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**Farag AA**
Plant Protection Research Institute, Agricultural Research Center, Dokki, Giza, Egypt

**Abd El-Rahman HA**
Plant Protection Research Institute, Agricultural Research Center, Dokki, Giza, Egypt

**Refaei AE**
Plant Protection Research Institute, Agricultural Research Center, Dokki, Giza, Egypt

**El Shamy EA**
Deb. of Agric. Zoology and Nematology, facu. of Agric., of Al-Azhar University, Assiut Branch, Cairo, Egypt

**Corresponding Author:**
**Farag AA**
Plant Protection Research Institute, Agricultural Research Center, Dokki, Giza, Egypt

# Effect of cannibalism phenomenon on some biological aspects and predation efficiency on *Tetranychus urticae* Koch of the ladybird beetle, *Coccinella undecimpunctata* Linnaeus

**Farag AA, Abd El-Rahman HA, Refaei AE and El Shamy EA**

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**Abstract**
The coccinellid predator, *Coccinella undecimpunctata* (L.) is one of the most important insect predator, which plays an important role in regulation of too many insect pests in Egypt and worldwide. Cannibalism phenomenon is a well-known behavioral feature in this predator, as the larvae and adults prey upon each other. The consumption capacity of this predator on *Tetranychus urticae* Koch, as well the eggs, first and second larval instars of the this coccinellid was evaluated.
The adults and 4th larval instar and adults of *C. undecimpunctata* devoured more prey compared to those devoured by 1st, 2 and 3rd larval instars. The fourth larval instar of the coccinellid fed upon an average of 96.7 ± 1.2 eggs and 12.0 ± 0.7 larvae of first larvae instar of the same species in Petri dish, in the absence of the spider mite (non – choice feeding). In the presence of the mite and eggs of *C. undecimpunctata*, the fourth larval instar fed upon 2.2 ± 0.8 eggs and consumed only 1.0 ± 0.5 larvae in 1st larval instar of *C. undecimpunctata* (choice feeding), and consumed and consumed 126.0 ± 1.0 individual of spider mite in the absence of other prey (non- choice feeding). The adult of the coccinellid fed upon 10.52 ± 0.9 eggs and 5.09 ± 0.5 1st larval instars, in the absence of the mite, but fed upon 1.08 ± 0.15 eggs in the presence of the spider mite and *C. undecimpunctata* eggs in the same dich. Also, the coccinellid adult fed upon 0.19 ± 0.21 first larval instars in the presence of *C. undecimpunctata* larval and mites found in the same Petri dish. The adults of *C. undecimpunctata* consumed 45.83 ± 1.17 individual of the spider mite in the absence of eggs and larvae of *C. undecimpunctata*.
Data of cannibalism and predatory efficiency show that eggs and 1st larval instars of *C. undecimpunctata* are more devoured by *C. undecimpunctata* adults comparing to 4th larval inster and larvae of the coccinellid. The two-spotted spider mite is the preferred to all stage of the coccinellid. Results show that scarcity of the prey is one the main reason to cannibalism phenomenon, but it is a conspecific behavior of all coccinellids to keep all species.

**Keywords:** *Coccinella undecimpunctata*, spider mite, cannibalism, consumption, survival

## Introduction
The eleven-spotted ladybird beetle, *Coccinella undecimpunctata* Linnaeus (Coleopteran: Coccinellidae) is one of the most commonly known natural enemies [1] against the two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae). *C. undecimpunctata* larvae and adults and *Chrysoperla carnea* larvae are generalist polyphagous predators of many economically important pest species. They feed upon aphids, whiteflies, mealybug, thrips, jassids, leafhoppers, mites, scale insects and lepidoptera insects in agricultural habitats and open field and thus were used successfully in biological control programs [2, 3, 4, 5].
Cannibalism is a well-known behavioral feature of the ladybird beetles, *Scymnus interruptus*, and it was found that the 4th larval instar is a powerful predator against 1st, 2nd and 3rd instars of mealybugs [6, 7, 8] showed that feature of cannibalism gives high indications on the population dynamics of many insect species, especially ladybird predators. In case of absence or presence of prey, *C. septempunctata* behaved as a conspecific predator. Many studies showed that scarcity of prey was the absolute reason of cannibalism in *C. septempunctata* [9]. The scarcity of prey may not be the important reason for cannibalism in *C. septempunctata* [6]. The cannibalism efficiency may be high when the prey is low [10], but some insects' species like *Harmonia axyridis* showed the cannibalistic activity even when the diet was abundant [11, 1].

A high percentage of ladybird beetle eggs in the field and laboratory is cannibalized by conspecific adults [12]. *C. undecimpunctata* adults are considered more cannibalistic than larvae [13], which leads to development of the linkage between kin recognition and cannibalism, discrimination among own and the same species eggs [14, 15] egg cannibalism by 4th instar larvae and adult was still considerably higher even in the presence of prey [16]. Egg cannibalism in the ladybird beetles, *C. undecimpunctata* differs with gender, life cycle and reproduction status. It was found that the females were more cannibalistic than males. During the laboratory studies, larvae and adults of coccinellids and larvae of *Chrysoperla. carnae* were fed on *T. urticae* [17]. The eggs and 1st and 2nd larval instars of *C. undecimpunctata* are more vulnerable than 4th larval instar and adults in the laboratory and field [18, [19, 20].

The objective of this work was to investigate: of 1) the cannibalism competition interspecific and its effect on the predation potential and the growth and survival and also, its impact on their mass rearing of cannibalism, 2) effect of cannibalism on the consumption efficiency and biological aspects of *C. undecimpunctata* fed on eggs and larvae conspecific of the two spotted spider mites, *Tetranychus urticae* and, *C. undecimpunctata* + *T. urticae* under laboratory conditions.

## Materials and Methods

### Rearing of *T. urticae*

A culture of the two-spotted spider mite, *T. urticae* was originally obtained from infested cotton plants collected from unsprayed cotton fields. The mites were transferred to clean sweet potato leaves, that were fixed with parts of sweet potato stems in glass vials (4 liters each) having water for refreshing the leaves. The glass jars were placed in wire cages (1.5 × 1.5 × 1m) and kept in the wooden house at 30 ± 2 ºC, 65 ± 5% RH. and photoperiod of 13.11. The newly potato plants were replaced daily by new ones for feeding the mite and receiving eggs, to complete the next trials. All experiments were conducted at Sakha Branch, Plant Protection Research Institute, Mite Department, Kafr El-Shiekh Governorate (Fig. 1)

### Culture of *C. undecimpunctata*

The adults of *C. undecimpunctata* were collected from unsprayed cotton plants, transferred to the laboratory, reared on *T. urticae* under laboratory conditions of 30 ± 2 ºC and 6 ± 5% RH. The newly hatching coccinellid larvae, the newly emerged adults and eggs of *C. undecimpunctata* were used. The first larval instar and eggs of *C. undecimpunctata* were obtained from Predators Mass Rearing Laboratory, Faculty of Agriculture, Cairo University, Egypt. However, eggs laid by the ladybirds and the newly hatching larvae were placed in 9-cm diameter glass Petri dishes. The coccenillid were kept individually in Petri dishes with prey for trails. To absorb any water vapor, the dishes were lined with filter paper (Fig.2).

### Cannibalism of eggs and larvae by ladybird beetle

A group of plastic Petri dishes was prepared for each larval instar and adult of *C. undecimpunctata*, then four replications were made for each instar in predator and adults. Fresh cotton leaves with petioles were placed individually inside each plastic petri dish. The petiole was passed through an opening made underneath each dish and immersed in 1% sucrose solution to keep the leaves alive and the mites settled. The first larval instar of the predator was removed and placed singly inside 9 - cm dimeter plastic petri dishes and4 larvae of the same instar of 1st larval instar was starved for 12 h in order to induce the same instar as prey in Petri dishes. Accordingly, the predatory instar of the prey is determined, with a known number of prey, that had been previously reared on mite, *T. urticae* (20 individuals). The fresh eggs of *C. undecimpunctata* (30 eggs), larvae (20 in the first larval instar in the same predator), predator eggs + mite (30 + 10, respectively), predator larvae + mite (20 + 10, respectively) and predator eggs + predator larvae (30 + 20, respectively). *C. undecimpunctata* larvae were introduced into dishes along with a known number of the prey, and were replaced daily as well as gradually increased till the end of each larval instar of the ladybird beetle in each Petri dishes. The adults of *C. undecimpunctata* were individually placed in petri dishes with known numbers of prey (70 eggs, 50 larvae, 70 mites, 20 mite +70 eggs, 50 larvae +70 eggs and 20 mites 50 larvae) were introduced in dishes for feeding. The number of consumed prey was recorded daily and all obtained results were checked against the adult entire life. Therefore, prey consumption of the larvae, mortality and survival percentages were recorded. Thus, the same procedures were carried out with 2nd, 3rd and 4th instar larval of *C. undecimpunctata*, as well as the numbers of offered prey were gradually increased with each instar. Number of cannibalism and consumed grubs and eggs during larval instars and adults were daily calculated in the absence and presence of the mite (Fig 2).

### Statistical analysis

The results collected on the cannibalism of *C. undecimpunctata* and daily consumption were analyzed by the ANOFA and significant difference were determined using Duncan, s Multiple Range Test [21] at .05 probability.

**Fig 1:** Culture of the two-spotted spider mite, *Tetranychus urticae* Koch

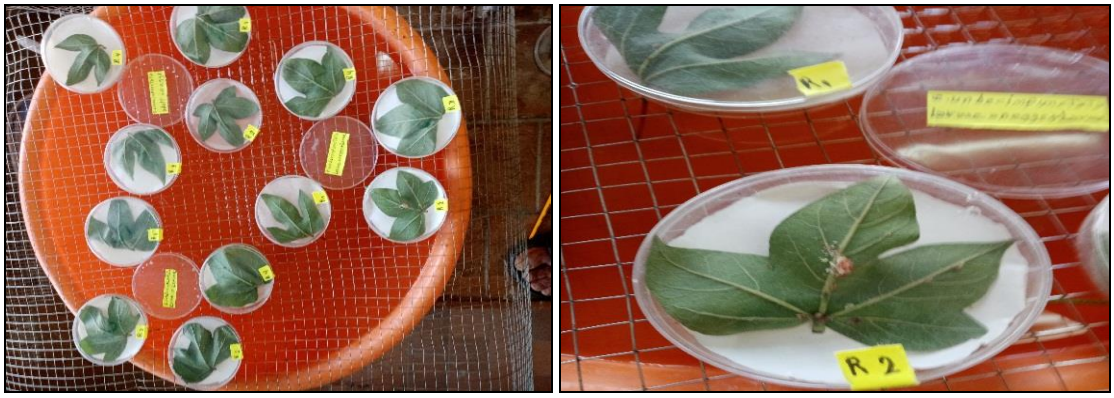


**Fig 2:** Cannibalism of the immature stages by larvae and adults of *Coccinella. undecimpunctata* Linnaeus

## Results

### Cannibalism of *C. undecimpunctata* larvae

Results present in Table (1) revealed that the fourth larval instar of *C. undecimpunctata* were more devouring compared to cannibalism on the first larval instar as well on eggs as compared to 1st, 2nd and 3rd instar larvae. On the other hand, the consumption rate of *T. urticae* was significantly higher with the advance of the larval instar of *C. undecimpunctata*. The absence of the immature stage for predator 4th fourth instars revealed high cannibalism on different immature stages or eggs and 1st larval instar from interspecific and its predation efficiency was significantly higher, consumed 96.75 ±1.21 eggs compared to the younger instar larvae followed by third instar grub which consumed 58.5 ± 0.71 eggs of interspecific in the absence of the two spotted spider mite.

**Table 1:** Cannibalism of the immature stage**s** by larvae stages of *Coccinella undecimpunctata* Linnaeus in the presence and the absence of times.

| Prey | | Cannibalism of immature stage of *C. undecimpunctata* | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **1st instar larvae** | **2ndinstar larvae** | **3rdinstar larvae** | **4thinstar larvae** | **Total consumption** | **Daily consumption** | **Survival (day)** |
| eggs | | 15.0±0.5 a | 25.7±0.8 a | 58.5± 0.7 b | 96.7±1.2 b | 195.5±2.8 b | 21.1±1.8 b | 09.2± 0.9 a |
| 1st instar larvae | | 00.5±0.1 d | 01.2±0.3 d | 06.7±0.6 d | 12.0±0.7 d | 20.4±1.0 d | 02.3±0.2 c | 08.7±1.2 b |
| Mite | | 10.5±0.4 b | 17.5±0.7 b | 88.2±0.5 a | 126.0±0.1 a | 242.2±3.1 a | 30.2±1.9 a | 08.0 ±1.0 b |
| Eggs+ mite | Eggs | 00.2±0.1 d | 00.5±0.4 d | 00.5±0.3 d | 02.2±0.8 e | 03.5 ±0.4 e | 0 0.3±0.2 d | 09.0±1.1 a |
| | Mite | 03.0 ±1.2 c | 07.0±0.9 c | 15.0±1.2 c | 18.7±2.1 c | 43.7±1.5 c | 04.8±0.4 c | |
| Eggs+ larvae | Eggs | 04.5±0.9 c | 07.7±1.2 c | 14.0±2.1 c | 23.5±2.1 c | 49.7±1.9 c | 06.0±0.9 c | 08.2±0.8 c |
| | Larvae | 00.2±0.2 d | 00.0±0.0 d | 00.5±0.1 d | 00.5±0.0 e | 01.2±0.3 e | 00.1± 0.7 a | |
| Mite+ larvae | Mite | 04.0±0.8 c | 07.7±1.1 c | 15.7±1.9 c | 28.2±3.1 c | 55.6±1.8 c | 05.9±1.1 c | 09.3±1.0 a |
| | larvae | 00.0±0.0 d | 00.2±0. 3a | 00.0±0.0 d | 01.0±0.5 e | 01.2± 0.1 e | 00.1±0.3 d | |
| LSD | | 3.41 | 3.11 | 1.73 | 2.11 | 4.23 | 1.82 | 0.81 |

Different letters showed that Means are significantly different ($P< 0.05$).

The presence of mite caused a significant, lower eggs and younger larval instars cannibalism by all larval instars, specific 3rd and 4th consuming o.50 ± 0.30 and 2.25 ± 0.81 eggs and 15.0 ± 1.21and 18.75 ± 2.11 mite, respectively. The 1st larval instars with eggs consumed 14.5 ± 2.10 and 23.5± 2.11 eggs and 0.50 ± 0.12 and 0.50 ± 0.00 larva during 3rd and 4th, respectively fourth instar larvae of *C. undecimpunctata* exhibited more voracious feeder significantly amounts of 1st instar larva (12.00 ± 0.71) compared to younger larval instars in the absence of mite. The presence of mites caused a significant reduction in cannibalism and a fraction of 1st instar larval were consumed (1.00 ± 0.51 larva). The fourth instar larvae of *C. undecimpunctata* was significantly the most devouring as compared to 1st, 2nd and 3rd instar larvae which consumed 126.00, 88.25, 17.50 and 10.50 mites, respectively. Tata also revealed a significant difference between the cannibalism of the 1st larval instar and eggs of *C. undecimpunctata* in the absence and presence of *T. urticae*. In the present study, the mean survival of *C. undecimpunctata* larval stage significantly prolonged to 9.25 and 8.75 days in case of cannibalism on eggs and 1st larval instar of the ladybird in the absence mite of compared to the larval stage, and survival ranged from 3.25 days when the larvae preyed eggs + 1st instar larval of the interspecific. The mean survival of *C. undecimpunctata* larvae was also shorter in the presence of mite with 1st instar larval (9.00 days) than that in the presence mite + eggs (9.25 days).

### Cannibalism of *C. undecimpunctata* Linnaeus adult

Results present in Table (2, 3) revealed that *C. undecimpunctata* adults showed more significant cannibalism and predation efficiency than its larval instars. In the absence of immature stage of *C. undecimpunctata* and calculated mean daily consumption of 45.83 ± 1.17 individuals of mite. Data showed that adult female of the eleven spotted coccinellid beetles exhibited more cannibalism towards eggs and 1st instar larval in absence of *T. urticae*, with a daily cannibalism of 10.52 ± 0.91 eggs and 5.09 ± 0.54 larvae. In free choice trails, conspecific (eggs) was significantly the most voracious eater of *C. undecimpunctata* adult compared to the mite and consumed the highest number of 1.08 ±0.15 eggs and 0.79 ± 0.11 mites. While in the case of the presence of larvae + mite, *C. undecimpunctata* adult consumed the highest number (0.95 ± 0.15) mite which differed significantly from 0.19 ± 0.21 larvae of intra-specific. The results on cannibalism of eggs and 1st instar larvae by adult of *C. undecimpunctata* showed that cannibalism was higher than larvae recording mean total consumption of 31.25 eggs and 4.25 1st instar stages in the absence of the two-spotted spider mite.

**Table 2:** Effect of cannibalism on consumption and survival rate by adults of *Coccinella undecimpunctata* L. in the presence and absence of mites

| prey | | Cannibalism of immature stage by adult | | | | | |
|---|---|---|---|---|---|---|---|
| | | Consumption | | Survival | | | |
| | | Total consumption | Mean daily consumption | Survival (days) | Pre-oviposition | oviposition | Post-oviposition |
| Eggs | | 134.35±2.81 b | 10.52±0.91 b | 12.75±1.81 c | 2.25±0.13 b | 5.00±0.64 d | 5.50±0.21 a |
| 1st instar larvae | | 117.25±1.91 b | 5.09±0.54 c | 23.00±1.01 b | 2.25±0.42 b | 17.25±0.80 c | 3.50±0.91 a |
| Mite | | 641.75±5.11 a | 45.83±1.17 a | 14.00±1.45 c | 3.25±0.32 a | 7.25±0.91 d | 3.50±1.01 a |
| Eggs+ Mite | Eggs | 29.50±1.05 c | 1.08±0.15 d | 27.25±o.16 a | 3.00±0.12 a | 21.25±0.21 b | 3.00±0.42 a |
| | Mite | 21.75±0.91 c | 0.79±0.11 d | | | | |
| Eggs+ larvae | Eggs | 31.25±1.04 c | 1.07±0.23 d | 29.0±1.01 a | 3.25±0.18 a | 22.51±0.11 b | 3.25±0.31 a |
| | Larvae | 4.25±1.21 d | 0.14±0.01 d | | | | |
| Mite+ larvae | Mite | 33.75±2.00 c | 0.95±0.15 d | 35.25±0.92 a | 3.75±1.01 a | 27.75±0.77 a | 3.75±0.22 a |
| | larvae | 7.00±0.94 d | 0.19±0.21 d | | | | |
| LSD | | 8.82 | 1.21 | 2.54 | 1.01 | 1.32 | 0.91 |

Different letters showed that Means are significantly different ($P< 0.05$).

Immature stage cannibalism is influenced by laid eggs, survival of the immature stage, incubation periods and total life cycle. However, the average number of laid eggs by cannibalism on eggs, larvae, mite, eggs + larvae and mite + larvae ranged from 177.75 to 196.00 eggs /female. The lowest average number laid eggs cannibalism on mite + larvae and the highest from the ones cannibalism on interspecific eggs. The longest mean survival of adult life cycle was calculated for the beetle cannibalism on mite + 1st instar larvae and eggs + mite ranged from 50.75 and 43.75 days, respectively comparing to cannibalism on eggs and mite prolonged to 28.50 and 30.35 days, respectively. Also, the mean survival of *C. undecimpunctata* total immature stage cannibalism on mite + 1st instar larvae were shortest (21.25 days) and the longest on intraspecific 1st instar larvae (25.50 days). Generally, when *C. undecimpunctata* larvae was fed in free choice trail, the survival of their larval instars were significantly different that of no choice.

**Table 3:** Effect of cannibalism on laid eggs and life cycle of *Coccinella undecimpunctata* Linnaeus in the presence and absence of mites.

| Prey | No. of laid eggs | Duration of immature stage | | | Life cycle | % Hatchability |
|---|---|---|---|---|---|---|
| | | Egg incubation period | Pupal stage | Immature stages | | |
| eggs | 195.25±1.9 a | 6.26±1.1 b | 6.50±0.1 b | 21.25±1.2 b | 34.71±1.4 c | 85.01 |
| 1st instar larval | 181.00±0.6 b | 8.00±0.9 a | 8.75±0.4 a | 25.45±1.4 a | 48.45±1.9 b | 70.30 |
| Mite | 181.50±0.7 b | 7.25±0.8 a | 8.25±0.9 a | 23.50±0.9 a | 37.50±0.8 c | 94.61 |
| Eggs+mite | 190.25±0.8 a | 5.76±0.6 b | 7.50±0.4 a | 22.26±0.7 b | 49.51±1.0 b | 54.53 |
| Eggs+larvae | 196.00±2.0 a | 6.50±0.4 b | 7.75±0.5 a | 22.77±0.9 b | 51.50±1.5 a | 40.56 |
| Mite+larvae | 177.75±1.5 b | 5.75±0.7 b | 6.25±1.1 b | 21.35±1.1 b | 56.55±2.1 a | 56.82 |

Different letters showed that Means are significantly different ($P< 0.05$).

## Discussion

The phenomenon of cannibalism is one of the factors affecting on both development stages, preference, predation efficiency and survival period for all stages. These results are in agreement with the findings of [22, 1] who informed that the cannibalism phenomenon in the ladybird is found if prey is scarce and the 4th larval instar and adult were more cannibalistic than the other three instars in the presence of prey, there absolute of less cannibalism when aphids are abundant and the higher numbers of eggs devoured by adults was related to their survival and development period. The adults seemed more consuming when fed on eggs and the first larval instar. The increasing populations of consumed eggs by the fourth larval instar was also related to developmental and survival period. These findings were in line with those of [23] who mentioned that the relative effect of predatory and cannibalism on the survival and development of 4th instar larvae was evaluated in *Coccinella septempunctata* and the impact of feeding aphids and conspecific on larvae performance and duration of *C. septempunctata* larvae was significantly lower when eating heterospecific larvae than aphids. [24] Indicated that the cannibalism of the third and fourth larval instars, negatively impacts the larval duration of *C. septempunctata* and the mean devoured reaction was less than 20%.

Many authors have suggested that the fourth larval instar is more consuming than 1st, 2nd and 3rd larval instar. On the other hand, [25] reported that the 4th instar larvae of *C. septempunctata* were more consuming when eating 1st instar larvae and eggs as comparing to the second and third larval instar and the adult consumed more eggs than larvae. [19] indicated that the phenomenon of cannibalism of smaller larval instars, eggs and pupae by older larvae and adults is found in the laboratory and field and most vulnerable to cannibalism by all stages.

The cannibalism in *C. undecimpunctata* is a well – known phenomenon and is one of the most important mortality factors of ladybird larvae. The scarcity of prey many not be the important reason in cannibalism phenomenon in all development stages. The fourth instar larvae were the most voracious in eggs cannibalism and smaller larvae instars. Generally, the fourth larval instar was higher in cannibalism. A similar impact of interspecific was recorded of *Scymnus interraptus* in other predator species [7]. Indicated that the fourth instar larvae devoured significantly more *Maconellicoccus hirsutus* than other three instars. The average life cycles of this predator on *S. interraptus*, *M. hirsutus* and *S. interraptus* + *M. hirsutus* were 41.11, 34.25 and 46.18 days, respectively [13]. Found that the cannibalism phenomenon of *C. undecimpunctata* and *C. vicini* cause, longer duration rate and shorter larval lifespan [26]. Found that interspecific did not directly impact factors, but increased

instars grub survival ship of *Harmonia axyridis* larvae (Pallas) in the presence of prey and eggs. [27] reported that in the case of *Harmonia axyridis*, production of eggs is considered an impact factor for the target of cannibalism and give the missing feeder in their food and therefore eggs were more important than instar stages for cannibalism, which when eat is scarcity [28, 29]. However, many researcher [30, 9], these proved that most insects are reluctant of self-predation. All stages of observed different stages of eggs cannibalism as well as the fourth larval instars of coccinellid seemed the increased consumed compering other instars, whether feeding eggs cannibalism [31, 33].

## Conclusion

In the present work, cannibalism occurred in both larval and adult stages of *C. undecimpunctata*. However, some investigations indicated that the scarcity of food was not an effective reason for cannibalism in *C. undecimpunctata* which shows a target towards the ability of larvae to complete their development. The 4th instars grubs showed more voracity specifically consumption than to other three stage larvae while eat on eggs and the first and second larvae. However, the adult stages possessed more voracious feeder than larvae.
This research work suggests that both predators were efficient and can be successfully as a potential biocontrol against *T. urticae* under the Egyptian circumstances.

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