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Full Length Research Paper

Effects of food type on adult performance of black blister beetle *Meloe proscarabaeus* (Coleoptera: Meloidae)

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The black blister beetle *Meloe proscarabaeus* was firstly recorded in Egypt 1970s. The current study was carried out to investigate the effect of different host plants on the adult performance parameters. Feeding on the pea *Pisum sativum* detrimentally affected the survival potential because 100% female mortality and 80% male mortality were recorded. On the other hand, the lettuce *Lactuca sativa* was found suitable for the beetle survivorship. The longest total longevity of both sexes was recorded after feeding on *L. sativa* but was remarkably shortened by feeding on the clover *Trifolium alexandrinum*. On comparing with the faba bean *Vicia faba*, a slight increase in the body weight was estimated for both sexes after feeding on *T. alexandrinum* but a slight decrease after feeding on *L. sativa* or *P. sativum*, during the pre-oviposition (or pre-copulation) period. A different trend was detected during the oviposition (or copulation) period. Feeding on *T. alexandrinum* induced the females to be more fecund but feeding on *L. sativa* deleteriously reduced the fecundity. Higher hatchability was estimated by mother feeding on *T. alexandrinum* but lower hatchability was found on *L. sativa*.

Key words: ovarian maturation period, post-oviposition period, body weight, fecundity, egg-mass, fertility, *Vicia faba*, *Trifolium alexandrinum*, *Lactuca sativa*, *Pisum sativum*.

INTRODUCTION

The Meloidae is a beetle family with about 120 genera and 3000 species, primarily distributed in temperate steppic and arid regions, and in sub-tropical and tropical savannas or other open habitats. These insects, commonly known as blister beetles and morphologically very heterogeneous are virtually cosmopolitan, absent only from New Zealand, Antarctica and most Polynesian islands (Bologna and Di Giulio, 2011). The bodily fluids of blister beetles contain the skin irritant cantharidin, giving the family its common name (Borror et al., 1989). When disturbed, meloid beetles will often purposely exude cantharidin-rich haemolymph from their leg joints (White, 1983).

In regard to insect-host plant interactions, it is very useful to determine the influence of different host plants/cultivars on the performance of insect herbivores (Azidah and Sofian-Azirun, 2006; Saeed et al., 2009). Host plant quality is a key determinant of the fecundity of herbivorous insects. The egg production in phytophagous insects is related with the quality and quantity of food ingested (McCaffery, 1975; Manoharan et al., 1987). Components of host plant quality (such as carbon, nitrogen, and defensive metabolites) directly affect potential and achieved herbivore fecundity. A multitude of studies documented pronounced effects of diet quality and quantity on female reproductive output in insects and thereby on fitness (Willers et al., 1987; Braby and Jones, 1995). Fitness, however, is composed of various components, such that determining individual fitness is a challenging enterprise. Frequently, traits such as fecundity and/or egg size are used as proxies for individual fitness (Braby and Jones, 1995; Bernardo, 1996; Caley et al., 2001), while studies also taking offspring survival into account appear

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*Corresponding author. E-mail: dodi_elwi@yahoo.com to be much rarer (Quickenden and Roemhild, 1969; Mevi-Schütz and Erhardt, 2003).

Host plant quality also affects insect reproductive strategies: Egg size and quality, the allocation of resources to eggs, and the choice of oviposition sites may all be influenced by plant quality, as may egg or embryo resorption on poor-quality hosts (Caroline and Simon, 2002). Therefore, study of the influence of different host plants on the growth and development and fecundity of insects is very useful to understand host suitability of plant infesting insect species (Shahout et al., 2011).

The black blister (oil) beetle, *Meloe proscarabaeus* Linnaeus 1758. (Coleoptera: Meloidae) was firstly recorded in Egypt by Alfieri (1976). Then, it was recorded as an agricultural pest on different Egyptian crops, particularly the faba bean (*Vicia faba*), (Ali et al., 2005a, b). To our knowledge this beetle naturally occurs in El-Farafra oasis (in western desert of Egypt near latitude 27.06° North and longitude 27.97° East, at 580 km from Cairo) and may be occur in some other parts in the country. Evaluating the available literature indicates that the present study is the pioneer in the world, under controlled laboratory conditions, aiming to investigate the effects of different host plants, viz. faba bean *Vicia faba*, Egyptian clover *Trifolium alexandrinum*, lettuce *Lactuca sativa* and pea *Pisum sativum*, on the adult performance parameters of *M. proscarabaeus*.

MATERIALS AND METHODS

Experimental beetle

The adult beetles of *M. prpscarabaeus* had been collected just after the emergence using pit-fall traps in bean and clover fields in El-Farafra oasis (Egypt). For maintaining a continuous culture under the laboratory conditions (23±2°C, 46±10% RH, 12L:12D photoperiod), much effort was done by feeding the first instar larvae (triungulins) on a diet containing bee honey and wax combs with clutches of honeybee, *Apis mellifera* (Hymenoptera: Apidae) or some egg-pods of the desert locust, *Schistocerca gregaria* (Orthoptera: Acrididae). In both trials, triungulins gave no interest in the diet until death. Therefore, the newly emerged adult beetles of both sexes (males have knee-shaped antennae while females have straight antennae) were collected from the faba bean and Egyptian clover fields in El-Farafra oasis and directly transferred to the laboratory. The adults were kept and fed on different host plants, faba bean *Vicia faba* (Fabaceae), Egyptian clover Trifolium alexandrinum (Leguminosae), pea *Pisum sativum* (Fabaceae) and lettuce *Lactuca sativa* (Asteraceae), separately.

Adult performance parameters

Just after transportation of the newly emerged adult females and males from the field to the laboratory, the beetles were assorted to female groups (10 females/group) and male groups (10 males/group). Each of female groups male groups was allowed to feed on each of the four host plants. All beetles were provided every day with clean fresh plant food and carefully checked for recording the body weight along the whole longevity, as well as other following parameters.

Survival potential

Survival potential was indicated by the calculated means of mortality percent of adults. Mortality counting was begun a day after feeding.

Adult longevity

For both sexes, the longevity (in days) was measured through three compartments: pre-oviposition (for females) or pre-copulation (for males) period, reproductive life time (oviposition period for females and copulation period for males), and post-oviposition period for females. No post-copulation period of males could be measured because they continue to copulate until death.

Fecundity

After the sexual maturity, 10 mating pairs, one male with one female, were confined in suitable glass cylinders.

Each mating pair was observed daily to count the laid eggs. It is important to report that each female usually lays one egg-mass. The egg laying was finished through some hours within a day. The female fecundity is estimated by the average number of laid eggs/ female (10 replicates/ host plant). As well as, the freshly laid egg-masses of these replicates were weighed in mg, and the dimensions of eggs (length × width) were measured in mm.

Incubation period

Under the laboratory conditions, the time interval from the day of oviposition to the day of hatching is considered as the "incubation period" which is calculated as an average period in days.

Fertility

Fertility was usually expressed in the hatching percentage of eggs.

Statistical analysis of data

Data obtained were calculated as mean ±SD and analyzed using the Student *t* -distribution and were refined by Bessel's correction (Moroney, 1956) for testing the significance of difference between means at probability

Table 1. Adult mortality (%) of black blister beetle, *Meloe proscarabaeus*, fed on different plant hosts.

Host plants	**Ovarian maturation (or pre-copulation) period**		**Reproductive life time (or copulation period)**		**Post-oviposition (or post-copulation) period**	
	Females	**Males**	**Females**	**Males**	**Females**	**Males**
Vicia faba	20	30	10	70	70	*
Trifolium alexandrinum	20	20	0	80	80	*
Lactuca sativa	0	10	0	90	100	*
Pisum sativum	100	80	-	20	-	*

*: Adult males have no post-copulation period because they continue to copulate until the natural death.

Table 2. Female adult longevity (Mean days ± SD) of black blister beetle, *Meloe proscarabaeus*, fed on different plant hosts.

Host plants	**Ovarian maturation (pre-oviposition) period**	**Reproductive life time (Mean hours ±SD)**	**Post-oviposition period**	**Total longevity**
Vicia faba	23.78±1.09	7.68± 2.32	3.00 ±1.23	27.50±1.43
Trifolium alexandrinum	18.56±0.73 d	7.21± 2.02 a	3.00 ±0.87 a	22.70±0.95 d
Lactuca sativa	25.3±1.57 b	7.18± 2.85 a	3.20 ±1.14 a	29.40±1.84 b
Pisum sativum	5.90 ±1.73 d	-	-	5.90 ±1.73 d

Faba bean (*Vicia faba*) was used as standard host plant for the comparison purpose. No. of adult ♀♀ = 10. The reproductive lifetime is considered as a day for all adult females. Mean ± SD followed with the letter (a): non-significantly different (P>0.05), (b): significantly different (P<0.05), (c): highly significantly different (P<0.01), (d): very highly significantly different (P<0.001). – : Female beetles died on *Pisum sativum* before oviposition.

0.05, 0.01 and 0. 001.

RESULTS

Adult survival potential

Table 1 shows that feeding of adult *M. proscarabaeus* on *Pisum sativum* detrimentally affected the survival potential because 100% female mortality and 80% male mortality were recorded throughout the first time interval of adult life (ovarian maturation period of females and pre-copulation period of males). Also, another interesting observation is the suitability of *Lactuca sativa* for the adult beetles because no female mortalities and only 10% male mortalities were recorded during this time interval. Feeding on *Vicia faba* resulted in 20% female mortalities and 30% male mortalities while feeding on *Trifolium alexandrinum* resulted in 20% mortality of both sexes.

Moving to the next time interval in the adult life (reproductive lifetime or oviposition period of females and copulation period of males), data of the same table show the highest survival potential of females on *T. alexandrinum* because no mortality was observed but only 10% mortality was recorded for females fed on *V. faba*. With regard to males, the survival potential was severely influenced at the end of their copulation period (which extended until the natural death, i.e., no post-copulation period occurred) because 80% mortality was recorded. In conclusion, *L. sativa* is the most suitable host plant for the adult beetles but *P. sativum* is the most unsuitable one.

Adult longevity

Data assorted in Tables 2 and 3 indicate the longer total longevity of females than males, regardless of the host plant. The longest longevity of females was recorded in 29.40±1.84 days after feeding on *L. sativa* and the longest longevity of males was recorded in 23.40±2. 76 days after feeding on the same host. For investigating the differential effect of host plants on the adult female longevity, data given in Table 2, clearly show a lengthening effect of *L. sativa* because the longevity was 89.4±1.84 days (P<0.05) while it was 22.70±0.95 days (P<0.001) after feeding on *T. alexandrinum* and 27.50±1.43 days after feeding on *V. faba*. It is noteworthy to mention that the adult females died on *P. sativum* just after the ovarian maturation period and hence their calculated longevity does not accurately informative.

On using *V. faba* as a base or standard host plant for comparison purposes, the female longevity was significantly shortened by feeding on *T. alexandrinum* but was remarkably prolonged by feeding on *L. sativa* (Table 2). Similar observation was recorded for adult males (Table 3).

For more details, data distributed in Table 2 reveal some effects of host plants on the three major

Table 3. Male adult longevity (Mean days ± SD) of black blister beetle, *Meloe proscarabaeus*, fed on different plant hosts.

Host plants	Pre-copulation period	Copulation period	Total longevity
Vicia faba	6.65 ±1.59	19.00 ±1.87	25.60±0.52
Trifolium alexandrinum	5.33 ±1.12 (a)	12.89 ±1.97 d	18.10±1.10 d
Lactuca sativa	8.70 ±1.16 c	14.11 ±2.76 d	23.40±2. 76 b
Pisum sativum	5.30 ±0.93 a	0.40 ±0.65 d	6.17±1.89 d

Faba bean (*Vicia faba*) was used as standard host plant for the comparison purpose. No. of adult ♂♂ = 10. Mean ± SD followed with the letter (a): non-significantly different (P>0.05), (b): significantly different (P<0.05), (c): highly significantly different (P<0.01), (d): very highly significantly different (P<0.001) .

Table 4. Adult body weight (Mean mg ±SD) of the black blister beetle, *Meloe proscarabaeus*, as affected by fed on different host plants.

Host plants	Pre-oviposition (or copulation) period		Oviposition (or copulation) period		Post-oviposition period	
	Females	Males	Females	Males	Females	Males
Vicia faba	754.42 ±656.2	108.75 ±39.07	1604.34 ±79.7	545.79 ±243.2	1510.14 ±32.67	–
Trifolium alexandrinum	773.39 ±676.7 a	116.67 ±47.61 a	1527.72 ±84.17 a	648.67 ±248 a	1279..63 ±78.79 a	–
Lactuca sativa	621.37 ±602 a	97.56 ±29.85 a	1482.16 ±41.59 b	559.04 ±23.41 a	1431.1 ±2.47 d	–
Pisum sativum	72.01 ±3.64 a	77.95 ±5.51 a	*	78.30 ±0.00 d	*	–

Faba bean (*Vicia faba*) was used as a standard host plant for the comparison purpose. No. of adult ♀♀ or ♂♂ = 10. *: Female beetles died on *Pisum sativum* before oviposition. -: Post-copulation period of males could not be measured because they have copulated until death. Mean ± SD followed with the letter (a): non-significantly different (P>0.05), (b): significantly different (P<0.05), (c): highly significantly different (P<0.01), (d): very highly significantly different (P<0.001).

compartments of longevity: ovarian maturation (pre-oviposition) period, reproductive lifetime (oviposition period) and post-oviposition period. As seen in the total longevity, the ovarian maturation period appeared in the same trend, i.e., shorter after feeding on *T. alexandrinum* but considerably longer (P<0.001) after feeding on *L. sativa*, when compared to the ovarian maturation period after feeding on *V. faba* (18.56±0.73 and 25.3±1. 57 days, respectively, compared to 23.78±1.09 days on *V. faba*). Data of the same table show another trend of effect on the reproductive lifetime because it was calculated as 7.68±2.32 days after feeding on *V. faba* and non-significantly shortened after feeding on both *T. alexandrinum* and *L. sativa* (P>0.05).

Recalling Table 3, data obviously reveal different effects of host plants on the pre-copulation period of adult males. Feeding on *V. faba* resulted in 6.65±1. 59 days of pre-copulation period while slightly shortened period (5.33±1.12 days, P>0.05) was recorded after feeding on *T. alexandrinum* but pronouncedly longer one (8.70±1. 16 days, P<0.01) was resulted by feeding on *L. sativa*, as well as non-significantly longer period was estimated by feeding on *P. sativum* (6.89±0.93 days). On comparing data of both Tables 2 and 3, it is concluded that the sperm maturation in testes of males was generally faster than the ovarian maturation in females, regardless of the food plant.

Data given in Table 3, also, displays some effects of food plants on the pre-copulation period of adult males when compared to *V. faba* because shorter period was found by feeding on *T. alexandrinum* (5.33±1.12 days), markedly longer period was found by feeding on *L. sativa* (8.70±1.16 days) and slightly longer period was found by feeding on *P. sativum* (6.89±0.93 days). To a great extent, similar trend was appreciated to the copulation period of males.

Adult biomass

To shed some light on the effects of different host plants on the adult body weight, the mean weights were estimated during the different longevity compartments for both females and males and compiled in Table 4.

Dealing with the mean body weights of adult females and males after feeding on *V. faba*, the females attained much more weights than males whatever the compartment of longevity. No body weight could be determined for males during the post-copulation period because they usually continue to copulate until natural death. This is a general observation in the present work.

On comparing with the body weights after feeding on *V. faba*, the same Table 4 unambiguously demonstrated that a slight increase (P<0.05) in the body weights of females and males by feeding on *T. alexandrinum* but a slight decrease was determined by feeding on *L. sativa* or *P. sativum* during the pre-oviposition (or pre-copulation).

Table 5. Female fecundity (Average No. of eggs/female ± SD) and egg- mass weight (Average mg± SD) of black blister beetle*, Meloe proscarabaeus*, fed on different plant hosts.

Host plants	*Vicia faba*	*Trifolium alexandrinum*	*Lactuca sativa*	*Pisum sativum*
Fecundity	1499.52±14.18	1763.31±55.55 d	1446.37±30.41 d	*
Egg-mass weight	573.32 ±63.27	599.62 ±19.83 a	531.43 ±131.75 a	*

Faba bean (*Vicia faba*) was used as a standard host plant for the comparison purpose. No. of adult ♀♀ = 10. *: Female beetles died on *Pisum sativum* before oviposition. Mean ± SD followed with the letter (a): non-significantly different ($P>0.05$), (b): significantly different ($P<0.05$), (c): highly significantly different ($P<0.01$), (d): very highly significantly different ($P<0.001$).

Table 6. Fertility and dimensions of eggs laid by adult females of black blister beetle *Meloe proscarabaeus* as affected by feeding on different food plants.

Host plants	Egg dimensions (Mean mm ±SD)		Fertility (Hatching % ±SD)	Embryonic developmental duration (Mean days ± SD)
	Length	Width		
Vicia faba	1.14 ±0.14	0.29 ±0.027	88.06±3.82	16.11±1.45
Trifolium alexandrinum	1.12 ±0.13 a	0.29 ±0.025 a	90.51±3.60a	13.55±1.67 c
Lactuca sativa	1.07 ±0.13 c	0.28 ±0.021 a	52.41±4.56c	24.13±2.59 d
Pisum sativum	*	*	*	*

Faba bean (*Vicia faba*) was used as a standard host plant for the comparison purpose. Mean ± SD followed with the letter (a): non-significantly different ($P>0.05$), (b): significantly different ($P<0.05$), (c): highly significantly different ($P<0.01$), (d): very highly significantly different ($P<0.001$). *: No eggs were laid because female beetles died on *Pisum sativum* before oviposition.

period. A different trend was detected during the oviposition (or copulation) period for females and males by feeding on the different host plants. Also, a sexual dimorphism was observed because females attained little body weights and males gained more biomass, after feeding on *T. alexandrinum* or *L. sativa*. As compared to data of *V. faba*, a drastically decreased body weight was determined for males by feeding on *P. sativum* ($P<0.001$) on which the females died (may be due to the insufficient food requirements). Because no post-copulation period could not be estimated to males, female body weights had been slightly diminished ($P>0.05$) by feeding on *T. alexandrinum* or *L. sativa* (Table 4).

Reproductive potential

Female fecundity

The data of fecundity and egg-mass weight as affected by feeding of adult females (mothers) on different host plants were presented in Table 5. Depending on these data, no female fecundity, and subsequently no egg-mass weight, could be measured after feeding on *P. sativum* because females died before oviposition. After feeding on *V. faba*, adult females laid 1499.5±14.18 eggs in a single egg mass while feeding of *T. alexandrinum* induced the females to be more fecund (1763.31±55. 55 on *T. alexandrinum* vs. 1499.53±14. 18 eggs/ on *V. faba*, $P<0.001$) but feeding on *L. sativa* deleteriously reduced the fecundity (1446.37±30.41 on *L. sativa* vs. 1499.52±14. 18 eggs/ on *V. faba*, $P<0.001$).

On the comparison with feeding on *V. faba*, also, the egg-mass weight was insignificantly heavier after feeding of mothers on *T. alexandrinum* (599.62±19. 83 vs. 573.32±63.27 mg on *V. faba*, $P>0.05$) but insignificantly lighter after feeding of mothers on *L. sativa* (531.43±131.75 vs. 573.32±63.27 mg on *V. faba*, $P>0.05$). Thus, the difference in weight of egg-mass may explain the influenced fecundity by the host plant.

In addition, the dimensions of eggs and the hatchability (fertility) as well as the embryonic development duration (incubation period), as affected by feeding of mothers on different plants can be informed by data arranged in Table 6. As easily seen in this table, only the egg length was slightly affected by feeding on *T. alexandrinum* ($P< 0.05$) but profoundly affected by feeding on *L. sativa* ($P> 0.01$) in comparison with feeding on *V. faba* while the egg width was almost not affected. For some details, adult feeding on *T. alexandrinum* resulted in egg length of 1.12±0.3 mm and feeding on *L. sativa* resulted in egg length of 1.07±0.13 mm, in comparison with egg length of 1.14±0.14 mm after adult feeding on *V. faba*.

Egg hatchability

With regard to fertility (hatching %), data of the same table exiguously show higher fertility after adult feeding on *T. alexandrinum* but lower fertility after adult feeding on *L. sativa* (90.51±3.60 and 52.41±4.56%, respectively, vs. 88.06±3.82% after adult feeding on *V. faba*). In other words, the calculated sterility index was smallest (-20.86) but largest (+52.5) by adult feeding on *T. alexandrinum* and *L. sativa*, respectively, after using the faba bean as a base of host plants for calculations.

Embryonic developmental duration

A reverse trend could be easily considered for the embryonic developmental duration since it was remarkably shortened after parent feeding on *T. alexandrinum* ($P<0.01$) but prominently prolonged after parent feeding on *L. sativa* ($P>0.001$)(13.55±1.67 and 24.13±2.59 days, respectively, vs. 16.11±1.45 days after adult feeding on *V. faba*). This reflects some effects of parent food on the embryonic developmental rate in the produced eggs which was faster after feeding on *T. alexandrinum* but slower after feeding on *L. sativa*, than that rate after feeding on *V. faba*.

DISCUSSION

Many investigators have previously suggested that host plant quality greatly affects survivorship, growth, and reproductive output in many insect herbivores (McCaffery, 1975; White, 1976, 1984; McNeill and Southwood, 1978; Rhoades, 1979, 1983; Mattson and Haack, 1987; Joern and Gaines, 1990; Jones and Coleman, 1992; Joern and Behmer, 1997). As for example, demographic attributes of adult grasshoppers (such as growth rate, developmental rate, survival, and fecundity) routinely vary in response to nitrogen (protein) levels in the diet, largely in response to internal nutrient economics (Hill et al., 1968; Tobe and Loughton, 1969; Lee and Wong, 1979; Lim and Lee, 1981; Van Heusdon et al., 1987).

Adult survival potential

The effect of food quality on the survivorship had been studied for several blister beetle species. Zhu and Higgins (1994), as for example, investigated the effects of different cultivars of alfalfa on three -striped blister beetle *Epicauta occidentalis* and margined blister beetle *Epicauta funebris*. In the current study, newly emerged adult females and males of the black blister beetle *Meloe proscarabaeus* were fed on *Vicia faba*, *Trifolium alexandrinum*, *Lactuca sativa* or *Pisum sativum* under laboratory conditions. Feeding on *P. sativum* detrimentally affected the survival potential because complete female mortality and 80% male mortality were recorded through the first time interval of adult life (ovarian maturation period of females and pre-copulation period of males). Another interesting observation was documented since the feeding on *L. sativa* resulted in no mortality among females and only 10% mortalities among males during this life interval. These results of the food quality effects on survivorship may be understood in view of reported results for other insect species since Soliman (1968) observed the survival of the grasshopper *Euprepocnemis plorans* adults normally upon clover (*T. alexandrinum*), maize (*Zea mays*) and cotton (*Gossypium barbadense*), but heavy mortality was recorded by feeding on rice (*Oryza glaberrima*) or wheat (*Triticum* spp.). Also, *T. alexandrinum* was recorded as the most suitable food plant for the survivorship, among 13 species of cultivated and wild plants, for the grasshopper *Chrotogonus lugubris* (Ibrahim, 1971). The highest survival potential of the grasshopper *E. plorans* was observed after feeding on *V. faba* and decreased after feeding on *T. alexandrinum* and the lowest survival potential was recorded for adults fed on *Z. mays* (Ghoneim et al., 1994 a, 1995). Cabbage, cotton and sweet potato were found to be more preferred for the cotton leafworm *Spodoptera litura* life than soybean, cowpea and alligator weed (Shahout et al., 2011). However, the current results on *M. proscarabaeus* obviously indicate that *L. sativa* was the most suitable food plant in relation to survivorship of adult beetles but *P. sativum* was the most harmful food plant, particularly for females which completely died on it at the end of their ovarian maturation period.

Adult longevity

Adult longevity varies among various species and genera of blister beetles (Meloidae) and varies, also, in the same species, according to the sex and emergence time. In nature, females generally survived 100-128 days but males survived 87-116 days in the black blister beetle *M. proscarabaeus* (El-Shiekh, 2007), while Selander and Fasulo (2000) reported that adults of the meloid beetle *Nemognatha plazata* commonly live three months or more. Under the previously mentioned laboratory conditions, *M. proscarabaeus*, in the current study, the longest longevity of adult females was recorded in 29.40 days after feeding on *L. sativa* and the longest longevity of adult males was recorded in 23.40 days after feeding on the same food plant. Thus, these results, to some extent, are in line with previous findings of different insect species. Feeding of the grasshopper *Aiolopus thalassinus* on *Z. mays* resulted in prolonged adult life (Hafez and Ibrahim, 1962). The female or male longevity of the spiny bollworm *Earias vittella* was prolonged by feeding on okra and shortened by feeding on cotton or *Abutilon indicum* (Rehman and Ali, 1981; Sundraraj and Divid, 1987). Adult longevity of the epilachna beetle,

Henosepilachna vigintioctopunctata was longer on tomato compared to aubergine (Patel and Purohit, 2000). After feeding of female of another epilachna beetle *Epilachna dodecastigma* on four host plants (Teasel gourd *Momordica dioica*, bitter gourd *Momordica charantia*, sponge gourd *Luffa cylindrica* and yardlong bean *Vigna sesquipedalis*), the longest longevity was recorded on yardlong bean, which was statistically identical to those fed on teasel gourd and lowest was on bitter gourd and sponge gourd (Hossain et al., 2009). Females of the fruit-feeding tropical butterfly *Bicyclus anynana* had a significantly longer life-span when fed with banana as compared to sugar-based diets (Bauerfeind and Fischer, 2005; Bauerfeind et al., 2007). Adults of the bug *Nysius huttoni* lived longer life when fed on diet containing certain concentrations of glucose than on diet containing water alone (Weia, 2012).

As aforementioned for the present beetle *M. proscarabaeus*, the adult females lived for longer longevity than that of their male congeners which result recorded previously for some grasshopper species such as *Calephorus compressicornis* (Ezz El-Din, 1981) and *E. plorans* (Ghoneim et al., 1995). On the contrary, male longevity was longer than the female longevity in the desert grasshopper *Sphingonothus carinatus* (Hafez and Ibrahim, 1964) and in the spiny bollworm *E. vittella* (Syed et al., 2011). If *V. faba* is used as a standard food plant for *M. proscarabaeus*, in the present study, the female longevity was remarkably shortened by feeding on *T. alexandrinum* but was pronouncedly prolonged by feeding on *L. sativa*. More or less, similar results had been obtained for *E. plorans* since feeding on *T. alexandrinum* led to shorter longevity but feeding on *V. faba* or *Z. mays* resulted in longer longevity (Ghoneim et al., 1995).

Generally, the adult longevity includes three major compartments: pre-oviposition (ovarian maturation in females) period or pre-copulation (testicular maturation in males) period, oviposition (or copulation) period, and post-oviposition (or post-copulation) period. In the present study, no post-copulation period was observed for males of *M. proscarabaeus* because they continue to copulate until the natural death (under laboratory conditions). The ovarian maturation period (in females) was shorter after feeding on *T. alexandrinum* but considerably longer after feeding on *L. sativa*, when compared to that period after feeding on *V. faba*. Concerning the adult males, the pre-copulation period was slightly shortened after feeding on *T. alexandrinum* but was significantly prolonged after feeding on *L. sativa* or *P. sativum*. To some extent, similar effect of food quality on the pre-oviposition period had been reported for some insects. After feeding of the grasshopper

Hieroglyphus perpolita on *Z. mays*, among other host plants, led to a shorter pre-oviposition period (Sultana and Wagan, 2010). Also, the pre-oviposition period of *E. vittella* was shortened by feeding on *Abutilon indicum* and prolonged on cotton (Syed et al., 2011).

Depending on the current results, sperm maturation in testes of male *M. proscarabaeus* was generally faster than the ovarian maturation in females, regardless of the food plant. According to the present study, it can be concluded that feeding on *T. alexandrinum* accelerates the ovarian maturation in females and sperm maturation period in males of *M. proscarabaeus* while feeding on *L. sativa* delays the gonad maturation in general. Generally, feeding on food plants poor in nutritional value might have delayed oocyte development resulting in prolonged pre-copulation period (Sultana and Wagan, 2010).

Dealing with the reproductive lifetime (oviposition or copulation period) of adults of *M. proscarabaeus*, in the current study, feeding on *T. alexandrinum* or *L. sativa* led to insignificantly shortened period ($P>0.05$) in females, when compared to feeding on *V. faba*. Also, feeding on *T. alexandrinum* led to slightly shortened period in males but feeding on *L. sativa* led to slightly lengthened one. The current results, to a great extent, agree with those results obtained by Ghoneim et al. (1995) for the grasshopper *E plorans* because feeding on *T. alexandrinum* enhanced the ova or sperm developmental duration. The epilachna beetle *E* females laid eggs on all tested host plants but the longest oviposition period was observed in yardlong bean *Vigna V sesquipedalis* and the shortest in teasel gourd *M dioica* (Hossain et al., 2009). The oviposition period of *E. vittella* was the shortest by feeding on *Abutilon indicum* and the longest on cotton (Syed et al., 2011). However, the present data comparably indicate the rich nutritional value of *T. alexandrinum* in relation to the induction and investment of gonad maturation in *M. proscarabaeus*. These variations might be due to the difference in nutritive values of the host plants. This is appreciated evidence because the protein content of *T. alexandrinum* is the largest among other food plants used (Morrison, 1951). Of course, protein is prerequisite component for the gonad maturation but the following data of female fecundity of *M. proscarabaeus* may explain this ambiguous issue.

Adult biomass

The adult female body weight is considered among some good indicators to determine the availability and suitability of the food plants for the reproductive output of insects such as grasshoppers (Ghoneim et al., 1994b). The aubergine leaves, and not the tomato leaves, enhanced the body weight of adults of the epilachna beetle, *H vigintioctopunctata* (Patel abd Purohit, 2000). Also, the adult females of Sunn pest, *Eurygaster integriceps* (Hemiptera), produced from nymphs grown on wheat had the highest body weight followed by barley and rye (Ameri et al., 2010).

In the present study on *M. proscarabaeus*, adult females attained much more body weights than male congeners. On comparing with the body weight after feeding on *V. faba*, an insignificant increase was estimated for both sexes by feeding on *T. alexandrinum* but a slight decrease was estimated by feeding on *L. sativa* or *P. sativum*, during the ovarian (or testicular) maturation period. Moreover, the body weight of adult females was drastically reduced by feeding on *P.*

sativum, along the ovarian maturation period at which end, they died and could not survive to oviposit. This may be attributed to the insufficient nutritional requirements in this food plant or to the presence of a toxic or lethal material. However, these results may be supported by some reported results of other insects such as the grasshopper *E. plorans* for which Ghoneim et al. (1995) recorded the heaviest females body weight after feeding on *V*. *faba* but the lightest weight after feeding on *Z. mays*. Based on the current data, the best body condition was observed by feeding on *T. alexandrinum* while the worst body condition was observed by feeding on *L. sativa* or *P. sativum* which result informative to the availability of nutritional milieu of these food plants (Morrison, 1951).

Reproductive potential

Generally, female fecundity depends on the ingestion of proteins which are necessary for egg development whereas male reproductive capability does not highly depend on proteins. Moreover, insects generally are unable to convert lipids to monosaccharides by themselves and carbohydrates are one nutrient that both sexes use as a primary energy source (Carrel and Tanner, 2002). Nutritional factors reportedly had profound short-term and long-term effects on the development and reproduction of insects (Cooper and Schal, 1992). Even though the nutritional requirements of most insects are relatively similar, the optimal sources, types, and proportions of nutrients widely vary among species and reproductive stages (Cooper and Schal, 1992). Egg production depends mainly on the food consumed by the adult and was little affected by larval diet which, however, influenced the potential egg production of obviously inadequate for larval development (Kehat and Wyndham, 1972). Some studies highlight the complex interactions between storage reserves (from larval-derived nutrients) and adult income, and that the adult diet may contribute significantly to reproductive output in Lepidoptera (Leather, 1995; Mevi -Schütz and Erhardt, 2005).

Female fecundity

Evaluating the available literature reveals that the female fecundity (egg production) depends on the condition of life because the reproductive potential of the grasshopper *E. plorans*, as for example, in the field differed from that exhibited under the laboratory conditions (Chapman and Robertson, 1958). Food is an environmental factor that would be expected to exert influence on reproduction. Several experimental studies have shown noticeable differences in the fecundity of the same species fed on different plants (Pickford, 1958; Karolina, 1960; Kaufman, 1965; Ibrahim, 1971, 1980; Moustafa, 1985; Wall and Begon, 1987; Ghoneim et al., 1994a). On the other hand, increasing body weights by feeding on certain food plants may lead to greater fecundity (Mulkern, 1967; Hewitt, 1968; Johnson and Mundel, 1987). In the present study, each of adult females of *M. proscarabaeus* lays one egg batch (or mass) under controlled laboratory conditions although several authors reported more than one egg mass for different blister beetle species under field conditions, such as the violet blister beetle *Meloe violaceus* (Cros, 1930), the blister beetle *Lytta nuttalli*,

Lytta viridana and *Lytta cyanipennis* (Church and Gerber, 1977). Also, some other beetle species had been observed to lay more than one egg -mass under laboratory conditions (Erickson and Werner, 1974). After feeding of female epilachna beetle *E dodecastigma* (Coccinellidae), they laid eggs on all tested host plants (Teasel gourd *M dioica*, bitter gourd *Momordica charantia*, sponge gourd *L cylindrica* and yardlong bean *V sesquipedalis*). The highest fecundity was recorded on teasel gourd leaves and next on sponge gourd, bitter gourd, and yard long bean (Hossain et al., 2009).

In the present study on *M. proscarabaeus*, feeding of adult females on *V. faba* resulted in fecundity measured in 1499.50 eggs per female in a single egg -mass. On comparing with other blister beetles, *M. proscarabaeus* has low fecundity as ranged from 1995 to 2290 eggs under field conditions (El -Shiekh, 2007). For some details, the blister beetle *M. violaceus* lays 3000-4000 eggs (Cros, 1930), the red-striped oil beetle *Meloe majalis* lays several thousand eggs in each batch (Cros, 1912). As well as, Erickson and Werner (1974) recorded no fewer than 22800 eggs laid by each of 4 species of bee-associated meloid beetles under laboratory conditions, and Luckmann and Assmann (2005) recorded a reproductive potential up to 40000 eggs per female for 9 meloid beetles from Central Europe. On the other hand, the present experimental beetle has fecundity almost comparable to some other blister beetles as reported by Church and Gerber (1977) for *L*. *nuttalli* (320 eggs/female), *L. cyanipennis* (340 eggs/female), and *L. viridana* (390 eggs/female).

In addition, the obtained results demonstrate some differences in the female fecundity of *M. proscarabaeus* after feeding on various food plants because feeding on *T. alexandrinum* induced the female to be more fecund, compared to the feeding on *V. faba* while feeding on *L. sativa* deleteriously prohibited the female fecundity. To some extent, our results are in accordance with those results obtained by McCaffery (1975) for the African migratory locust *Locusta migratoria migratorioides* which exhibited reduced egg production by feeding on poor low-protein lush grass *Agropyron repens*; Manoharan et al. (1987) for the blister beetle *Mylabris pustulata* after feeding on two different food plants; Sankarperumai et al. (1989) for the cotton leafworm *Spodoptera littoralis* which had higher fecundity on cator oil plant *Ricinus communis* leaves than on sunflower *Helianthus annus* and groundnut *Archis hypogea*; Bauerfeind et al. (2007) for the butterfly *B. anynana* which exhibited significantly higher reproductive output by feeding on banana as compared to sugar-based diets; and Sultana and Wagan (2010) for the grasshopper *H. perpolita* which showed considerably higher fecundity on the plants *Saccharum bengalense* and *Oryza sativa* among other tested plants. On the other hand, the current results are in contrast to reported results for some insects, such as the grasshopper E. plorans of which fecundity was promoted by feeding on *Z. mays* but prohibited by feeding on *T. alexandrinum* (Ghoneim et al., 1994a). Furthermore, feeding of the grasshoppers *Aiolopus thalassinus*, *Pyrgomorpha conica*, *H. littoralis*, *Calephorus compresscornis* and *Catantops axillaris* resulted in completely sterile females after feeding on *Z. mays*.

The affected egg production capacity by parental feeding on different host plants may be understood in view of Wheeler (1996) who stated that the egg-laying capacity in insects is determined by oogenesis, a biological process influenced by the availability of nutrients present in the female's body. Many workers have reported positive correlations between the protein content of host plants and fecundity of insects (for reviews, see Wiggles worth, 1965; Slansky, 1982; Hinks et al., 1993; Leather, 1995). For some details, high protein and nitrogen contents in the lufah *L cylindrica* was said to be the causative factors for the increased fecundity in the predatory mired bug *Cyrtopeltis tenuis* (Raman and Sanjayan, 1984); as well as certain host plant seeds on the fecundity of the seed bugs *Oxycarenus hyalinipennis* and *Spilostethus hospes* (Ananthakrishnan et al., 1982 a, b), okra for the spiny bollworm *E. vittella* (Sundararaj and David, 1987); and *R. communis* for *S. litura* (Sankarperumai et al., 1989).

However, it is important to point out that the increasing or decreasing female fecundity of *M. proscarabaeus*, in the present study, after feeding on different food plants may be due to the females' efficiency of conversion of food into the biomass. In other words, the higher efficiency of conversion of digested food plant enhanced a higher fecundity. The available literature contains several works substantiating this idea such as Bailey and Mukerji (1976) who found that the efficiency of conversion of digested food into body tissues of the grasshopper *Melanoplus bivittatus* was the lowest by feeding on *Z. mays* which accompanied with significantly lower egg production. On the contrary, the grasshopper *E. plorans* exhibited the highest efficiency of conversion of digested food by feeding on the same host plant (Ghoneim et al., 1994a). However, the correlation between the efficiency of conversion of digested food into biomass and the egg production (fecundity) of the present black blister beetle should be carry out in the forthcoming future!! Also, the correct nutrient levels of food play a vital role, triggering the endocrine system activity for oocyte development. It is generally supposed that the endocrine system activity is generated by the stimulation of foregut stretch receptors during increased feeding (Hill et al., 1968).

Egg fertility

On comparing with feeding on *V. faba*, in the current work, feeding of adult females on *T. alexandrinum* led to a slightly heavier egg-mass but lighter egg-mass after feeding on *L. sativa*. Also, the egg dimensions had been affected by feeding on different food plants. The present results show slightly affected egg length by feeding on *T. alexandrinum* ($P>0.05$) but remarkably affected one by feeding on *L. sativa* ($P<0.01$). On comparing with feeding on *V. faba*, also, no difference was observed for the egg width after feeding on *T. alexandrinum* or *L. sativa*. For explaining the effect of food quality on the egg dimensions, the available literature is scanty albeit Ghoneim et al. (1994a) reported insignificantly affected egg dimensions for the grasshopper *E. plorans* by feeding on various food plants. After feeding of female epilachna beetle *E dodecastigma* on four host plants, they laid eggs on all tested plants with the longest length and width on teasel gourd *M. dioica* but the lowest was in yardlong bean *V. sesquipedalis* (Hossain et al., 2009). On the contrary, no effect was reported for the egg size after feeding of the tropical butterfly *B. anynana* on different diets (Geister et al., 2008). Unfortunately, we have no reliable interpretation to the affected egg length of the present beetle *M. proscarabaeus* by the tested food plants rightnow!!

Depending on the present results for *M. proscarabaeus*, the egg hatchability (fertility) was higher by feeding on *T. alexandrinum*, but lower by feeding on *L. sativa*, as compared to fertility after feeding on *V. faba*.

The effect of food quality on fertility of *M. proscarabaeus*, as obviously seen, can be substantiated by similar results reported for insect species outside the family Meloidae. Feeding of *E. plorans* on *Z. mays* severely arrested the egg hatching but feeding on *V. faba* or *T. alexandrinum* promoted the adult females to produce more viable eggs (Ghoneim et al., 1994a). Feeding of the butterfly *B. anynana* females on banana enhanced the egg hatching success, among other diets (Geister et al., 2008).

On the other hand, feeding of female epilachna beetle *Epilachna dodecastigma* on four host plants, no significant effect on egg hatching was recorded (Hossain et al., 2009). As aforementioned interpretation of the affected fecundity of *M. proscarabaeus*, in the current study, the arrested egg hatching or the reduced fertility can be associated with the nutritional values of the food plants or be attributed to the efficiency of the beetle itself to convert the digested food into vitellogenin requirements for the vitellogenesis.

Embryonic development

The incubation period of eggs can be used as an informative indicator to the embryonic developmental rate. Therefore, the present results may show some effects of the maternal food plants on the embryonic developmental rate in the eggs. Prominently shortened incubation period ($P<0.01$) was determined after parental feeding on *T. alexandrinum* but markedly prolonged period ($P<0.001$) of *M. proscarabaeus* was recorded after feeding on *L. sativa*, as compared to that recorded period after feeding on *V. faba*. Although the incubation period in the present study on *M. proscarabaeus* ranged from 13.55 to 24. 13 days (at 23±2°C, 46±10% RH), the reported range for some other blister beetles was almost contradicted since *Zonilis immaculate* had 4 weeks under normal field conditions and some other blister beetle species take 5 months during colder seasons or overwinter in the egg stage (egg diapause). Also, eggs of *L. nuttalli*, *L. viridana* and *L. cyanipennis*, in the field, develop fairly uniformly at temperatures 15 -30 ^{o}C and appeared to take 2-3 weeks as incubation period (Church and Gerber, 1977). On the other hand, a near range of incubation period of the present beetle species, *M. proscarabaeus*, was recorded in the field with minimum of 23 days (at 17°C, 30% RH) and maximum of 30 days (at 21°C, 36% RH)(El -Shiekh, 2007). Literature, however, contains several reports for the affected incubation period by feeding on different host plants. Females of the epilachna beetle *E dodecastigma* laid eggs on all tested host plants but the longest incubation period was recorded on bitter gourd *M charantia* and shortest on yard long bean *V. sesquipedalis* (Hossain et al., 2009). The shortest incubation period of the spiny bollworm *E. vittella* was recorded on okra and China rose, while the longest incubation period was recorded on *Abutilon indicum* as host plant (Syed et al., 2011).

However, the present findings do not coincide with other reports of the incubation period in some other blister beetles which may be due to the species differences, the varied environmental conditions or the differed host plants. It should be mentioned that food plants affected the embryonic developmental rate in the eggs produced by the present beetle, *M. proscarabaeus*, since feeding of parents on *T. alexandrinum* resulted in faster rate but feeding on *L. sativa* resulted in slower rate than that recorded after feeding on *V. faba*.

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