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Telenomus remus Nixon is an Egg Parasitoid: An Overview

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ABSTRACT: *Telenomus remus* parasitizes the eggs of several lepidopterous insects. In several nations, it is currently raised and released to control crop pests of the Spodoptera genus, especially *Spodoptera litura* and *Spodoptera frugiperda*. A review is given of *Telenomus remus* biology, ecology, dispersal capacity, pattern, the effect of kairomones and pesticides, behavioral patterns and parasitism efficacy, historical use in pest control, and taxonomy conundrums. Research is required to increase the effectiveness of this parasitoid's field pest control, and suggestions for increasing its use are presented.

Keywords: *Telenomus remus*, parasitism, biology, ecology, dispersal capacity, kairomones.

INTRODUCTION

Telenomus remus Nixon (Hymenoptera: Platygatridae) is an egg parasitoid. It is efficient against different pest species of the genus *Spodoptera* and has a strong potential for use in augmentative biological control due to its high reproductive capability. (Lepidoptera: Noctuidae) (Pomari *et al*., 2012; Bueno *et al*., 2008). Pests are currently treated with synthetic insecticides, however, biological management provides a more cost-effective and sustainable alternative. As a result, several biological control alternatives are being considered, such as the introduction of *Telenomus remus*, the main egg parasitoid of *Spodoptera frugiperda* in the Americas, where it is already used in augmentative biological control programs. There is an urgent need for the creation of a sustainable, economical management plan. Identifying potential native natural enemies in the agricultural ecosystem under the recently invaded habitat is also important. This egg parasitoid may be used in the early stages of the crop as an integrated pest management strategy to lower the pest population.

This review report examines the material that has been written about *Telenomus remus,* including its biology, ecology, taxonomy, how kairomones and pesticides affect it, and how it is used in pest management programs. Discussions are had over issues with the taxonomy and identification of *Telenomus species* that are related to *Telenomus remus*. Additionally, suggestions for expanding the usage of this parasitoid and the research required to increase its efficacy in pest control are discussed.

Taxonomy of *Telenomus remus*: *Telenomus remus* was described from Ulu Gombak, just NE of Kuala Lumpur, Malaysia (Nixon, 1937). In the original description, Nixon states: ‘This species is probably *Telenomus Spodoptera* Dodd, which was described from four females labeled “from eggs of a moth *Spodoptera* sp. on sugar beet, Krebet, Java dated 23rd July 1913”. Nixon was hesitant to adopt Dodd's name because he believed the first description to be insufficient and that there may have been a significant variance in the forewing proportions. At least two more Telenomus species resemble *Telenomus remus* morphologically (including male genitalia): *Telenomus nawai* Ashmead was described from Gifu, Japan (Ashmead, 1904). Cock (1985) states that a species of *Telenomus* that commonly parasitizes eggs of *Spodoptera* spp. in the Dominican Republic crosses with *Telenomus remus* and produces fertile offspring.

Parasitism of *Telenomus remus* on host species: Due to its ability to infect the entire egg mass, it is a crucial biological control agent (Figueiredo *et al*., 2002). To ensure the high quality of the parasitoids created in laboratories utilizing *Corcerya cephalonica* eggs as a fictitious host, parasitoids did not lose their capacity to parasitize eggs of natural hosts (Fernandes *et al*., 2015). According to estimates, up to 90% of *Spodoptera frugiperda* eggs might get parasitized when 5000–8000 parasitoids are released per hectare. (Hernandez *et al*., 1989; Gonzalez and Zocco, 1996; Cave, 2000).The majority (52%) of the species used in augmentative releases for pest management are hymenopteran parasitoids. (Van Lenteren, 2012). The *Spodoptera frugiperda* egg, egg larva, larva, and larval pupal stages are all parasitized by five different parasitoids. The frequencies of egg parasitism for *Trichogramma chilonis* Ishii and *Telenomus remus* Nixon were 15.81-23.87% and 5.44-8.78%, respectively. The parasitism of *S. frugiperda* larvae by the larval parasitoids was 9.18% (Navika *et al*, 2021). In maize-bean, maize-squash, maize-bean-squash polycultures, and maize monoculture, the percentages of parasitism in the jarochocrema maize genotype rose by 87.88±3.27%, 89.75±1.99, 99.50±0.19, and 86.88±2.66%, respectively, while in the yellow maize genotype they decreased by 70.00±7.05, 64.50±5.63, 77.88±6.51 and 63.25±5.20%. The various genotype of maize, bean, and squash, polyculture system, weeds, densities of the host eggs, and numbers and quality of egg masses were found effects the percentage of *Telenomus remus* parasitism on *Spodoptera frugiperda* eggs (Antonio *et al*., 2012). The parasitism caused by *Telenomus remus* in natural populations is moderate in the Americas, but it is used successfully as an additional biological control agent in several nations. Augmentative releases of *Telenomus remus* in maize fields can result in 80–100% parasitism, which provides complete control of *Spodoptera frugiperda* (Cave, 2000; Gutierrez *et al*., 2012; Pomari *et al*., 2013).

To prevent superparasitism, a female typically produces 270 eggs in her lifetime, usually laid individually in each host egg (Cave, 2000). The female of *Telenomus remus* was also able to parasitize the entire mass of eggs, in contrast to other egg parasitoids like Trichogramma species, which often only parasitize the external layer (Cave and Acosta 1999). Studies conducted in Venezuela and Colombia demonstrated that *Telenomus remus* parasitized *Spodoptera frugiperda* at levels more than 60% in field conditions, which was related to a decrease in insecticide use. (Ferrer, 2001; Garcia *et al*., 2002; Hernandez *et al*., 1989). Further evidence that the environment can have an impact on how well this parasitoid performs comes from the fact that *Telenomus remus* egg parasitism was 28% greater during the V8-V9 stage than the V4-V5 stage, when the humidity was roughly 3.5% higher (Pomari-Fernandes *et al*. (2018). It has been reported that tropical areas have high egg mass predation (Sa *et al*. 1993). It has been pointed out that predation by insects can reach up to 50% in maize (Yu and Byers 1994). *Spodoptera frugiperda* mortality in maize was considered to be largely influenced by predation (Figueiredo *et al*., 2002; Varella *et al*., 2015).An increase in the host's storage duration reduces parasitoid survival, according to earlier studies (Ayvaz *et al*., 2008; Bayram *et al.,* 2005; Colinet & Hance 2010; Lopez & Botto 2005). Low temperatures can impair the growth and development of the embryo, making it an unsuitable host for the parasitoid (Kidane *et al*., 2015; Rathee & Ram 2018). *Spodoptera frugiperda* eggs stored at 5°C for less than 3 days produced low adult emergence of *Telenomus remus*; under these circumstances, there was also high egg mortality; however, the emergence of *Telenomus remus* remained high at 15°C for at least 9 days, and this result was the same for both males and females (Paolo *et al*., 2020). In Venezuela, this parasitoid has been widely employed in IPM-maize projects, and inundative releases of *Spodoptera frugiperda* eggs have resulted in parasitism rates of up to 90% of the eggs (Ferrer, 2001).

Behavioral patterns and parasitism efficacy: On egg masses of *Spodoptera frugiperda* with and without scales, researchers looked at the behavioral patterns and parasitism effectiveness of *Telenomus remus*, *Trichogramma pretiosum,* and *Trichogramma dendrolimi*. *Trichogramma dendrolimi* and *Trichogramma pretiosum* had much lower parasitism proportions than *Telenomus remus*. When compared to egg masses without scales, the proportion of *Trichogramma pretiosum* and *Trichogramma dendrolimi* parasitism on egg masses with scales was much lower. However, on egg masses with and without scales, *Telenomus remus* displayed a comparable amount of parasitism. In comparison to *Trichogramma pretiosum* and *Trichogramma dendrolimi, Telenomus remus* had considerably longer residence times, longer oviposition times, more frequent oviposition, higher risks of finding a host, and higher parasitism risks. *Trichogramma dendrolimi* and *Trichogramma pretiosum* females were unable to parasitize any eggs within the egg mass; in contrast, *Telenomus remus* females frequently snuck into the scale layer covering the egg masses. Females of *Trichogramma pretiosum* and *Telenomus remus* both exhibited comparable levels of superparasitism. Therefore, *Telenomus remus* is *Spodoptera frugiperda's* main egg parasitoid, which has significant ramifications for the development of supplemental biological control measures for *Spodoptera frugiperda* (Dong *et al.,* 2021).

The biological control of *Spodoptera frugiperda* eggs can be biologically controlled with *Telenomus remus* at a release rate of 100,000 adults/ha, and based on the parasitoid dispersal capacity, they advised 70 release points/ha at this release density (Paolo *et al*., 2020).

Effect of kairomones on *Telenomus remus*:

Telenomus Remus Nixon females were detained after coming in contact with kairomones taken from *Spodoptera frugiperda* eggs, but not males (J. E. Smith) Bioassays were utilized to analyze the wasp retention in the kairomone-treated area. The size of the treated area and the kairomone dose both had an impact on how long stayed in the treated region. The kairomone arrested female wasps for a longer time at the start of the scotophase because they were more sensitive to it. Young wasps that were 2 to 4 days old showed the most reaction. Kairomones taken from the complete bodies of adult male or female moths were also used to stop the wasps (Gazit *et al*., 1996).

Females of the *Telenomus remus* react to (Z)-9-tetradecane-1-ol and (Z)-9-dodecane-1-of acetate, which caused a rise in parasitism (Lewis & Nordlund 1984), which are components of the sex pheromone of *Spodoptera frugiperda* (J. E. Smith) (Nordlund *et al*., 1983). Additionally, kairomones from the female accessory gland of *S. frugiperda* induce *Telenomus remus* to lay its eggs (Lewis & Nordlund 1984). It has been hypothesized that a variety of factors may work in concert to decide whether *Telenomus remus* accepts and oviposits in a host (Nordlund *et al*., 1983). There has been a decline in offspring emergence with increasing host age, which may be related to *Telenomus remus* preference for and performance on older *Spodoptera frugiperda* eggs due to a decline in the chemical cues the parasitoid uses to recognize and accept the host or in the host's nutrient content as the host ages (Penaflor *et al*., 2012).

Dispersal capacity and pattern of *Telenomus remus*: The dispersion ability of *Telenomus remus* affected the parasitism of *Spodoptera frugiperda* eggs (Bueno *et al.,* 2012; Geremias & Parra 2014). The crop's phenological stage had an impact on *Telenomus remus* potential for dissemination. It is well recognized that the crop's growth stage has a significant impact on the dispersion and, consequently, the effectiveness of natural enemies (Sa & Parra 1993). It revealed that *Telenomus remus* spread more widely during the younger stage of maize, likely because taller plants could limit *Telenomus remus* ability to spread, as was the case with other egg parasitoids (Geremias & Parra 2014; Pomari-Fernandes *et al*., 2018). It was reported that *Telenomus remus* egg parasitism similarly decreased with distance from release points, but that phenological stage (V2-V3, V5-V6, or V8-V9) or other factors like the host, crop (soybean or maize), or season had no bearing on this impact (Pomari-Fernandes *et al*., 2018).

Extremely low or high dispersal rates were detrimental to the establishment, dissemination, and efficacy of the biological control agent. Therefore, a thorough understanding of the parasitoids' ability to disperse and move about is crucial for the implementation of effective biological control strategies. Because of differences in temperature and leaf area for foraging, agricultural conditions, such as the microclimate inside the canopy, might affect parasitoid dissemination capacity (Biever, 1972). The ability of the released parasitoids to spread and find adult hosts, food, and shelter is necessary for augmentative biological control to be successful (Paranhos *et al*., 2007). To ensure *Telenomus remus* distribution over 100% of the region in the worst-case scenario, *Telenomus remus* should be released at a minimum density of 35 points/hectare in soybean crops and 34 points/hectare in maize crops. The release strategy should be chosen by the wind conditions, maybe with a preference for a perimetric dispersion of the released insects, as wind direction affects the *Telenomus remus* dispersal pattern. (Fernandes *et al*., 2018).

Biology and ecology: *Telenomus remus* adults are between 0.5 and 0.6 mm long. The black body is gleaming. In contrast to the male, who has light brown tibiae and femora. In contrast to the male's antenna, which lacks any discernible club, the female's antenna bears a four-segmented club. The forewing's edges are subparallel and a little over three times longer than it is broad. A single egg is laid by the female inside the inside of the growing host embryo and superparasitism has been seen in the lab, however only one Telenomus remus larva can develop to full maturity due to mortality from competing larvae and/or food deficiency in the host egg. The biology of *Telenomus remus* development was studied by Gerling (1972), Gomez de Picho (1987); Hernandez & Diaz (1995, 1996). Only eggs that are less than 72 hours old are parasitized, and *Telenomus remus* seldom infects eggs in which the embryo has reached full development (Dass & Parshad, 1983). Egg stage duration ranged from 10 hours at 30°C to 18–24 hours at 15.5°C (Hernandez & Diaz 1996; Gomez de Picho, 1987). There were no variations in the parasitism rate of *Telenomus remus* on *Corcyra cephalonica* eggs when held for 14 days at 5°C or 21 days at 10°C (Queiroz *et al.,* 2017). It was shown that the best storage conditions were probably dependent on the particular host-parasitoid species interaction (Paolo *et al*., 2020).

There are two instars in the *Telenomus remus* larva. The first instar is unsegmented. The second instar is clearly segmented and lacks caudal spines; the mandibles are short and straight. It has a pair of vertically moving mandibles and two caudal spines, one small and one long and curved. The larval stage varies from 4 days at 30°C to 7 days at 15.5°C. (Hernandez & Diaz 1996; Gomez de Picho, 1987).

Pupation takes place inside the host egg. The pupa is initially opaque white with somewhat rosy eyes. The body gradually turns grey and then black. Pupal stage duration ranged from 112 hours at 30°C to 15 days at 15.5°C.(Hernandez & Diaz 1996., Gomez de Picho, 1987).

The most significant abiotic parameters during *Telenomus remus* rearing are temperature and relative humidity. It was reported that the overall development period from egg deposition to adult emergence varied between 13.7 days and 7 days at different temperatures, with ambient relative humidity not affecting the development rate (Gautum, 1986). Gupta & Pawar (1985) obtained parasitism levels higher than 90% only when relative humidity (RH) was greater than 50% at temperatures between 25 and 41°C. The peak of the parasitism occurred at 27°C and 75% RH (Gautum, 1986).

Maximum *Telenomus remus* adult emergence results from storing *Spodoptera frugiperda* eggs at 15°C for about 9 days. This storage method increases *Telenomus remus* adoption for augmentative biological control against *Spodoptera frugiperda* and improves control efficacy while lowering production and marketing costs (Paulo *et al*., 2020). Producing this biocontrol agent costs US$ 0.0004 when using *Spodoptera frugiperda* eggs and US$ 0.0002 when using *Corcyra cephalonica* eggs (Vieira *et al.,* 2017).

Effect of Pesticide: There are both fatal and sub-lethal effects of pesticides on insects that are not the intended target (Desneux *et al*. 2007; Stark and Banks 2003). Even though adverse side effects have been observed, IGRs are typically thought to be less toxic to beneficial insects than other chemical classes (Santos *et al*., 2006). Several pyrethroid insecticides have been reported to harm beneficial arthropods (Croft 1990; Croft and Whalon 1982; Sterk *et al*., 1999).

The parasitoid was harmed by chlorpyrifos, acephate, beta-cyfluthrin, imidacloprid, spinosad, and pyrethroids, but not by methoxyfenozide, diflubenzuron, or flufenoxuron. Only 2, 4-D amine and glyphosate + imazethapyr were determined to be risk-free on the first and second days of parasitism among the herbicides tested; paraquat was the most dangerous. On the first day of parasitism, other herbicides had no effect; however, on the second day, they reduced the parasitism of *Telenomus remus* to varying degrees, while the fungicides had little to no effect (Carmo *et al,* 2010). Therefore, effects on fertility as well as the viability of the biological control agents must be considered when evaluating pesticide selectivity. No unfavorable tritrophic effects of genetically modified soybean (Bt) MON 87701–MON 89788 were seen in *Telenomus remus* (Bortolotto *et al*., 2015).

Use in pest control: In the New World, *Telenomus remus* was initially introduced in Barbados in 1971–1972, where levels of parasitism of more than 60% were noted in several crops. This parasitoid is thought to have a significant role in the decline of Spodoptera spp. populations (Alam, 1974, 1979)

The first use of *Telenomus remus* in classical biological control occurred in 1963 when the parasitoid was introduced from Papua New Guinea to India (Sankaran, 1974). It was later introduced to other Asian countries (Joshi *et al*., 1976; Patel *et al.,* 1979). The reduction of *Spodoptera litura* eggs in taro during an integrated pest management program in Samoa was reportedly caused by the increase in *Telenomus remus* population density (Braune, 1985). Releases of *Telenomus remus*, along with two additional parasitoids, namely *Trichogramma chilonis* Ishii and *Tetrastichus howardi* Ollif and a predator, decreased the prevalence of *Spodoptera litura* in potatoes by 60% in India (Ansari *et al*., 1992). During 1975–1977, an attempt was made to establish *Telenomus remus* in southeastern Florida (USA). More than 660,000 individuals were released in maize and sorghum during this time, however, parasitism levels did not rise over 43% (Waddill & Whitcomb 1982). In three separate releases over the course of three weeks, 5000 *Telenomus remus* were released in maize. At locations 30–1400 m from the release point, parasitism peaked at 78–100% up to two months after release in Venezuela (Hernandez *et al.,* 1989). To eradicate the pest on 87.5 ha, farmers in Venezuela released 400–6000 wasps per hectare of corn over the course of ten weeks, producing 350,000 *Telenomus remus* adults (Linares, 1998).

Challenges: The barriers to its wider use are the challenges of mass-producing *Telenomus remus* on its natural hosts and the demand for developing rearing methods on artificial hosts (Vieira *et al*., 2017; Pomari *et al*., 2015). Due to the high expense and difficulty of rearing *Telenomus remus* on sentinel hosts, augmentative releases of this insect have not been widely used to control *Spodoptera frugiperda* in maize, and need for more knowledge on its performance under field conditions (Vieira *et al*., 2017).

Furthermore, the needs for parasitoids in programs for supplemental biological control are typically time-varying, necessitating the storage of hosts for varying lengths of time (Kivan & Kilic 2005, Ogburn & Walgenbach 2019). However, it's frequently unknown what the best storage conditions for hosts are for maximizing parasitoid generation. Understanding these elements might lower production and marketing expenses, increasing the uptake of biological controls (Colinet & Boivin 2011).

CONCLUSIONS

To create more effective and efficient techniques for releasing *Telenomus remus* in the field, more study is required. It is necessary to fine-tune the timing of releases by crop and pest phenology. To achieve the best ratio of *Telenomus remus* to host egg masses, the quantity of wasps released and the frequency of releases must be investigated in various agricultural areas with various climatic circumstances. Future success in using *Telenmus remus* to manage Spodoptera species populations likely depends on the ability to create a cottage industry of for-profit and semi-profit insectaria devoted to mass-producing the parasite. The release of *Telenomus remus* demonstrates its viability as a component of integrated pest management systems, both on its own and in combination with other control methods.

REFERENCES

Alam, M. M. (1974). Biological control of insect pests of horticultural crops in Barbados. In: Braithwaite, C.W.D., Phelps, R.H.; Bennett, F.D. (eds) Crop protection in the Caribbean. Trinidad & Tobago; the University of the West Indies, pp. 253-261.

Alam, M. M. (1979). Attempts at the biological control of major insect pests of maize in Barbados, W. I. *Proceedings of the Caribbean Food Crops Society, 15*, 127-135.

Ansari, M. A., Pawar, A. D., & Kumar, D. A. (1992). Possibility for biocontrol of tropical armyworm, *Spodoptera litura* (Lepidoptera: Noctuidae) on potato. *Plant Protection Bulletin* (Faridabad) *44,* 27-31.

Antonio GutiAcrrez-Mart Anez, Alfredo Tolon-Becerra and Xavier B. Lastra-Bravo Bueno (2012). Biological Control of *Spodoptera frugiperda* Eggs Using *Telenomus remus* Nixon in Maize-Bean-Squash Polyculture. *American Journal of Agricultural and Biological Sciences*, *7* (3), 285-292.

Ashmead, W. H. (1904). Descriptions of new Hymenoptera from Japan. *JSTOR*, *12,* 65–84.

Ayvaz, A., Karasa, E., Karaborklu, S., & Tuncbilek, A. (2008). Effects of cold storage, rearing temperature, parasitoid age, and irradiation on the performance of *Trichogramma evanescens* Westwood (Hymenoptera: Trichogrammatidae). *Journal of Stored Products and Research*, *44* (3), 232–240.

Bayram, A., Ozcan, H., & 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). *Biological Control*, *35*(1), 68–77.

Bortolotto O. C., Silva G. V., Bueno A. de Freitas, Pomaria A.F., Martinelli S., Head G. P., Carvalho R. A. and Barbosa, G. C. (2015). Development and reproduction of *Spodopt eraeridania* (Lepidoptera: Noctuidae) and its egg parasitoid *Telenomus remus* (Hymenoptera: Platygastridae) on the genetically modified soybean (Bt) MON 87701 × MON 89788. *Bulletin of Entomological Research*, *105*, 259–260

Braune, H. J., (1985). Die Entwicklungeinesintegrierten Pflanzenschutz-Systems in Samoa. *Giessner Beitragezur Entwicklungsforschung*, *12,* 167-182.

Bueno, R.C.O.D.F., Carneiro, T.R., Pratissoli, D., Bueno, A.D.F., Fernandes, O.A., (2008). Biology and thermal requirements of *Telenomus remus* reared on fall armyworm *Spodoptera frugiperda* eggs. *Ciencia Rural*, *38*, 1-6.

Bueno, R. C. O. F., Parra, J. R. P., & Bueno, A. D. F. (2012). *Trichogramma pretiosum* parasitism and dispersal capacity: A basis for developing biological control programs for soybean caterpillars. *Bulletin of Entomological Research*, *102*(1), 1–8.

Biever, K. D. (1972). Effect of the temperature on the rate of search by *Trichogramma* and its potential application in field releases. *Environ. Entomol. 1,* 194-197.

Carmo E. L., Bueno A. F. and Bueno R. C. O. F. (2010). Pesticide selectivity for the insect egg parasitoid. *Biocontrol*, *55,* 455–464.

Cave, R. D. (2000). Biology, ecology, and use in pest management of *Telenomus remus*. *Biocontrol News Inf*., *21*, 21–26.

Cave, R. D. and Acosta, N. M. (1999). *Telenomus remus* Nixon: Un parasitoid en el control biologico del gusanocogollero, *Spodoptera frugiperda* (Smith). *Ceiba*, *40,* 215–227. (In Spanish)

Cock, M. J. W. (1985). A review of biological control of pests in the Commonwealth Caribbean and Bermuda up to 1982. Farnham Royal, UK; *Common wealth Institute of Biological Control*, 218 pp.

Colinet, H., & Hance, T. (2010). Inter-specific variation in the response to low-temperature storage in different aphid parasitoids. *Annals of Applied Biology*, *156*(1), 147–156.

Colinet, H., & Boivin, G. (2011). Insect parasitoids cold storage: A comprehensive review of factors of variability and consequences. *Biological Control*, *58*(2), 83–95.

Croft, B. A. (1990). Arthropod biological control agents and pesticides, 2nd edn. John Wiley & Sons, New York, p 826

Croft, B. A., & Whalon, M. E. (1982). The selective toxicity of pyrethroid insecticides to arthropod natural enemies and pests of agricultural crops. *Entomophaga, 27*, 3–21

Dass, R. & Parshad, B. (1983). Influence of age of *Spodoptera litura* (Fabricius) egg on parasitization by *Telenomus remus* Nixon (Hymenoptera: Scelionidae. *Journal of Entomological Research*, *7*, 18-20.

Desneux N, Decourtye A. & Delpuech J M. (2007). The sublethal effects of pesticides on beneficial arthropods. *Annu Rev Entomol., 52*, 81–106.

Dong Hui, Kai-hui Zhu, Qian Zhao, Xue-ping Bai, Jin-cheng Zhou, Lisheng Zhan (2021). Morphological defense of the egg mass of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) affects parasitic capacity and alters the behaviors of egg parasitoid wasps. *Journal of Asia-Pacific Entomology*, *24* (2021) 671–678.

Fernandes A. Pomari, A. F. Bueno, A. P. Queiroz and S. A. De Bortoli, (2015). Biological parameters and parasitism capacity of *Telenomus remus* Nixon (Hymenoptera: Platygastridae) reared on natural and factitious hosts for successive generations. *African Journal of Agricultural Research*, *10*(33), 3225-3233.

FernandesAlinePomari-, Adeney de Freitas Bueno, Sergio Antonio De Bortoli, Bruna Magda Favetti (2018). Dispersal capacity of the egg parasitoid *Telenomus remus* Nixon (Hymenoptera: Platygastridae) in maize and soybean crops. *Biological Control, 126,* 158-168

Ferrer, F. (2001). Biological control of agricultural insect pests in Venezuela: Advances, achievements, and future perspectives. *Biocontrol News and Information, 22*(3), 67–74.

Figueiredo, M. L. C., Della Lucia, T. M. C., & Cruz, I., (2002). Effect of *Telenomus remus* Nixon (Hymenoptera: Scelionidae) density on control of *Spodoptera frugiperda* (Smith) (Lepidoptera: Noctuidae) egg masses upon release in maize field. *Rev. Bras. Milho Sorgo, 1,* 12–19.

Garcia, F. R., Mosquera, M. T., Vargas, C. A., & Rojas, L. A.,(2002).Control biologico, microbiologicoyfisico de Spodoptera frugiperda (Lepidoptera: Noctuidae), plaga del maizyotroscultivos en Colombia. *Revista Colombiana de Entomologia*, *28,* 53–60.

Gautum, R. D. (1986). Effect of different temperatures and relative humidities on the efficiency of the parasitoid, *Telenomus remus* Nixon (Scelionidae: Hymenoptera) in the laboratory. *Journal of Entomological Research*, *10,* 34-39

Gazit Yoav, Lewis W. J. and Tumlinson J. H. (1996). Arrestment of *Telenomus remus* (Hymenoptera: Scelionidae) by a Kairomone Associated with Eggs of Its Host, *Spodoptera frugiperda* (Lepidoptera: Noctuidae). *Biological control, 6,* 283-290.

Geremias, L. D., & Parra, J. R. P. (2014). Dispersal of *Trichogramma galloi* in corn for the control of *Diatraea saccharalis*. *Biocontrol Science and Technologic*, *24*(7), 751–762.

Gerling, D. (1972). The developmental biology of *Telenomus remus* Nixon (Hym.: Scelionidae). *Bulletin of Entomological Research*, *61*, 385-488.

Gomez de Picho, H. (1987). Biologia de *Telenomus remus* Nixon (Hymenoptera: Scelionidae). *Revista Peruana de Entomologisa, 30*, 29-32.

Gonzalez, C. E. and Zocco, J. L. (1996). Integrated Control of *Spodoptera frugiperda* Smith by utilizing *Telenomus remus* Nixon on Zea mays L. *Revista de Investigacion Agricola*-DANAC *1*, 201-219.

Gupta, M. & Pawar, A. D. (1985). Multiplication of *Telenomus remus* Nixon on *Spodoptera litura* (Fabricius) reared on artificial diet. *Journal of Advanced Zoology, 6,* 13-17.

Gutierrez-Martinez, A., Tolon-Becerra, A., Lastra-Bravo, X. B. (2012). Biological control of *Spodoptera frugiperda* eggs using *Telenomus remus* Nixon in maize-bean-squash polyculture. *Am. J. Agr. Biol. Sci.*, *7*, 285–292.

Hernandez, D., & Diaz, F. (1995). Efecto de la edaddelparasitoide *Telenomus remus* Nixon (Hymenoptera: Scelionidae) sobresucapacidad de ovipostura y proporcion sexual de la descendencia. *Boletin de Entomologia Venezolana*, *10,* 161-166.

Hernandez, D. & Diaz, F. (1996). Efecto de la temperaturasobre el desarrollo de *Telenomus remus* Nixon (Hymenoptera: Scelionidae) parasitoide de *Spodoptera frugiperda* (Smith) (Lepidoptera: Noctuidae). *Boletin de Entomologia Venezolana*, *11*, 149-153.

Hernandez, D., Ferrer, F. and Linares, B. (1989). Introduction of the *Telenomasremus* Nixon (Hym.: scelionidae) for control of *Spodoptera frugiperda* (Lep.: noctuidae) on yaritagua-venezuela. *Agronomía Tropical*, *39*, 45-61.

Joshi, B. G., Ramaprasad, G., Sitaramaiah, S., & Sathyanarayana, C. V. V. (1976). Some observations on *Telenomus remus* Nixon, an egg parasite of the tobacco caterpillar, *Spodoptera litura* (F.). *Tobacco Research*, *2*, 17-20.

Kidane, D., Yang, N. W., & Wan, F. H. (2015). Effect of cold storage on the biological fitness of *Encarsiasophia* (Hymenoptera: Aphelinidae), a parasitoid of *Bemisiatabaci* (Hemiptera: Aleyrodidae). *European Journal of Entomology*, *112*(3), 460–469.

Kivan, M., & Kilic, N. (2005). Effects of storage at low temperatures of various heteropteran host eggs on the egg parasitoid *Trissolcus Semistriatus*. *Biocontrol, 50*(4), 589–600.

Lewis, W. J. & Nordlund, D. A. (1984). Semiochemicals influencing fall armyworm parasitoid behavior: implications for behavioral manipulation. *Florida Entomologist*., *67,* 343-349.

Linares, B. (1998). Farm family rearing of egg parasites in Venezuela. *Biocontrol News and Information 19*, 76N.

Lopez, S. N., & Botto, E. (2005). Effect of cold storage on some biological parameters of *Eretmocerus corni* and *Encarsia formosa* (Hymenoptera: Aphelinidae). *Biological Control*, *33*(2), 123–130.

Navika Omprakash, Shylesha A. N., Patil Jagadeesh, Venkatesan T., Lalitha Y., & Ashika, T. R. (2021). Damage, distribution, and natural enemies of invasive fall armyworm *Spodoptera frugiperda*(J. E. Smith) under rainfed maize in Karnataka, India. *Crop protection, 143*, 105536.

Nixon, G. E. J. LIV. (1937). Some Asiatic Telenominæ (Hym., Proctotrupoidea). *Annals Mag. Natl. Hist*., *20*, 475.

Nordlund, D. A., Lewis, W. J., & Gueldner, R. C. (1983). Kairomones and their use for the management of entomophagous insects: XIV. Response of *Telenomus remus* to abdominal tips of *Spodoptera frugiperda* as well as to (Z)-9-tetradecene-1-ol acetate and (Z)-9-dodecene-1-ol acetate. *Journal of Chemical Ecology, 9*, 695-701.

Ogburn, E. C., & Walgenbach, J. F. (2019). Impact of temperature storage conditions of *Halyomorpha halys* (Hemiptera: Pentatomidae) eggs on parasitism by *Anastatus reduvii* (Hymenoptera: Eupelmidae). *Journal of Economic Entomology*, *113*(1), 98–107.

Paolo Salazar-Mendoza, Cesar Rodriguez-Saona and Odair Aparecido Fernandes (2020). Release density, dispersal capacity, and optimal rearing conditions for *Telenomus remus,* an egg parasitoid of *Spodoptera frugiperda*, in maize. *Biocontrol Science and Technology, 30*(10), 1040–1059.

Patel, R. C., Yadav, D. N., & Saramma, P. U. (1979). Impact of mass releases of *Chelonus heliopae* Gupta and *Telenomus remus* Nixon against *Spodoptera litura* (Fabricius). *Journal of Entomological Research, 3,* 53-56.

Penaflor, M. F. G. V., de MoraesSarmento, M. M., Bezerra da Silva, C. S., Werneburg, A. G., & Bento, J. M. S. (2012). Effect of host egg age on preference, development, and arrestment of *Telenomus remus* (Hymenoptera: Scelionidae). *European Journal of Entomology*, *109*(1), 15– 20.

Pomari, A.F., Bueno, A. F., Bueno, R.C.O.F., & Menezes Junior, A. O. (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,* 72-81.

Pomari, A. F., Bueno, A. D. F., Bueno, R. C. O. D. F., Junior, M., de Oliveiras, A., & Fonseca, A. C. P. F. (2013). Releasing the number of *Telenomus remus* (Nixon) (Hymenoptera: Platygastridae) against *Spodoptera frugiperda* Smith (Lepidoptera: Noctuidae) in corn, cotton, and soybean. *Ciencia Rural*, *43*, 377–382.

Pomari-Fernandes, A., De Queiroz, A. P., de Freitas Bueno, A., Sanzovo, A. W., & De Bortoli, S. A. (2015). The importance of relative humidity for *Telenomus remus* (Hymenoptera: Platygastridae) parasitism and development on *Corcyra cephalonica* (Lepidoptera: Pyralidae) and *Spodoptera frugiperda* (Lepidoptera: Noctuidae) eggs. *Ann. Entomol. Soc. Am*., *108,* 11–17.

Pomari-Fernandes, A., Bueno, A. F., De Bortoli, S. A., & Fevetti, B. M. (2018). Dispersal capacity of the egg parasitoid *Telenomus remus* Nixon (Hymenoptera: Platygastridae) in maize and soybean crops. *Biological Control*, *126,* 158–168.

Queiroz, A. P., Bueno, A. F., Pomari-Fernandes, A., Grande, M. L. M., Bortolotto, O. C., & Silva, D. M. (2017). Low-temperature storage of *Telenomus remus* (Nixon) (Hymenoptera: Platygastridae) and its factitious host Corcyra cephalonica (Stainton) (Lepidoptera: Pyralidae). *Neotropical Entomology, 46*(2), 182–192.

Rathee, M., & Ram, P. (2018). Impact of cold storage on the performance of entomophagous insects: An overview. *Phytoparasitica, 46*(4), 421–449.

Sa, L. A., & Parra, J. R. P. (1993). Effect of the number and interval between releases of *Trichogramma pretiosum*

Riley on the parasitism and control of *Helicoverpazea* (Boddie) in corn. *Scientia Agricola*, *50*(3), 355–359.

Sankaran, T. (1974). Natural enemies introduced in recent years for biological control of agricultural pests in India. *Indian Journal of Agricultural Science, 44*, 425-433.

Santos, A. C., Bueno, A. F., & Bueno, R. C. O. F. (2006). Seletividade de defensivos agrícolas aos inimigos naturais. *PINTO, AS* 221-227.

Stark, J. D., & Banks J. E. (2003). Population-level effects of pesticides and other toxicants on arthropods. *Annu Rev Entomol., 48,* 505–519.

Sterk, G., Hassan, S. A., Baillod, M., Bakker, F., Bigler, F., Blümel, S., & Vogt, H. (1999). Results of the seventh joint pesticide testing programme carried out by the IOBC/WPRS-Working Group 'Pesticides and Beneficial Organisms'. *Bio Control*, *44*, 99-117.

Van Lenteren, J. C. (2012). The state commercial augmentative biological control: Plenty of natural enemies, but a frustrating lack of uptake. *Biocontrol*, *57*(1), 1–20.

Varella, A. C., Menezes-Netto, A. C., Alonso, S. J. D., Caixeta, D. F., Peterson, R. K., & Fernandes, O. A. (2015). Mortality dynamics of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) immatures in maize. *PLoS One, 10*(6).

Vieira, N. F., Pomari-Fernandes, A., Lemes, A. A., Vacari, A. M., De Bortoli, S. A., & de Freitas Bueno, A. (2017). Cost of production of Telenomus remus (Hymenoptera: Platygastridae) grown in natural and alternative hosts. *Journal of economic entomology*, *110*(6), 2724-2726.

Vieira, N. F., Pomari-Fernandes, A., Lemes, A. A., Vacari, A. M., De Bortoli, S. A., & deFreitas Bueno, A. (2017). Cost of production of *Telenomus remus* (Hymenoptera: Platygastridae) grown in natural and alternative hosts. *J. Econ. Entomol*, *110*, 2724–2726.

Waddill, V. H., & Whitcomb, W. H. (1982). Release of Telenomus remus (Hym.:Scelionidae)against *Spodoptera frugiperda* (Lep.: Noctuidae) in Florida, USA. *Entomophaga, 27*, 159-162

Yu, D. S., & Byers, J. R. (1994). Inundative release of *Trichogramma brassicae* Bezdenko (Hymenoptera: Trichogrammatidae) for control of European corn borer in sweet corn. *The Canadian Entomologist*, *126*(2), 291–301.

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