Asian Journal of Biology

10(2): 34-42, 2020; Article no.AJOB.61719
ISSN: 2456-7124

Meteorus gyrator (Thunberg) (*Hymenoptera*: *Braconidae*) In Egypt: Geographical Distribution and Mass-production

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Authors' contributions

This work was carried out in collaboration between both authors. Author MAG suggested the research idea, designed the experiments, collecting data field, statistically analyzed the data, wrote the manuscript, reviewed data, manages tables, edited and approved the manuscript. Author ARE approved the suggested research idea, made the experiments, collecting and recording data field, preparation of tables, assist in writing and approved the manuscript. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJOB/2020/v10i230105
Editor(s):
(1) Dr. Md. Abdulla Al Mamun, The University of Tokyo, Japan.
Reviewers:
(1) Eduardo Mitio Shimbori, University of São Paulo - ESALQ, Brazil.
(2) Rudra Narayan Borkakati, Assam Agricultural University, India.
(3) Maibam Sharmila Devi, NG. Mani College, India.
Complete Peer review History: http://www.sdiarticle4.com/review-history/61719

Original Research Article

Received 25 July 2020
Accepted 30 September 2020
Published 16 October 2020

ABSTRACT

Background: The larval internal parasitoids in the genus *Meteorus* attack certain lepidopterous larvae in different Egyptian fields. Two species*, M. rubens* and *M. gyrator* were the most abundant species reared from several lepidopterous larval species, which feed on different host plants in the two selected Governorates in Egypt throughout two successive years.
Aim: This work presents a method specifically designed to improve the abundance and the parasitizing potential of *M. gyrator* in open fields to parasitize and develop on a broad range of noctuid's pests by releasing considerable number of the parasitoid adults. Also it deals with some aspects of the basic biology of *M. gyrator* parasitizing *Spodoptera littoralis* and *Autugrapha ni,* as mass-rearing hosts.
Methodology: 1- Population Dynamics

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Biweekly samples of lepidopterous larvae were collected from different host plants in the fields of Giza and Faiyum Governorates, for two successive years (November, 2017 to October, 2019). Collected larvae were confined individually under constant conditions until pupation or the emergence of the internal parasitoid's larvae for pupation.
2- Laboratory Rearing
Cultures of some insect larvae, *Heliothis armigera, Spodoptera exigua*, *Agrotis ipsilon*, *Sesamia cretica*, *S. littoralis* and *Autographa ni* were reared in laboratory under constant conditions to act as hosts for mass-production of the parasitoid, *M. gyrator*.
Results: Obtained results reveal that *A. ipsilon* was the main host of *M. rubens,* it was more abundant in both years and localities of the survey. *Meteorus gyrator* was recorded at fewer numbers; it was reared from *S. littoralis*, *S. exigua*, *S. critica*, *Heliothis* spp. and *Autographa* spp. The parasitism percentage by *M. rubens* averaged 23.10% at Giza. While in the case of *M. gyrator* it averaged 3.25%. In Faiyum, the corresponding figure averaged 12.96% parasitism for *M. rubens*; while it averaged 6.93%, for *M. gyrator*. To increase the efficacy of *M. gyrator*, mass production experiments were carried out, suggesting that *Autographa ni* was the most suitable for mass-rearing than *S. littoralis*.
Conclusion: To increase the efficacy of *M. gyrator* as an endoparasitoid, its numbers in the field should be increased by releasing a considerable number of adults, to control lepidopterous larval pests.

Keywords: Survey; internal larval parasitoids; Meteours spp.; mass-production; Meteorus gyrator.

1. INTRODUCTION

The braconid wasps, *Meteorus* spp. (Hymenoptera, Braconidae) are known worldwide as endoparasitoids for a broad range of lepidopterous pest larvae. These internal parasitoids have an ample host range; it attacks several noctuids, geometrid, and lymantriid pests [1,2,3]. Thompson [4] referenced the wide host-range of *Meteorus gyrator* (Thunberg) as an endoparasitic solitary wasp, which has a wide geographical distribution. Available literature showed a record concerning *M. gyrator* as a larval parasitoid on the gypsy moth, *Ocneria dispar* L. (Family Erebidae) in USSR [1]. Investigation by El-Sheikh et al. [5] in his work on *Mythimna loreyi* (Family Noctuidae) (Duponchel) larvae, and Bell et al. [6,7] on the tomato moth, *Lacanobia oleracea* (L.) (Family Noctuidae) larvae, indicates that *M. gyrator* attacks a wide range of lepidopteran species both in open-fields and in glasshouse crops in the UK and Europe.

In Egypt *Meteorus* spp. were reported to parasitize *Agrotis ipsilon* (Noctuidae) [8,9]; and *Plutella maculipennis* Curtis (Plutellidae) [10]. *Meteorus gyrator* was observed in many surveys mainly concerned by the most economically influential lepidopterous pests in Egypt, *i.e.*, *Spodoptera littoralis* Boisd., *S. exigua* Hb., *Heliothis armigera* Hb., *Autographa* spp. and *Sesamia cretica* Lederer, in untreated fields of clover, maize, and vegetables [11,12,13, 14,15,16].

This work presents a method specifically designed to improve the abundance and the parasitazion potential of *Meteorus gyrator* in the open fields to parasitize and develop on a broad range of noctuid's pests by releasing considerable number of the parasitoid adults. Also it deals with some aspects of the basic biology of *M. gyrator* parasitizing *Spodoptera littoralis* and *Autugrapha ni,* as mass-rearing hosts.

2. MATERIALS AND METHODS

2.1 Population Dynamics

Biweekly, samples of lepidopterous larvae were collected, by means of manual picking, all year round, from the fields of Giza and Faiyum Governorates, for two successive years (November, 2017 to October, 2019). The surveyed host plants were, clover, cabbage, okra, tomato, maize, jew's mallow, bean, soybean, cotton, pea and lettuce. Collected larvae were confined individually under constant conditions (25±2°C & 65±5% RH) fed on their natural host plant until pupation or the emergence of the internal parasitoids larvae of *Meteorus* spp. for pupation.

2.2 Laboratory Rearing

Cultures of some insect larvae, *Heliothis armigera, Spodoptera exigua*, *Agrotis ipsilon*, *Sesamia cretica*, *S. littoralis* and *Autographa ni* (fed on their natural host plant) were reared in laboratory under constant conditions (25±2°C and 65±5% RH) to act as hosts for mass-production of the parasitoid, *M. gyrator* that fed on honey solution 10%.

2.3 Biological Studies

Preliminary experiments were conducted using *M. gyrator* for parasitism on the abovementioned larvae as hosts for mass-production.

Under laboratory conditions, *S. littoralis* and *Autographa ni* were both used as hosts for *M. gyrator* mass-production. These two species were chosen since they are the most suitable and the easiest to handle in the process of rearing the parasitoid. Both host larvae were at the 3rd instar when used, and the whole experiment was replicated thrice.

Third larval instar of both species (*S. littoralis* and *A. ni*) was confined individually in glass test tube (3cm in diameter and 15cm depth, supplied with piece of castor bean leaf, for larval feeding, and honey droplets, for female parasitoid feeding). Adult mated female parasitoid was introduced into each test tube, covered with muslin, and then incubated overnight at the same mentioned constant conditions.

2.4 Statistical Analysis

Statistical Product and Service Solutions (SPSS) computer statistical package was used through the "Student t-Test" to discriminate between the obtained results.

3. RESULTS AND DISCUSSION

3.1 Population Dynamics

Two *Meteorus* species, namely *M. rubens* (Nees) (gregarious parasitoid) and *M. gyrator* (Thunberg) (solitary parasitoid), were reared from several lepidopterous larvae that attack different host plants in the two selected Governorates in Egypt (Giza and Faiyum), during the course of the two years of investigation (2017-2019). The surveyed host plants were clover, cabbage, okra, tomato, maize, jew's mallow, bean, soybean, cotton, pea, and lettuce.

Meteorus rubens was the predominant braconid species, compared to *M. gyrator.* It was found during both seasons and in both regions with comparatively higher counts. The presence period of *M. rubens* mostly elapsed from February to June in the different localities (Figs. 1-4); being one month earlier or one month later in the different years. It appeared that this period is the active period of its main host larvae, *A. ipsilon*. The presence period of the other two hosts *S. cretica* and *S. exigua* were mostly during May-July. Conversely, the dynamic period of the other braconid species, *M. gyrator,* varied in the different localities according to the existence of the different insect hosts on the different host plants.

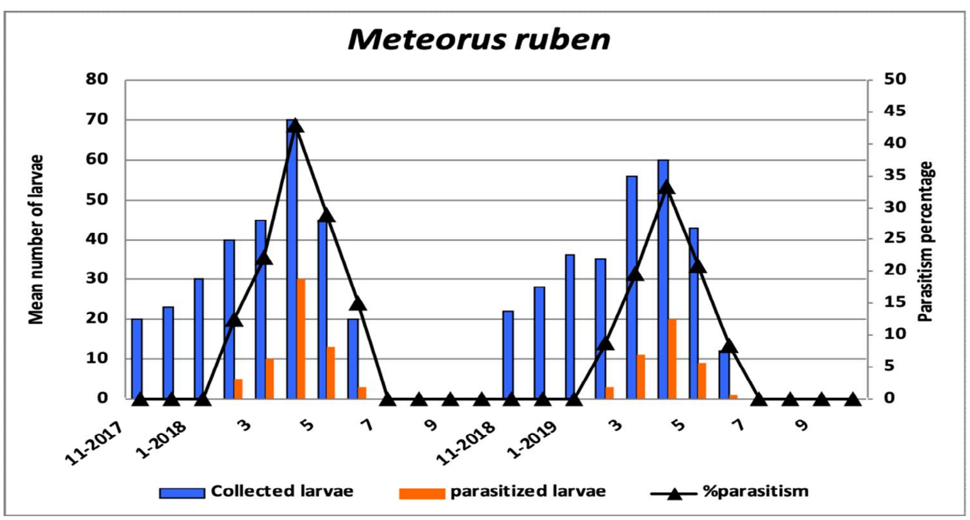

Fig. 1. Mean number of collected and parasitized *Agrotis ipsilon* larvae and percentage of parasitism by *M. rubens* throughout two successive years (November 2017 to October 2019) in Giza region

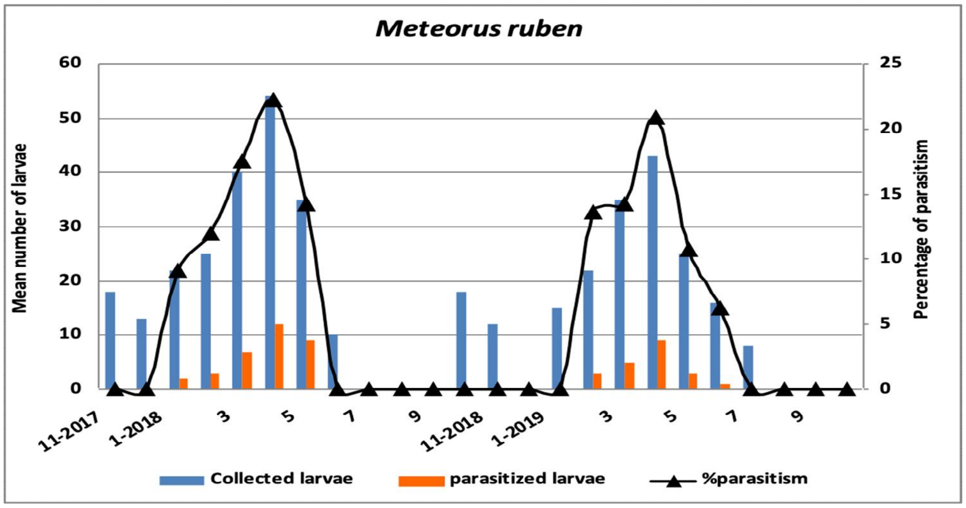

Fig. 2. Mean number of collected and parasitized *Agrotis ipsilon* larvae and percentage of parasitism by *M.rubens* throughout two successive years (November 2017 to October 2019) in Faiyum region

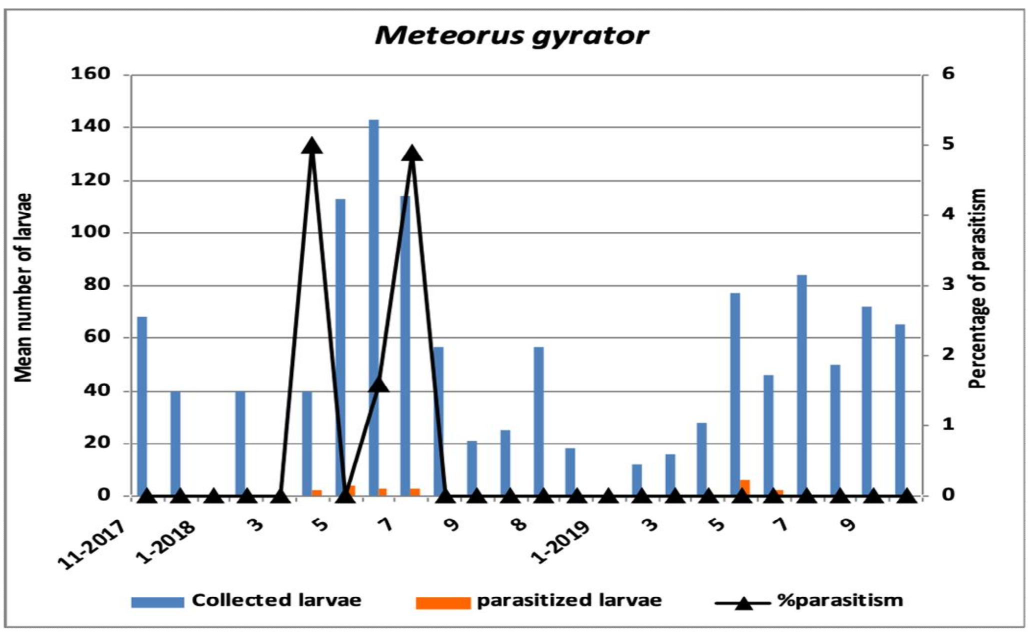

Fig. 3. Mean number of collected and parasitized *Spodoptera* spp., and percentage of parasitism by *M.gyrator* throughout two successive years (November 2017 to October 2019) in Giza region

Rate of parasitism by *M. rubens* varied according to regions, seasons, and the host insect. In association with the main host, *A. ipsilon,* the general rate of parasitism in the different localities and the different seasons ranged from 3.30 to 42.90% with a mean of 23.10% in Giza. While in the case of *M. gyrator* it only ranged between 1.50 to 5.00% with a mean of 3.25%. In the Faiyum region, the corresponding figures were 3.70 to 22.22% with an average of 12.96% for *M. rubens*; and ranged between 2.50 to 11.36%, with an average of 6.93% for *M. gyrator* (Figs. 1-4).

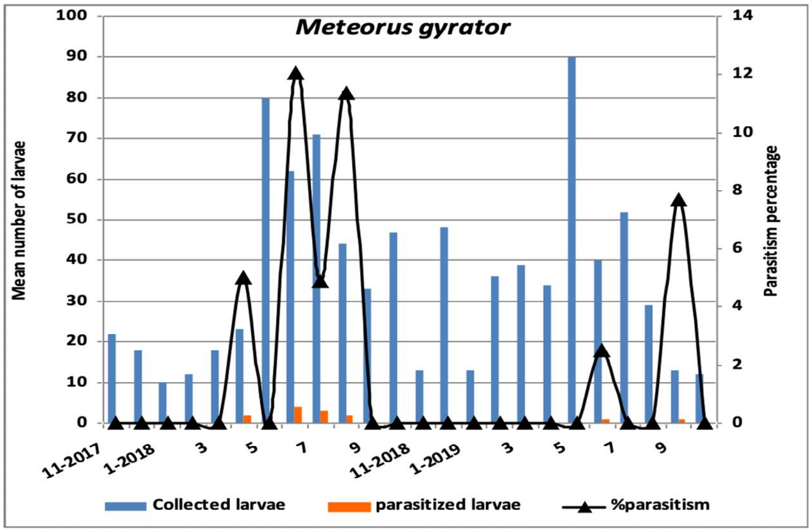

Fig. 4. Mean number of collected and parasitized *Spodoptera* spp., and percentage of parasitism by *M.gyrator* throughout two successive years (November 2017 to October 2019) in Faiyum region

These findings agreed with those reported by El-Heneidy and Hassanein [14] in their survey on different host larvae established on different host plants. Also, it agreed with Gesraha [15] in his work on the same parasitoids, that records nearly the same results. Also, these findings agreed with Zaki et al. [17] that mentioned in their work on the same insects (*M. rubens* and *A. ipsilon)*, they applied kairomone before releasing *Meteorus rubens* to increase its efficacy in parasitism from 16.70% at 0-time to reach 43.30% after 10 days of application. Results also matched those of El-Husseini et al. [16] in their survey on numerous lepidopterous larvae collected from different crop and vegetable fields in different localities of Egypt, where they reported that *M. gyrator* was the common parasitoid on *S. littoralis*, *S. exigua* and *Autographa* spp.

3.2 Biological Parameters

3.2.1 The ovipositional activity of *M. gyrator*

First-round experiments were conducted to investigate the potentiality of the aforementioned host larvae (*Heliothis armigera, Spodoptera exigua*, *Agrotis ipsilon*, *Sesamia cretica*, *S. littoralis,* and *Autographa ni*) as hosts for *M. gyrator* mass production. *Autographa ni* and *Spodoptera littoralis* were the most suitable of all tested hosts. *Meteorus gyrator* was introduced to, *S. littoralis* and *A. ni*, being used as parasitoid mass-rearing host larvae, under constant conditions (25±2°C and 65±5% RH), to allow for ovipositional activity. The outcome data are summarized in Tables (1 & 2).

The incubation periods were 3.30 and 2.30 days for *S.littoralis* and *A.ni*, respectively; being significantly shorter in *A. ni* (T_8= 2.599*). The 1st larval instar significantly varied between the two tested host larvae (T_8= 4.914**), where it lasted longer time in case of *A.ni*. Both the 2nd and the 3rd larval instars variations were insignificant (T_8= 1.134^{NS} and T_8= 0.806 ^{NS}), respectively. Finally, the total larval periods varied significantly, it was longer in case of *A.ni* (T_8= 3.810**) (Table 1).

Data presented in Table 2 shows that the prepupal stage did not varied between the two host larvae, as both lasted only one day. The pupal stage and the total developmental period of both hosts recorded significant variations (Table 2). It was observed that male longevity recorded insignificant variation (T_8=1.238^{NS}) between the two tested host larvae. In contrast, female longevity of *A. ni* recoded a significantly longer period than *S.littoralis* (T_8=2.828*). Lastly, the lifecycle of *A.ni* was significantly shorter than *S.littoralis* (T_8=2.477*). Also, data revealed that the longevity of mated females averaged shorter period (14.50±0.50 days) for *S.littoralis* than that of *A.ni* (16.00±0.45 days); being significantly varied (T_8=2.828*) (Table 2).

Table 1. Durations (in day) of egg and larval stages of *Meteorus gyrator* reared in both *Spodoptera littoralis* and *Autographa ni* host larvae at 25±2°C and 65±5% R.H

Host larvae	Egg stage	Larval ins tars			Total larval period
		1st	2nd	3rd	
S.littoralis	3.30±0.34a (3-4)	3.40±0.19b (3-4)	2.60±0.18a (2-3)	1.30±0.18a (1-2)	7.30±0.34b (6-9)
A.ni	2.30±0.10b (2-3)	4.70±0.20a (2-5)	2.50±0.19a (2-3)	1.60±0.19a (1-2)	8.80±0.20a (5-10)
T-value (df=8)	2.599*	4.914**	1.134^{NS}	0.806^{NS}	3.810**

Table 2. Durations (in days) of prepupa, pupa, adult stage, total developmental period and life cycle of *Meteorus gyrator* reared in both *S. littoralis* and *A. ni* (at 25±2°C and 65±5% RH)

Host larvae	Prepupal stage	Pupal stage	Total developmental peroid	Adult longevity		Life cycle
				Male	Female	
S.littoralis	1.00±0.00a (1-1)	7.50±0.22a (7-8)	19.10±0.75a (17-22)	11.60±0.30a (10-13)	14.50±0.50b (13-16)	20.10±0.80a (18-23)
A.ni	1.00±0.00a (1-1)	6.40±0.19b (6-7)	16.40±1.05b (14-20)	12.70±0.30a (12-14)	16.00±0.45a (15-17)	18.80±1.11b (15-21)
T-value (df=8)	---	3.751**	2.328*	1.238^{NS}	2.828*	2.477*

***= Highly Significant* **= Significant* *NS= Not Significant*

Numbers between bracts = Range

Means in a single column followed with the same letters are not significantly different (P=5%)

Data obtained in (Table 3) shows that the number of parasitized host larvae/female averaged 33.30±0.95 and 46.50±1.20 larvae for *S. littoralis* and *A. ni,* respectively; being significantly different (T_8=8.594**). These numbers were recorded during the respective ovipositional periods of 11.00±0.95 and 13.80±0.35 days, they showed a significant deviation between them (T_8=2.767*). Consequently, the daily numbers of parasitized host larvae/female averaged 2.30±0.23 (l.80-2.70), and 2.80±0.11 (2.30-3.20) larvae for *S.littoralis* and *A.ni,* respectively, being insignificantly different ($T_8=1.917^{NS}$) (Table 3).

The maximum daily number of parasitized host larvae (4.50 larvae on average) was recorded on the 6th and the 8th day of the parasitoid female longevity for *S. littoralis*, as well as on the 8th day (6.5 larvae on average) for *A. ni.* Conversely, the lowest daily number of parasitized host larvae averaged 0.7 on the 14th day for *S. littoralis*, while it averaged 0.5 individuals on the last day of the parasitoid female longevity *A. ni* (Figs. 5 & 6).

Table 3. Oviposition periods of *Meteorus gyrator*, average numbers of parasitized host larvae of both *Spodoptera littoralis* and *Autographa ni* (at 25±2ºC and 65±5% RH)

Host larvae	Mean ± SE					
	Average oviposition periods (in days)			Average female longevity	Avg. number of parasitized larvae/female	Average daily parasitism
	Pre-	Oviposition	Post-			
S.littoralis	2.00±0.00a (2-2)	11.00±0.95b (9-12)	1.50±0.22a (1-2)	14.50±0.50b (13-16)	33.30±0.95b (23-43)	2.30±0.23a (1.8-2.7)
A. ni	2.00±0.00a (2-2)	13.80±0.35a (13-15)	0.70±0.11b (0-2)	16.50±0.50a (15-17)	46.50±1.20a (39-55)	2.80±0.11a (2.3-3.2)
T-value (df=8)	---	2.767*	3.187*	2.828*	8.594**	1.917^{NS}

***= Highly Significant* **= Significant* *NS= Not Significant*

Numbers between bracts = Range

Means in a single column followed with the same letters are not significantly different (P=5%)

The preoviposition period was 2.0 days for both hosts, while the postoviposition period for *S. littoralis* was considerably longer than that of *A. ni* (T_8=3.187*). The oviposition period was significantly longer in the case of *A. ni* than that of *S. littoralis* (T_8=2.767*) (Table 3).

Pupae resulted from parasitized larvae of *S. littoralis* averaged a significantly lower number than that of *A. ni* (T_8=3.857**) (Table 4). The numbers recorded of the resultant progeny had nearly the same trend, also showing a significant difference (T_8=3.761**). The percentage of females among the resultant progeny in association with the abovementioned two hosts were in respective 29.20±1.36 and 40.00±1.30%; being significantly varied (T_8=5.740**) (Table 4).

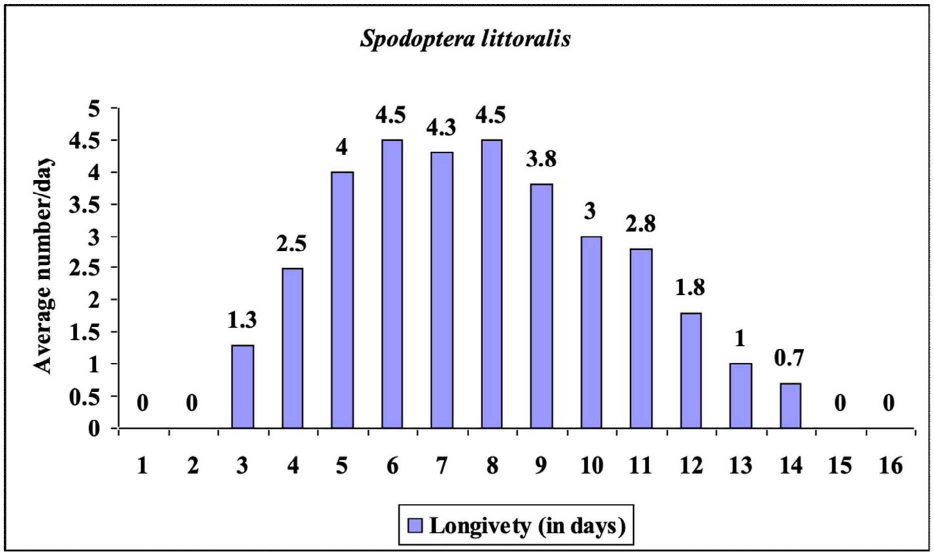

Fig. 5. Average daily numbers of parasitized *Spodoptera littoralis* 3rd larval instar along *Meteorus gyrator* female longevity (at 25±2ºC and 65+5% RH)

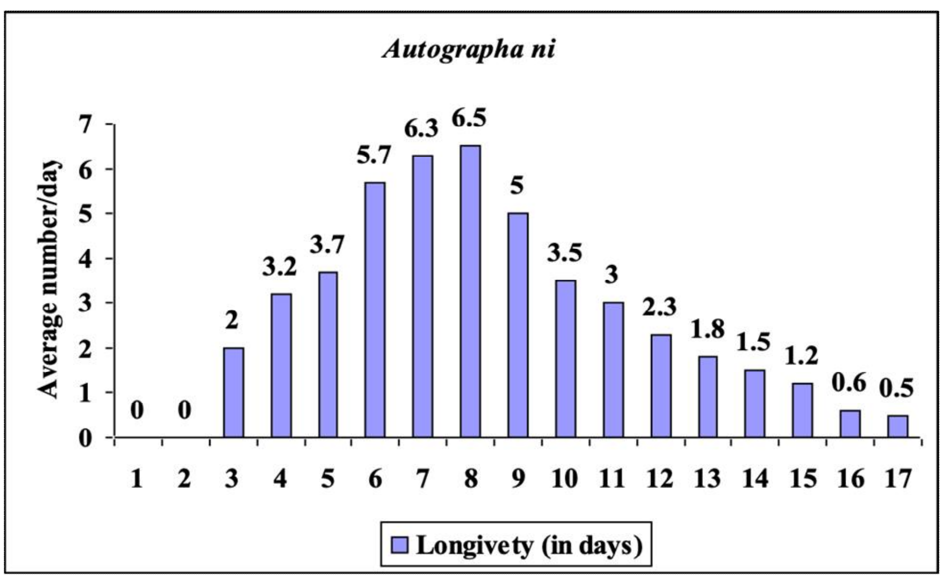

Fig. 6. Average daily numbers of parasitized *Autographa ni* 3rd larval instar along *Meteorus gyrator* female longevity (at 25±2ºC and 65+5% RH)

Table 4. Produced progeny of one *Meteorus gyrator* female reared on larvae of *Spodoptera littoralis* and *Autographa ni* (at 25±2ºC and 65±5% RH)

Host larvae	Mean ± SE		
	Average number of formed pupae	Average number of emerged adults	(%) Resulted females
S. littoralis	31.00±3.11 b (22-40)	31.30±4.10 b (21-40)	29.20±1.36 b (26-34)
A. ni	46.50±2.54 a (39-55)	46.5±2.54 a (39-55)	40.00±1.30 a (35-42)
T-value (df=8)	3.857**	3.761**	5.740**

***= Highly Significant NS= Not Significant Numbers between bracts = Range*
Means in a single column followed with the same letters are not significantly different (P=5%)

Our obtained results reveals that the longevity of mated female parasitoid averaged longer time in case of *A. ni* than that recorded for *S. littoralis*, while the former host reflects no post-oviposition period. This means that the female parasitoid deposited their eggs until the end day of its life when attacking *A. ni*. Nevertheless, in case of *S. littoralis*, the parasitoid females stop laying eggs for 2 days post-oviposition period. This phenomenon means that the exposure period of host larvae will increase; consequently, the whole number of the parasitized larvae will be increased in case of *A. ni*. In addition, the maximum number of daily-parasitized host larvae was 1.44 folds in *A. ni* more than that in the case of *S. littoralis*. The entire number of resulted progeny from parasitized larvae was about 1.5 folds in *A. ni* than that of *S. littoralis*. All things considered, it appears that *A. ni* seems to be more preferable as a host for *M. gyrator* than *S. littoralis,* because of the oviposition period was significantly longer, and the total numbers of parasitized larvae, formed pupae and emerged adults were significantly greater.

These results agreed with that reported by [15] for his findings on the same species. Our obtained results also matched those reported by [18], when they examined the impact of both, host stages and temperature, on some developmental parameters of *M. gyrator*. Results, also, matched those of [19] in their work on the comparative biology of *M. gyrator* on five noctuid pest species: *Lacanobia oleracea*, *Mamestra brassicae*, *Spodoptera exigua*, *Spodoptera littoralis,* and *Chrysodeixis chalcites*. They reported that female parasitoid attacked all larval examined stages, but they preferred the 3rd larvae instar, which was parasitized most frequently, in all species, with parasitized percentage ranged between 3.10 to 94.00% according to the host species.

4. CONCLUSION

In order to increase the efficacy of *M. gyrator* as a biological control agent, its adults population should be increased in the field by means of mass-rearing, and then by releasing a considerable number of its adults, either mated females or males and females synchronously, at the same time, for controlling the prevailing larval lepidopterous pests.

ACKNOWLEDGEMENT

The authors are very grateful to all colleges, for their valuable assistance and advice. Much appreciation to all peoples' help in fieldwork.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
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