# *Original Research Article*

Maximizing the role of the internal larval parasitoid, *Meteorus gyrator* (Thunberg) in the open field as a biological control agent considering the effects of climatic changes




**Abstract:**

**Background** and **Aim**: Members of Braconidae, *i.e., Meteorus* spp. assault certain lepidopterous larvae in Egyptian fields. The recorded species *M.rubens* (gregarious) and *M.gyrator* (solitary) were the most species reared from some lepidopterous larvae attacking various host plants in two chosen Governorates in Egypt through two experimental years. This work aims to increase the parasitizing efficiency of *M.gyrator* in fields by releasing an impressive number of parasitoid adults.

**Methods**:

1- Samples of lepidopteran larvae were picked up from the prevailing plants in fields of El-Ghaebia and El-Sharkia Governorates, for two successive years (2020 to 2021). The prevailing plants are: clover, cabbage, okra, tomato, maize, jew's mallow, bean, soybean, cotton, pea, and lettuce. Collected larvae were reared under optimal conditions until their pupation or in anticipation of the migration of the full-grown endoparasitoid's larvae for pupation.

2- Parasitoid's production

Species of some lepidopterous larvae were reared in the NRC laboratory for large-scale manufacturing of the parasitoid *Meteorus gyrator*.

**Results**: Acquired results uncover that *Agrotis ipsilon* was the primary noctuid host larvae of *M.rubens* during its abundant periods (February-May). While in case of *M.gyrator* it was recorded in fewer numbers (at its abundant periods, May-August); which was raised from other lepidopteran larvae.

The *M.rubens* parasitism percentage reached 26.50 and 21.79% at El-Gharbia Governorate through the two experimental years, respectively; whereas in the case of *M.gyrator* it was 2.25% in the 2$^{nd}$ experimental year only. In El-Sharkia, *M.rubens* parasitism percentage was 18.60 and 28.60%, respectively throughout the two experimental years; while it was 10.00% for *M.gyrator* in the first year only.

**Conclusion**: To boost the productivity of this solitary internal parasitoid as a bio-control agent, it is mandatory to increase its adults population in any field.

**Keywords**: Internal larval parasitoids, *Meteorus rubens*, *M.gyrator*, mass-production, releasing parasitoid, open field.

## 1. Introduction

Environmental change truly affects the variety, appropriation, rates, propagation, development, advancement, and phenology of insect pests. Increasing temperature, upset rainfall, vaporous organization production, and so on can cause an increase in the population and movement of insect pests. Nonetheless, environmental change acts distinctively on various species, large effects of environmental change appear to build the annoyance general public, alongside their movement and ensuing harm in horticulture. Numerous species have developed resistance and have had the option to adjust to the new climate **[1,2].**

Skendži'c et al. **[3]** revealed that a portion of the vulnerabilities concerning various parts of environmental change that are pertinent to insect pests incorporate temperature increment, expansion in climatic $CO_2$, precipitation designs, relative humidity, and a few different variables. The impacts of environmental change on insects are confusing, as environmental change inclines toward certain insects and represses others while affecting their dissemination, variety, overflow, improvement, development, and phenology. Moreover, it is normal that there will be a general expansion in the number of nuisance episodes including a more extensive scope of insect pests. Insect pests would probably grow their geographic conveyance (particularly toward the north) with lessening the viability of the organic control agents, *i.e.*, regular natural enemies.

To avoid these adverse effects, modifications in IPM programs are crucial **[4]**. The Braconidae family comprises a large number of parasitic wasps which are uses in biological control [**5**]. *Meteorus* wasps are very important and active wasps. This genus comprises many species recorded in many countries worldwide (Fig. 1&2) attacking numerous lepidopterous larvae infesting plentiful vegetables as reported by some authors

(Kotenko **[6]** on *Ocneria dispar* L.; Askew & Shaw **[7]** and Goto et al. **[8]** on attacking several noctuids, geometrid, and lymantriid species; Bell et al. **[9,10]** in larvae of *Lacanobia oleracea* (L.); El-Sheikh et al. **[11]** in larvae of *Mythimna loreyi* (Duponchel); Foster **[12],** and Veire **[13]** who stated that, this solitary species attacks an extensive variety of lepidopteran larvae in both field or glasshouse crops in the UK and Europe.

Our survey in Egypt revealed that there are two active species, *Meteorus rubens* (the gregarious larval internal parasitoid; its recorded abundant periods lasted from February to May) and *Meteorus gyrator* (the solitary larval internal one; its abundant periods started from May to August) **[14,15].** *M.gyrator* was recorded throughout other researches which was directed mainly towards some economic pests of lepidopterous insects in Egypt, such as *Autographa* spp., *Heliothis armigera* Hb., *Sesamia cretica*, *Spodoptera littoralis* Boisd., and *S. exigua* Hb., in different fields of vegetables, clover, and maize **[16,17,18,19,20].**

**This work** aims to maximize the role of the widespread solitary internal parasitoid, *Meteorus gyrator* as a trial to face the prospective population increments in some lepidopterous insect pests accordingly to the climatic changes.

## 2. Materials and Methods

### 2.1- Population Dynamics [Population fluctuation]

Biweekly samples of lepidopteran larvae were collected manually all-round the year from the fields of El-Gharbia (Coordinates: 30.867°N 31.028°E) and El-Sharkia (Coordinates: 30.7°N 31.63°E) Governorates, for two successive years (2019-2020 to 2020-2021), from all the prevailing host plants vis clover, cabbage, okra, tomato, maize, jew's mallow, bean, soybean, cotton, pea, and lettuce (Fig.3). Collected larvae were confined individually under constant conditions (25±2°C & 65±5% RH) till pupation of the collected larvae or till the emergence of the full-grown internal *Meteorus* spp. larvae for pupation outside the cadavers **[14.15].**

### 2.2- Laboratory cultures of some alternative hosts

Cultures of some pest larvae, which were already recorded as hosts for the solitary parasitoid, *Meteorus gyrator* as *Heliothis armigera*, *Spodoptera littoralis, S.exigua*, *Agrotis ipsilon*, *Sesamia cretica*, and *Autographa* spp. were reared in the laboratory under the same constant conditions to act as hosts for mass-rearing of the parasitoid *M.gyrator*. (Fig. 4)

**2.3- Biological Parameters for *M.gyrator* on tested host larvae**

Experiments were conducted using *M.gyrator* for parasitism on the selected host larvae for mass-rearing purposes. Under laboratory conditions, the utilization of *Spodoptera littoralis* and *S.exigua* as well as *Autographa ni* 3rd larval instar as host larvae for *M.gyrator* was because they were more suitable and easy to handle for rearing.

**2.4- Statistical analysis**

Complete Block Randomise Design with three relicates were applyied. Analysis of variance (ANOVA) test was applied through the SPSS Computer Statistical Package to discriminate between the three tested host larvae. Means were discriminated by applying Duncan's Multiple Range Test **[21].**

## 3. Results and Discussion

### 3.1- El-Gharbia Governorate

Biweekly samples of different lepidopterous larvae that attacked the prevailing host plants were collected from untreated fields. Out of 80 collected larvae 22 of them were parasitized with *M.rubens* throughout the first year, with a maximum parasitism percentage of 27% during the May-June period. The corresponding figure in the 2nd year was 75 collected larvae which comprised 18 parasitized larvae that represented 22% parasitism percentage throughout the April-May period (Fig. 5).

As for *M.gyrator*, the collected larvae were 120 and 180 larvae during the 1st and the 2nd experimental years, respectively. During the two surveyed years 0 and 2 parasitized larvae were recorded respectively, which represented only 0.0 and 2.25% parasitism percentage (Fig. 6). These results indicated the poor abundance of the 2nd species (*M.gyrator*) compared to *M.eubens*, throughout all collected lepidopterous larvae. These findings were agreed and confermed by many authors **[14,15,19,20].** On the other view, it was observed that *M.gyrator* preferred warmer temperatures than *M.rubens* for its maximum activity. The obtained results were matched with that reported **[14,15,19, 20,22].**

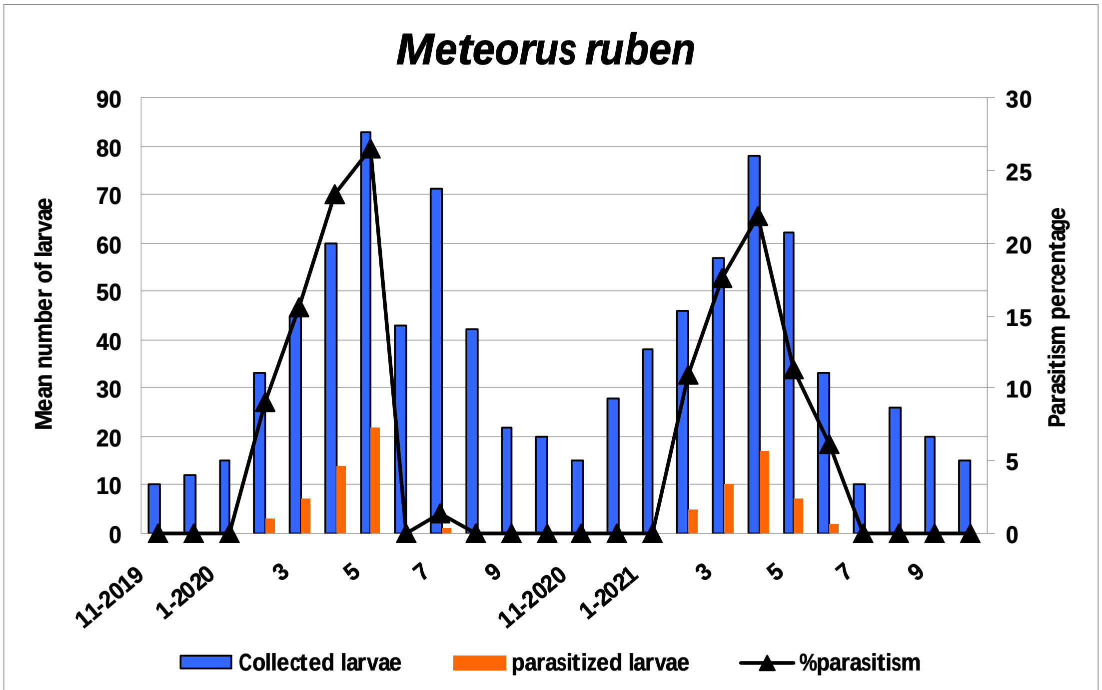


Fig. (5): Collected different lepidopterous larvae and the percentage of parasitism by *M.rubens* within the active periods of the parasitoid over the two years.

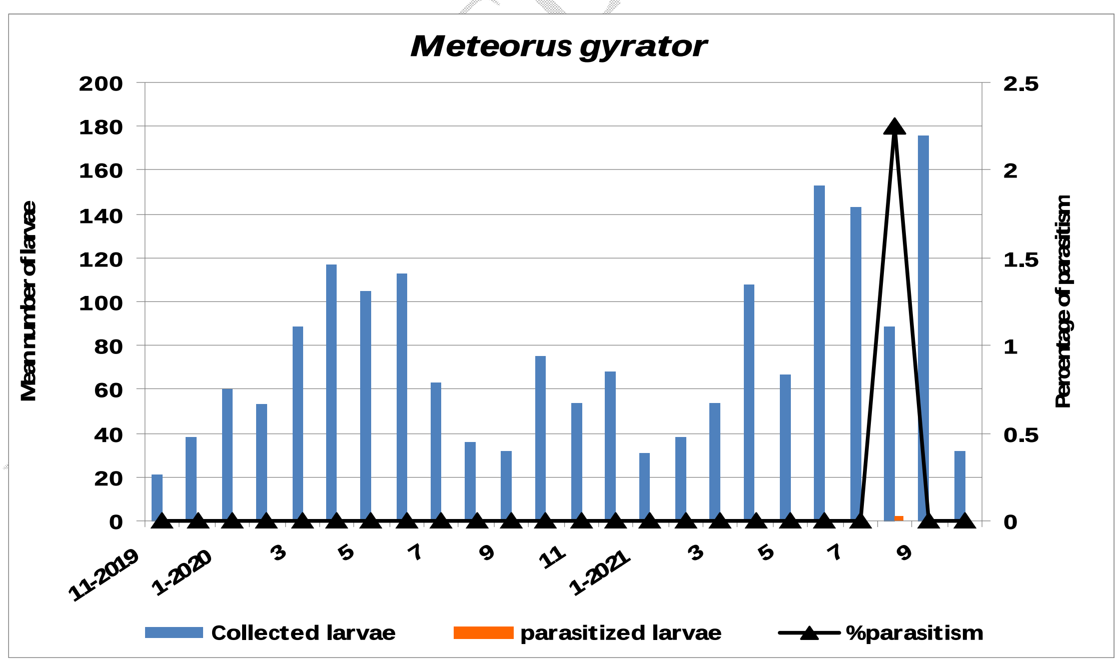


Fig. (6): Collected different lepidopterous larvae and the percentage of parasitism by *M.gyrator* within the active periods of the parasitoid over the two experimental years.

### 3.2- El-Sharkia Governorate

The information obtained from the survey in El-Gharbia Governorate was identical to the results recorded in El-Sharkia Governorate, *i.e.*, the abundance of *Meteorus rubens* was represented by 18.60 and 28.6% parasitism percentage through the 1st and the 2nd years of the survey, respectively, which was greater than the abundance of *M.gyrator*, that was not recorded at the 2nd year, but recorded only once in the 1st year represented with only 10% parasitism percentage at June (Figs. 7&8).

Our findings were in accordance with those reported by other authors in their investigations on some lepidopteran larvae that were collected from different vegetables & crops in diverse zones of Egyptian fields, where they stated that the solitary parasitoid was common on *S.littoralis*, *S.exigua*, and *Autographa* spp. **[14,15,19,20,22].**

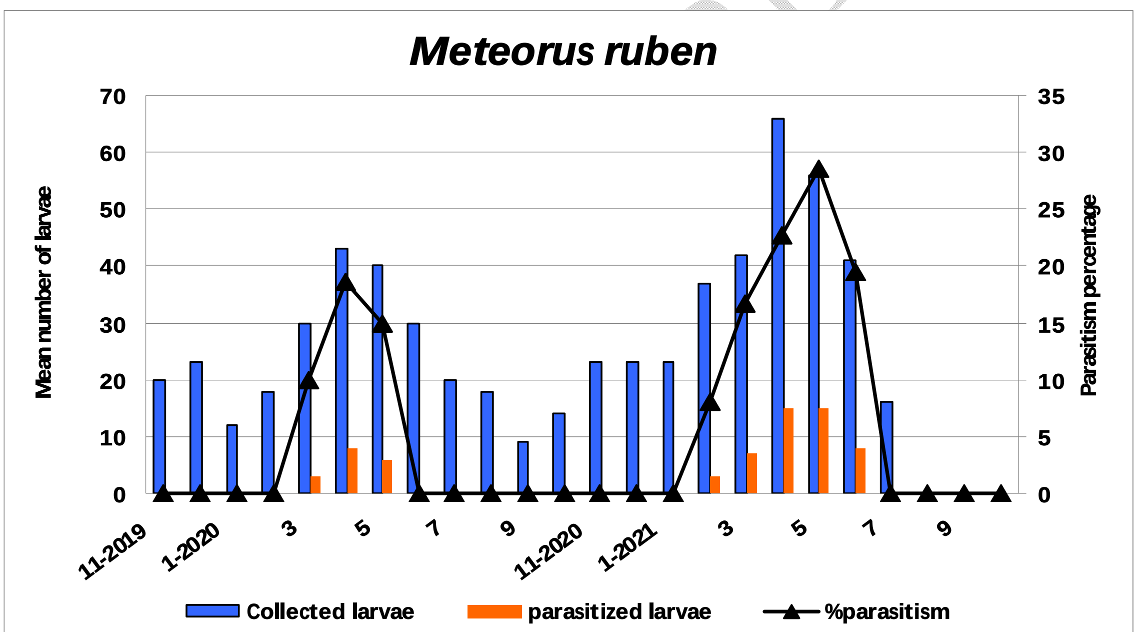


Fig. (7): Collected different lepidopterous larvae and the percentage of parasitism by *M.rubens* within the active periods of the parasitoid.

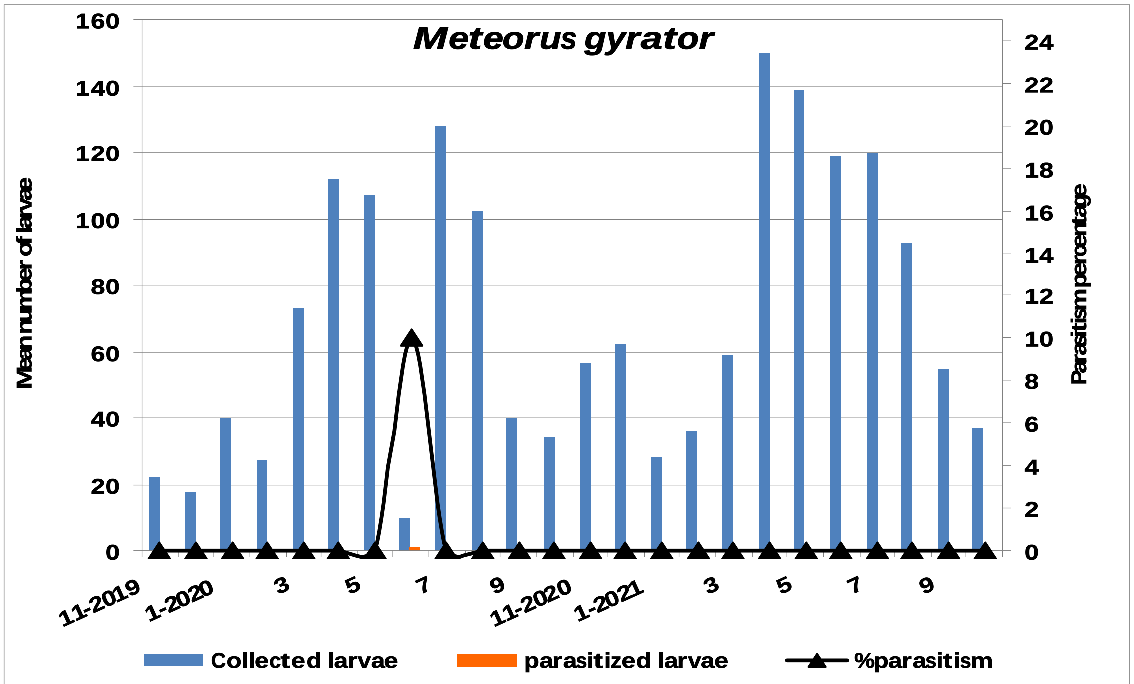


Fig. (8): Collected different lepidopterous larvae and the percentage of parasitism by *M.gyrator* within the active periods of the parasitoid along the two experimental years.

Because of the poor rate of *M.gyrator* abundance, and its wide parasitism range, mass rearing of adults was a solution for overcoming the shortage of its efficiency as an internal larval parasitoid.

### 3.3- *M.gyrator* Biological Studies

**Duration of the immature stages and adult longevity of *M.gyrator***

Duration of the different stages of *M.gyrator* was estimated in association with the three hosts, *S.littoralis*, *S.exigua*, and *A.ni* under the same mentioned constant conditions. The data obtained are tabulated in Table (1).

**Egg stage:** The incubation periods of *M.gyrator* eggs deposited by females inside the three tested hosts were significantly varied ($F_{2.12}$= 4.831*) (Table 1).

**Larval stage:** The total larval periods of *M.gyrator* were averaged in respective 7.66±0.85 and 8.10±0.97, and 8.74±0.72 days for *S.littoralis*, *S.exigua*, and *A.ni*; being insignificantly longer in the case of the two later insects ($F_{2,12}$=0.060$^{NS}$).

**Pupal stage:** The pupal stage durated 7.50, 6.80, and 6.28 days for the three tested host larvae; being significantly different between *S.littoralis* and *A.ni*, while *S.exigua* was insignificantly different with the other hosts ($F_{2,12}$=4.923*) (Table 1).

The same tendency in the case of the total developmental period was observed with a significant difference between *S.littoralis* (19.84 days) and *A.ni* (15.20 days); *S.exigua* was intermediate (18.25 days), being insignificantly different with the two others ($F_{3,12}$= 6.782*)(Table 1).

**Lifecycle:** Although there were differences between the lifecycle period (from egg to egg) of the mated females for the three tested host larvae, it was insignificantly varied between each other ($F_{2,12}$= $0.956^{NS}$)(Table 1).

**Adult longevity:** The average duration of the parasitoid's females resulted from larvae reared in *S.littoralis, S.exigua* and *A.ni* were significantly varied ($F_{2,12}$=4.865*). It is obvious that females reared from *A.ni* host larvae lived significantly longer periods than the other tested host larvae (Table 1).

***M. gyrator* oviposition parameters:** Ovipositional activity of *M.gyrator* towards the three tested host larvae under the same constant conditions are summarized in Table (2).

The obtained results revealed that the activity and the potential capacity of the female parasitoid for parasitism on different host larvae/female were also varied significantly ($F_{2,12}$=3.931*). The recorded number for *A.ni* was significantly varied with *S.littoralis,* but *S.exigua* was intermediate among the other tested species (Table 2). Such numbers were achieved during the respective ovipositional periods of 10.20, 12.48, and 14.36 days, respectively for the three tested larval pests, where divergence was significant between them ($F_{2,12}$=17.131**). Thus, the daily numbers of the parasitized host larvae/female averaged 2.38, 2.59, and 2.73 larvae, respectively for *S.littoralis, S.exigua,* and *A.ni,* which varied significantly between the *A.ni* and the others ($F_{2,12}$=6.806**)(Table 2).

The postoviposition period was 1.70, 1.00, and 0.70 days for the parasitoid females attacking the tested host larvae, *S.littoralis, S.exigua,* and *A.ni,* respectively; which was significantly varied ($F_{2,12}$=4.164*)(Table 2).

These results were obtained under laboratory conditions, that it resmpling to the conditions of the fields which larval pest were colleted from.

The resultant parasitoid pupae from *S.littoralis*, *S.exigua* and *A.ni* were in respective, 31.00, 43.30, and 48.10 pupae; being significantly varied between *S.littoralis* and the two other host larvae ($F_{2,12}$=10.465**). The corresponding records of the resultant F1 progeny ranged between 31.02 and 47.70 individuals; showing also the same significant difference ($F_{2,12}$=6.235*)(Table 2). The percentages of the females among the resultant progeny ranged between 28.84 and 39.80 individuals, with the majority towards *A.ni* tested host; being insignificantly diverse ($F_{2,12}$=13.543**)( Table 2).

The present findings concurred with the findings of Gesraha **[14]** on the same insects. The outcomes likewise coordinated with Bell et al. **[23]** on their work on the effection of the temperatures and host stages, on the resulted *M. gyrator*. The outcomes of Smethurst et al. **[24]** coordinated with those obtained results when they work on the comparative biological studies of *M. gyrator* on some noctuid pests, *vis Spodoptera exigua*, *Spodoptera littoralis, Lacanobia oleracea*, *Mamestra brassicae*, *Lacanobia oleracea*, *Mamestra brassicae*, and *Chrysodeixis chalcites*. They stated that the female parasitoid is capable to attack all tested larval stages, focusing on that female parasitoid preferred the 3$^{rd}$ larvae instar. They reported also that the parasitism percentage ranged between 3.10 to 94.00% according to the host species.

Table (1). Duration (in days) of different stages of *Meteorus gyrator* reared in the three tested host pests

| Host larvae | Egg stage | Larval stage | Pupal stage | Total developmental period | Adult longevity | | Female Life cycle |
|---|---|---|---|---|---|---|---|
| | | | | | Male | Female | |
| *S.littoralis* | 3.46±0.23a | 7.66±0.85a | 7.50±0.22a | 19.84±0.82a | 11.52±0.00a | 14.50±0.50b | 34.34±1.83a |
| *S.exigua* | 2.72±0.37ab | 8.10±0.97a | 6.80±0.37ab | 18.28±0.63ab | 11.44±0.39a | 14.06±0.68b | 32.34±2.34a |
| *A.ni* | 2.26±0.19b | 8.74±0.72a | 6.28±0.20b | 15.20±0.73b | 12.74±0.37a | 16.28±0.37a | 31.48±1.16a |
| F-value | 4.831* | 0.060 NS | 4.923* | 6.782* | 2.940 NS | 4.865* | 0.956 NS |
| *P*-value | 0.029 | 0.942 | 0.27 | 0.011 | 0.091 | 0.028 | 0.412 |

Table (2) *Meteorus gyrator* different parameters on parasitized host larvae of the three tested hosts

| Host larvae | Mean ± SE | | | | | | |
|---|---|---|---|---|---|---|---|
| | Average oviposition periods (in days) | | Avg. number of parasitized larvae/female | Average daily parasitism | Average number of formed pupae | Average number of emerged adults | (%) Resulted females |
| | Oviposition | Post-oviposition | | | | | |
| *S.littoralis* | 10.20±0.58c | 1.70±0.20a | 33.06±4.05b | 2.38±0.15b | 31.00±3.88b | 31.02±3.21b | 28.84±1.60b |
| *S. exigua* | 12.48±0.50b | 1.00±0.00ab | 39.48±3.57ab | 2.59±0.11b | 43.30±2.84a | 44.64±4.51a | 31.30±1.77b |
| *A. ni* | 14.36±0.41a | 0.74±0.37b | 46.10±3.02a | 2.73±0.17a | 48.10±2.45a | 47.70±2.61a | 39.80±1.28a |
| F-value | 17.131** | 4.164* | 3.931* | 6.806** | 10.465** | 6.325* | 13.543** |
| *P*-value | 0.000 | 0.042 | 0.071 | 0.011 | 0.002 | 0.013 | 0.001 |

**= Highly Significant *= Significant NS= Not Significant df=2,12

Means in columns followed with a similar letter (s) are not significantly distinctive (*P*=5%)

**4- Conclusion**

With the purpose of maximizing the efficacy of *Meteorus gyrator* as an efficient biological control agent, it is mandatory to increase the parasitoid adults' populations in the field worldwide by mass production, and then liberating extensive numbers of adults, *i.e.*, males plus females or mated females simultaneously in the open-fields, to control the existing and/or the predicting lepidopteran pests.

**Author Declaration**: All authors declare that this script has not been published before somewhere else and it is unique research.

**Ethics approval and consent to participate**: Not applicable

**Consent for publication**: Not applicable

**Availability of data and materials**: All data and materials are available.



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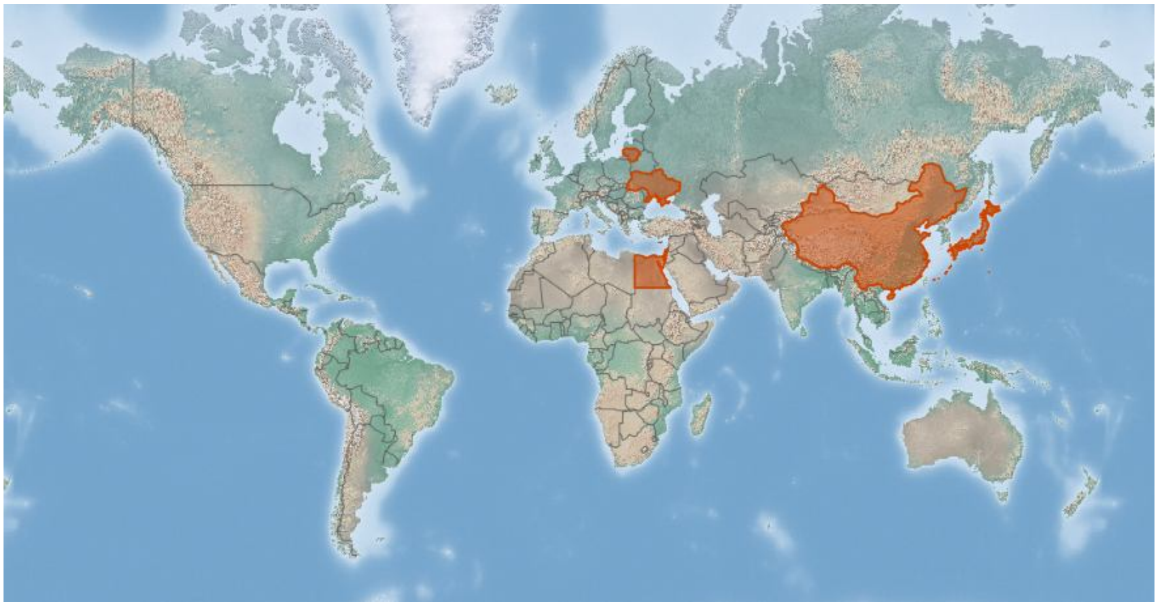
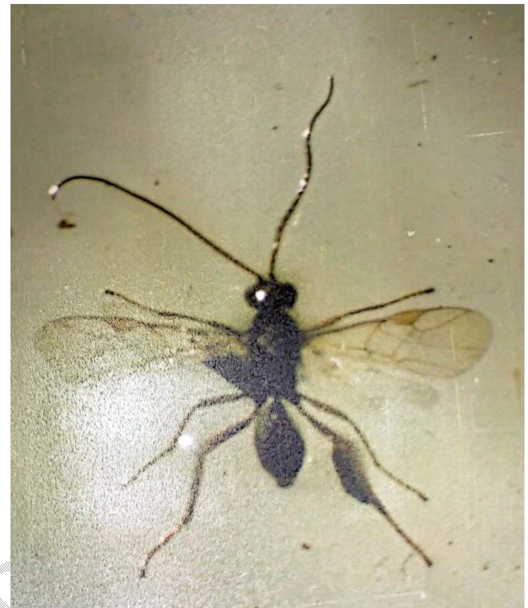


**Fig. (1): Geographical distribution of *Meteorus gyrator* (CABI Summary Data).**

**Fig. (2): *Meteorus gyrator***

**Meteorus gyrator female**



**Meteorus gyrator male**

**Meteorus gyrator 1st instar larvae**

**Meteorus gyrator 3rd instar larvae (full grown larvae)**

Cabbage

Maize

**Fig. (3): Injuries and damagig caused by lepidopteran larvae**

*Autographa* spp

**Fig. (4): Some lepidopteran pest larvae**