

Cold-Storage of *Piezodorus guildinii* (Hemiptera: Pentatomidae) Eggs for Rearing *Telenomus podisi* (Hymenoptera: Platygasteridae)

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ABSTRACT

Piezodorus guildinii (Hemiptera: Pentatomidae) is an important soybean pest, and one of its main natural enemies is *Telenomus podisi* (Hymenoptera: Platygasteridae). Rearing of the parasitoid is constrained by the hosts' egg quality, which deteriorates after few generations in laboratory, therefore, cold-stored host eggs utilization could be a useful tool for augmentative biological control. Thus, the objective was to evaluate the quality of *P. guildinii* cold-stored eggs, on the performance of parental and F₁ generation of *T. podisi*. Host eggs 24 hour old were stored at -18°C for one (N= 53), two (N= 28) or three months (N= 29), and approximately 40 host eggs were offered to a *T. podisi* female per treatment, for 48 hours. The control treatment consisted of 24-hour-old non-frozen host eggs, obtained and kept at 24°C (N= 55). Parental generation parasitism and progeny's emergence on frozen eggs was significantly lower than on non-frozen eggs, even for the shorter storage period. Male proportion and preimaginal development time of the progeny increased with freezing period. However, parasitism proportion caused by adults of F₁, and emergence, male proportion, and preimaginal development time of F₂ were not affected. Although the performance of *T. podisi* on frozen *P. guildinii* eggs was significantly lower than on nonfrozen ones, host eggs storage for up to two months allowed obtaining a parasitism rate of 40% with a high emergence rate. This could be helpful enough to maintain mass rearings, mainly during the host hibernation period, and to enhance field parasitism when host is scarce.

Keywords: Host storage, Mass-rearing, Parasitoids.

INTRODUCTION

Phytophagous hemipterans of the family Pentatomidae, commonly known as stink bugs, are important soybean pests. Among them, *Piezodorus guildinii* Westwood (Hemiptera: Pentatomidae) is the one that most affects the quality and viability of seeds and causes greater leaf retention when compared to other common bugs like *Nezara viridula* L. and *Euschistus heros* (F.) (Hemiptera: Pentatomidae) (Husch *et al.*, 2014). *Piezodorus guildinii* is a Neotropical multivoltine species, highly mobile and more difficult to control as it is less

susceptible than other bugs to labeled insecticides such as pyrethroids and organophosphates (Temple *et al.*, 2013a). It is one of the most predominant stink bugs and a serious pest of soybean in the south Nearctic and whole Neotropical regions (Castiglioni *et al.*, 2010; Corrêa-Ferreira, 2008; Massoni and Frana, 2006; Temple *et al.*, 2013b). In the last two decades *P. guildinii* relative abundance has been increasing significantly and has currently become the most important species in Buenos Aires and other provinces of Argentina (Cingolani, 2012; Cingolani *et al.*, 2014).

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In the Neotropical region the most common egg parasitoid species of *P. guildinii* are *Telenomus podisi* (Ashmead), *Trissolcus urichi* (Crawford) and *Trissolcus basalis* (Wollaston) (Hymenoptera: Platygasteridae) (Castiglioni *et al.*, 2010; Cingolani *et al.*, 2014; Corrêa-Ferreira, 2005; Molinari, 2005). Over 20 species of platygastriid wasps have been used for biological control of stink bugs in several countries (Luck, 1981; van Lenteren and Bueno, 2003). *Trissolcus basalis* releases mainly to control *N. viridula* have been made in Argentina (Crouzel and Saini, 1983), Brazil (Corrêa-Ferreira and Moscardi, 1995; Corrêa-Ferreira and Moscardi, 1996), Italy (Colazza and Bin, 1995) and the United States (Hoffmann *et al.*, 1991), and to control this stink bug and *Agonoscelis glitters* F. (Hemiptera: Pentatomidae) in Australia (Clarke, 1990). *Telenomus podisi* has been used to control *E. heros*, *P. guildinii* and *N. viridula* in soybean organic production fields in Brazil (Sujii *et al.*, 2002).

A frequent difficulty when implementing augmentative biological control is to obtain large numbers of control agents of appropriate quality, at the time they are required (Orr, 1988). Various techniques have been developed to optimize the maintenance of large parasitoids' rearing in the laboratory. Some of them are focused on parasitoids, such as cold storage of parasitized hosts (Bayram *et al.*, 2005; Dass and Ram, 1983; Gautam, 1986; Noble, 1937), in vitro development of parasitoids (Shirazi, 2006), and cold storage of pupae or adults of the parasitoid (Bayram *et al.*, 2005; Foerster *et al.*, 2004; Foerster and Doetzer, 2006; Gautam, 1986). Other techniques focus on ensuring a constant availability of enough host, such as the development of artificial diets (Fortes *et al.*, 2006; Panizzi *et al.*, 2000), irradiation of host eggs with gamma (γ) rays to increase the time during which they are likely to be parasitized (Nordlund *et al.*, 1983) and cold storage of healthy (not parasitized) hosts (Alim and Lim, 2010; Corrêa-Ferreira, 1998; Doetzer

and Foerster, 2013; Favetti *et al.*, 2014; Kivan and Kilic, 2005; Mahmoud and Lim, 2007).

Several intrinsic platygastriids characteristics, such as simplicity of adults' diet, lack of hyperparasitoids and pathogens, good reproductive capacity, and small size (and therefore minimum space requirements) make the rearing of these wasps feasible. However, supporting large colonies of these parasitoids is strongly constrained by the quality of their hosts, which deteriorates after few generations with currently used laboratory techniques (Parra and Cônsoli, 2009). For the specific case of *P. guildinii*, the establishment of large colonies is quite difficult due to the fact that very few individuals, obtained from eggs collected from field, can reach the adult stage. In addition, reproduction begins just after the sixth week of life (15 days after the imaginal molt), only 60 or 70% of the females are fertile (Panizzi and Slansky, 1985), and each of them performs only three to five egg masses of on average of 14 eggs each, during its lifetime. Another important factor is the high nymphal mortality (60%) that is registered with the commonly used rearing techniques (Serra and La Porta, 2001) and the difficulty of maintaining the colony throughout the year, because even under optimal temperature and photoperiod conditions, reproduction is interrupted each year due to hibernation, at least in the geographic region between 30°-35° S latitude (Zerbino *et al.*, 2013).

There is evidence that cold storage of host eggs can have positive, negative or neutral effects on the performance of platygastriids parasitoids (Orr, 1988 and references therein), and no adverse effects were found in F₁ generation (Alim and Lim, 2010; Mahmoud and Lim, 2007). The objective of this study was to evaluate the quality of *P. guildinii* eggs preserved at low temperatures for different storage periods and to assess the parasitism rate, and progeny's emergence, sex ratio and preimaginal development time, of parental and F₁ generations.

MATERIALS AND METHODS

Insects and Rearing Procedures

Colonies of stink bugs and wasps were established from field collected individuals. Adults of *P. guildinii* were fed *Phaseolus vulgaris* (L.) pods replaced every two days, and maintained in cages (15x15x30cm) at 24±1°C, 70±10% RH and 14:10 L:D. Deposited eggs were collected daily, and *T. podisi* was reared on these eggs, and kept in test tubes under the same laboratory conditions with honey as food source. All parasitoids females used in experiments were inexperienced, two-days old and fed ad-libitum.

Cold Storage Treatments

Piezodorus guildinii eggs 24-hour-old were stored at -18°C for one, two, or three months (treatments) wrapped in aluminum foil, following the methodology proposed by Corrêa-Ferreira and Moscardi (1993). After the storage period, eggs were kept at 5°C for two hours and then at 24°C for another two hours for acclimation of stored eggs before being offered to the parasitoids (Albuquerque *et al.*, 2000). On each treatment, a group of approximately 40 host eggs were offered to *T. podisi* females. Fifty-three replicates for one month stored eggs, 28 replicates for two months stored eggs, and 29 replicates for three months stored eggs were performed. In order to avoid pseudoreplication, replicates of each treatment periods were performed starting at different times over the year. The control treatment consisted of 24-hour-old nonfrozen host eggs, obtained and kept at 24°C (N= 55). Eggs were exposed to one female parasitoid for 48 h and then were kept under controlled conditions (24±1°C, 70±5% RH, 14:10 L:D) until emergence of parasitoids. Eggs from which no parasitoid

emerged after 12 days i.e. average preimaginal parasitoid development time at 24°C, (Corrêa-Ferreira, 1993) were dissected a week later to check presence of pupa or dead adult parasitoids inside the host.

We evaluated parasitism by parental generation, and emergence, male proportion, and preimaginal development time of F₁ on nonfrozen and frozen eggs. Additionally, we evaluated parasitism by F₁ and emergence, male proportion and preimaginal development time of F₂ (2nd filial generation).

Statistical Analysis

Parasitism rate (number of eggs from which a pupa or an adult parasitoid was observed/total number of offered eggs) and emergence proportion (number of emerged wasps/number of eggs from which a pupa or an adult parasitoid was observed) were compared among treatments, using the Kruskal-Wallis test ($P < 0.05$). We performed the Kruskal-Wallis *H* test only when ANOVA assumptions were not met, even after applying transformations to our data. We counted the total number of females and males developed in each treatment. We used χ^2 of 2x4 contingency table to analyze if the number of adults of both sexes among treatments differed from what could be expected by chance, and subdivided contingency tables were analyzed to find significant differences between pairs of treatments (Zar, 1996). We also compared female progeny's preimaginal development time (from the beginning of the experiment to emergence) among treatments, using the Kruskal-Wallis *H* test.

In addition, the effect of one month host egg refrigeration on F₁ generation of the parasitoid was assessed. Forty *T. podisi* females randomly selected among the group of adult parasitoids emerged from one month stored host eggs, and 55 *T. podisi* females selected among group of adult



parasitoids emerged from nonfrozen eggs were provided with approximately 40 nonfrozen eggs of *P. guildinii* for 48 h in controlled conditions ($24\pm1^{\circ}\text{C}$, $70\pm5\%$ RH, 14 hours photophase). Proportion parasitism, emergence rate, and preimaginal development time were compared using ANOVA. Sex ratio was analyzed using χ^2 of a 2×2 contingency table.

RESULTS

No host nymphal development was recorded from frozen eggs. Parasitism rate by parental generation was significantly lower on frozen host eggs than on nonfrozen ones ($H_{(3, N=165)} = 71.060$; $P < 0.001$), and the lowest value was recorded for the storage period of three months (Figure 1). Similarly, the progeny of the parental generation had a significantly lower emergence proportion than those developed in nonfrozen eggs ($H_{(3, N=135)} = 36.299$, $P < 0.001$) (Figure 1). Also, the parental generation progeny's sex ratio

differed among treatments ($\chi^2 = 28.925$, $\text{df} = 3$, $P = 0.05$), and only in the three months frozen eggs, the sex ratio was different, as suggested by a subdivided contingency table considering three months frozen eggs versus all other treatments ($\chi^2 = 23.865$, $\text{df} = 2$, $P = 0.05$) (Table 1).

Preimaginal development time of the female progeny of the parental generation was significantly longer in wasps developed from one month frozen eggs ($H_{(3, N=107)} = 26.796$, $P < 0.001$) (Table 1). In every case, males emerged the day before females' emergence date.

For the F_1 , parasitism rate caused by *T. podisi* females emerged from one month frozen eggs was similar to that of females emerging from nonfrozen eggs ($F = 1.720$, $\text{df} = 1$, $P = 0.193$) (Figure 2). Emergence rate ($F = 0.74$, $\text{df} = 1$, $P = 0.393$) (Figure 2), sex ratio ($\chi^2 = 3.059$, $\text{df} = 1$, $P = 0.08$) and preimaginal development time of the progeny of F_1 generation (i.e. F_2) ($F = 0.24$, $\text{df} = 1$, $P = 0.625$) (Table 2) were also similar between storage treatments.

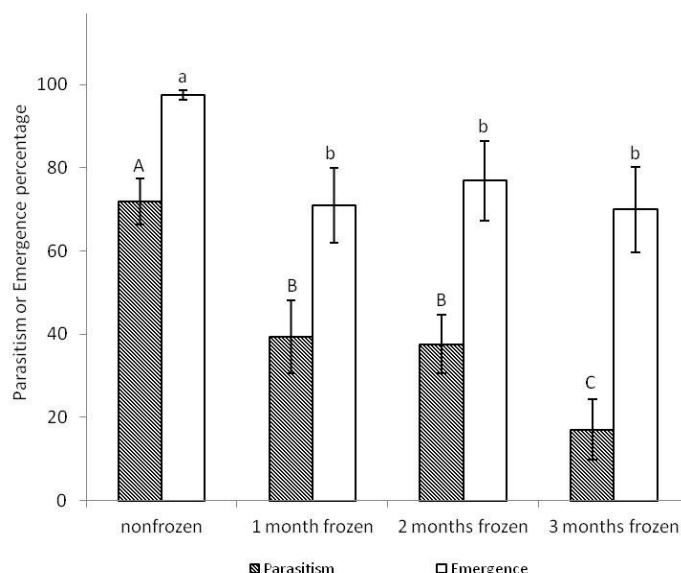


Figure 1. Parasitism and progeny's emergence proportion of the parental generation of *Telenomus podisi*, from nonfrozen or frozen *Piezodorus guildinii* eggs. Bars indicate the confidence interval at 95%. Different letters indicate significant differences (by Kruskal-Wallis) on parasitism (upper-case letters) and emergence (lower-case letters) among non-frozen and frozen eggs.

Table 1. Progeny's male proportion [Male/(Male+Female)] and females' preimaginal development time (days) (mean±SE) of the parental generation of *T. podisi* developed in nonfrozen and frozen eggs of *P. guildinii* stored during one, two or three months.^a

Treatment	Progeny's male proportion	Females' preimaginal development time
Nonfrozen	0.126±0.008a (n= 55)	12.982±0.057a (n= 55)
1 month frozen	0.091±0.011a (n=32)	15.125±0.206b (n= 32)
2 months frozen	0.084±0.014a (n= 26)	13.125±0.189a (n= 16)
3 months frozen	0.250±0.015b (n= 16)	12.500±0.147a (n= 4)

^a Numbers in each column followed by a different letter are significantly different (P< 0.05) for contingency table (progeny's male proportion) or Kruskal-Wallis.

Table 2. Progeny's male proportion [Male/(Male+Female)] and females' preimaginal development time (days) (mean±SE) of the parental generation and F₁ (1st filial generation) of *T. podisi* developed in non-frozen *P. guildinii* eggs.^a

Parasitoid generation	Progeny's male proportion ^{ns}	Females' preimaginal development time ^{ns}
Parental	0.132±0.007 (df= 54)	12.982±0.057 (df= 54)
F ₁	0.106±0.007 (df= 39)	13.075±0.083 (df= 39)

^a ns: Non significantly different (P< 0.05) for contingency table.

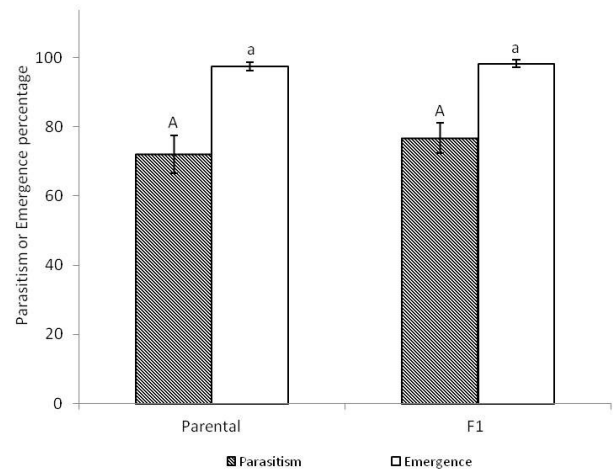


Figure 2. Parasitism and progeny's emergence proportion of the parental generation and F₁ (1st filial generation) of *Telenomus podisi* in nonfrozen *Piezodorus guildinii* eggs. Bars indicate the confidence interval at 95%.



DISCUSSION

Mass-rearings of platygastriid parasitoids demand large numbers of host eggs, as it has not been possible to maintain platygastriids species colonies without rearing the host up to the present (Orr, 1988 and references therein; Shirazi, 2006; Strand *et al.*, 1988; Volkoff *et al.*, 1992). Besides, stink bugs rearing are constrained, as they have a poorer development on artificial diets (Fortes *et al.*, 2006; Silva and Panizzi, 2008). In this sense, cold storage of host eggs seems to be interesting to obtain large numbers of control agents of appropriate quality, at the time they are required.

Our results showed that *P. guildinii* eggs storage for up to two months allowed obtaining an acceptable parasitism rate by *T. podisi* with high emergence. Parasitism on frozen host eggs was significantly lower than that observed on nonfrozen eggs, and had halved when eggs were preserved in freezer for one month. Other authors have shown that parasitism and progeny's emergence from cold stored hosts were variable with different temperatures and storage periods (Corrêa-Ferreira and Moscardi, 1993; Orr, 1988). *Nezara viridula* eggs preserved at temperatures between -2 and -10°C remained viable for parasitism by *T. basalis* for less than 60 days (Albuquerque *et al.*, 2000) while if the preservation of eggs occurred in freezer, as in this study, parasitoid development was not affected until a storage period of 150 days. In contrast, *Dolycoris baccarum* (L.) (Hemiptera: Pentatomidae) freezer stored eggs have remained viable for *Trissolcus nigripedius* Ashmead (Hymenoptera: Platygastriidae) for only 8 days (Mahmoud and Lim, 2007).

Telenomus podisi progeny's emergence was lower from frozen eggs than from nonfrozen ones. We observed many parasitoid pupae and adults dead inside the host egg. This may indicate a decrease in egg quality as a resource, which could have diminished larval development and/or the capacity of developed adults to emerge. On the other hand, freezing and subsequent thawing could also have

provoked changes in the hardness of the host egg chorion (Kivan and Kilic, 2005), making it more difficult for the wasps to cut it with their mouth parts for emergence.

The proportion of female wasps developed in frozen host eggs stored for three months was the lowest. As usually happens with hymenopteran parasitoids, *T. podisi* have a haplo-diploid sex-determination system, female being able to choose the sex of their progeny by controlling fertilization (Flanders, 1946). Distortions of sex ratio may come from a modification of the proportion of fertilized eggs oviposited i.e. primary sex ratio, or from a differential mortality between sexes i.e. secondary sex ratio. The sex ratio found in this study would indicate that an increase in storage time of frozen eggs made host quality to diminish, pushing females to oviposit more male progeny.

The longer preimaginal development time needed by wasps to complete their development on one month frozen eggs also denotes a decline in hosts' quality. In this study, only a low number of adults could emerge from eggs stored for longer period (three months), and 20% of the parasitoids died at pupal stage. This may suggest that the low quality of this host would have prevented wasps to complete their development.

Parasitism rate by the F_1 and emergence of F_2 from host eggs frozen for one month was not affected. Similarly, other authors did not find negative effects of pentatomids' eggs cold storage on platygastriids' second generation (Alim and Lim, 2010; Mahmoud and Lim, 2007).

Although the performance of *T. podisi* on frozen *P. guildinii* eggs was significantly lower than on non-frozen eggs, storage for up to two months allowed obtaining a parasitism rate of 40% with an emergence rate of almost 80%. This could be helpful enough to maintain mass rearing mainly during the host hibernation period, or to face adverse circumstances that can cause unsynchronization of host-parasitoids rearing.

An important technique for maintaining suitable host for longer periods is the storage of host eggs in liquid nitrogen. For example,

Graphosoma lineatum (L.) (Hemiptera: Pentatomidae) eggs remained suitable for *Trissolcus simoni* (Mayr) (Hymenoptera: Platygasteridae) for as long as five years (Gennadiev and Khlistovskii, 1980). Even though, when a short storage period is sufficient, the use of frozen host eggs could be a cheaper and handier technique than maintaining hosts in liquid nitrogen.

Interestingly, cold-stored host eggs could also be useful to build up the population of natural enemies in the field by mass releasing non-viable host eggs when hosts is limiting in the field (Leopold, 1998). Lim and Mahmoud (2009), Alim and Lim (2011) and Mainali *et al.* (2012) have demonstrated that this tool could help to increase platygasterids field parasitism.

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REFERENCES

1. Alim, M. A. and Lim, U. T. 2010. Biological Attributes of *Ooencyrtus nezarae* Ishii (Hymenoptera: Encyrtidae) Reared on Refrigerated Eggs of *Riptortus pedestris* (= *clavatus*) Fabricius (Hemiptera: Alydidae). *J. Asia-Pacific Entomol.*, **13**: 139-143.
2. Alim, M. A. and Lim, U.T. 2011. Refrigerated Eggs of *Riptortus pedestris* (Hemiptera: Alydidae) Added to Aggregation Pheromone Traps Increase Field Parasitism in Soybean. *J. Econ. Entomol.*, **104**: 1833-1839.
3. Albuquerque, F. A., de Sousa Lobo Lima, S., Zabini, A. V., Pattaro, F. C. and Maestro Borges, L. 2000. Viabilidade de Ovos de *Nezara viridula* (L.) Armazenados a Baixas Temperaturas para o Parasitismo por *Trissolcus basalis* (Woll.). *Acta Sci.*, **22**: 963-967.
4. Bayram, A., Ozcan, H. and Kornosor, S. 2005. Effect of Cold Storage on the Performance of *Telenomus busseolae* Gahan (Hymenoptera: Scelionidae), an Egg Parasitoid of *Sesamia nonagrioides* (Lefebvre) (Lepidoptera: Noctuidae). *Biol. Control*, **35**: 68-77.
5. Castiglioni, E., Ribeiro, A., Alzugaray, R., Silvam H., Ávila, I. and Loíaconom M. S. 2010. Prospección de Parasitoides de Huevos de *Piezodorus guildinii* (Westwood) (Hemiptera: Pentatomidae) en el Litoral Oeste de Uruguay. *Agrociencia Uruguay*, **14**: 22-25.
6. Cingolani, M. F. 2012. Parasitismo de Huevos de *Piezodorus guildinii* (Hemiptera: Pentatomidae) por *Trissolcus basalis* y *Telenomus podisi* (Hymenoptera: Scelionidae) en el Noreste de la Provincia de Buenos Aires. PhD. Dissertation, Facultad de Ciencias Naturales y Museo (UNLP), Argentina.
7. Cingolani, M. F., Greco, N. M. and Liljesthröm, G. G. 2014. Egg Parasitism of *Piezodorus guildinii* and *Nezara viridula* (Hemiptera: Pentatomidae) in Soybean, Alfalfa and Red Clover. *Revista de la Facultad de Ciencias Agrarias, UNCuyo*, **46**: 15-27.
8. Clarke, A. R. 1990. The Control of *Nezara viridula* L. with Introduced Egg Parasitoids in Australia. A Review of a "Landmark" Example of Classical Biological Control. *Aust. J. Agr. Res.*, **41**: 1127-1146.
9. Colazza, S. and Bin, F. 1995. Efficiency of *Trissolcus basalis* (Hymenoptera: Scelionidae) as an Egg Parasitoid of *Nezara viridula* (Heteroptera: Pentatomidae) in Central Italy. *Environ. Entomol.*, **24**: 1703-1707.
10. Corrêa-Ferreira, B. S. 1993. Utilização do Parasitóide *Trissolcus basalis* (Wollaston) No Controle de Percevejos da Soja. Embrapa, Londrina, Brazil, 40 PP.
11. Corrêa-Ferreira, B. S. 1998. Viability of *Nezara viridula* (L.) Eggs for Parasitism by *Trissolcus basalis* (Woll.), under Different Storage Techniques in Liquid Nitrogen. *Anais Sociedade Entomológica do Brasil*, **27**: 101-107.



12. Corrêa-Ferreira, B. S. 2005. Suscetibilidade da Soja a Percevejos na Fase Anterior ao Desenvolvimento das Vagens. *Pesqui. Agropecu. Bras.*, **40**: 1067-1072.
13. Corrêa-Ferreira, B. S. 2008. *Trissolcus basal* Para o Controle de Percevejos da Soja. In: "Controle Biológico no Brasil: Parasitóides e Predadores", (Eds.): Parra, J. R. P., Botelho, P. S. M., Corrêa-Ferreira, B. S. and Bento, J. M. S.. Mandole, Piracicaba, Brazil, PP. 449-471.
14. Corrêa-Ferreira, B. S. and Moscardi, F. 1993. Técnicas de Armazenamento de Ovos do Percevejo-verde Visando à Multiplicação do Parasitoide *Trissolcus basal* (Wollaston). *Pesqui. Agropecu. Bras.*, **28**: 1247-1253.
15. Corrêa-Ferreira, B. S. and Moscardi, F. 1995. Seasonal Occurrence and Host Spectrum of Egg Parasitoids Associated with Soybean Stink Bugs. *Biol. Control*, **5**: 196-202.
16. Corrêa-Ferreira, B. S. and Moscardi, F. 1996. Biological Control of Soybean Stink Bugs by Inoculative Releases of *Trissolcus basal*. *Entomol. Exp. Appl.*, **79**: 1-7.
17. Crouzel, I. S. and Saini, E. D. 1983. Importación de *Trissolcus basal* (Wollaston) (Hym. Scelionidae) en la Argentina para el Control Biológico de *Nezara viridula* (L. (Hem. Pentatomidae). *Revista de la Sociedad Entomológica Argentina*, **42**: 257-260.
18. Dass, R. and Ram, A. 1983. Effect of Frozen Eggs of *Corcyra cephalonica* Staiton (Pyralidae: Lepidoptera) on Parasitism on *Trichogramma exiguum* (Pinto and Platner) (Trichogrammatidae: Hymenoptera). *Indian J. Entomol.*, **45**: 345-347.
19. Doetzer, A. K. and Foerster, L. A. 2013. Storage of Pentatomid Eggs in Liquid Nitrogen and Dormancy of *Trissolcus basal* (Wollaston) and *Telenomus podisi* Ashmead (Hymenoptera: Platygastriidae) Adults as a Method of Mass Production. *Neotrop. Entomol.*, **42**: 534-538.
20. Favetti, B. M., Butnariu, A. R. and Doetzer, A. K. 2014. Storage of *Euschistus heros* Eggs (Fabricius) (Hemiptera: Pentatomidae) in Liquid Nitrogen for Parasitization by *Telenomus podisi* Ashmead (Hymenoptera: Platygastriidae). *Neotrop. Entomol.*, **43**: 291-293.
21. Flanders, S. E. 1946. Control of Sex and Sex-limited Polymorphism in the Hymenoptera. *Q. Rev. Biol.*, **21**: 135-143.
22. Foerster, L. A. and Doetzer, A. K. 2006. Cold Storage of the Egg Parasitoids *Trissolcus basal* (Wollaston) and *Telenomus podisi* Ashmead (Hymenoptera: Scelionidae). *Biol. Control*, **36**: 232-237.
23. Foerster, L. A., Doetzer, A. K. and Ferreira de Castro, L. C. 2004. Emergence, Longevity and Fecundity of *Trissolcus basal* and *Telenomus podisi* after Cold Storage in the Pupal Stage. *Pesqui. Agropecu. Bras.*, **39**: 841-845.
24. Fortes, P., Magro, S. R., Panizzi, A. R. and Parra, J. R. P. 2006. Development of a Dry Artificial Diet for *Nezara viridula* (L.) and *Euschistus heros* (Fabricius) (Heteroptera: Pentatomidae). *Neotrop. Entomol.*, **35**: 567-572.
25. Gautam, R. D. 1986: Effect of Cold Storage on the Adult Parasitoid *Telenomus remus* Nixon Scelionidae: Hymenoptera and the Parasitised Eggs of *Spodoptera litura* Fabr. *Noctuidae Lepidoptera. J. Entomol. Res.*, **10**: 125-131
26. Gennadiev, V. G. and Khlistovskii, E. D. 1980. Long Term Cold Storage of Host Eggs and Reproduction in Them of Egg Parasites of Insect Pest. *Zh. Obshch. Biol.*, **41**: 314-319.
27. Hoffmann, M. P., Davidson, N. A., Wilson, L. T., Ehler, L. E., Jones, W. A. and Zalom, F. G. 1991. Imported Wasp Helps Control Southern Green Stink Bug. *Calif. Agr.*, **45**: 20-22.
28. Husch, P. E., de Olivera, M. C. N. and Sosa-Gómez, D. R. 2014. Characterization of Injury Caused by *Edessa meditabunda* (F.), *Chinavia impicticornis* (Stål), and *Piezodorus guildinii* (West.) (Hemiptera: Pentatomidae) to Soybean. *Neotrop. Entomol.*, **43**: 276-281.
29. Kivan, M. and Kilic, N. 2005. Effects of Storage at Low-temperatures of Various Heteropteran Host Eggs on the Egg Parasitoid, *Trissolcus semistriatus*. *BioControl*, **50**: 589-600.
30. Leopold, R. A. 1998. Cold Storage of Insects for Integrated Pest Management. In: "Temperature Sensitivity in Insects and Application in Integrated Pest Management", (Eds.): Hallman, G. J. and Denlinger, D. L.. Westview Press, Oxford, UK, PP. 235-267.
31. Lim, U. T. and Mahmoud, A. M. A. 2009. Inoculation of Refrigerated Non-viable Eggs of *Riptortus clavatus* (Heteroptera: Alydidae) to Enhance Parasitism by Egg Parasitoids in Soybean Field. *Appl. Entomol. Zool.*, **44**: 37-45.
32. Luck, R. F. 1981. Parasitic Insects Introduced as Biological Control Agents for Arthropod Pests. In: "Handbook of Pest Management in Agriculture", (Ed.): Pimentel, D.. CRC Press, Boca Ratón, USA, PP. 125-284.

33. Mahmoud, A. M. A. and Lim, U. T. 2007. Evaluation of Cold-stored Eggs of *Dolycoris baccarum* (Hemiptera: Pentatomidae) for Parasitization by *Trissolcus nigripedius* (Hymenoptera: Scelionidae). *Biol. Control*, **43**: 287-293.
34. Mainali, B. P., Kim, S. and Lim, U. T. 2012. Effects of Combining Releases of Non-viable Host Eggs with Insecticide Application on *Riptortus pedestris* Population and Its Egg Parasitoid. *J. Asia-Pacific Entomol.*, **15**: 299-305.
35. Massoni, F. and Frana, J. 2006. Enemigos Naturales del Complejo de Chinchas Fitófagas y Evaluación de su Acción Ecológica en un Cultivo de Soja. *Publicación Miscelánea INTA EE Rafaela*, **106**: 163-165.
36. Molinari, A. 2005. *Control Biológico. Especies Entomófagas en Cultivos Agrícolas*. Ediciones INTA, Centro Regional Santa Fe. EEA Oliveros, Santa Fe, Argentina, 80 PP.
37. Noble, N. S. 1937. An Egg Parasite of the Green Vegetable Bug. *Agric. Gazette New South Wales*, **48**: 337-341.
38. Nordlund, D. A., Lewis, W. J. and Gueldner, R. C. 1983. Kairomones and Their Use for Management of Entomophagous Insects. XIV. Response of *Telenomus remus* to Abdominal Tips of *Spodoptera frugiperda*, (Z)-9-tetradecene-1-ol Acetate and (Z)-9-dodecene-1-ol Acetate. *J. Chem. Ecol.*, **9**: 695-701.
39. Orr, D. B. 1988. Scelionid Wasps as Biological Control Agents: A Review. *Fla. Entomol.*, **71**: 506-528.
40. Panizzi, A. R., Postali, J. R., Santos, C. H. and Rodriguez Carvalho, D. 2000. Rearing the Southern Green Stink Bug Using an Artificial Dry Diet and an Artificial Plant. *Pesqui. Agropecu. Bras.*, **35**: 1709-1715.
41. Panizzi, A. R. and Slansky, F. 1985. Review of *Phytophagous pentatomids* (Hemiptera: Pentatomidae) Associated with Soybean in the Americas. *Fla. Entomol.*, **68**: 184-214.
42. Parra, J. R. P. and Cônsoli, F. L. 2009. Criação Massal e Controle de Qualidade de Parasitoides de Ovos. In: "*Controle Biológico de Pragas: Produção Massal e Controle de Qualidade*"; (Ed.): Bueno, V. H. P.. Editora UFPA, Lavras, Brazil, PP. 169-198.
43. Serra, G. V. and La Porta, N. C. 2001. Aspectos Biológicos y Reproductivos de *Piezodorus guildinii* (West.) (Hemiptera: Pentatomidae) en Condiciones de Laboratorio. *Agriscientia*, **18**: 51-57.
44. Shirazi, J. 2006. Investigation on the *In vitro* Rearing of *Trissolcus grandis* an Egg Parasitoid of *Eurygaster integriceps* by Use of Artificial Diet. *Pak. J. Biol. Sci.*, **9**: 2040-2047.
45. Silva, F. A. C. and Panizzi, A. R. 2008. The Adequacy of Artificial Oviposition Substrates for Laboratory Rearing of *Piezodorus guildinii* (Westwood) (Heteroptera, Pentatomidae). *Revi. Bras. Entomol.*, **52**: 131-134.
46. Strand, M. R., Vinson, S. B., Nettles, W. C. and Xie, Z. N. 1988. *In vitro* Culture of the Egg Parasitoid *Telenomus heliothidis*: The Role of Teratocytes and Medium Consumption in Development. *Entomol. Exp. Appl.*, **46**: 71-78.
47. Sujii, E. R., Pires, C. S., Schmidt, F. V. G., Armando, M. S., Moreira Borges, M. M., Guimarães Carneiro, R. and Viana Valle, J. C. 2002. Controle Biológico de Insetos-praga na Soja Orgânica do Distrito Federal. *Cadernos de Ciência Tecnologia*, **19**: 299-312.
48. Temple, J. H., Davis, J. A., Hardke, J. T., Moore, J. and Leonard, B. R. 2013a. Susceptibility of Southern Green Stink Bug and Redbanded Stink Bug to Insecticides in Soybean Field Experiments and Laboratory Bioassays. *Southwest. Entomol.*, **38**: 393-406.
49. Temple, J. H., Davis, J. A., Micinski, S., Hardke, J. T., Price, P. and Leonard, B. R. 2013b. Species Composition and Seasonal Abundance of Stink Bugs (Hemiptera: Pentatomidae) in Louisiana Soybean. *Environ. Entomol.*, **42**: 648-657.
50. van Lenteren, J. C. and Bueno, V. H. P. 2003. Augmentative Biological Control of Arthropods in Latin America. *BioControl.*, **48**: 123-139.
51. Volkoff, N., Vinson, S. B., Wu, Z. X. and Nettles, W. C. J. 1992. *In vitro* Rearing of *Trissolcus basalis* [Hym., Scelionidae] an Egg Parasitoid of *Nezara viridula* [Hem., Pentatomidae]. *Entomophaga*, **37**: 141-148.
52. Zar, J. H. 1996. *Biostatistical Analysis*. 3rd Edition, Prentice Hall, New Jersey, USA, 662 PP.
53. Zerbino, M. S., Altier, N. A. and Panizzi, A. R. 2013. Effect of Photoperiod and Temperature on Nymphal Development and Adult Reproduction of *Piezodorus guildinii* (Heteroptera: Pentatomidae). *Fla. Entomol.*, **96**: 572-582.



نگهداری تخم *Piezodorus guildinii* (Hemiptera: Pentatomidae) در
سردخانه برای پرورش *Telenomus podisi* (Hymenoptera: Platygasteridae)

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چکیده

از آفت های مهم سویا حشره *Piezodorus guildinii* (Hemiptera: Pentatomidae) می باشد که یکی از دشمنان طبیعی آن *Telenomus podisi* (Hymenoptera: Platygasteridae) است. پرورش این پارازیتوید محدود به کیفیت تخم میزبان است که بعد از چند نسل در آزمایشگاه تخریب می شود و بنا براین استفاده از تخم میزبان نگهداری شده در سردخانه می تواند روش مفیدی برای رهاسازی انبوه در کنترل زیستی آن باشد. از این قرار، هدف این پژوهش ارزیابی کیفیت تخم های *P. guildinii* نگهداری شده در سردخانه و تاثیر روی عملکرد نسل والدی و F1 حشره *T. podisi* بود. به این منظور، تخم های میزبان که ۲۴ ساعت از تولیدشان می گذشت در شرایط ۱۸- درجه سانتی گراد به مدت های یکماه (تعداد $N=53$)، ۲ ماه ($N=28$) و سه ماه ($N=29$) نگهداری شد و سپس در حدود ۴۰ تخم میزبان در طی ۴۸ ساعت به حشره ماده *T. podisi* در هر تیمار داده شد. در تیمار شاهد از تخم های میزبان که ۲۴ ساعت از تولیدشان می گذشت و در حرارت ۲۴ درجه سانتی گراد نگهداری شده بودند ($N=55$) استفاده شد. بر اساس نتایج، حتی در مورد تخم هایی که زمان کوتاهتری در سردخانه بودند رفتار انگلی (*parasitism*) نسل والدی و ظهور فرزندان (نتاج) در مورد تخم های یخ زده به طور معنی داری کمتر از تخم های یخ نزده بود. با افزایش دوره یخزدگی، نسبت نرها و دوره رشد قبل از بلوغ (*preimaginal*) نتاج زیاد می شد اما، نسبت رفتار انگلی ناشی از حشرات بالغ F1 و نیز ظهور نتاج، نسبت حشرات نر، و طول دوره رشد قبل از بلوغ در F2 تحت تاثیر دوره یخزدگی قرار نگرفت. هر چند عملکرد *T. podisi* روی تخم های یخ زده *P. guildinii* به طور معنی داری کمتر از تخم های یخ نزده بود، نگهداری تخم های میزبان در سردخانه تا دو ماه، دستیابی به نرخ انگلی تا حد ۴۰٪ و نیز نرخ بالای ظهور نتاج را مقدور ساخت. از این قرار، این روش برای پرورش انبوه حشره به ویژه در طی دوره خواب زمستانی میزبان و تشدید رفتار انگلی آن در مزرعه در زمانی که شمار میزبان کم است می تواند به اندازه کافی مفید باشد.