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Evaluation of various diets and oviposition substrates for rearing *Orius albidipennis* Reuter

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Abstract

A suitable diet and oviposition substrate are two basic needs for successful mass rearing of *Orius* spp. and this may reduce their production costs. The effect of various foods containing eggs of *Ephestia kuehniella* and *Sitotroga cerealella* with various pollens were investigated on the biological parameters of *O. albidipennis* in the laboratory. Moreover, survival, hatching rate and fecundity of the predatory bug on various natural substrates were compared. Nymphal developmental time of the bug on diets including *E. kuehniella* and *S. cerealella* varied from 13 to 14.2 and 14 to 15.3 days, respectively. The nymph and adult survival and consumption rate were not significantly affected by the dietary treatments. Because of a more rapid development with food containing eggs of *E. kuehniella*, they are the best nymphal diets for mass rearing of *O. albidipennis*. It must be noted that *S. cerealella* eggs are six times cheaper than *E. kuehniella* eggs. Therefore, the foods containing eggs of *S. cerealella* may be more economic for mass rearing of the bug despite a slower development of nymphs that fed on them. Also, composition of *S. cerealella* and date palm pollen is the most suitable diet for mass rearing of *O. albidipennis* adults due to a higher fecundity and longevity of the adults and lower costs of the diet. Female longevity, total eggs and hatching percentage of the predatory bug on *Sedum ternatum* were significantly higher than other natural substrates. These results may have practical implications for mass rearing of *O. albidipennis* as part of a biological control program.

Key words: minute pirate bug; diet; oviposition substrate; mass rearing; biological control

چکیده

ارزیابی جیره‌های غذایی و بسترهای تخم‌گذاری مختلف برای پرورش سن شکارگر *Orius albidipennis* Reuter

نسترن صفایی، علی رجب‌پور و علی‌اصغر سراج

یک جیره غذایی و بستر تخم‌ریزی مناسب دو نیاز اساسی برای پرورش انبوه موفق گونه‌های جنس *Orius* spp. می‌باشد که می‌تواند هزینه‌های تولید آنها را کاهش دهد. تأثیر جیره‌های غذایی مختلف حاوی تخم‌های بید آرد و بید غلات به‌صورت مخلوط با گرده‌های گیاهی مختلف روی پارامترهای زیستی *O. albidipennis* در آزمایشگاه مورد مطالعه قرار گرفت. هم‌چنین، نرخ بقاء، نرخ تفریخ و زادآوری این شکارگران روی بسترهای طبیعی مختلف تخم‌ریزی مقایسه شد. طول دوره رشد پوره‌های این سن روی جیره غذایی شامل تخم بید آرد و تخم بید غلات به‌ترتیب از ۱۳ تا ۱۴/۲ و ۱۴ تا ۱۵/۳ روز متغییر بود. نرخ بقای پوره‌ها و بالغین و نرخ مصرف غذایی آنها به‌صورت معنی‌داری تحت تأثیر تیمار غذایی قرار نگرفت. به‌دلیل نرخ رشد بالاتر این سن در جیره‌های غذایی حاوی تخم بید آرد، این نوع جیره‌های غذایی بهترین جیره غذایی برای پرورش دوره پورگی سن *O. albidipennis* بود. قابل ذکر است که تخم‌های بید غلات حدود شش برابر ارزان‌تر از تخم‌های بید آرد هستند. بنابراین شاید تخم‌های بید آرد علی‌رغم سرعت رشد کم‌تر پوره‌های تغذیه‌کننده از آنها، از نظر اقتصادی برای پرورش سن‌های *O. albidipennis* مقرون به صرفه‌تر باشند. هم‌چنین ترکیب تخم بید غلات و گرده ذرت به‌دلیل زادآوری بالاتر و طول عمر بیش‌تر و هم‌چنین قیمت ارزان‌تر، مناسب‌ترین جیره غذایی برای پرورش بالغین *O. albidipennis* بود. طول عمر ماده‌های بالغ، تعداد کل تخم‌گذاری و نرخ تفریخ سن‌هایی که روی گیاه نازگوشتی فعالیت کرده بودند به‌صورت معنی‌داری بیش‌تر از سایر بسترهای تخم‌ریزی مورد مطالعه بود. نتایج این تحقیق می‌تواند دارای کاربردی عملی برای پرورش انبوه *O. albidipennis* به‌عنوان بخشی از برنامه کنترل بیولوژیک توسط این شکارگر باشد.

واژگان کلیدی: سن شکارگر، جیره غذایی، بستر تخم‌ریزی، پرورش انبوه، کنترل بیولوژیکی

Introduction

Orius spp. (Hemiptera: Anthocoridae) are important predators of economically major pests (Lattin, 1999) such as thrips (Tommasini et al., 2004), mites, aphids (Akramovskaya, 1978), pentatomid eggs (Pericart, 1972) and whiteflies (Stansly, 2010). *Orius albidipennis* Reuter is a common predator in many regions of Iran and has been shown to have a potential as a biological control agent under field and greenhouse conditions (Dehghani Zahedani et al., 2011). *O. albidipennis* is an ideal choose for mass rearing for biological control programs in subtropical and tropical zones because of its capability to tolerate high temperatures and the lack of photoperiod-induced diapauses (Sobhy et al., 2010).

Mass rearing of insect biological control agents needs special methods and adaptations in comparison with small-scale rearing in laboratory (Panizzi & Parra, 2012). Mass rearing methods for *Orius* continue to improve, with decreasing cost and increasing efficiency of production as primary goals (Shapiro & Ferkovich, 2006).

In the current mass rearing methods for *O. albidipennis* and many other *Orius* bugs, eggs of *Ephestia kuehniella* Zeller are used as the diet (Bonte & De Clercq, 2010). Omnivore predators often benefit from or even require pollen as part of their diet. Survival and fecundity of the insects can be improved by feeding on plant pollen as alternative food resource (Wong & Frank, 2013). For example, when *E. kuehniella* eggs were supplemented with pollen, total fecundity and longevity of *O. albidipennis* significantly increased (Cocuzza et al., 1997). Pollen obtained from different plant species differ in nutritional value (Lundgren, 2009) and so its effects on developmental time and fecundity of the predators can be different.

Orius predatory bugs use plant tissues as substrates for oviposition. The bugs insert their eggs into plant tissue using an ovipositor. Furthermore, the bugs feed on xylem and mesophyll contents to ingest water and small amounts of other nutrients from the plants. Therefore, the plant tissues could influence the survival of *Orius* offspring (Bonte & De Clercq, 2010). A suitable ovipositional substrate is crucial for successful mass rearing of *Orius* predatory bugs. A green bean pod, *Phaseolus vulgaris* L., is usually used as oviposition substrate for mass rearing *Orius* spp in commercial insectaries. Reliance on fresh bean as an ovipositional substrate in colony maintenance of the bugs can cause problems because of its limited seasonal availability and its potential for introducing pathogens. Moreover, pesticide residues may be a disadvantage of using bean pods (Castane & Zalom, 1994). When humidity is high enough to ensure egg hatching (>70% R.H.), the bean pods often become mouldy and decompose before *Orius* eggs have completed their development. In this situation, if hatching does occur, the first instar nymphs can get caught in the mycelium or condensation and are unable to feed (Richards & Schmidt, 1996a).

Presence of alternative food resources and oviposition substrates may cause reduction in production costs of natural enemies (Bonte & De Clercq P. 2008). The suitability of different diets for *Orius* spp. could be evaluated by comparing their development time, survival and fecundity (Yano et al., 2002)

The aim of this study consists of two parts. First, a comparison and selection of some lepidopteran eggs (*E. kuehniella* and *Sitotroga cerealella* Olivier) and various plant pollens (corn, sunflower, date palm and bee collected pollen) as the best diet for mass rearing of *O. albidipennis*. Second, the evaluation of various natural substrates as ovipositional substrate for mass rearing of the bugs.

Materials and methods

Insect collection

O. albidipennis, were collected from unsprayed open corn fields. Females were isolated in a Plexiglas cylinder container (18 cm high, 7.5cm diameter) covered with a fine gauze lid on the top and margin for ventilation. At least one male was selected from the offspring of each female, which was then identified by using Pericart's keys (1972).

Diet experiments

Frozen eggs of *E. kuehniella* and *S. cerealella* were used as factitious preys. The eggs were supplied by Khuzestan's plant protection organization. Different pollens obtained from corn (*Zea mays* L.), sunflower (*Helianthus annuus* L.), date palm (*Phoenix dactyliferal* L.) and commercial bee pollen granules (BCP) were separately used with each factitious prey. Because of the effect of pollen moisture on the growth of moulds in the rearing container, the pollen was dried at 50 °C for 24 hours in an oven. BCP granules were milled using the Moulinex coffee grinder AR100G161.

Fifty eggs of each factitious egg were attached to a piece of filter paper (7 × 2 cm). Each experimental pollen (0.1g) was added to this paper and was placed in each rearing container. In addition, a piece of bean pod (3 cm) was placed (inside each rearing container) to provide water and an ovipositional substrate for the predatory bugs. The bean pod and the diet paper were replaced every day. The Plexiglas cylinders were lined with crumpled papers to provide a hiding place to rest and reduce cannibalism. All experiments were performed in an incubator set as 25 ± 1 ºC, 60 ± 5% RH, and 16: 8 h (L: D).

To determine the effect of different diets on the nymphal life stage, ten first instar nymphs (6 hours old) were placed in each rearing container with a diet paper and a piece of a bean pod. The rearing container and the diet paper were checked every day. Mortality, life stages of the bugs and numbers of eaten eggs were recorded until adult emergence. Based on these data, survival%, consumption rate and developmental time of each nymphal stage were estimated. After adult emergence, sex ratio, survival longevity, number of eggs (per female/day) and oviposition duration were recorded. Each treatment (diet) had fourteen replications.

Ovipositional substrate experiments

Leaves of *Sedum ternatum* Michx. (Crassulaceae), *Pelargonium hortorum* L. and *Portulaca oleraceae* L. (Portulacaceae) and bean (*Phaseulus vulgaris* L.) pods were used as natural ovipositional substrates. Two leaves with the same diameter of *S. ternatum* and *P. oleraceae*, one leaf (3 cm in diameter) of *P. horterum* and a piece of bean pod (5 cm) were used in the experiments.

A diet paper (100 eggs of *E. kuehniella* and 0.1 g of corn pollen) was placed with each ovipositional substrate in a petri-dish (diameter = approximately 14.5 cm) covered by a lid with a hole sealed with gauze. A mated female of *O. albidipennis* (48 hours old) was introduced in each petri-dish. The diet paper and ovipositional substrate were replaced every day and longevity, number of eggs and hatching percentage of the bug were recorded until death of the last bug. Each treatment had fourteen replications.

Data analysis

Statistical comparisons were conducted by analysis of variance (ANOVA). The data were transformed log + 1 prior to analysis for normalizing their distribution. Survival percentages in various treatments were compared by ANOVA with the general linear model (GLM) procedure. The sex ratio was tested for deviation from 1:1 using a Chi Square, Goodness of Fit test ($P \leq 0.05$). All analysis was conducted using SPSS 16.0 (SPSS Inc. Chicago, Il).

Results

Diet experiments

Nymph and adult developmental times of *O. albidipennis* fed on the experimental diets are presented in table 1. A significant difference was observed between nymphal developmental times where nymphs were fed on various diets (df = 7, 111; F = 3.47; P = 0.04). Nymphal developmental time in diets with *S. cerealella* was significantly longer than diets including *E. kuehniella* eggs. Nymphal developmental time of the bug on diets including *E. kuehniella* and *S. cerealella* varied from 13 to 14.2 and 14 to 15.3 days, respectively. Male longevity of the bug had no significant difference (df = 7, 111; F = 1.73; P = 0.228) but female longevity when fed on *E. kuehniella* egg + corn pollen was significantly higher than with other diets (df = 7, 111; F = 7; P < 0.001) (Table 1).

Survival percentages of *O. albidipenis* reared on the various diets were not significantly different in nymph (df = 7, 111; F = 1.14; P = 0.33) and adult (df = 7, 111; F = 0.02; P = 0.96) life stages. The same results were obtained for adult bugs (Table 1). Nymph and adult consumption rates of *O. albidipennis* on the diet treatments were not significantly different (df = 7, 111; F = 0.599; P = 0.815 and df = 7, 111; F = 0.76; P = 0.86, respectively) (Table 2). The consumption rates varied from 7.6 to 11 and 9.1 to 16 in nymphs and adults, respectively.

Female sex ratio, number of eggs (per female/day) and oviposition duration of *O. albidipennis* fed on various diet treatments are shown in table 3. The female sex ratio in diets consisting of corn pollen and a combination of *E. keuniella* and date palm pollen was significantly higher than 0.5 (χ^2 = 24.3; df = 1; p 0 < 001).

Table 1. Mean developmental time (day) ± SE of *O. albidipennis* fed on various experimental diets.

Diet	Mean developmental time			Survival%	
	Nymph	Male adult	Female adult	Nymph	Adult
E.kuehniella + BCP	13.7 ± 0.6bc	20 ± 0.5a	21.5 ± 0.8ab	50 ± 1.5a	35.71 ± 1.5a
S.cerealella + BCP	14 ± 0.2ab	19.5 ± 0.5a	21 ± 0.5b	42.8 ± 1.5a	42.8 ± 1.5a
E.kuehniella + corn pollen	14.2 ± 0.4ab	21.5 ± 0.2a	24.5 ± 0.5a	50 ± 0.5a	42.8 ± 1.5a
S.cerealella + corn pollen	15.2 ± 0.2a	22 ± 0.9a	22 ± 0.5b	57.1 ± 0.7a	57.1.8 ± 0.7a
E.kuehniella + sunflower pollen	13 ± 0.3c	22 ± 0.53a	24 ± 0ab	50 ± 1.7a	35.7 ± 1.7a
S.cerealella + sunflower pollen	15.3 ± 0.5a	21 ± 0.02a	23 ± 0.5ab	42.8 ± 1.5a	35.7 ± 1.5a
E.kuehniella + date palm pollen	13.2 ± 0.6bc	22 ± 0.2a	24.5 ± 0.2a	57.1 ± 0.5a	50 ± 0.7a
S.cerealella + date palm pollen	14.3 ± 0.2ab	22 ± 0.5a	23.5 ± 0.2a	42.8 ± 1.5a	35.7 ± 1.5a

*The means followed by same letters in each column are not significantly different (P < 0.05, LSD).

Table 2. Nymph and adult mean consumption rates (eggs) ± SE of *O. albidipennis* on various diets**.**

Diet	Nymph	Adult
E.kuehniella + BCP	11 ± 1.5a*	12 ± 2.6a
S.cerealella+ BCP	9.1 ± 1.7a	14.6 ± 4.5a
E.kuehniella + corn pollen	10.4 ± 0.6a	15 ± 2a
S.cerealella + corn pollen	10 ± 0.9a	14.4 ± 1.7a
E.kuehniella + sunflower pollen	7.6 ± 1.2a	9.1 ± 9.4a
S.cerealella + sunflower pollen	10.5 ± 2.3a	13 ± 2.3a
E.kuehniella + date palm pollen	11.2 ± 1.2a	16 ± 2.9a
S.cerealella + date palm pollen	8.8 ± 8a	11.7 ± 2.1a

*The means followed by same letters in each column are not significantly different (P < 0.05, LSD).

Table 3. Sex ratio, number of eggs (per female/day) and oviposition duration of *O. albidipennis* fed on various diets treatments.

Diet	Sex ratio ± SE (Female no. /male no.)	Mean Total number of eggs (per female/day) ± SE	Oviposition duration (days) ± SE
E.kuehniella + BCP	0.57	100.5 ± 2 bc	20.4 ± 0.29b
S.cerealella + BCP	0.57	89.4 ± 2.8d	19.8 ± 0.3b
E.kuehniella + corn pollen	0.71	113.57 ± 2.6a	24.4 ± 0.6a
S.cerealella + corn pollen	0.71	93.5 ± 1.7cd	22.4 ± 0.3a
E.kuehniella + sunflower pollen	0.42	57 ± 2.5 e	22.1 ± 0.4a
S.cerealella + sunflower pollen	0.57	94.5 ± 1.2 cd	22.8 ± 0.6a
E.kuehniella + date palm pollen	0.71	112.6 ± 2.1 a	21.8 ± 0.6a
S.cerealella + date palm *pollen*	0.57	108.1 ± 1.9 ab	21 ± 0.3 a

*The means followed by same letters in each column are not significantly different (P < 0.05, LSD).

Table 4. Female longevity, total eggs and hatching percentage of *O. albidipennis* on various natural ovipositional substrates.

Ovipositional substrate	Female longevity	Total eggs	Hatching %
pod of *P. vulgaris*	30 ± 0.2b*	104.4 ± 2.6b	67.9 ± 2.7bc
leaf of *Sedum ternatum*	30.5 ± 0.8a	145.2 ± 3.8a	84.9 ± 4a
leaf of *P. hortorum*	23.2 ± 0.8c	70.2 ± 4c	56.7 ± 3.3c
leaf of *P. oleracea*	29.6 ± 1.4b	97.8 ± 3.4c	76.4 ± 3.9b

*The means followed by same letters in each column are not significantly different (P < 0.05, LSD).

The dietary treatment significantly affected total egg numbers and oviposition duration of female adults (df = 7, 111; F = 8.73; P < 0.001). The best oviposition was observed in *E. keuniella* + corn and date palm pollen treatments. Total eggs in diets that included *E. kuehniella* eggs were more than in diets with *S. cerealella* eggs.

Ovipositional substrate experiments

Significant differences were observed in female longevity (df = 3, 55; F = 27.8; P < 0.0001), total eggs (df = 3, 55, F = 44.4; P < 0.0001) and hatching percentage (df = 3, 55; F = 12.9; P < 0.0001) of *O. albidipennis* on the natural ovipositional substrates.

Female longevity, total eggs and hatching percentage of the predatory bug on *S. ternatum* were significantly higher than on other natural substrates.

Discussion

Our results showed that nymphal developmental time and adult longevity were significantly affected by the diets. The shortest nymphal developmental time or the highest adult longevity were observed in bugs that fed on diets containing eggs of *E. kuehniella*. Similar results were reported by Vacante et al. (1997). The estimated nymphal developmental time was different from what obtained by Sobhy et al. (2010). This finding is in contrast with the reported nymphal developmental time of *O. insidiosus* on *S. cerealella* eggs (12±0.23 days) at 25 ^{0}C (Avellaneda et al., 2013). This result implicated that *S. cerealella* had undesirable effects on the developmental rate of nymphs. The shortest nymphal developmental time was related to *E. kuehniella* + sunflower pollen treatment. Although the nymph of the bug completed its development on all tested diets, but not all of the diets were equally suitable for its development. Reported developmental time of different *Orius* spp. varied considerably according to the kind of food provided (Richard and Smith, 1996b; Vacante et al., 1997; Sobhy et al., 2010). Vacante et al. (1997) demonstrated that the developmental time of *O. albidipennis* and *O. laevigatus* Fieber was strongly affected by the kind of lepidopteran eggs and plant pollen in the diet administered. It was reported that *O. albidipennis* on *E. kuehniella* eggs had a shorter nymphal development time than on *Tetranychus urticae* Koch and *Trialeurodes vaporarium* Westwood eggs and *Gynaikothrips ficorum* Marchal as factitious preys (Sobhy et al., 2010).

In contrast of male longevity, female longevity was significantly affected by the diets. The highest female longevity was observed in food containing *E. kuehniella* egg + corn pollen. The adult longevity of *O. albidipennis* obtained in this study was relatively different from that of *O. albidipennis* found by Cocuzza et al. (1997) (26 to 33 and 19 to 38 days for male and female, respectively) and Sobhy et al. (2010) (17.5-19 days), and from that of *O. sauteri* by Yano et al. (2002) (13.3 to 17.6 and 13.6 to 18.3 days for male and female, respectively). The longer adult longevity could be due to different diets, experimental conditions and predatory bug species in our study and the mentioned papers. Results similar to our study have been reported by van den Meiraker (1999) who showed that adult longevity of *O. albidipennis* fed on *E. kuehniella* eggs and fresh pollen was 20.5 days. Our results are in agreement with Cocuzza et al. (1997). They stated that diet compositions of *O. albidipennis* have no significant effect on male but female longevity is strongly affected by them.

Nymphal and adult survivals were not significantly different in the tested treatments. The effect of rearing diets on the survival of *Orius* spp. was noted by some researchers (Cocuzza et al., 1997; Richards & Schmidt, 1996a; Yano et al., 2002). Our result is similar to most other studies comparing the survival of *Orius* spp. fed on a combination of *E. kuehniella* with corn pollen versus other diets (Richards & Schmidt, 1996b; Vacante et al., 1997). The high quality of Lepidopteran eggs is likely related to their relatively high nitrogen content (Sobhy et al., 2010). Ferkovich et al. (2007) stated that the protein concentration in *E. kuehniella* eggs is higher than in other Lepidopteran eggs. It could contribute to a greater survival of *O. albidipennis* fed on the diet. The survival percentage of *O. insidiosus* fed on *S. cerealella* (Avellaneda et al., 2013) agrees with our result.

The consumption rate of the predatory bug was not significantly affected by the factitious eggs in its diet. The difference in the consumption of prey may be related to the nutritional quality of the prey. Mendes et al. (2002) showed that type of prey influences the consumption rate of *Orius insidiosus* Say. The consumption rate of the bug nymphs on *E. kuehniella* (37.03 eggs/nymphal stages) was significantly lesser than other tested diets, adults of *Caliothrips phaseoli*

Hood and nymphs of *Aphis gossypii* Glover (Mendes et al., 2002). The consumption rate of *E. kuehniella* eggs in our study was lower than the results obtained by Mendes et al. (2002). The lesser consumption rate of *E. kuehniella* in our study may have occurred as a function of the higher nutritional quality due to adding plant pollen. Supplementing a diet of animal prey with plant foods has been found to enhance development and reproduction in *Orius* predatory bugs (Cocuzza et al., 1997). *O. albidipennis* attempts to fulfill the nutritional gap caused by the low quality of the prey by increasing its consumption; however, a greater consumption is not due to a higher fecundity or longevity of the predatory bug (Mendes et al. 2002).

In nymphal diets, foods containing corn pollen and a combination of *E. keuniella* and date palm pollen cause a significantly higher female sex ratio. The female sex ratio of *O. insidiosus* fed on *S. cerealella* is 0.75 (Avellaneda et al., 2013). Similarly, the sex ratio of *O. laevigatus* is different according to its nymphal diet (Arijs & De Clercq, 2001). Conversely, Bonte et al. (2012) found that the sex ratio of *O. insidiosus* is not affected by the kind of diet.

Our finding suggests that the egg of *E. kuehniella* was better than that of *S. cerealella* for bug reproduction. Several studies have shown that *E. kuehniella* eggs constitute a nutritionally superior food for *Orius* bugs. Therefore, the diet causes more fecundity in many cases (Bonte & De Clercq, 2008; Bonte et al., 2012; Cocuzza et al., 1997; Ferkovich & Sapiro, 2005). Ferkovich & Sapiro (2005) stated that the fecundity of *O. insidiosus* is increased with the addition of a specific fraction of *E. kuehniella* egg proteins that are separated by isoelectric focusing. Moreover, some studies indicated that fat (Declercq et al., 2005) and amino acid (Specty et al., 2003) contents of *E. kuehniella* eggs are higher than in other preys, which contribute to the greater fecundity with this diet. Sobhy et al. (2010) reported that total fecundity of *O. albidipennis* fed on *E. kuehniella* is 1.6-2.7 times more than with other diets. The total fecundity of *O. insidiosus* fed on *S. cerealella* (60.29 eggs per female) is lesser than the present study. It may be due to adding pollen to the prey or to the natural reproductive difference of the two *Orius* species.

In addition, the oviposition duration of *O. albidipennis* was significantly different. The parameter varied from 19.8 to 24.4 in *S. cerealella* + BCP and *E. kuehniella* or *S. cerealella* + corn pollen, respectively. In contrast of total egg numbers, it seems that the oviposition duration is more affected by plant pollen than the egg's species. Vacante et al. (1997) described that *O. albidipennis* may derive some nutrients from pollen and this adaptation may permit populations of the bug to persist in a crop also in the absence of prey.

Among the tested substrates, the least female longevity, total eggs and hatching percentage were observed with the leaf of *P. hortorum*. Sobhy et al. (2005) showed that the bean pod is the best suitable ovipositional substrate for *O. albidipennis* among other tested substrates (not completely grown corn cob, small potted sweet pepper seedling and geranium leaves). Similarly, mean total laid eggs and their hatchability are significantly different in various ovipositional substrates that agree with our results. A similar conclusion was also reached by Richards & Schmidt (1996a) for *O. insidiosus*. In contrast, van den Meiracker (1999) reported that the fecundity of *O. insidiosus* and *O. albidipennis* on the geranium leaves as an ovipositional substrate is relatively higher than other substrates such as bean pods. He suggested that geranium leaves are probably more susceptible to desiccation and impairment than bean pods. *S. ternatum*, which is a cheap vegetable, is a suitable candidate for mass rearing of *O. albidipennis* and could be replaced with bean pods. The substrate plant is not only important for the oviposition process, but should also be suitable for the nutritional maintenance of females during periods of prey scarcity or for supplemental water. The moisture retention level of the substrates was one of the characteristics that affected oviposition preference of various substrates by *Orius* females. Observed differences in oviposition, hatchability and longevity of *O. albidipennis* on various substrates may be related to their different nutritional and moisture levels. Tan et al. (2014) stated that chemical composition and nutrition in plant substrates play important roles in oviposition and fecundity of *Orius* bugs. Moreover, plant substrates could be distinguished by the female bugs according to the toughness of their external tissues. The plant substrates that have the thinnest external tissue are preferred for egg laying by the females.

The longevity and fecundity of *Orius* species fed on *E. kuehniella* eggs had been studied using Spanish pepper plants (Cocuzza et al., 1997; Vacante et al., 1997), geranium leaves (Alauzet et al., 1994) and bean pods (Tommasini & Nicoli, 1993) as ovipositional substrates. In most cases, the average total fecundity and longevity of *O. laevigatus*, *O. majusculus* and *O. insidiosus* was between 100 and 200 eggs. In contrast to our finding, Tan et *al*. (2014) reported that female longevity of *O. sauteri* is not significantly different when various plants were used as its shelter (Table 4).

Conclusion

Because of the rapid development in diets containing *E. kuehniella* eggs, they are the best nymphal diet for mass rearing of *O. albidipennis*. It must be noted that *S. cerealella* eggs are six times cheaper than *E. kuehniella* eggs. Therefore, the diets consisting of *S. cerealella* may be more economic for mass rearing of the bug despite the lower survival and development of nymphs that fed on them. Furthermore, the composition of *S. cerealella* and date palm pollen is the most suitable diet for mass rearing of *O. albidipennis* adults due to a higher fecundity and longevity and lower costs of the diet. Our survey showed that a lower mould growth was observed in the diets consisting of date palm pollen. Hence, date palm pollen, that is cheap and available in tropical regions, is a good alternative food for *O. albidipennis* in mass rearing programmes. Our finding indicated that *S. ternatum* leaves are the best ovipositional substrate for mass rearing of the bug. The cheap herb could be replaced by commercial substrates, especially bean pods.

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