P-ISSN: 3009 – 7487
E-ISSN: 3009 – 788

JOURNAL OF PLANT AND FOOD SCIENCES June 2024

Automated Flight Capacity Assessment of Parasitoids on *Spodoptera frugiperda* Eggs Treated with Synthetic 2-Cyano-N-(3-(N-(Thiazol-2-yl) Sulfamoyl) Phenyl) Acetamide Derivatives

Abd El- Wahab, Rania A.*, Harraz, Nahla H. and Shoman, Sheren A.

Plant Protection Research Institute, Agricultural Research Center, Egypt
***Corresponding author:** Rania A. Abd El-Wahab
Received: 14th March 2024; in revised form: 1st June 2024 / Accepted: 2nd June 2024 / Published: 2nd June 2024
DOI: **10.21608/JPFS.2024.276397.1011**

ABSTRACT

New synthetic insecticides act as allies in IPM especially if they could support biological control. Synthetic 2-cyano-n-(3-(n-(thiazol-2-yl) sulfamoyl) phenyl) acetamide derivatives can control *Spodoptera frugiperda* and then its eggs successfully with no essential impact on the flight capacity of adult parasitoids exposed to LC50s residue. The flight capacity of both *Telenomus remus* and *Trichogramma pretiosum* in treatments compared with the control is determined through an automated ESALQ model to discriminate between "flyers" and "non-flyers" through three locations, top, glue ring, and bottom. The modification of the ESALQ model depends on powering the unit with solar energy and cool white light-emitting diodes (LEDs) were added and connected with a full Arduino system to be automated automatically. Results showed that the flight capacity was significantly higher of *T. remus* than *T. pretiosum* even in treatments or control in the top location of the automated ESALQ model. Consequently, flight capacity was directly proportional to α-glycerophosphate dehydrogenase (α-GPDH) activeness and vice versa.

Keywords: Automated ESALQ model, flight capacity, α-glycerophosphate dehydrogenase, egg parasitoids, *Spodoptera frugiperda*.

INTRODUCTION

Tentatively, both parasitoids *Telenomus remus* and *Trichogramma pretiosum* are effective parasitoids on *Spodoptera frugiperda* eggs. But *Telenomus remus* is the most efficient because of its high parasitism capacity to parasitize successfully with each layer of *S. frugiperda* eggs. *Telenomus remus* is an egg parasitoid of lepidopterous insects, particularly those of the genus Spodoptera (Cave 2000), with its intersection of egg-layers and coated with scales (Molina-Ochoa *et al.*, 2003) *T. remus* natural parasitism percentage is approx.30% on FAW eggs and a high emerged adult females' ratio of about 76% (Tang *et al.*, 2020), which means a high biotic potential parasitism on egg masses of *Spodoptera frugiperda.* In addition, the development time of *Trichogramma* species is affected by the different lepidopteran eggs' ages (Atashi *et al*., 2021). Noteworthy, contrasts were watched within the development time of several *Trichogramma* species when revealed to different egg ages of FAW. For *Trichogramma* species, there has even been evidence of the varying impact of egg age on the generation of female offspring (Atashi *et al.*, 2021). Furthermore, *Trichogramma* female oviposition and offspring production are influenced by the size of their host's egg (Jin *et al.*,2021). According to Iqbal *et al.*, (2020), the optimal number of siblings that emerge from a single host contributes to biological control by preventing the development of super parasitism. Further, the estimation of the FAW eggs is roughly 0.4–0.5 mm in diameter and 0.3–0.4 mm in height and the production of more than one offspring per FAW egg occurred by all seven *Trichogramma*

species (Jin *et al.*, 2021). This result proposed that one FAW egg can accept at least two eggs of *Trichogramma* and both parasitoid adults were supported to emerge successfully.

Regardless, negative impacts pose a hazard to pesticides which can cause even an outbreak, resurgence of mainly and secondary pests, or problems concerning resistance, in expansion to natural corruption (Fathipour, Sedaratian, 2013). Indeed, even though these ready-mixed compounds may be accommodating in pest control, their impacts on the common natural enemies are still obscure (Regupathy *et al.*, 2004). So, there is a target to assess the toxicity besides side effects of all compounds on parasitoids, such as specific effects on their biology, parasitism efficiency, capacity of flight, etc.

Nevertheless, α-glycerophosphate dehydrogenase (α-GPDH) plays an essential role in carbohydrate and lipid metabolism in insects. In the flight muscle of Drosophila, the glycophosphate cycle involves glycolysis in conjunction with oxidative phosphorylation, regenerating mainly NAD+ in the cytoplasm. In the mitochondria, this cycle results in reduction equivalents (FADH 2) for synthesizing ATP (Sacktor 1970). Thereby, glycophosphate synthesis in wasps and bees has been linked to age and flight capacity (Machado, Contel,1991), however, unlike Drosophila, thoracic glycophosphate activity progressively increases when the insect can fly (Sullivan *et al.*, 1983).

Hence, the purpose of this paper is to determine the flight capacity of the two parasitoids, *Telenomus remus* and *Trichogramma pretiosum* of *S.frugiperda* eggs that were exposed to three synthetic compounds of acetamides derivatives at a modified ESALQ model. Then, the result of the flight capacity of flyers and non-flyers parasitoids was explained on α-glycerophosphate dehydrogenase (α-GPDH) activity of parasitoids in treatments compared with the control.

MATERIALS AND METHODS

Maintenance of *Spodoptera frugiperda*:

Newly emerged *S. frugiperda* larvae were incubated under specified conditions (27°C, 70% relative humidity, and 12-hour photoperiod). They were placed in transparent plastic pots (25 cm), covered with filter paper, and fed castor leaves according to EL-Defrawi *et al.* (1964) with minor modifications to suit *S. frugiperda*, until the insect reached the pupal stage. Pupae were then placed in plastic pots (16 × 10 cm) covered with moist filter paper and incubated for about 12 days. When the adults left, 30 pairs were distributed in PVC cages covered with cotton paper (20 × 25 cm). Each cage was covered with a plastic sheet (25 × 25 cm) covered with filter paper as an egg-laying substrate, and the cages were sealed with PVC plastic film. Couples received a 10% (v/v) honey solution as an absorbent cotton swab in a 10 mL plastic tube. Until hatching, eggs were collected daily and transferred to transparent plastic pots (16 × 10 cm) covered with filter paper and fed to caterpillars produced according to a previously reported method.

Maintenance of egg parasitoids:

T. remus colony:

Colony of *T. remus* was conducted at Plant Protection Research Institute, Agricultural Research Center, Mansoura Branch at 25 ± 3 ˚C, RH 70 ± 10 %, with 12:12 (L: D) according to Pomari *et al.* (2012). Emerged adults were reared on *S.frugiperda* eggs which were attached to cards of paper (5cm L*2.5cm W) with double-sided taps and placed in glass tubes (8cm L*2.5 cm W). Inside the tubes, there were small droplets of honey were spread on the cage walls to support adults feeding. Then after 24 hours, the cards were removed and kept under controlled temperature till the emergence of a new generation of parasitoid adults.

***T. pretiosum* colony:**

Colony of *T. pretiosum* was conducted at Plant Protection Research Institute, Agricultural Research Center, Mansoura Branch at 25 ± 2 ˚C, RH 70 ± 10%, with 14:10 (L: D) according to Parra and Zucchi (1997). Emerged adults were reared on *S.frugiperda* eggs which were attached to cards of paper (6cm L*2cm W)with double-sided taps and placed in glass tubes (8cm L*2.5 cm W). Then after 24 hours, the cards were removed and kept under controlled temperature till the emergence of a new generation of parasitoid adults.

Synthetic Acetamide derivatives:

Experimental of derivatives:

Coupling reaction of the first compound with aromatic amine diazonium salts Compounds (General procedures): A cold solution of the appropriate diazonium chloride (0.002mol; was prepared by adding cold sodium nitrate solution (0.5 g,0.002 mol) to a cold suspension of appropriate aromatic amine (0.002mol) in conc. HCl (1.5ml) with stirring was added, with continuous stirring, to a cold solution (0.4g,0.002mol) at 0-5C^{O}in pyridine (20ml). After 2 hrs., the mixture is diluted with water, filtration, and recrystallized from ethanol. The products Ar1, Ar2, and Ar3 were obtained as shown in Fig. (1) and full substitutions of Ar (Figure 2).

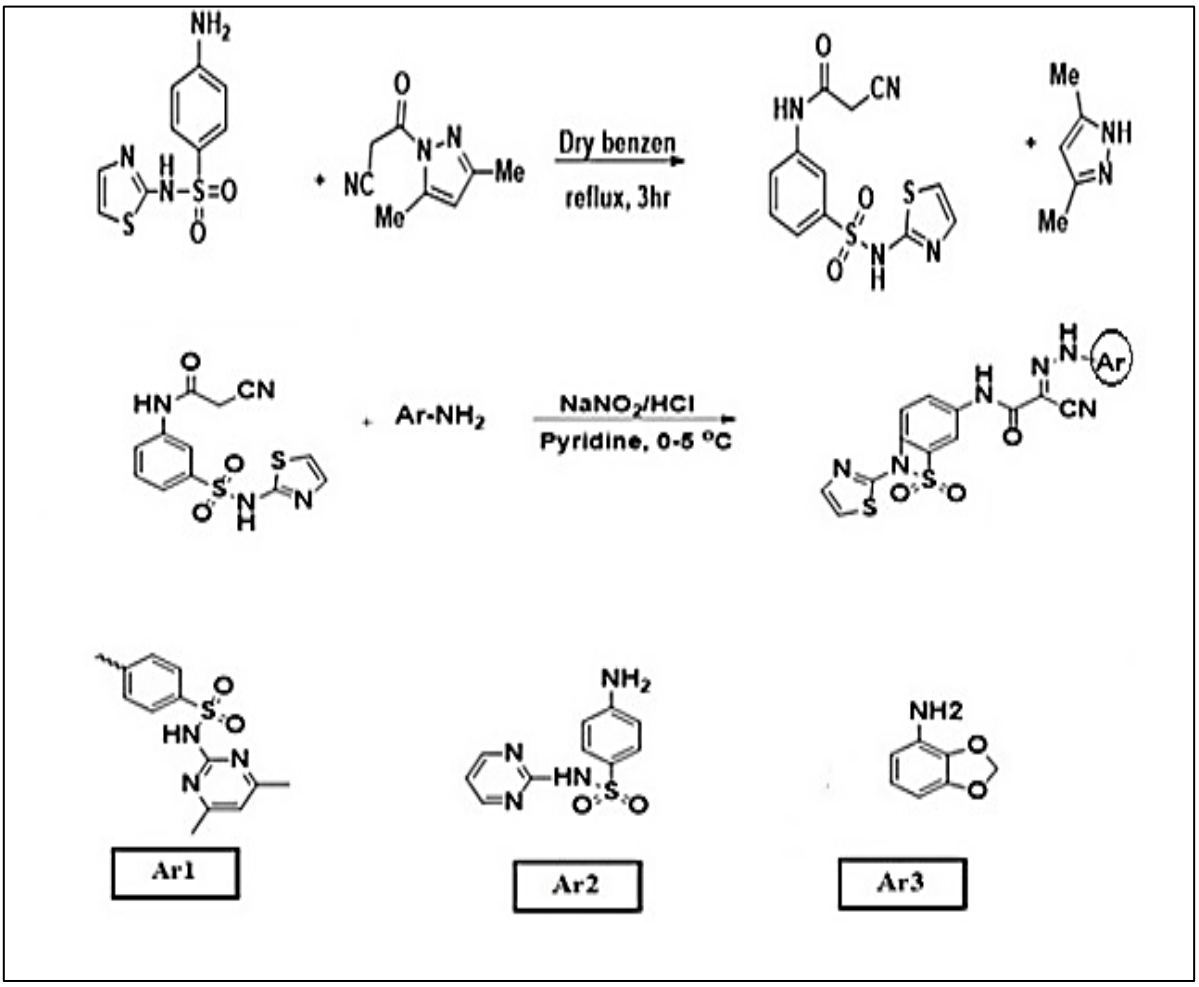


Fig.1: Synthesis of 2 Cyano-n-(3-(n-(thiazol-2yl) sulfamoyl) phenyl) acetamide derivatives.

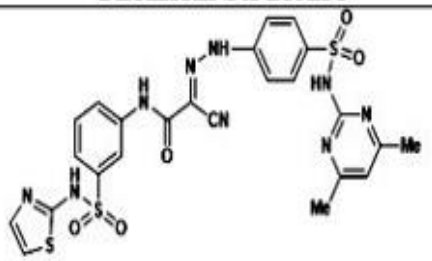
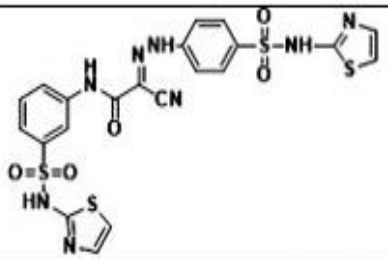
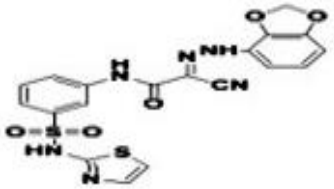
Substitutions	Chemical Name	Chemical Structure
Ar1	(E)-N-(4-(N-(4,6-dimethyl pyrimidin-2-yl) sulfamoyl) phenyl)-2-oxo-2-((3-(N-(thiazol-2- yl) sulfamoyl) phenyl) amino) acetohydrazonoyl cyanide	
Ar2	(E)-2-oxo-N-(4-(N-(thiazol-2-yl)sulfamoyl)phenyl)-2-((3-(N-(thiazol-2-yl)sulfamoyl) phenyl)amino)acetohydrazonoyl cyanide	
Ar3	(E)-N-(benzo[d][1,3]dioxol-4-yl)-2-oxo-2-((3-(N-(thiazol-2-yl)sulfamoyl)phenyl)amino) acetohydrazonoyl cyanide	

Fig.2: (Ar) Substitutions at synthetic acetamide derivatives.

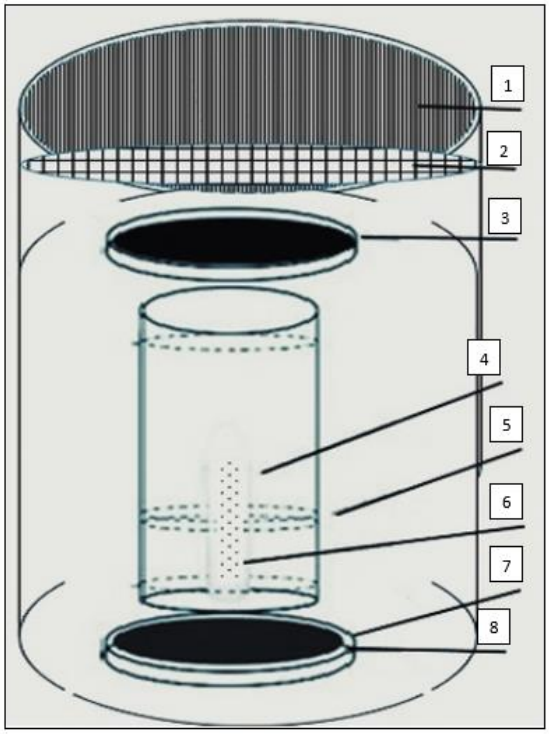
Sublethal effects of synthetic compounds on flight capacity:

The full bioassay was conducted in a completely randomized design. Cards with approximately 300 eggs of *S. frugiperda* were dipped for 5 seconds in the solutions of each compound with its LC50s as follows: 38.07, 51.14, and 87.55 ppm for derivatives Ar1, Ar2, and Ar3, resp., besides control cards of pest eggs which were dipped in water with Triton-X. Then they were kept at room temperature till dried and each card was placed in a glass tube (85 mm × 10 mm) with one parasitoid female, and each tube was considered as a replicate. So, each treatment was represented for 30 replicates. Surviving parasitoid females were offered a new, untreated card with *S. frugiperda* eggs every 24 hours until they died. Each removed card was placed in a new glass tube and checked within 7 days when all parasite tubes were in the pupal stage (Cônsoli *et al*., 1999). The number of black (parasitized) eggs was counted using a stereoscopic microscope (40x magnification). Subsequently, parasitized eggs were placed in each test unit (Figure 3). The emerged parasitoids from treated eggs were counted over 96 hours after the first emergence to regulate all possible emerged parasitoids. The numbers of adults glued on the bottom petri dish (not flying), on the walls (not flying), and on the upper dish (flying) were assessed per the total number of emerged adults of each parasitoid.

The flight capacity test unit:

The flight test unit utilized known as (ESALQ) proposed by Prezotti *et al.* (2002) based on Dutton and Bigler (1995), comprised a PVC cylinder (10 × 18 cm, diam × ht) with the best secured with a petri dish, tenable with a transparent glue to capture flying grown-ups of the parasitoid. The internal divider of the barrel was inviolable with a dark sheet of paper making the best of the flight test unit lighter than the foot. On this dark paper, a belt of stick 0.5 cm

thick was connected 3.5 cm from the foot of the tube, to make a barricade to capture insects that strolled upward. A card containing around 200 parasitized eggs, from which wasps were approximately to develop, was set at the foot of a glass vial (1.5 × 8.5 cm, diam × ht) within the center of the PVC barrel (Figure 3) (Prezotti *et al.,* 2002). This vial contained a droplet of pure honey placed within the upper divider as nourishment for the parasitoid grown-ups. Some modifications were made to increase the efficiency such as a fully automated ESALQ unit upon Arduino system programmed by C++ and powered by solar energy. Further, cool white light-emitting diodes (LEDs) were added and connected to the solar panel to be helpful in the detection of parasitoid numbers captured at each location with no effects on their directions besides specific modules that detect motion directly. The main components were a 10-watt monocrystalline solar panel- 14" X 12", 20-ft/18-gauge cables, 12V/3aH 20-hr battery, and a solar charge controller. Likewise, the full-flight capacity test units could be joined within a fully automated system designed upon the Internet of Things (IoT). Then certain parasitoids can be attached upon exposed pest, *Spodoptera frugiperda* to specific LED colors to allow the entrance of the parasitoid adults for testing the flight capacity (Abd El-Wahab,2017). However, in this research, each test unit was individually automated and powered as mentioned previously.



-The design consists of:
1-Solar Panel
2-LEDs with a cool white color with connected modules
3-Black paper with glue in a petri dish
4-Glass tube
5-Glue ring
6-Cards of parasitoids pupae
7-Petri dish
8-Black paper with glue
The full unit is automated by the Arduino system.

Fig.3: Automated ESALQ model unit to test the flight capacity of egg parasitoids.

Determination of cytoplasmic α-glycerophosphate dehydrogenase (α-GPDH) activity:

Flyers and non-flyers of both parasitoids were collected and frozen in liquid nitrogen before extraction of thoracic muscles. At that point, their thoracic were expelled, homogenized with 100 µl of chemical stabilizer (2mM dithiotreitol, 2mM aminocaproic acid, and 2mM EDTA, pH 7.3), and centrifuged at 15,000 g at 4ºC. At 25 °C, the activity of the Cytoplasmic α-glycerophosphate dehydrogenase (α-GPDH) was determined by spectrophotometry after the NADH was produced at 340 nm by the addition of substrate, bovine serum albumin (Chambers

et al., 1985). The protein concentrations were determined according to Bradford (1976). The particular activity is given in Units/mg of protein in muscle extracts.

Statistical Analysis:

Mainly IBM SPSS Statistics 20 (2020) is used for statistical analysis. The flight capacity was submitted to the non-parametric test of AFT Model Regression Parameters to screen the effects of synthetic acetamide derivatives on parasitoids and their passage among locations. Model Fit Statistics were used to discover the most significant treatment on the flight capacity compared to Akaike's Information Criterion (AIC) beside Hurvich and Tsai's Criterion (AICC). Therefore, significant differences among certain clusters of parasitoids exposed to acetamide derivatives were done through the Independent-samples Mann-Whitney U Test and ANOVA tests. Nonetheless, the calibration of relation forces was done through the relationship map. Moreover, P values were estimated significance of α-glycerophosphate dehydrogenase (α-GPDH) activity of flyers and non-flyers in both parasitoids.

RESULTS AND DISCUSSION

1-Effect of Acetamide derivatives on flight capacity of parasitoids on *Spodoptera frugiperda* eggs in the automated ESALQ unit:

Distribution among three locations of both parasitoids was registered as shown in Figure (4). Preliminary both parasitoids were distributed highly at the top location with slight differences.

Telenomus remus recorded the highest distribution with 87.68, 84.33, and 82.14% for those affected by A1, A2, and A3, resp., occurred at the top in comparison with control (88.14%). Followed by, *Trichogramma pretiosum* distribution which was recorded at 65.20, 64.81, and 60.87% for those affected by A1, A2, and A3, resp., which occurred at the top in comparison with control (69.22%). Worthy of mentioning that all individuals captured on the top location of the adapted ESALQ model unit had enlarged wings, especially since they reached the top flying and not walking.

At the glue ring position, *T.remus* recorded the lowest distribution with 11.11,9.47, and 3.05% for those affected by A1, A2, and A3, resp., while 10.39% were trapped in the glue ring of the control. Then, *T. pretiosum* distribution which was recorded at 12.39,10.80, and 8.42 % for those affected by A1, A2, and A3, resp., occurred at the glue ring position in comparison with control (14.51%).

At the bottom position, *T. remus* recorded the lowest distribution with 1.21,6.2, 14.94, and 1.47% for treatments by A1, A2, and A3, and control, resp.

Then, *T. pretiosum* distribution which was recorded at 22.41,24.39, and 30.71 % for those affected by A1, A2, and A3, resp., occurred at the bottom position compared to control (16.27%).

Upon AFT Model Regression Parameters, the high significant Chi-Squared value of parasitoids locations was at the glue ring =97.034** mainly for *T. pretiosum*.

Subsequently, the top location was the highest significance for *T. remus* with a Chi-Squared value =2.423**. Model Fit Statistics showed that among treatments, the derivative Ar1 was the most significant of both parasitoids at Akaike's Information Criterion (AIC)= 47.828**, and Hurvich and Tsai's Criterion (AICC)=51.161**. Independent-samples Mann-Whitney U Test of parasitoids showed that the mean rank of *T.pretiosum* (57.83*) was higher than *T. remus* (32.17) in the case of non-flyers.

Besides, upon ANOVA tests, F=243.200** at 1% among the two clusters of parasitoids exposed to certain LC50s of acetamide derivatives.

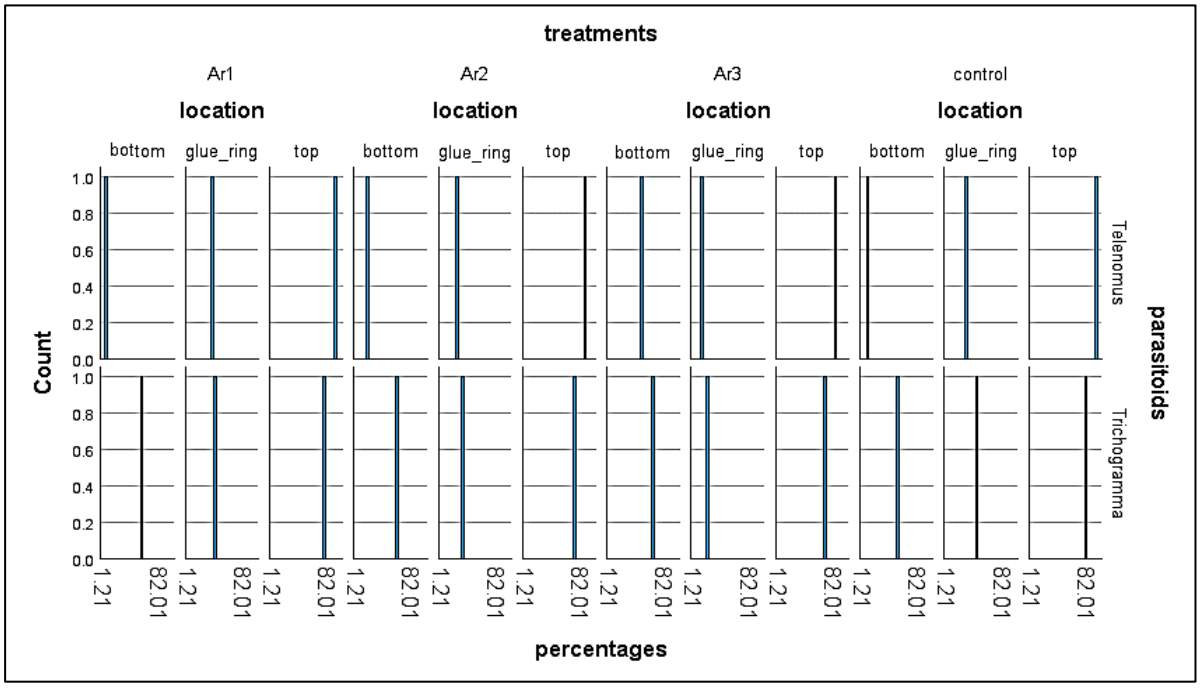


Fig.4: Effect of Synthetic 2-Cyano-N-(3-(N-(Thiazol-2-yl) Sulfamoyl) Phenyl) Acetamide on flight capacity of parasitoids on *S. frugiperda* eggs in the automated ESALQ unit.

2-Relationship map among certain factors

Through the determination of the force of treatments on the parasitoids, the relations among treatments, the pest, parasitoids, and their locations, are represented in Figure (5). Upon certain distributions of parasitoids and their locations toward the pest eggs, the relation is strong closely among control in the top location, Ar1 in the glue ring location, and Ar3 in the bottom location in the case of *Telenomus remus* against *S.frugiperda* eggs. In addition, the control in the top and glue ring locations, beside Ar3 in the bottom location in the case of *T. pretiosum* against *S.frugiperda* eggs. In contrast, gaps appeared among the rest of the relations with different volumes.

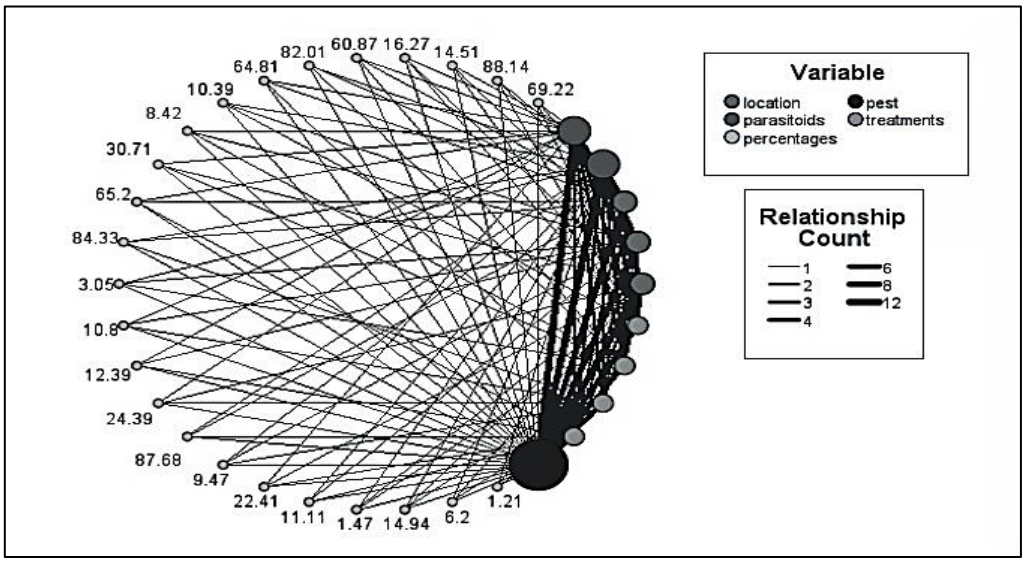


Fig.5: Relationship map among treatments, parasitoids, and their locations in an automated ESALQ model.

Notably, 2-Cyano-N-(3-(N-(thiazol-2-yl) sulfamoyl) phenyl) acetamide derivatives would be utilized as promising insecticides and anti-spinning silk threads compounds viably against *Spodoptera frugiperda* hatchlings with enrolled high mortality (Abd El-Wahab et al.,2024).LC50s of acetamide derivatives against the first larval instar of *S.frugiperda* were 781.56,844.37, and 990.39 µLL-¹ for Ar1, Ar2, and Ar3,resp.Besides so, the acetamide derivatives extended to prevent this instar from producing silk threads.

In addition, they were 904.39,1112.76 and 1159.33µLL^{-1} of the same arrangement of acetamide derivatives against the second larval instar of *S.frugiperda* which their larval strands were malformed in shape and diameter than control (Abd El-Wahab *et al*.,2024). Reasons amplified to clarify such an impact on ATPase also which is contrarily relative to glucose, triglyceride, and protein concentrations. This propensity was particularly articulated for proteins in early larval instars. This is often most likely due to an awfully powerful inhibition of layer pumps (e.g. Na+K+-ATPase) which anticipates dynamic transport and comes about within the testimony of a few metabolites. synthesized subsidiaries were able to cause microtubule disturbance which caused the pulverization of silk production glands that interpreted into contorted silk strands and lattice metalloproteinase but the extrusive mechanism is a hindrance of β-carbonic anhydrases (β-CAs).

Conspicuously, pesticides affect natural enemies in more aspects than just mortality. It is important to assess other biological characteristics of a parasitoid/predator (e.g. life span, reproduction rate, fertility, parasitizing/predation capacity, etc.), to ensure that the pesticide does not reduce the effectiveness of biological-control agents used in integrated pest management (IPM) (Desneux *et al*., 2007).

Pesticides such as chlorfenapyr, chlorpyrifos, and spinosad showed their side effects against *T.pretiosum* adult females that were exposed to *S. frugiperda* eggs treated with the mentioned insecticides. They caused a reduction of longevity, parasitism capacity of the maternal generation, and emergence ratio of the first generation. On the other hand, triflumuron was the most selective pesticide for *T.pretiosum* and didn't even affect its sex ratio (Souza *et al.,* 2013). The harmless effect of triflumuron is essentially due to belonging to the benzoylureas, Insect growth regulator (IGR) insecticides, which are nontoxic for adult parasitoids. Further, the selectivity of these insecticides is linked to the mechanism of action of the IGR, as they act as chitin synthesis inhibitors in immature stages only, which means no destructive effect on adult parasitoids (Carvalho *et al*., 2010; Maia *et al*., 2010).

Subsequently, the same is true of our acetamide derivatives, which influence juvenile hormone (JH), suppress silk glands, and tangentially raise the quantity of silk produced by *S.frugiperda* larvae. However, excessive ecdysteroids caused degeneration and regression, while insufficient amounts promoted the growth and function of the silk glands (Sehnal, Akai, 1990). Furthermore, after being treated with juvenile hormone analogs like sulphonamide to combat *Phthorimaea opercula*, JH was able to produce malformed pupae and adults and be as chemosterilant (Awasthi, Mahajan, 2008).

Also, ready-mix pesticides were classified upon emergence reduction of *T. pretiosum* pupae as Methanol+methomyl and lufenuron + profenofos were harmful, Cypermethrin + profenofos and cyproconazole + thiamethoxam were slightly harmful, while Chlorantraniliprole + lambda-cyhalothrin, abamectin + chlorantraniliprole, and alpha-cypermethrin + teflubenzuron were innocuous. Although a ready-mix of Abamectin + chlorantraniliprole was classified as harmless, the mixture reduced the parasitism, longevity, and specifically flight capacity which adults recorded at the top location the lower percentage (66.50%) and a higher percentage in the bottom location (19.50%) among tested pesticides (Paiva *et al.*,2020).

ESALQ model is so important to specify the flight capacity of parasitoids. They were split into three groups: those who could fly ("flyers"), those who could not fly but had no obvious distortion ("walkers"), and individuals who had visible deformation ("deformed"). Thus, parasitoids were bigger when grown on the natural host than on the fictitious host. However, there was no statistically significant difference between treatments in referring to the number of "flyers," "walkers," or "deformed" parasitoids. This suggests that, whereas growing *T. remus* on a counterfeit host impacts parasitoid growth, it does not necessarily affect parasitoid flying capacity (Pomari *et al*.,2016).

3-Effect on α-glycerophosphate dehydrogenase (α-GPDH) activity of parasitoids:

The activity of α-glycerophosphate dehydrogenase (α-GPDH) was changed upon treatments that affected the flight capacity of parasitoids on the activity of flyers of parasitoids on *S. frugiperda* eggs as shown in figures (6 and 7). It has appeared that α-GPDH activity is directly proportional to flight capacity in treatments compared with control. α-GPDH activity values of flyers at the top of *T. remus* affected by acetamide derivatives are recorded 117.78, 112.46,100.22, and 121.34 U/µg of protein for A1, A2, A3, and control, respectively (Fig. 6). Otherwise, α-GPDH activity values of flyers at the top of *T. pretiosum* affected by acetamide derivatives are lower than the other parasitoid. They were 87.47,80.39,77.78, and 95.09 U/µg of protein for A1, A2, A3, and control, respectively (Fig. 6).

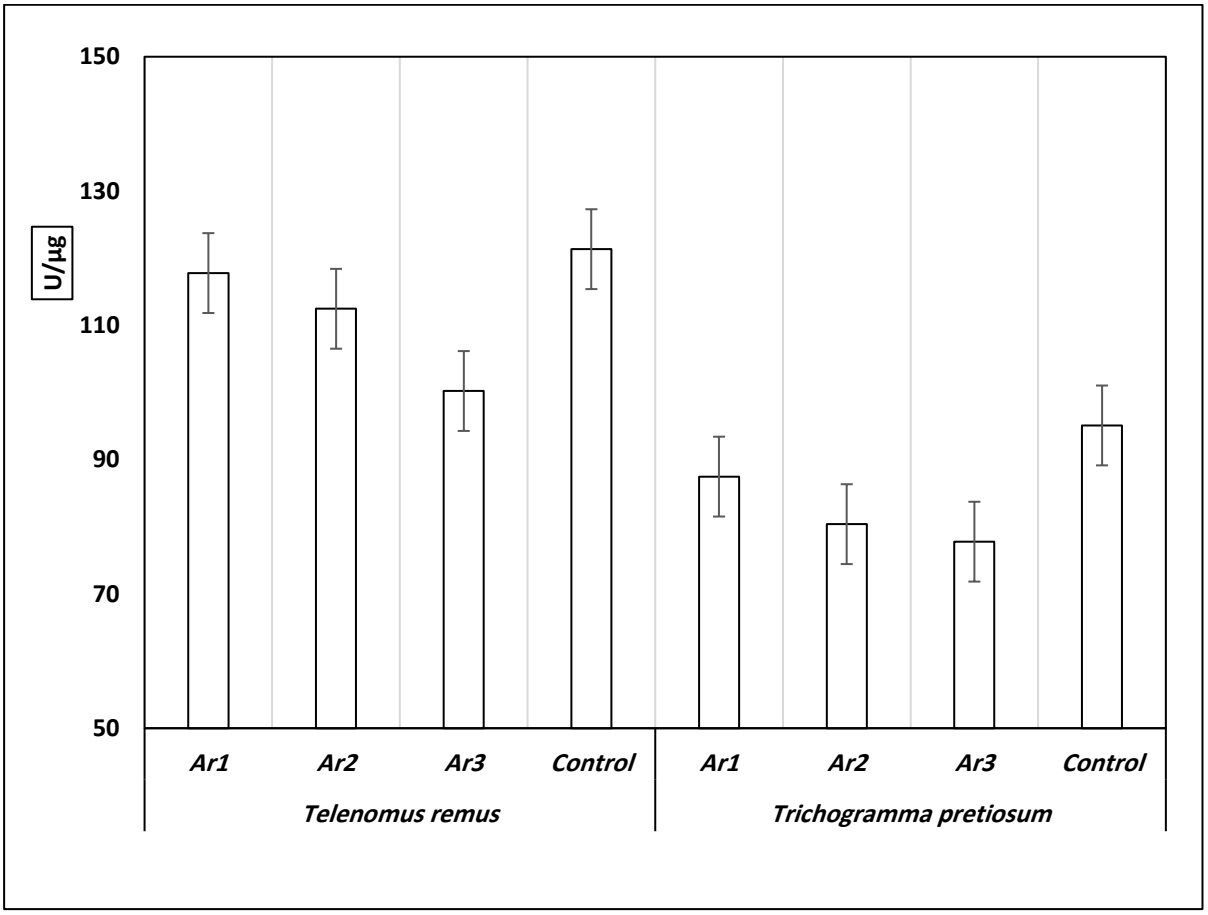


Fig.6: Effect of Synthetic Acetamide Derivatives on α-glycerophosphate dehydrogenase (α-GPDH) activity of flyers of parasitoids on *Spodoptera frugiperda* eggs.

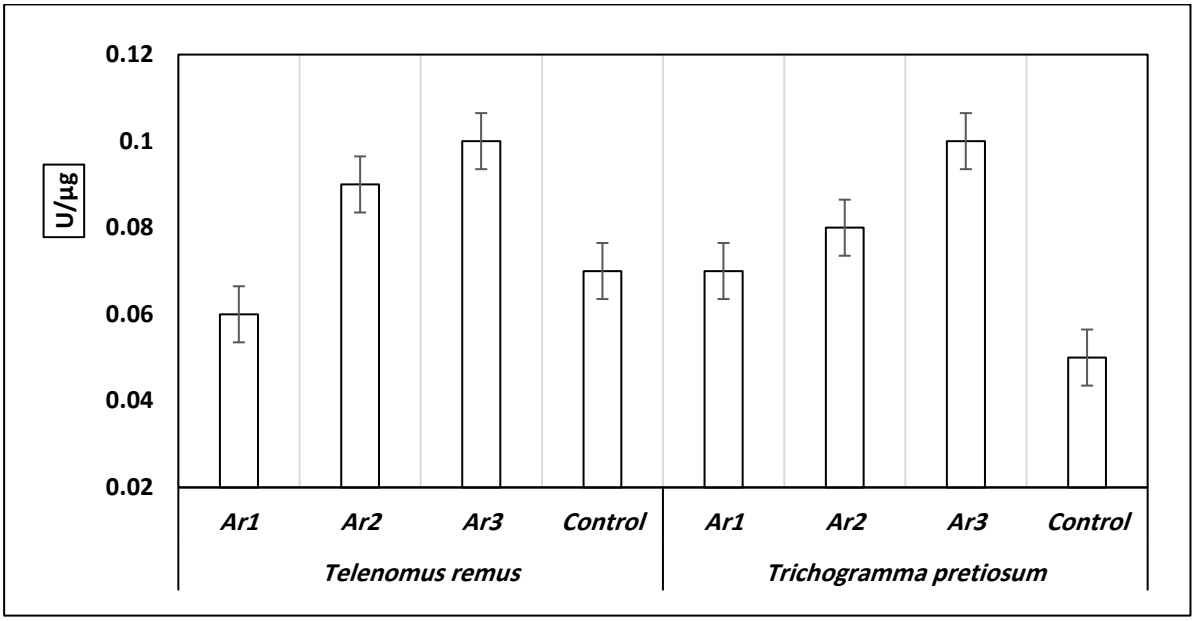


Fig.7: Effect of Synthetic Acetamide Derivatives on α-glycerophosphate dehydrogenase (α-GPDH) activity of non-flyers parasitoids on *Spodoptera frugiperda* eggs.

Concerning the α-GPDH activity of both non-flyers of parasitoids which were located at the bottom, the enzyme activity was lower than flyers (Fig. 7). α-GPDH activity values of non-flyers at the top of *Telenomus remus* affected by acetamide derivatives are recorded at 0.06,0.09,0.10, and 0.07, respectively. While, the activity of non-flyers of *Trichogramma pretiosum* were 0.07,0.08,0.10, and 0.05, respectively (Fig.7).

In both parasitoids, α-GPDH activity was significantly higher in flyers than in non-flyers in both species ($p<0.05$). P values were 0.0005 and 0.0100 in the case of *Telenomus remus* and *Trichogramma pretiosum*, resp.

The flight energy is acquired from lipid oxidation after utilization of carbohydrates as it were amid the primary minutes of flight since glycogen substance in flight muscles is low level (Ward *et al.*,1982). Mainly the metabolism of lipid and carbohydrate and coupling processes depend on α-GPDH which is soluble and highly concentrated in flight muscles (Sacktor, 1974). Once the flight muscle action is based on glycolysis, the foremost imperative function is re-oxidizing NADH. Still, when tri-acyl glycerides are the flight fuel, this chemical changes over glycerol-3-phosphate inferred from glycerol into dihidroxyacetone phosphate, a glycolytic intermediate to generate NAD + (Bewley, Miller, 1979).

Pesticides as IGRs pronounced the expanded action of cytoplasmic α- GPDH activity in treated larvae of *Musca domestica* (Mostafa, 1994), and it is clarified by IGRs' impact on the pattern of enzyme activity, very vacillation within the ontogenic range of cytoplasmic α- GPDH that varies from the control (Abdel-Moty *et al*., 1996). That can be because of depression or transformations of the directing genes capable of biosynthesis of the polypeptide chain building the protein (Hassan, 2009). Thereupon, acetamide derivatives affected α- GPDH activity gradually in comparison with the control of both parasitoids. In the case of flyers, the high amount of α- GPDH activity was found in control followed by Ar1, Ar2, and Ar3, resp. Otherwise, in the case of non-flyers, a high amount of α- GPDH activity was found in Ar3, Ar2, Ar1, and control, resp., which confirms the direct proportion between the flight capacity and cytoplasmic α-glycerophosphate dehydrogenase (α-GPDH). As well, the enzymatic activity in flight muscles was higher in flyers than non-flyers in other orders such as Hemiptera resembled by *Panstrongylus megistus* and *Triatoma sordida* (Soares, Santoro, 2000).

Future studies would be done to show and explain the side effects of used pesticides against *S.frugiperda* on parasitoids and predators as a comparative component of biological control contributed to the fully automated IPM through infotronic agriculture.

Conclusion

Ultimately, novel 2-Cyano-N-(3-(N-(thiazol-2-yl) sulfamoyl) phenyl) acetamide derivatives are prosperously beneficial to join integrated pest management (IPM) with biological control. Acetamide derivatives are adequate in controlling *Spodoptera frugiperda* eggs without impacting the flight capacity of egg parasitoids, *Telenomus remus,* and *Trichogramma pretiosum*. The flight capacity of *T. remus* and *T. pretiosum* is determined using an automated ESALQ unit powered by solar energy, showing higher capacity in *T. remus* even under treatments. Further, the flight capacity is directly related to the activity of α-glycerophosphate dehydrogenase (α-GPDH).

REFERENCES

Abd El-Wahab, R.A. (2017). Internet of Things (IoT) To Control the Two-Spotted Spider Mite, *Tetranychus urticae* Koch in Greenhouses. Egypt. Acad. J. Biolog. Sci., 9(3): 119-128. https://doi.org/ 10.21608/eajbsf.2017.17033

Abd El-Wahab, R.A., Harraz, N.H. & Shoman, S.A. (2024). Novel Synthetic 2-Cyano-N-(3-(N-(Thiazol-2-yl) Sulfamoyl) Phenyl) Acetamide Derivatives against Spinning Silk Threads in *Spodoptera frugiperda*. The Arab J. Agricul. Sci., 7 (21), 131 -156. https://doi.org/ 10.21608/ asajs.2024.336263

Atashi, N., Shishehbor, P., Seraj, A.A., Rasekh, A., Hemmati, S.A., Riddick, E.W. (2021). Effects of *Helicoverpa armigera* egg age on development, reproduction, and life table parameters of *Trichogramma euproctidis*. Insects 12(7):569. https://doi.org/10.3390/insects 12070569

Awasthi, P., Mahajan, R. K. (2008). Synthesis of some sulphonamide insect juvenile hormone - Part I. Indian J. Chem. Sec B, (47):1291-1297. https:// nopr.niscpr.res.in/bitstream/123456789/ 1921/1/IJCB%2047B%288%29%201291-1297.pdf

Bewley, E.R., Miller, S. (1979). Origin and differentiation of soluble alpha-glycerophosphate dehydrogenase isozyme in *Drosophila melanogaster*. In AR Liss, Current Topics in Biological and Medical Research,New York, p. 23-52.

Bradford, M.M. (1976). A rapid and sensitive method for the quantification of microgram quantities of protein utilizing the principle of protein-dye binding. Analyt. Biochem.,72: 248-254.

Carvalho, G.A., Godoy, M.S., Parreira, D.S., Lasmar, O., Souza, J.R., Moscardini, V.F. (2010). Selectivity of growth regulators and neonicotinoids for adults of *Trichogramma pretiosum* (Hymenoptera: Trichogrammatidae). Revista Colombiana de Entomología 36:195-201.

Cave, R.D. (2000). Biology, ecology and use in pest management of *Telenomus remus*. Biocontrol News Inf.,21:21–26. https://doi.org/10.1079/cabir reviews/ 20063 049829

Chambers, G.K., Felton, A.A., Ramshaw, J.A.M., Rigby, D.L., Sullivan, D.T. (1985). Structural analysis of glycerol-3-phosphate dehydrogenase from several Drosophila species. Biochem. Genet., 23: 801-815.

Cônsoli, F.L., Rossi, M.M., Parra, J.R.P. (1999). Developmental time and characteristics of the immature stages of *Trichogramma galloi* and *T. pretiosum*(Hymenoptera, Trichogrammatidae). Rev. Bras. Entomol. 43(3), 271–275.

Desneux, N., Decourtye, A., Delpuech, J.M. (2007). The sublethal effects of pesticideson beneficial arthropods. Ann. Rev. Entomol. 52, 81–106. https://doi.org/10.1146/annurev.ento.52. 110405.091440

Dutton, A., Bigler, F. (1995). Flight activity assessment of the egg parasitoid *Trichogramma brassicae* (Hym.: Trichogrammatidae) in laboratory and field conditions. Entomophaga 40: 223–233.

EL-Defrawi, M., Toppozada, A., Mansour, N., Zeid, M. (1964). Toxicological studies on the Egyptian cotton leafworm, *Prodenia litura*. 1-Suceptibility of different larval instars to insecticides. J. Econ. Entomol., 57 (4): 591–593.

Fathipour, Y., Sedaratian, A. (2013). Integrated management of *Helicoverpa armigera* in soybean cropping systems, in: Elshemy, H.A. (Ed.), Soybean – Pest Resistance. InTech, Rijeka, pp. 231–280. https://doi.org/10.5772/54522

Hassan,H.A. (2009). Efficiency of some new insecticides on physiological, histological and molecular level of cotton leafworm. Egypt. Acad. J. Biol. Sci., 2 (2): 197- 209.

IBM SPSS Statistics 20. (2020). https://www.ibm.com/support/pages/spss-statistics-20-available-download

Iqbal, A., Hou, Y.Y., Chen, Y. M., Ali, A., Monticelli, L. S., Desneux, N., Zang, L. S. (2020). Impact of *Trichogramma* parasitoid age on the outcome of multiparasitism in the factitious host eggs of Chinese oak silkworm, *Antheraea pernyi*. J. Pest Sci., 93:1347–1357. https://doi.org/10.1007/s10340-020-01239-1

Jin, T., Lin, Y., Ma, G., Liu, J., Hao, Z., Han, S., Peng, Z. (2021). Biocontrol potential of *Trichogramma* species against *Spodoptera frugiperda* and their field efficacy in maize. Crop Prot.,150:105790. https://doi.org/10.1016/j.cropro.2021.105790

Machado, F.M., Contel, E.P. (1991). Glycerol-3-phosphate dehydrogenase isozyme variation in adult meliponids (Hymenoptera: Apidae). Biochem. Genet., 29: 255-260.

Maia, J.B., Carvalho, G.A., Leite, M.I.S., Oliveira, R.L., Makyawa, L. (2010). Selectivity of insecticides used in corn crops to adult *Trichogramma atopovirilia* (Hymenoptera: Trichogrammatidae). Revista Colombiana de Entomología 36:2002-2006.

Molina-Ochoa, J., Carpenter, J.E., Heinrichs, E.A., Foster, J.E. (2003). Parasitoids and parasites of *Spodoptera Frugiperda* (Lepidoptera: Noctuidae) in the Americas and Caribbean basin: an inventory. Fla. Entomol.86(3):254–289. https://doi.org/10.1653/00154040(2003)086[0254:PAPO SF]2.0.CO;2

Parrra, J.R.P., Zucchi, R.A. (1997). Trichogramma e o controle biológico aplicado.Piracicaba: FEALQ, 324p.

Paiva, A.C.R. de, Iost Filho, F.H., Parro, E.A., Barbosa, D.P.L., Yamamoto, P.T. (2020).Do ready-mix insecticides cause lethal and sublethal effects on *Trichogramma pretiosum* pupa? J. Econom. Entomol.,113(3): 1227–1233. https://doi.org/10.1093/jee/toaa031

Pomari, A. F., Bueno, A.D.F., De Freitas Bueno, R.C.O., De Oliveira Menezes Junior, A. (2012). Biological Characteristics and thermal requirements of the biological control agent *Telenomus remus* (Hymenoptera: Platygastridae) reared on eggs of different species of the genus *Spodoptera* (Lepidoptera: Noctuidae). Ann. Entomol. Soc. Am.,105:73–81. https://doi.org/10.1603/AN11115

Pomari-Fernandes, A., Bueno, A.D.F., Bortoli, S.A.D. (2016). Size and flight ability of *Telenomus remus* parasitoids reared on eggs of the factitious host *Corcyra cephalonica*, Revista Brasileira de Entomologia, 60(2):177-181. https://doi.org/10.1016/j.rbe. 2016. 02.004

Prezotti, L., Parra, J.R.P., Vencovsky, R., Dias, C.T. dos S., Cruz, I., Chagas, M.C.M. (2002). Teste de vôo como critério de avaliação da qualidade de *Trichogramma pretiosum* Riley (Hymenoptera: Trichogrammatidae): adaptação de metodologia. Neotrop.Entomol., 31: 411–417.

Regupathy, A., Ramasubramanian, T., Ayyasamy, R. (2004). Rationale behind the use of insecticide mixtures for the management of insecticide resistance in India. J. Food Agric.Environ.,2(2):278-284.

Sacktor, B. (1974). Biological oxidations and energetics in insect mitochondria. In the physiology of insecta (4): 271- 353. Academic press. New York.

Sacktor, B. (1970). Regulation of intermediary metabolism, with special reference to the control mechanisms in insect flight muscle. Adv. Ins. Phys., 17: 167-347.

Sehnal, F., Akai, H. (1990). Insect silk glands: their types, development and function, and effects of environmental factors and morphogenetic hormones on them. Int. J. Insect Morph. Embryol., 19 (2):79-132. https://doi.org/10.1016/0020-7322(90)90022-H

Soares, R.P.P., Santoro, M.M. (2000). a-Glycerophosphate Dehydrogenase Activity in Flight Muscles of Triatomine Bugs *Panstrongylus megistus* and *Triatoma sordida*. Mem. Inst. Oswaldo Cruz 95 (5):707-709. https://doi.org/10.1590/S0074-02762000000500016

Souza, J.R., Carvalho, G.A., Moura, A.P., Couto, M.H.G., Maia, J.B. (2013). Impact of insecticides used to control *Spodoptera frugiperda* (J.E. Smith) in corn on survival, sex ratio, and reproduction of *Trichogramma pretiosum* Riley offspring. Chilean J.Agricul.Res.,73(2): 122-127. https://doi.org/10.4067/S0718-58392013000200006

Sullivan, D.T., Donovan, F.A., Skuse, G. (1983). Developmental regulation of glycerol-3-phosphate dehydrogenase synthesis in Drosophila. Biochem Genet 21:49-62.

Tang, J., Lyu, B., Lu, H., Ji, X., Yang, P., Su, H., Cai, B. (2020) Investigation and preliminary study of biological characteristic of parasitic wasps of *Spodoptera frugiperda* in Hainan. Chin J Trop Crops, 41:1189–1195. https:// doi.org/10.3969/j.issn.1000-2561. 2020. 06. 017

Ward, J.P, Candy, D.J., Smith, S.N. (1982). Lipid storage and changes during flight by triatomine bugs (*Rhodnius prolixus* and *Triatoma infestans*). J. Ins. Physiol., 28:527-534.