LABORATORY EVALUATION OF *SPHODROMANTIS VIRIDIS* FORSKAL (MANTODEA, MANTIDAE) AS PREDATOR OF THE LOCUST, *SCHISTOCERCA GREGARIA* FORSKAL (ORTHOPTERA, ACRIDIDAE).

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(Received 12.12.2005)

INTRODUCTION

The desert locust *Schistocerca gregaria* Forskal is well known in much of Africa and Asia for its potential to cause complete crop losses at the local level within hours of its arrival in swarms. Usually, the desert locust is a solitary insect that occurs at low levels. Locust is cited as pest of many plants as pome fruits, sugar beets, Cucurbitaceae, Leguminosae, Cruciferae and Solanaceae (Talhouk, 1969; Procter, 1961; Bullen, 1966; Chandra *et al.*, 1985 and Culmsee, 2002).

The desert locust, *S. gregaria* change phase in response to population density: "solitarious" insects avoid one another, but when crowded they shift to the gregarious phase and aggregate. This individual-level process is the basis for population-level responses that may ultimately include swarm formation (Heifetz *et al.*, 1996, Simpson *et al.*, 1999 and Despland *et al.*, 2000).

Control of grasshoppers and locusts has traditionally relied on synthetic insecticides, and for emergency situations this is unlikely to change. However, a growing awareness of the environmental issues associated with acridid control as well as the high costs of emergency control are expanding, the demand for biological control strategies with early interventions could reduce the financial and environmental costs associated with large scale plague treatments (Lomer *et al.*, 2001). To lessen dependence on chemicals, an integrated pest emphasis on biological control as an important component and this is also desirable elsewhere, but additional biocontrol components are needed. Current strategies for most pest acridoid rely on short-term destruction of outbreak population (Prior and Streett, 1997).

Sphodromantis viridis Forskal is highly predacious and feed on a variety of insects including moths, grasshoppers and flies (Roeder 1963, Hurd and Rathet, 1986 and Paradise and Stamp, 1991). For this, *S. viridis* considered as a generalist predators. Recently, the role of generalist natural enemies as pest control agents has become a subject of increasing interest in conservation or augmentation biological control (Settle *et al.*, 1996; Cheng and Karevia, 1999; Symondson *et al.*, 2002 and Ostman, 2004). An important first step in biological control is to evaluate the efficacy of natural enemies in the laboratory before using and releasing (DeBach and Bartlett, 1964). Evaluation is important because it examines the values and weaknesses of natural enemies and their efficacy in controlling a pest insect (DeBach *et al.*, 1976)

The present study was principally carried out to determine the consumption and predation rate of *S. viridis* adults on the desert locust, *S. gregaria* at different prey densities, referring to the most preferable prey stage to the predator.

MATERIAL AND METHODS

Sources of the desert locust and preying mantid

The desert locust, *S. gregaria* was obtained from parents reared in the Department of Entomology, Faculty of Science, Cairo University for many years. Rearing of *S. gregaria* was carried out under constant temperature of 25 ± 2° C and 65 ± 5 RH, with 13: 11 [L: D]. Nymphs and adults of the locust were reared in cages of 60 x 60 x 50 cm, provided with a constant diet of one of the food plant species commonly occurring in habitats. The food plants used were the crop plants *Sorghum* sp. and Egyptian clover, *Trifolium alexandrinum* L. The predator mantid, *S. viridis* was collected firstly as egg cases (oothecae) from *Acacia* trees. The egg cases were placed in plastic containers (12 x 9 x 5 cm) and kept moistened with wet paper towels untill hatching. The hatching nymphs were reared singly, each in plastic cup (20 x 20 x 15 cm). The newly formed adults were transffered to experimental cage (40 x 40 x 30 cm, one individual / cage). According to Zohdy and Younes (2003), small nymphs of *S. viridis* could not devour insects bigger than *Drosophila melanogaster*, so they were reared during the first three nymphal stages on *D. melanogaster* only. Starting from the fourth nymphal stage, predator nymphs were able to exploit preys of bigger sizes; hence at that stage they were provided with *Musca domestica* or even young nymphal stages of *S. gregaria*. The last nymphal stage and adults of the predator were provided with different ages of *S. gregaria*. Preliminary tests indicated that the predator females are most predacious than males, so adult *S. viridis* females were used in all experimental assays.

Consumption and predation rate determination

S. viridis adults, within 24 hour of moulting, were obtained from the laboratory colony. The predators were starved for 24 hours. Prey consumption and predation rate were assessed by placing a single adult predator female with a sufficient number of 1st, 2nd, 3rd, 4th or 5th nymphal stage, also the same assessed were obtained with adult male or female of *S. gregaria*. The tests were conducted for 24-hour period with five replicates for each experiment. At the end of the experiment, firstly the number of preys consumed by the predator was calculated and then the mean number of preys consumed / day were calculated. The rate of predation / day were calculated as follows: predation rate (%) = [(a-b) / a] x 100, where (a) is the number of introduced preys, (b) is the number of survived preys after the experimental period. Dead preys during the experiment were removed from the total count.

Effect of prey density on the predation rate

Effect of prey density on the predation rate was determined using 1st, 2nd, 3rd, 4th and 5th nymphal stage as well as adults of *S. gregaria*. The predator was provided with 5, 10, 15, 20, 25, 30, 35, or 40 preys / day. The mean number of preys consumed and so the predation rates of each case were calculated as mentioned above.

Prey preference

The prey preference was conducted by offering all *S. gregaria* stages to the predator. Five individuals from each nymphal stage or adult stage were offered / one predator/day. The mean number of preys consumed from each stage were calculated and then the predation rates were calculated. The experiment were repeated 10 times.

Statistical analysis

Data were analyzed using multivariate repeated measures ANOVA in SAS and Tukey's student range test for means separation (Anonymous, 1990).

RESULTS AND DISCUSSION

Prey consumption and predation rate of *S. viridis* on nymphs and adults of *S. gregaria*

Data obtained in table (1) shows the daily prey consumed and the predation rate of the mantid on both nymphs and adults of the locust. Prey consumption was marginally reduced when the 1st nymphal stage was present. In contrast, the mantid, after 24 hour, ate large numbers of preys when 2nd ,3rd, 4th, or 5th nymphal stages were present. The maximum mean of prey consumed (30 ± 2.03 preys / day) was obtained when *S. viridis* feed on the 3rd nymphal stage of *S. gregaria*.

TABLE (I)

Prey consumed and predation rate of the predatory mantid, *S. viridis* on nymphs and adults of the locust, *S. gregaria*.

The prey	Prey consumed / day Min. - Max.	Mean ± SE	Predation rate (Mean ± SE)
1st nymphal stage	3 - 9	6.5 ± 0.83a	16.3 ± 0.89a
2nd nymphal stage	12 - 24	20.9 ± 1.94b	52.2± 3.7b
3rd nymphal stage	21 - 35	30 ± 2.03c	75 ± 2.1c
4th nymphal stage	24 - 33	27.5 ± 1.38c	68.7 ± 2.7c
5th nymphal stage	25 - 32	26 ± 1.15c	65 ± 2.5c
Adult male	2 - 6	4.2 ± 0.60a	10.5 ± 0.8a
Adult female	2 - 5	3.8 ± 1.16a	9.5 ± 0.7a

Means in the same column followed by the same letter are not significant differ (P > 0.05).

Obtained data also showed that, adult mantid could consume both male and female locust. Statistically , no significant differences (P > 0.05) were obtained comparing the mean number of preys consumed when the mantid feed on 3rd, 4th or 5th nymphal stage. On the other hand, significant difference (P < 0.05) was obtained in comparing the mean number of the 1st or 2nd nymphal stage consumed and those nymphs of the other stages (table 1).Concerning the mean number of adult male and female locust consumed / day, no significant difference (P > 0.05) was obtained, but significant differences were obtained in comparison adults prey consumed with consumed preys of 2nd, 3rd, 4th, or 5th nymphal stage. Considering the predation rate, the maximum predation rate (75 %) was obtained when the mantid fed on locust 3rd nymphal stage. Statistically, significant differences (P < 0.05) were obtained when comparing the predation rate on prey of 3rd, 4th, or 5th nymphal stages with those preys of 1st nymphal stage, adult males or adult females. On the other hand, no significant differences (P>0.05) were obtained between the predation rates on the 3rd, 4th, and 5th nymphal stages. Also no significant difference (P>0.05) was obtained considering the predation rate of the predator on the adult locust males and adult locust females.

The proposed increase in the use of biological control agents based on a national commitment to reduce pesticide reliance is under intense scrutiny due to fears that organisms introduced for biological control purposes may have adverse effects on biodiversity and may contribute to the decline of nontarget species (Simberloff and Stiling, 1996). The introduction of natural enemies for biological control is the only purposeful human activity that has the power to permanently

TABLE (II)

Effect of *Schistocerca gregaria* prey density on the daily consumed preys of *Sphodromantis viridis*.

The prey	Consumed preys / day (mean ± SE) at density							
	5	10	15	20	25	30	35	40
1st nymphal stage	0 ± 0 a	0±0 a	0.8±0.37ac	1.8±0.7ab	3±0.51ab	5.2±0.7bc	6.6±0.35bc	7.2±0.58b
2nd nymphal stage	1.2±0.37a	3.2±0.58a	5.6±0.53a	7.2±0.51ac	11.8±1.2bc	15.2±0.7bd	20±1.1de	21±1.2e
3rd nymphal stage	3.8±0.37a	7.6±0.5ab	10.8±0.56b	15.2±0.7c	18.8±0.5ce	22.2±0.4de	25.2±1.2d	33.2±0.87f
4th nymphal stage	4.8±0.44a	9.4±0.4ab	14±0.58be	17.2±0.6ce	21.2±1.4cd	24.2±0.94d	26.4±0.86f	27±1.4f
5th nymphal stage	4.8±0.44a	9.6±0.24b	14±0.32c	17.8±0.49d	22±0.71de	23.8±0.8e	25.6±0.58f	26.8±0.92f
Adult male	3±0.37a	4.4±0.51a	4.2±0.51a	4.4±0.37a	4.6±0.51a	4.6±0.37a	4.8±0.32a	4.8±0.37a
Adult female	3.4±0.24a	3.4±0.24a	3.8±0.21a	4±0.32a	3.8±0.37a	3.8±0.37a	4±0.31a	4±0.31a

Means in the same raw followed by the same letter are not significant differ (P > 0.05).

TABLE (III)

Effect of *Schistocerca gregaria* prey density on the daily predation rate of *Sphodromantis viridis* at different prey density.

The prey	Prey density							
	5	10	15	20	25	30	35	40
1st nymphal stage	0 ± 0a	0 ± 0a	5.3 ± 2.4a	9 ± 3ab	15 ± 3.5b	17.3±1.3b	18.8 ± 1.4b	18 ± 1.2b
2nd nymphal stage	24 ± 7.4a	32 ±5.8a	37.3 ± 3.5a	39 ± 1.8ab	47 ± 5.1bc	50 ± 2.3cd	58.8 ± 5d	52.5±3.8d
3rd nymphal stage	76 ± 6.2a	76 ± 5a	72 ± 3.9a	76 ± 1.9a	75.2 ± 4.9a	74 ± 2.9a	71.4±2.8a	79.5 ±2.4a
4th nymphal stage	92 ± 4.8a	94 ± 4a	93.3 ± 2.1a	85 ± 3.2ab	84.8±4.3ab	76.8±3.2ab	74.4±3.7ab	68.2±2.7b
5th nymphal stage	96 ± 4a	96 ±2.4a	93 ± 2.1a	89 ± 2.4ac	88 ± 2.8ac	79.3±2.3bc	73 ± 2.7bc	67 ± 2.5b
Adult male	76 ±7.2a	44 ± 5c	28 ± 1.3bc	22 ± 2.5bc	17.6±1.6b	15.3±1.7b	13.7 ± 1.1b	12 ± 0.9b
Adult female	68 ± 4.8a	34 ±2.4c	25.3±1.3bc	20 ± 1.6bc	15.2±1.5b	12.6 ± 1.2b	11.4 ± 0.9b	10 ± 0.7b

Means in the same raw followed by the same letter are not significant differ (P > 0.05).

restore balance to systems that are in ecological decline due to the destructive effects of adventure pest species and that in so doing allows the damaged ecosystem to regenerate and recover once pest densities are reduced (DeBach, 1964; DeBach and Rosen, 1991 and Van Driesche and Bellows, 1996). This study has confirmed that adult mantids have the ability to devour different stages of the locust, *S. gregaria*. The data obtained showed that the prey consumption and so the predation rate were differed according to the prey stage. Also, data showed that, 3rd, 4th, and 5th nymphal stages of the locust were consumed more than the others nymphal stages. This may resulted from that, the adult mantid had difficulties in catching the 1st and the 2nd prey nymphal stages as a result of their sizes which were very small comparing with the adult mantids.

Effect of prey density on consumption and predation rate of the predator

The mean consumption and the average predation rate of adult *S. viridis* were obtained with different prey densities of nymphs and adults of the locust (tables 2 and 3). Prey density had a significant effect ($P<0.05$) on the mean number of prey consumed and the predation rate of all tested nymphal stages tested. The mean number of consumed preys was increased from zero at density of 5 preys to 7.2 consumed preys / day at density of 40 preys in case of the 1st nymphal stage and from 1.2 consumed preys / day to 21 consumed preys / day in case of 2nd nymphal stage. The same results were obtained also with the preys of 3rd, 4th and 5th nymphal stages where the daily prey consumed was increased with increasing the prey densities. Statistically, significant differences ($P<0.05$) were obtained between the mean number of the preys consumed at different densities as shown in table (3). On the other hand, no significant differences ($P>0.05$) were obtained when the mantids predator were fed on different densities of the adult locust males and females.

When a comparison was made between the results obtained considering the mantid predation rate at different prey densities, significanltly fewer predation rates were obtained with the high densities in case of the 4th and 5th nymphal stage and also for preys of adult males or females. The predation rate obtained for example, at the density of 5 preys were 92, 96, 76 and 68 for 4th and 5th nymphal stages and for adult males and females prey, respectively. These predation rates declined to 79.2, 68.2, 67, 12 and 10 % at the densities of 40 preys considering the same previous mentioned prey stages (table 3). Statistically significant differences ($P<0.05$) were obtained between the predation rates of the predator at the lower densities and that of higher densities. On the other hand, an increasing in the predation rates were obtained considering the 1st and the 2nd nymphal stages. The predation rates begin as zero and 24 % at prey density of 5 and then reached 18 and 52.5 % at prey density of 40 preys. Also data obtained in table (3) showed that, the predation rate of the mantid predator feeding on different densities of the 3rd nymphal stages of the locust had no significant differences (P>0.05).

The predatory mantid showed an increase in the daily prey consumption with increased prey density. This was achieved only when the preys were nymphs whereas this did not achieved in case of adults. This was probably because the adult prey (locust) was large in sizes and easily to catched than their nymphs and so the predators take their nutritional requirement from the low density (5 preys / day) and so increasing adult prey density could not increased the number of prey consumed.

TABLE (IV)

Prey preference by the predatory mantid, *S. viridis* among different stages of the locust, *S. gregaria*.

The prey	Prey consumed (mean ± SE) (%)		Daily predation rate (mean ± SE)
1st nymphal stage	0 ± 0 a	0	0 ± 0a
2nd nymphal stage	1.16 ± 0.8b	23.2	3.3 ± 0.26b
3rd nymphal stage	2.5 ± 1.05b	50	7.1± 0.34b
4th nymphal stage	4.6 ± 1.4c	92	13.1± 0.49c
5th nymphal stage	4.1 ± 1.4c	83.2	11.9 ± 0.89c
Adult male	1.8 ± 1.02b	36	5.1 ± 0.12b
Adult female	1.5 ± 0.98b	36	4.3 ± 0.23b

Means in the same column, followed by the same letter, are not significant differ (P > 0.05).

Prey preference

Data obtained in table (4) showed that, mantid predator had a prey preference type when different preys were found in the same area. The adult mantid consumed more preys from the 4th and the 5th locust nymphal stages than the other stages. Statistically, significant differences (P<0.05) were obtained between the mean number of prey consumed or the predation rate / day of both 4th and 5th nymphal stages and the other stages. On the other hand, obtained data showed that, the mantid predator could not prefer the 1st nymphal stage of the locust prey when this was found with different others stages. The mean number of prey consumed and also predation rate obtained for the 1st nymphal stage were zero. Data also showed that, the more preferred preys were 4th, 5th, 3rd nymphal stage, adult male, adult female and then the 2nd nymphal stage, respectively.

Results of the prey preference experiment indicated that, the predator mantid, *S. viridis* had the ability to choose their preys. Prior and Greathed (1989) stated that, biological control programs of locust seek to increase natural enemies through the adoption of more benign farming practices, under the assumption that higher predator densities will lead to more effective pest suppression. It can be concluded that, the predator mantid (*S. viridis*) can be regarded as a biological control agent capable of helping to limit the density of the locust (*S. gregaria*) in the fields when present in sufficient population. The mantids have a high consumption and so predation rate. Thus, quantitative experiments in the fields are required to demonstrate the efficacy of this predator.

SUMMARY

The effectiveness of the predatory mantid, *Sphodromantis viridis* as a natural enemies of the locust, *Schistocerca gregaria* was evaluated in the laboratory. Observations on the consumption and rate of predation on *S. gregaria* showed that, a single female mantid of *S. viridis* consumed an average of 6.2, 20.9, 30, 27.5 and 26 preys / day with predation rate of 16.3, 52.2, 75m 68.7 and 65 % considering 1st, 2nd, 3rd, 4th and 5th nymphal stage of the locust, respectively. Also adult mantid consumed an average of 4.2 locust males and 3.8 locust female/day with a predation rate of 10.5 and 9.5 (%), respectively.

The effect of prey density on the consumption and predation rate of the predator was obtained. A significant increase in the prey nymphal stage consumed was obtained with increasing the nymphal stage density whereas no significant increase was obtained with increasing the adult locust density. For the predation rate, an increase was obtained with increasing the density of 1st or 2nd nymphal stage while a decrease was obtained by increasing the density of 4th or 5th nymphal stage or also increasing the density of adult prey. Significantly, no changes were obtained in the predation rate of the 3rd nymphal stage with the different densities.

When offered a prey mixture of nymphal and adult stages, the predatory mantid showed a preferable prey choices. These results supports the view that the predatory mantid could be a relevant biological control agent against the locust.

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