological enemies with the greatest fundamental rate of increase (r) in the absence of other standards (Kontodimas et al., 2007). Several previous studies were conducted on the life tables of *R. cardinalis* in different regions of the world and under various environmental conditions (Cuaston et al. (2004), Ghanim et al. (2006), and Abdel-Salam et al. (2013)

Conclusions

Life tables are a very important method in assessing the performance of natural enemies in controlling many pests under different weather conditions and in different regions. The current study provided many results and valuable information that seriously contribute to helping in the effective control of the types of mealybugs by *R. cardinalis* predator. The various capability of evolution, stay alive and proliferation of *R. cardinalis* nutrition on the three mealybugs *I. purchasi*, *P. ficus*, and *P. longispinus* recommend that this predator could be chosen as an active biocontrol factor for

these three types, particularly in the Integrated control program of *I. purchasi*. The results of the study also showed the possibility of raising the natural enemy, *R. Cardinalis* successfully and in large numbers on many types of mealybugs. The study of the releasing processes of many natural enemies and their effect on controlling many different pests under different environmental conditions factors is a fertile field for further research and study in the future.

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