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Biological Performance, Development and Life Table of Bird Cherry-Oat Aphid *Rhopalosiphum padi* (L) (Hemiptera: Aphididae) on some Egyptian Wheat Cultivars

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ABSTRACT

The bird Cherry-oat aphid *Rhopalosiphum padi* (L) causes serious damage in cereal producing countries including Egypt. The biological performance and development of *R. padi* on ten Egyptian wheat cultivars including Giza 148, Giza 152, Giza 156, Gimmiza 11, Misr 1, Misr 2, Shandwel 1, Sids 1, Sids 12 and sids 13 were investigated at seedling stage of wheat. The results revealed that Misr 2 expressed the lowest percentage of nymphal mortality (20.76%), the longer adult longevity (11.8 days), and the highest mean total number of offspring/ female (50.33 nymph). On contrast, Sids 13 had the lowest mean number of offspring/ female (9.33 nymph) than all cultivars except Gimmiza 11 (10.33 nymph). Furthermore, Sids 13 showed shorter adult longevity (3.3 days). On the other hand, Gimmiza 11 assured that significantly the lowest mean offspring number/ reproduction day (2.13 nymph) compared to the tested cultivars except Sids 13 and Sids 1 (2.67 and 3.20 nymph. Respectively). Also, Gimmiza 11 recorded that higher percentage of the nymphal mortality (60.35%). In addition, life table parameters were estimated for *R. padi.* Aphids fed on Misr 2 had significantly the highest R_0 values (53.43 aphids per aphid). While Gimmiza 11 and Sids 13 cleared that the lowest values (5.53 and 6.35 aphids/ aphid, respectively). Sids 13 and Gimmiza 11 showed that the lowest values for mean generation time (T_c) (2.94 and 3.89 days) than all cultivars. No significant differences were found among all tested cultivars for innate capacity for increase (r_c).

Keywords: *Rhopalosiphum padi*, Development, Fecundity, Egyptian wheat cultivars, Life table

INTRODUCTION

The bird cherry-oat aphid, *Rhopalosiphum padi* (L.), is infesting cereal crops worldwide. It considered a vector of important plant disease called yellow dwarf viruses which cause high yield losses for cereal crops (Finlay and Luck, 2011). Egyptian relaying on wheat as an important stable foo, which consuming about 12,4 million tons. The local grown area by wheat is about 3.4 million feddan with a production of 9.4 million tons in 2014/2015 growing season. The bread wheat occupied 90% of wheat growing area and only 10% for durum wheat (Rashed *et al*. 2016). The most reduction in yield was caused by feeding by sucking the sap and depriving the plant of nutrients during the seedling stage. The loss of yield could be reach up to 60% if the mean density of aphids reached about 10-20 aphids per tiller (Taheri *et al*., 2010 and Papp and Mesterhazy, 1993).

The plants mechanisms of defending against herbivory (Nuñez-Farfán *et al*., 2007) are highly involved in the coevolution between plants and insects (Ehrlich and Raven, 1964 and Rhoades and Cates, 1976). Many insect performances such as growth rate, pupal mass, fecundity, survival influenced negatively by selection pressures which resulted by the plant defense mechanisms (Fenny, 1970).

The level of resistance of particular plant to insect species influenced by some factors that associated with the development of growing plants such as plant phenology (Jansson and Smilowitz, 1985; Panda and Khush, 1995; Smith, 2005). For some practical reason aphids can be restrict to particular parts of the plant which has an impact on the daily measurement of survived aphids and fecundity. When aphids have access to the whole plant then the biological performance can be correctly measured because the aphids will be allowed to reach the complete phenological mosaic, under these conditions, feeding site preference and performance can interact (Pelletier, *et al*. 2010).

The objective of this study aimed to evaluate the survival, fecundity and development of *R. padi* on ten Egyptian wheat cultivars and study the life table parameters of this insect. Reaching to results from this research may help in reduction of aphids that attacking wheat plants during the growing season by candidate some cultivars for wheat breeders that convey complete or partial resistance to aphids.

MATERIALS AND METHODS

1. Aphid Colony

Aphids used in this study were obtained from greenhouse in the department of Entomology and Plant Pathology, North Carolina State University. The aphids were collected from Egyptian wheat plants which were growing for various experimental purposes. The identification of aphid species was confirmed by North Carolina plant disease and insect clinic. Before being used in the experiment, aphid population reared for three generations on wheat seedling. Then plastic framed cages (134.1×146.3×152 cm) were used under greenhouse, (conditions of 20 ± 1°C, 60 ± 5% RH and 14:10 L:D), for maintaining the aphids with transferring 20-25 aphids from infested to a new non-infested seedling.

2. Wheat cultivars

Ten different Egyptian wheat cultivars were chosen to evaluate the development and biological performance of *R. padi* on these cultivars including recent growing wheat cultivars (Sids-1, Sids-12 and sids-13, Misr-1, Misr-2, Giza-148, Giza-152, Giza-156, Gimmiza-11, and Shandwel-1,). Wheat seeds were obtained from Agriculture Research Center, Dokki, Cairo, Egypt. The plants were grown under greenhouse conditions of 20 ± 1°C, 60 ± 5% RH and 14:10 L:D (Department of Entomology and Plant Pathology, NCSU).

3. Antibiosis experiment or (survival and fecundity experiments)

Two leaf stage for each wheat cultivar was cut into small segments, and 3-4 ones were arranged in parallel way in 35 mm small plastic cup filled at quarter with 1% agar solution to keep wheat segments moisturized and the cups were enclosed with a cartoon lids. Apterous aphids adults were randomly selected from the colony and transferred to wheat leaf segments with a fine hairbrush and adults allowed to reproduce nymphs for 24 hrs. Then adult and all produced nymphs were removed from each plastic cup except one nymph/ cup was left. The remaining nymphs for all cups were monitored daily to appraise the development time, fecundity rates and adult longevity of the aphid on the cultivars. There were 10 replicates for each cultivar. On reaching maturity, the fecundity (nymphs produced per reproduction day) was recorded daily. Newborn nymphs were removed daily after counting to minimize the difficulty of recognizing newly born nymphs and to ensure effective monitoring of the insect's life cycle.

In a separate experiment to study the nymphal mortality, three adult apterous aphids were confined to 35mm small plastic cup filled with agar solution and had small segments of two-leaf-stage wheat plants, following the same process. After 24 hrs, the adult was removed and a cohort of three or four newly born nymphs were retained in each cup/ cultivar. A total of 5 replicates/ cultivar were studied to determine the percentage of nymphal mortality in the process of reaching adulthood.

4. Life table calculations

A. Mortality rate percent

Aphid adult mortality was recorded daily till all the adults died. The same method was used for constructing life-tables according to (Morris and Miller, 1954).

$$q_x = (d_x/lx) \times 100$$

Where x: Age of the insect

lx: Number of individuals that survive at the beginning of each age interval 'x' out of 100

dx: Number of individuals that died during the age interval 'x' out of 100

100 $_x$: Percent mortality

B. Construction of life and fertility table

The number of nymphs laid by the female on each day was counted till the death of the adults. The life table for female was constructed from column lx as described (Birch, 1948 and Poole, 1974)

x: Pivotal age of female in days

l_x: Number of females alive at the beginning of each age interval 'x' (as fraction of initial population of one)

m_x: Average number of nymphs laid per female in each age interval assuming 1 as sex ratio

C. Estimation of population growth attributes

Net reproductive rate (R_0):

The values of 'x', 'l_x' and 'm_x' were calculated from the data given in life tables. The sum total of the products 'l_x x m_x' is the net reproductive rate (R_0) (Lotka, 1925). The 'R_0' is the rate of multiplication of population in generation measured in terms of females produced per generation was calculated by the following formula,

$$R_0 = \sum 1X\ x\ mX$$

Mean generation time (Tc):

The appropriate value of generation time (Tc) i.e., the mean age of the mothers in a cohort at the birth of female offspring was calculated by using the following formula.

$$T_c = \frac{\sum 1X\ x\ mX\ x\ X}{R_0}$$

Innate capacity for increase (rc):

The above rc is an approximate value of intrinsic rate of natural increase (r_m) and is slightly lower than rm value for insects with overlapping generations (Laughin, 1965 and Southwood, 1972).

$$R_c = \frac{\mathrm{Log_e}\, R_0}{T}$$

5. Statistical analysis

Parameters of development, fecundity and life table parameters were analyzed by SPSS software; means were compared by the least significant difference (LSD) test after the significant F-test at $\alpha = 0.05$ (IBM SPSS Statistics version 9.0) (1998).

RESULTS

1. Developmental time and survivorship of the nymphal stage

The developmental time of the nymphal stages of *R. padi* indicated that no significant differences among the ten tested Egyptian wheat cultivars (ANOVA- one way: F = 1.77, df = 9, P > 0.05). Nymphs reared on Shandwel-1 had significantly longer development time (7.7 days) than Giza-148, Giza-156 and Misr-2 (6.1, 6.3 and 6.3 days, respectively). While nymphs reared on Giza-148 had significantly shorter development time (6.1 days) than Sids-12 and Shandwel-1 (7.4 and 7.7 days, respectively) (Figure 1).

The percentage of nymphal mortality was calculated for tested cultivars (Figure 1). Significant differences were found among cultivars (F = 2.33, df = 9, P < 0.05). The percentage of nymphal mortality was significantly higher for Gimmiza-11 (60.35%) than Giza-148, Misr-2, Sids-12 and Sids-13, where ranged between 20.76-33.07%. Otherwise, no significant differences were found between Gimmiza-11 and the rest of tested cultivars. While, Misr-2 showed the lowest percentage of nymphal mortality (20.76%) compared to Giza-152, Giza-156, Gimmiza-11 and Misr-1, where ranged between 48.62-60.35%. But no significant differences were found between Gimmiza-11 and the rest of tested cultivars.

2. Adult longevity and reproductive ability

The adult longevity was determined and results showed that no significant differences were found among tested cultivars (ANOVA- one way: F = 1.37, df = 9, P > 0.05). Misr-2 showed longer adult longevity (11.8 days) compared to Sids-13, Gimmiza-11 and Giza-156 (3.3, 4.7 and 5.5 days, respectively). Otherwise, shorter adult longevity was recorded for Sids-13 (3.3 days) than Giza-152, Sids-1 and Misr-2 (10.5, 11.3 and 11.8 days, respectively).

The mean total number of offspring produced by each aphid female was significantly different among the tested cultivars (F =2.17; df = 9; P <0.05). Misr-2 showed highest mean total number of offspring/ female (50.33 nymph) than Sids-13 and Gimmiza-11 (9.33 and 10.33 nymph, respectively). While no significant differences were found between Misr-2 and other tested cultivars (Figure 2). Otherwise, Sids-13 had the lowest mean number of offspring/ female (9.33 nymph) than all cultivars except Gimmiza-11 (10.33 nymph).

The mean offspring number/ reproduction day cleared that significant differences among cultivars (F =3.33; df = 9; P <0.01). Giza-156 had significantly the highest mean offspring number/ reproduction day (5.46 nymph) than other cultivars except Misr-1 and Giza-148 (4.36 and 4.49 nymph, respectively). On the other hand, Gimmiza-11 showed significantly the lowest mean offspring number/ reproduction day (2.13 nymph) compared to tested cultivars except Sids-13 and Sids-1 (2.67 and 3.20 nymph. Respectively) (Figure 2).

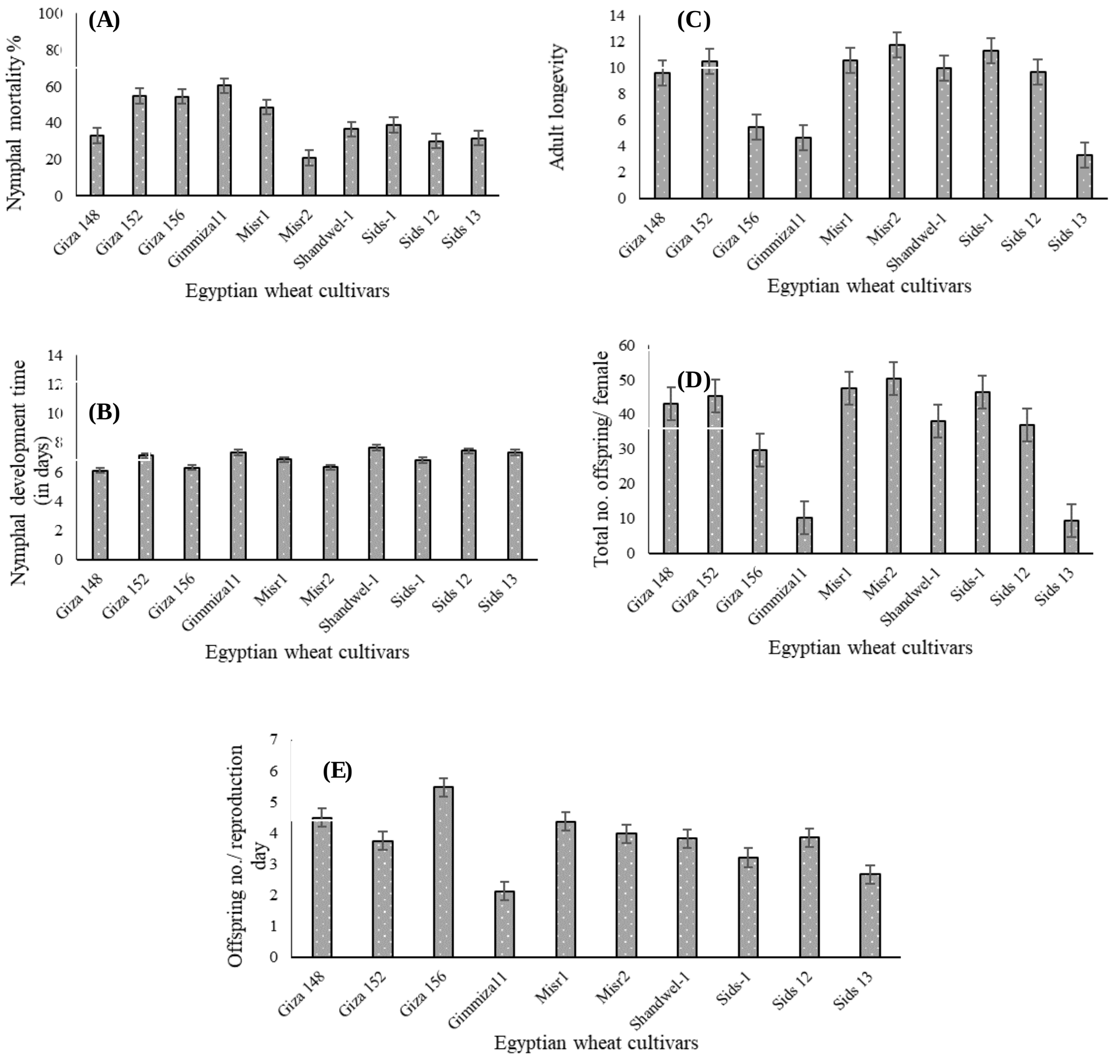

Figure 1. Nymphal mortality (%) (A), Nymphal development time (B), adult longevity (C), total no. of offspring/ female (D) and offspring no./ reproductive day (E) of *R. padi* on ten tested Egyptian wheat cultivars

3. Life table

Age specific survivorship (I_x)

Results showed that there is a significant difference among cultivars in age specific survivorship (df=9, F=2.64, P<0.01). Misr-1 and Misr-2 had similar number of survivals with slight more on Misr-2 (0.613 and 0.618 survived individuals, respectively). Misr-2 had significantly the highest number of survivals than Giza-152, Gimmiza-11, Shandwel-1, Sids-12 and Sids-13, where the number of survived aphids ranged between 0.313-0.467 survived individuals. While, the lowest survival was observed on Sids-13 (0.313 survived individuals) than all tested cultivars except Gimmiza-11, which had 0.322 survived individuals (Table 1).

Mortality (d_x) and percent mortality rate (q_x)

Adult mortality was recorded daily until the end of the experiment and percent mortality rate was calculated (Table 1). Sids-13 showed significantly the highest mortality followed by Gimmiza-11 (0.125 and 0.111 died individuals, respectively) than all tested cultivars. Otherwise, lower and similar mortality was recorded by Giza-152 and Sids-12 (0.040 died individuals) than Gimmiza-11 and Sids-13 (0.111 and 0.125 died individuals, respectively), but not significant with the rest of cultivars.

Sids-13 showed significantly the highest percent mortality rate (25.42%) than other cultivars, followed by Gimmiza-11 (22.59%) and Giza-156 (18.61%). Giza-152 and Sids-12 showed similar percent mortality rate with slightly higher for Sids-12 (9.47% and 9.72%, respectively), but not significant with all cultivars except Giza-156, Gimmiza-11 and Sids-13 (18.61%, 22.59% and 25.42%, respectively).

4. The life and fertility table (fecundity m_x)

The number of progenies/ female/ day was recorded for each aphid adult female on ten Egyptian wheat cultivars (Table 1). Significant differences were found among cultivars in fecundity. Giza-156 showed the highest fecundity (number of progenies/ female) (5.001 nymph) compared to other cultivars except Giza-148 (4.099 nymph) and Misr-1 (4.272 nymph). Otherwise, lower fecundity was recorded for Gimmiza-11 (2.028 nymph) followed by Sids-13 (2.563 nymph) than Giza-148, Giza-156 and Misr-1 ranged between 4.099-5.001 nymph.

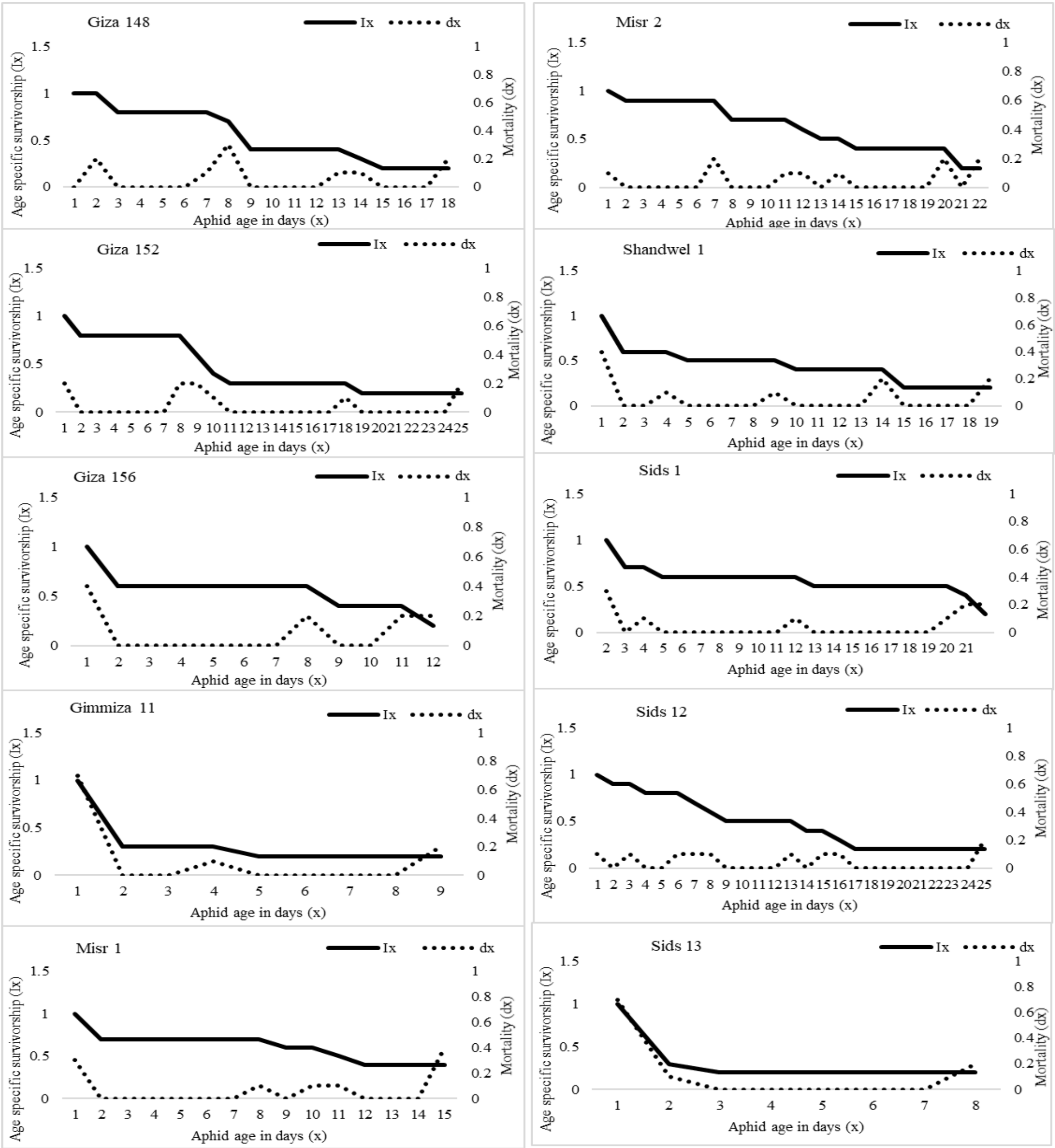

Figure 2. Age specific survivorship (I_x) and fecundity (m_x) of *R. padi* on ten tested Egyptian wheat cultivars

Table 1. Life table, fertility table and population growth attributes parameters measured for *R. padi* on ten tested Egyptian wheat cultivars

Wheat cultivar	Life table				Fertility table	Population growth attributes		
	I_x	d_x	q_x	% Mortality rate ($100 \times q_x$)	m_x	R_0	T_c	r_c
Giza-148	0.544	0.056	0.129	12.98	4.099	47.33	6.02	0.278
Giza-152	0.456	0.040	0.095	9.47	3.202	44.71	7.13	0.231
Giza-156	0.550	0.083	0.186	18.61	5.001	34.81	5.24	0.294
Gimmiza-11	0.322	0.111	0.226	22.59	2.028	5.53	3.89	0.191
Misr-1	0.613	0.067	0.126	12.06	4.272	41.02	7.41	0.218
Misr-2	0.618	0.045	0.106	10.60	3.375	53.43	7.54	0.229
Shandwel-1	0.437	0.053	0.119	11.93	3.075	30.03	6.10	0.242
Sids-1	0.562	0.048	0.110	11.00	2.858	35.10	8.32	0.186
Sids-12	0.476	0.040	0.097	9.72	3.067	48.56	6.70	0.252
Sids-13	0.313	0.125	0.254	25.42	2.563	6.35	2.94	0.273

I_x: Age specific survivorship **d_x: Mortality** **q_x: % Mortality rate** **m_x: Fecundity**
R_0: Net reproductive rate **T_c: Mean generation time** **r_c: Innate capacity for increase**

5. Population growth attributes

Based on determination of age specific survivorship (I_x) and fecundity (m_x), the net reproductive rate (R_0), mean generation time (T_c) and innate capacity for increase (r_c) were calculated (Table 1). The values of the net reproductive rate (R_0) of aphids indicated significant differences among all tested cultivars (P<0.05). Aphids fed on Misr-2 had significantly the highest R_0 values (53.43 aphids per aphid) compared to tested cultivars, while not significantly different with Giza-148 and Sids-12 (47.33 and 48.56 aphids per aphid). While Gimmiza-11 and Sids-13 had the lowest values (5.53 and 6.35 aphids/ aphid, respectively). The mean generation time (T_c) values of *R. padi* was higher for Sids 1 (8.32 day) compared to Sids-13 and Gimmiza-11, but not significantly with the rest of tested cultivars. Sids-13 and Gimmiza-11 showed the lowest values for mean generation time (T_c) (2.94 and 3.89 days) than all cultivars. In addition, no significant differences were found among all tested cultivars for innate capacity for increase (r_c).

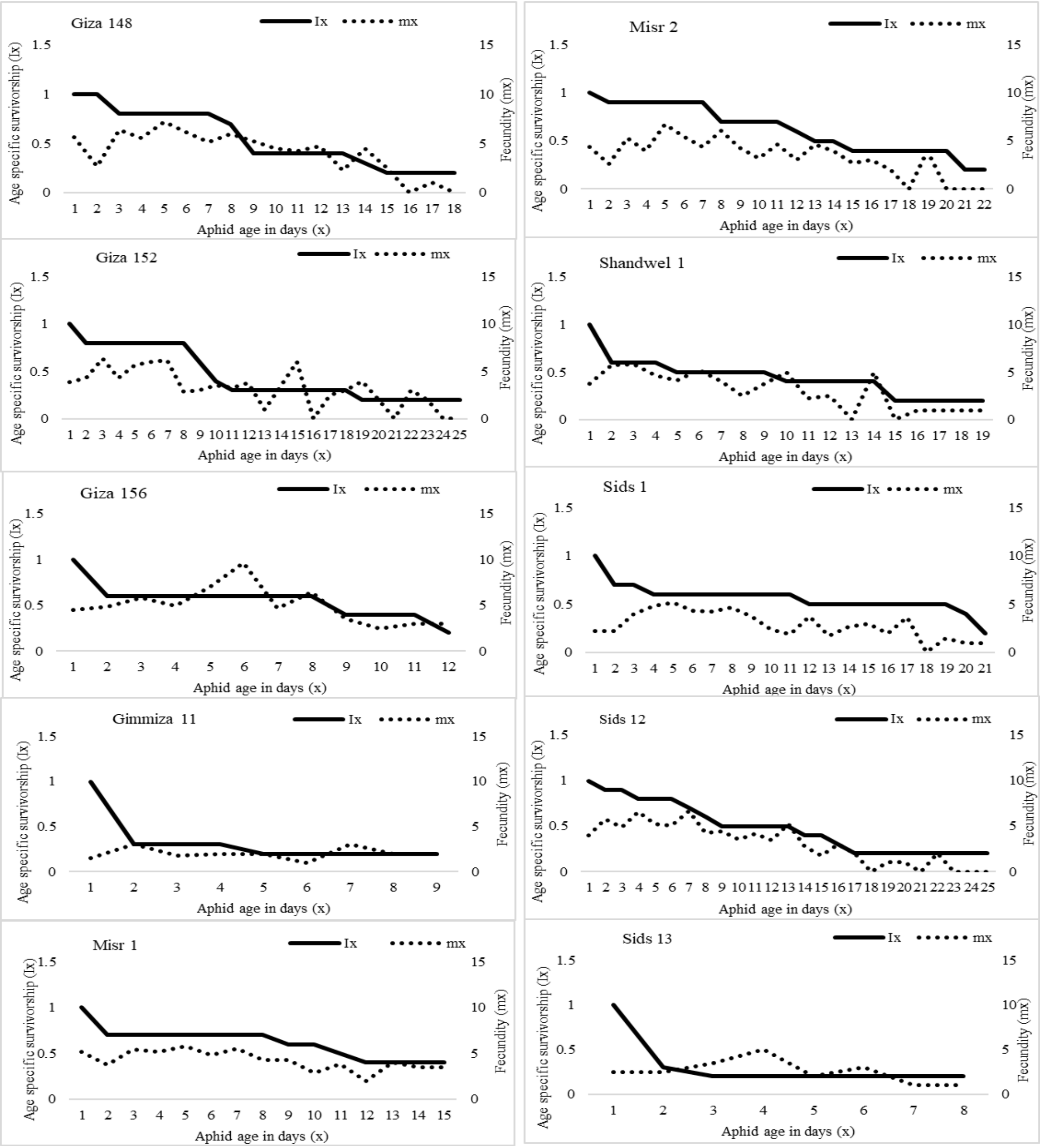

Figure 3. Age specific survivorship (I_x) and mortality (d_x) of *R. padi* on ten tested Egyptian wheat cultivars

DISCUSSION

The knowledge of population growth parameters of any pest, and well understanding of biology and life history traits of a pest on host cultivars would facilitate the designing of a comprehensive pest management program. The rate of population growth in the current and next generation of an insect pest could be assumed by studying the population growth parameters (Frel *et al*. 2003).

For improving the management strategies of aphids in particular area the biology of aphids on different cultivars need to be well studied to provide the required information (Xia *et al*. 1999; Razmjou *et al*. 2006). The acquired data obviously documented that various wheat cultivars studied here differ considerably in terms of their quality as hosts for the *R. padi*, an important pest of wheat. The high biological performance and development of this aphid on Misr-2 mostly resulted from the longer adult longevity, highest mean total number of offspring/ female produced on this cultivar and lowest percentage of nymphal mortality. Conversely, the poor performance of *R. padi* on Sids-13 which correlated with lowest mean number of offspring/ female and shorter adult longevity. Similar poor performance happened in Gimmiza-11 which had lowest mean offspring number/ reproduction day and higher percentage of nymphal mortality. Additionally, highest R_0 values for Misr-2 and lowest values for net reproductive rate for Gimmiza-11 and Sids-13 plus lowest values for mean generation time (T_c) So, the suitability of Misr-2 for aphid adult longevity and fecundity or unsuitability of Sids-13 and Gimmiza-11 may refer to the morphology or chemical compounds of these wheat cultivars. However, a previous studie by Weathersbee and Hardee (1994) revealed that some factors such as leaf surface structure, plant nutrition, leaf age, and secondary compounds could be affecting the variation of aphids population. Using a resistance or even a partial resistance cultivars which only allow low pest population growth is an important and essential part for designing a successful integrated pest management (IPM). Therefore, this study presenting valuable information which consider helpful in the management of bird cherry-oat aphid in Egypt. Growing wheat cultivars that showing complete or partial resistance to the *R. padi* population growth, pest outbreaks may be suppressed or delayed, reducing the need for chemical control measures.

CONCLUSION

The study of *R. padi* biology and life table parameters provided information regarding longer life span of adults and thereby higher food requirements leading to the visibility of the pest and symptoms, respectively on wheat cultivars. Then laboratory results could be utilized for proper assessment for the aphid control in the field too. Hence, this information would be helpful for the development and success of the Integrated Pest Management Program (IPM) for *R. padi*.

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الاداء البيولوجي، التطور وجدول الحياة لحشرة من الشوفان علي بعض اصناف القمح المصرية

مروة فاروق كامل علي
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يتسبب من الشوفان في اضرار شديدة في الدول المنتجة للحبوب ومنها مصر. تم تقييم الاداء البيولوجي وتطور حشرة من الشوفان علي عشرة من اصناف القمح المصرية : جيزة 148، جيزة 152، جيزة 156، جميزة 11، مصر 1، مصر 2، شندويل 1، سيدس 1، سيدس 12 و سيدس 13 عند ظهور ورقتين علي نبات القمح. اظهرت النتائج ان مصر 2 حقق اقل نسبة مئوية لموت الحوريات (20.76%)، اطول مدة بقاء للحشرة الكاملة (11.8 ايام) و اعلي متوسط لعدد النسل الناتج لكل انثي(50.33 حورية). علي النقيض كان سيدس 13 قد حقق اقل متوسط لعدد النسل الناتج لكل انثي (9.33 حورية) بالنسبة لكل الاصناف ما عدا جميزة 11 (10.33 حورية). علاوة علي ذلك، قد اظهر سيدس 13 اقل مدة بقاء للحشرة الكاملة (3.3 ايام). من جانب اخر، اظهر جميزة 11 معنويا اقل متوسط لعدد النسل الناتج لكل يوم لانتاج الحوريات (2.13 حورية) مقارنة بالاصناف المختبرة ما عدا سيدس 13 و سيدس 1 (2.67 و 3.20 علي التوالي). أيضا، اظهر جميزة 11 اعلي نسبة مئوية لموت الحوريات (60.35%). بالاضافة الي ذلك تم حساب مقاييس جدول الحياة لحشرة من الشوفان. وقد وجد ان المن الذي تم تغذيته علي صنف مصر 2 اظهر معنويا اعلي قيمة لصافي معدل الانجاب (53.43 حشرة لكل حشرة). بينما اظهر جميزة 11 و سيدس 13 اقل قيم لصافي معدل الانجاب (5.53 و 6.35 من لكل من علي التوالي). سيدس 13 و جميزة 11 اظهروا اقل قيم لمتوسط مدة الجيل (2.49 و 3.89 ايام) مقارنة بكل الاصناف. لا توجد فروق معنوية بين الاصناف المختبرة في السعة او القدرة الداخلية للزيادة.