Biological Control of Spodoptera frugiperda Eggs Using Telenomus remus Nixon in Maize-Bean-Squash Polyculture

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Received 2012-05-16, Revised 2012-06-19; Accepted 2012-07-16

ABSTRACT

The maize earworm, Spodoptera frugiperda (J.E. Smith) (Lepidoptera: Noctuidae), is an important pest in maize. Telenomus remus Nixon (Hymenoptera: Scelionidae) is an important control agent of this pest due to its capacity to invade the whole egg mass. The percentage of parasitism by Telenomus remus Nixon (Hymenoptera: Scelionidae) on Spodoptera frugiperda (J.E. Smith) (Lepidoptera: Noctuidae) eggs was evaluated in maize-bean, maize-squash and maize-bean-squash polycultures and maize monoculture systems. Data were analyzed statistically by using a Poisson regression (log-linear model). The analysis showed highly significant differences in the percentage of parasitism of S. frugiperda eggs by T. remus in plots with jarocho crema maize in polyculture systems (91.00±1.42%) compared to the yellow maize genotype (68.90±3.10%). Parasitism percentages increased in the jarocho crema maize genotype in maize-bean, maize-squash, maize-bean-squash polycultures and maize monoculture by 87.88±3.27%, 89.75±1.99, 99.50±0.19 and 86.88±2.66%, respectively and in the yellow maize genotype they dropped by 70.00±7.05, 64.50±5.63, 77.88±6.51 and 63.25±5.20%, respectively. The percentage of T. remus parasitism on S. frugiperda eggs was found to be affected by the genotype of maize, bean and squash, polyculture system, weeds, densities of the host eggs and numbers and quality of egg masses.

Keywords: International Institute of Biological Control (IBCI), Polyculture System, Analyzed Statistically, Causing Severe Damage, Important Lepidoptera Pests, Temperature Variation

1. INTRODUCTION

The maize earworm, Spodoptera frugiperda (J.E. Smith) (Lepidoptera: Noctuidae), is an important pest in maize and other crops in neotropical and subtropical regions of America (Bennett, 1994). When there are heavy outbreaks of this blight, the losses and cost of control on the American Continent may surpass $300 million (Gross and Pair, 1986). It is the most important maize pest in Mexico, Central America, South America and the Pacific Basin (Ashley et al., 1989; Mitchell et al., 1984).

In Mexico, S. frugiperda is present in all of the regions where maize is grown, causing severe damage in the tropical and subtropical climate regions (Sifuentes, 1967). In Chiapas it causes losses between 53 and 60% (Silva, 1977). The maize earworm mainly attacks the leaves and tender shoots of maize, one of the basic grains in the local diet (Marenco et al., 1992; Kumar and Mihn, 2002). This pest has been the subject of many studies, but most of them focus on chemical control. To date, no plant protection program has included biological control as its cornerstone.

On the other hand, Ashley (1979) reported 53 species of parasitoids of the maize earworm belonging to 43 genera and 10 families, of which the family Tachinidae comprises 53% of the species. Molina-Ochoa et al. (2003) reported 150 species of parasitoids and parasites of S. frugiperda in the Americas and the Caribbean basin belonging to 14 families, nine in Hymenoptera, four in Diptera and one in Nematoda. The family Tachinidae is not only the most diverse of the Diptera, but overall as well (55 species). To date none of these species of parasitoids has had a controlling effect on the maize earworm, because their reproduction in the laboratory is not easy. However, Telenomus remus Nixon (Hymenoptera: Scelionidae) can be grown relatively easily under laboratory conditions. It is an important
control agent due to its capacity to invade the whole egg mass (Figueiredo et al., 2002). This primary parasitoid of insect eggs has been used in biological control programs of important Lepidoptera pests with excellent results (Alam, 1974; Dass and Parshad, 1984). It has been estimated that the release of 5000-8000 parasitoids per hectare can cause up to 90% parasitism of S. frugiperda eggs (Hernández et al., 1989; González and Zocco, 1996; Cave and Acosta, 1999; Cave, 2000). It has been reproduced in the laboratory on the eggs of S. littoralis Boisduval (Lepidoptera: Noctuidae) (Gerling, 1972), S. littura F. (Gautam, 1986), S. frugiperda and other Lepidoptera (Wojcik et al., 1976).

Telenomus remus was first introduced in India in 1963 from New Guinea to control Achaea janata (Linneus) (Lepidoptera: Noctuidae) and S. littura (Sankaran, 1974). It was later introduced in Israel from India in 1969, in an attempt to control S. littoralis (Schwartz and Gerling, 1974). T. remus comes from Sarawak and New Guinea, where it is found in nature (Rothschild, 1970) and has become established in some regions where it has been released (Gross and Pair, 1986).

The International Institute of Biological Control (IBCI) in England has provided T. remus for control of S. frugiperda in the United States, the Caribbean and South and Central America (Yassen et al., 1981; Bennett, 1994). It was first introduced in Mexico in 1979 by the Secretaría de Agricultura y Recursos Hidráulicos (Secretariat for Agriculture and Hydraulic Resources) (Bennett, 1979; Cock, 1985). T. remus has been successfully established on eggs of S. frugiperda in (Alam, 1974; 1979; Wojcik et al., 1976) with parasitism levels varying from 47-90% (CIBC, 1980; Bennett 1994), in Venezuela (Hernández et al., 1989; Hernández and Díaz, 1995; 1996) with parasitism levels of 60-100% (Lacayo, 1978; González and Zocco, 1996) and Ferrer, 2001) in Honduras (Cortés and Andrews, 1979; Cave, 1995). But it failed to become established in Trinidad (Bennett, 1981) or in Florida (Waddill and Whitcomb, 1982). In Mexico, Montoya-Burgos (1979), Morales-Pérez (1982), Cansequo-Román (1988), García-Lagunas (1988) and Barilla-Vera (1989) have reported the presence of T. remus in maize crops as a parasitoid of S. frugiperda eggs.

The purpose of this study was to evaluate T. remus parasitism of S. frugiperda eggs in maize-bean, maize-squash, maize-bean-squash polyculture and monoculture maize systems to determine what variables favor or affect its establishment.

2. MATERIALS AND METHODS

2.1. Study Area

This study was done under seasonal conditions of the spring-summer cycle, in Predio Santa Elena, located 7 kilometers from the seat of municipal government, Villa Flores, Chiapas, Mexico. It is located in the Central Depression at 16°C14’ latitude north and 93°C16’ longitude west, at an altitude of 610 m a.s.l., with a total area of 1 232 km² (Gomez, 1987). The study area has the driest of the warm sub-humid climates Aw, (w)(ij)g (García, 1973), with rain in summer, a dry winter and a temperature variation of less than 5-7°C. Annual mean rainfall is 1198.2 mm, with mid-summer drought in August. The mean annual temperature is 24.3°C and the minimum is 21.6°C, with a well-defined dry season from November to May.

2.2. Treatments and Experimental Design

A complete random block design was used with two repetitions and 64 experimental units in an 8 * 2 factor array. The experimental plots were 11 * 11 m = 121 m². jarocho crema (J) and yellow (A) Creole genotypes of maize (Zea mays L.) were used in this study as well as jumapa beans (Phaseolus vulgaris L.) and seasonal squash (Cucurbita maxima Duch. C. moschata L.).

The culture systems were maize Monoculture (M), Maize-Bean polyculture (MB), Maize-Squash polyculture (MS) and Maize-Bean-Squash polyculture (MBS). The genotype and culture system combinations resulted in eight different treatments, jarocho crema maize monoculture (M-J), jarocho crema Maize-Bean polyculture (MB-J), jarocho crema Maize-Squash polyculture (MS-J), jarocho crema Maize-Bean-Squash polyculture (MBS-J), yellow maize monoculture (M-A), yellow Maize-Bean polyculture (MB-A), yellow Maize-Squash polyculture (MS-A) and yellow Maize-Bean-Squash polyculture (MBS-A).

Soil preparation was begun by collecting the residue from the previous harvest to allow free movement of the tiller and uniform tillage. Then the soil was plowed up so any weeds that had sprouted would dry out and die, for which the land was left in that condition for six days. After that the ground was harrowed to loosen and level the soil completely. The ground was left that way for three days so the loose soil could take on good consistency with the rain and achieve more uniform germination.

Maize, beans and squash were sown in alternating rows. This was done manually at the same time for all four crops. For the two types of maize, two seeds (20 000 plants h⁻¹) and four seeds (40 000 plants h⁻¹) were deposited per point, at a distance of 1 m between furrows and plants. For beans, from four to five seeds were deposited per point at a separation of 1 m between furrows and 25 cm between plants, for a density of 200 000 plants h⁻¹. For squash, three to four seeds per point were deposited at a distance of 3.67 m between furrows and plants for a density of 2 352 plants h⁻¹.
2.3. Release of Parasitoids

The parasitoids were donated by Dr. Ronald D. Cave of the Pan-American School of Agriculture Center for Biological Control in Central America, El Zamorano, Honduras. They were taken to the field for release in the plots when the maize, bean and squash plants were 12 days old. Before that, *S. frugiperda* egg masses were evaluated to be sure there were no natural biological controls present and parasitoids were found to be absent.

For the first inoculation, about 15,000 adult *T. remus* were released. Five hundred parasitoids were released around the edges and in the center of each plot assigned parasitoids. The sex ratio was 2:1. The first release took place when the maize, bean and squash plants were 12 days old (following emergence in the first growth stage). The procedure for release consisted of uncovering containers with the parasitoids, which left slowly and dispersed onto the maize leaves. Release was done in this way to facilitate dispersion in the crop. Later at 20 days in the active growth stage of maize, 12,000 *T. remus* were released in four consecutive releases (every eight days). About 100 parasitoids were released in each plot, by the same method described above.

One hundred plants/plot of maize sampled at random were inspected every eight days. The *S. frugiperda* egg masses collected were taken to the entomology laboratory at the Chiapas Autonomous University School of Agricultural Science, Campus V in Villa Flores. The egg masses were separated in plastic jars by treatment and repetition to determine the percentage of egg masses parasitized. The control plots were also sampled to quantify the number of egg masses parasitized by *T. remus*.

2.4. Statistical Analysis

A Poisson regression-Log-linear model (p < 0.05), taking the percentage of parasitism as the dependent variable and the maize genotype, the culture system and the treatment as fixed factors, was applied to determine whether the polyculture system and variety of maize influenced the amount of *T. remus* parasitism on *S. frugiperda* eggs. The data were analyzed using the general linear model procedure available in PASW Statistics 2009.

3. RESULTS

The percentages of *S. frugiperda* eggs parasitized by *T. remus* varied from 36 to 100% (Table 1). Highly significant statistical differences in parasitism were observed among maize genotype (R² = 0.11%, F₁,₁₂₅ = 17.42, P = 0.00005), culture system (R² = 0.11%, F₁,₁₂₅ = 6.21, P = 0.001) and treatments (R² = 0.10%, F₇,₁₂₅ = 3.04, P = 0.006). More parasitism was observed in the *jarocho crema* maize genotype and in both MBS treatments (Fig. 1).

Significant differences were observed among treatments with the *jarocho crema* maize genotype (R² = 0.33%, F₁,₂₉ = 6.16, P = 0.02), which had 91.0±1.4% (mean±SE) parasitism. In the yellow maize genotype, the percentage of parasitism was 68.9±3.1% and no significant differences were observed among treatments (R² = 0.17%, F₁,₂₉ = 1.18, P = 0.34). The percentages of parasitism in the *jarocho crema* maize genotype varied from 87.88±3.27-99.50±0.19% compared to the yellow maize genotype where they were 63.25±5.20-77.88±6.51%.

Higher percentages of parasitism were observed in the polyculture systems, but no statistically significant differences were found among them (R² = 0.05%, F₁,₆₃ = 1.99, P = 0.13). Parasitism was 75.06±4.15% in M, 77.13±4.35% in MS and 88.69±6.21% in MBS.

Significant differences (R² = 0.44%, F₁,₆₃ = 8.01, P = 0.000001) were also observed between treatments. The widest differences observed were between treatments M-J and MS-J with MBS-A (Table 2). Only MS-A was not statistically different from any of the other study treatments. The parasitism percentages were higher in the polyculture system with the *jarocho crema* maize genotype 87.88±3.27% was recorded in MB-J, 89.75±1.99% in MS-J and 99.50±0.19% in MBS-J compared to 86.88±2.66% in M-J. Furthermore, average percentages of parasitism were lower in the yellow maize genotype. In the MB-A it was 70.00±7.05%, MS-A 64.50±5.63%, MBS-A 77.88±6.51% and in M-A 63.25±5.20%.

### Table 1. Percentage parasitism of *Spodoptera frugiperda* eggs by *Telenomus remus*

| Treatment  | % Treatment | % Treatment | % Treatment | % Treatment |
|------------|-------------|-------------|-------------|-------------|
| M-J        | 87          | 91          | 57          | 57          |
| M-J        | 82          | 97          | 42          | 42          |
| M-J        | 94          | 87          | 84          | 84          |
| M-J        | 100         | 94          | 57          | 57          |
| M-J        | 77          | 83          | 70          | 70          |
| M-J        | 80          | 94          | 60          | 60          |
| M-J        | 86          | 81          | 83          | 83          |
| M-J        | 89          | 91          | 53          | 53          |
| MB-J       | 98          | 99          | 57          | 57          |
| MB-J       | 90          | 99          | 59          | 59          |
| MB-J       | 83          | 99          | 50          | 50          |
| MB-J       | 72          | 100         | 53          | 53          |
| MB-J       | 82          | 100         | 100         | 100         |
| MB-J       | 100         | 100         | 69          | 69          |
| MB-J       | 93          | 100         | 100         | 100         |
| MB-J       | 85          | 100         | 72          | 72          |
| MB-J       | 85          | 99          | 72          | 72          |

### Table 2. P values of statistical differences according to Tukey’s test

| M-J MB-J MS-J MBS-J M-A MB-A MBS-A |
|-----------------------------------|
| 0.015 1.000 0.004 0.968 0.009 0.352 0.00002 |
| - 0.025 1.000 0.189 1.000 0.867 0.54200 |
| - 0.007 0.990 0.016 0.468 0.00005 |
| - 0.071 1.000 0.618 0.81200 |
| 0.138 0.929 0.00100 |
| 0.792 0.64200 |
| 0.03400 |
| - 0.000002 |

Note: Antoio Gutiérrez-Martínez et al. / American Journal of Agricultural and Biological Sciences 7 (3) (2012) 285-292
Fig. 1. Box diagrams showing levels of parasitism in maize genotypes, culture systems and treatments
4. DISCUSSION

High percentages of T. remus parasitism on S. frugiperda eggs in the jarocho crema maize genotype have also been reported in studies by Wojcik et al. (1976) in Florida, CIBC (1980), Rojas and Garcia (1995) in Colombia and Hernández et al. (1989), Hernández and Diaz (1995; 1996), González and Zocco (1996), Morales et al. (2000; 2001) and Ferrer (2001) in Venezuela, where percentages were 65-100%. This parasitoid control on the number of eggs per egg mass was mainly due to the increase in eggs laid by the female S. frugiperda which coincided with the time of release of this parasitoid and with the maize genotype (the jarocho crema genotype is more attractive than yellow maize) (Hernández and Diaz, 1995; 1996; Morales et al., 2000; 2001). This increase observed in the number of eggs invaded by T. remus when the density of the host was increased corresponds to the results of similar studies done with other species of parasitoids and predators (Holling, 1959; 1961; Messenger, 1968; Hull et al., 1977; Morales and Burandt, 1985; Cave and Gaylor, 1989; Morales, 1991).

The percentages found for parasitism by polyculture system with jarocho crema maize genotype coincide with those recorded in Ithaca, New York (Root 1973), in Costa Rica (Risch, 1981), in Philippines (Hasse, 1981) and in Minnesota (Andow, 1991), where it was shown that parasitism is higher in polycultures than in monocultures.

The lower percentages of parasitism in the polycultures systems with the yellow maize genotype are due to T. remus having more difficulty in locating S. frugiperda eggs in them. One of the factors that influenced these results was masking by volatile chemicals released by the maize, bean, squash crops and eggs (Root, 1973; Risch, 1981; Hasse, 1981; Altieri, 1980; Andow, 1991).

The evidence of parasitism in maize-bean, maize-squash, maize-bean-squash polyculture and maize monoculture systems in both genotypes of maize suggests that the T. remus parasitoid has great potential as a biological control agent for S. frugiperda eggs. Studies by Schwartz and Gerling (1974), Yassen et al. (1981), Hernández et al. (1989), Gomez (1987), Corrêa-Figueiredo et al. (1999), Morales et al. (2000; 2001), Oliveira-de-Freitas-Bueno et al. (2008) also show the high potential of T. remus as a biological control. Furthermore, T. remus can develop throughout the year under field conditions (Oliveira-de-Freitas-Bueno et al., 2008), has been demonstrated to adapt well to the absence of the host (S. frugiperda) and can be kept for several days in the laboratory when release is not possible (Carneiro et al., 2009). Carmo et al. (2010) point out that in integrated pest management including T. remus, it should be noted that it is not compatible with the use of pyrethroids and organophosphates and would be an alternative to insect growth regulators as they are less harmful to beneficial arthropods. De-Souza-Tavares et al. (2009) found that Asteraceae family (Eremanthus elaeagnu and Lychnophora ericoides) extracts are more selective for T. remus, so their use is not recommended in combination with biological control of S. frugiperda.

5. CONCLUSION

According to the results of this study, the percentage of T. remus parasitism on S. frugiperda eggs was affected by maize genotype, bean, squash and polyculture system. Other factors that influenced the percentage of parasitism were the presence of weeds, densities of host eggs, numbers of masses and quality of eggs, temperature and kairomones in eggs of female S. frugiperda (Altieri and Letourneau, 1982; Powell, 1986; Gazit et al., 1996; Altieri and Nicholls, 2010; Oliveira-de-Freitas-Bueno et al. 2010). Furthermore, it is highly probable that it may already have become established in the region of Frailesca, Chiapas, Mexico.

6. ACKNOWLEDGMENT

This article was written under PCI-09 A/022974/09 and A/022976/09 Projects and the PCI-10 A/030041/10 Project.

7. REFERENCES

Alam, M.M., 1974. Biological control of insect pests of horticultural crops in Barbados. Proceeding of the Prot. Hortic.Crops Symp. Prot. Hortic. Crops.

Alam, M.M., 1979. Attempts at the biological control of major insect pests of maize in Barbados. Proceedings of a Symposium on Maize and Peanut, Nov. 13-18, Paramaribo, Suriname, pp: 127-135.

Altieri, M.A. and C.I. Nicholls, 2010. Diseños agroecologicos: Para incrementar la biodiversidad de entomofauna benéfica en agroecosistemas, Sociedad Científica Latinoamericana de Agroecología (SOCLA), Medellin, Colombia.

Altieri, M.A. and D.K. Letourneau, 1982. Vegetation management and biological control in agroecosystems. Crop Protection, 1: 405-430. DOI: 10.1016/0261-2194(82)90023-0

Altieri, M.A., 1980. Diversification of corn agroecosystems as a means of regulating fall armyworm populations. Florida Entomol., 63: 450-456. DOI: 10.2307/3494529
Andow, D.A., 1991. Vegetational diversity and arthropod population response. Ann. Rev. Entomol., 35: 561-586.

Ashley, T.R., 1979. Classification and distribution of fall armyworm parasites. Florida Entomol., 62: 114-123.

Ashley, T.R., B.R. Wiseman, F.M. Davis and K.L. Andrews, 1989. The fall armyworm: A bibliography. Florida Entomol., 72: 152-202.

Barilla-Vera, M., 1989. Técnica de cría del gusano cogollero y sus parasitoides. In: Proceedings of 12th Reunion Nacional de Control Biologico, Secretaría de Agricultura y Recursos Hidráulicos-DGSV, Nov. 22-24, Torreon, Coahuila, México, pp: 59-62.

Bennett, F.D. 1994. Fall armyworm. In: Pest Management in the Subtropics: Biological Control- a Florida Perspective, Rosen, D., F.D. Bennett and J.L. Capinera, (Eds.). Intercept Limited, United Kingdom, ISBN 0 946707046.

Bennett, F.D., 1979. Report of work carried out april 1978-march 1979. 1st Edn., Commonwealth Institute of Biological Control, England, pp: 87.

Canseco-Román, O., 1988. Método para la cría de Spodoptera Frugiperda Smith y sus parasitoides Telenomus spp. Proceedings of 11th Reunion Nacional de Control Biologico, Secretaría de Agricultura y Recursos Hidráulicos, Aug. 15-17, Hermosillo, Sonora, pp: 11-11.

Carmo, E.L., A.F. Bueno and R.C.O.F. Bueno, 2010. Pesticide selectivity for the insect egg parasitoid Telenomus remus. BioControl, 55: 455-464. DOI: 10.1007/s10526-010-9269-y

Carneiro, T.R., O.A. Fernández and I. Cruz, 2009. Influencia da competição intra-específica entre fêmeas e da ausência de hospedeiro no parasitismo de Telenomus remus Nixon (Hymenoptera, Scelionidae) sobre ovos de Spodoptera Frugiperda J.E. Smith Lepidoptera. Noctuidae’ Revista Brasileira de Entomol., 53: 482-486.

Cave, R.D., 2000. Biology, ecology and use in pest management of Telenomus remus Nixon. Biocontrol News and Information 211: 21N-26N.

CIBC, 1980. Annual Reports. Commonwealth Institute of Biological Control, England, http://trove.nla.gov.au/work/17663149

Cock, M.J.W., 1985. A Review of Biological Control of Pests in the Commonwealth Caribbean and Bermuda up to 1982. 1st Edn., Published on behalf of CIBC by the Commonwealth Agricultural Bureaux, United Kingdom, ISBN: 10-0851985505, pp: 218.

Cortés, M.R. and K.L. Andrews, 1979. Evaluacion de enemigos naturales nativos e importados de las principales plagas del maíz. Proceedings of Reunión Anual del Programa Cooperativo Centroamericano para el Mejoramiento de Cultiivos Alimenticios, Mar 19-23, Tegucigalpa, pp: M47-1/M47-10.

Dass, R. and B. Parshad, 1984. Rearing of important lepidopterous pests on known artificial diet and screening for preferred hosts of parasite, Telenomus remus Nixon (Hymenoptera: Scelionidae). J. Entomol. Res., 81: 89-92.

De-Souza-Tavares, W., I. Cruz, F. Petacci, S.L. de Assis-Júnior and S. de-Sousa-Freitas et al., 2009. Potential use of Asteraceae extracts to control Spodoptera Frugiperda (Lepidoptera: Noctuidae) and selectivity to their parasitoids Trichogramma pretiosum (Hymenoptera: Trichogrammatidae) and Telenomus remus (Hymenoptera: Scelionidae) Industrial Crops Prod., 30: 384-388. DOI: 10.1016/j.indcrop.2009.07.007

Ferrer, F., 2001. Biological control of agricultural insect pests in Venezuela; advances, achievements, and future perspectives. Biocontrol News Inform., 223: 67-74.

Figueiredo, M.L.C., T.M.C.D. Lucia and I. Cruz, 2002. Screening for preferred hosts of parasite, Telenomus remus Nixon (Hymenoptera: Scelionidae) density on control of Spodoptera Frugiperda (Smith) (Lepidoptera: Noctuidae) egg masses upon release in a maize field. Revista Brasileira de Milho e Sorgo, 12: 12-19.

García, E., 1973. Modificaciones al sistema clasificacion climática de Koppen. 2nd Edn., Instituto de Geografía de la Universidad Nacional Autonoma de México, México, pp: 246.
García-Lagunas, E.D., 1988. Evaluacion del parasitoide Telenomus solitus y Telenomus remus Hymenoptera: Scelionidae sobre huevecillo de Spodoptera Frugiperda Smith en condiciones de campo en Emiliano Zapata, Mor. Proceedings of the 11th Reunion Nacional de Control Biologico, pp: 12.

Gautam, R.D., 1986. Variations in amino acids in fertile and unfertile eggs of Spodoptera litura Fabr. contribute towards parasitism by Telenomus remus Nixon Hymenoptera: Scelionidae. J. Entomol. Res., 102: 161-165.

Gazit, Y., W.J. Lewis and J.H. Tumlinson, 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.

Gerling, D., 1972. The developmental biology of Telenomus remus Nixon (Hym., Scelionidae). Bulletin Entomol. Res., 61: 385-388. DOI: 10.1017/S00074853000047283

Gomez, H., 1987. Biología de Telenomus remus Nixon Hymenoptera: Scelionidae. Revista Peruana de Entomología 30: 29-32.

González, C.E. and J.L. Zocco, 1996. Control integrado de Spodoptera Frugiperda Smith utilizando Telenomus remus Nixon en Zea mays L. Revista de Investigacion Agrícola-DANAC 1: 201-219.

Gross, H.R. and S.D. Pair, 1986. The fall armyworm: Status and expectations of biological control with parasitoids and predators. Florida Entomologist, 69: 502-512.

Hasse, V., 1981. The influence of vegetational diversity on host-finding and larval survivorship of the Asian corn borer Ostrinia furnacalis Guenée (Lepidoptera:Pyralidae). 1st Edn., Justus Liebig Universität Giessen, Giessen, pp: 174.

Hernández, D., and F. Díaz, 1995. Efecto de la edad del parasitoide Telenomus remus nixon (Hymenoptera: Scelionidae) sobre su capacidad de oviposutura y proporción sexual de la descendencia. Proceeedings of the Jornadas de Investigación del Decanato de Agronomía de la Universidad Centroccidental "Lisandro Alvarado". Barquisimeto, Jun. 1-5, Venezuela, pp: 39-39.

Hernández, D. and F. Díaz, 1996. Efecto de la edad del hospedero Spodoptera Frugiperda J. E. Smith Lepidoptera: Noctuidae sobre el parasitismo y la proporción sexual de la descendencia PSD de Telenomus remus Nixon Hymenoptera: Scelionidae’ Boletín de Entomología Venezolana NS112: 149-153.

Hernández, D., F. Ferrer and B. Linares, 1989. Introduccion de Telenomus remus Nixon (Hym.: scelionidae) para controlar Spodoptera Frugiperda (Lep.: noctuidae) en yaritagua-venezuela. Agronomía Tropical, 39: 45-61.

Holling, C.S., 1959. The components of predation as revealed by a study of small mammal predation of the European pine sawfly. Canadian Entomol., 91: 293-320.

Holling, C.S., 1961. Principles of insect predation. Ann. Rev. Entomol., 6: 163-182. DOI: 10.1146/annurev.en.06.010161.001115

Hull, L.A., D. Asquith and P.D. Mowery, 1977. The functional responses of stethorus punctum to densities of the European red mite. Environ. Entomol., 6: 85-90.

Kumar, H. and J.A. Mihn, 2002. Fall armyworm (Lepidoptera: Noctuidae), southwestern corn borer (Lepidoptera: Pyralidae) and sugarcane borer (Lepidoptera: Pyralidae) damage and grain yield of four maize hybrids in relation to four tillage systems. Crop Protection, 21: 121-128. DOI: 10.1016/S0261-2194(01)00071-0

Lacayo, L., 1978. Apuntes sobre Telenomus remus Nixon Hymenoptera: Scelionidae.

Marenco, R.J., R.E. Foster and C.A. Sánchez, 1992. Sweet corn response to fall armyworm (Lepidoptera: Noctuidae) damage during vegetative growth. J. Econ. Entomol., 85: 1285-1292.

Messenger, P.S., 1968. Bioclimatic studies of the aphid parasite Praon exsoletum, 1. Effects of temperature on the functional response of females to varying host densities. Canadian Entomol., 100: 728-741.

Mitchell, E.R., V.H. Waddill and T.R. Ashley, 1984. Population dynamics of the fall armyworm (Lepidoptera: Noctuidae) and its larval parasites on whorl stage corn in pheromone-permeated field environments. Environ. Entomol., 13: 1618-1623.

Molina-Ochoa, J., J.E. Carpenter, E.A. Heinrichs and J.E. Foster, 2003. Parasitoids and parasites of Spodoptera Frugiperda (Lepidoptera: Noctuidae) in the americas and caribbean basin: An inventory. Florida Entomologist, 863: 254-289.

Montoya-Burgos, J.A., 1979. Estudio preliminar del ecotoprasiso del género Euplectrus del gusano cogollero Spodoptera Frugiperda. Proceedings of the 7th Reunion Nacional de Control Biologico, pp: 4-4.

Morales, J. and C.H. Burandt, 1985. Interactions between cycloneda sanguinea and the brown citrus aphid: adult feeding and larval mortality. Environ. Entomol., 14: 520-522.
Morales, J., 1991. Respuesta funcional de Cycloneda sanguinea al áfido negro de las cítricas. Bioagro, 3: 27-32.

Morales, J., J. Gallardo, C. Vásquez and Y. Ríos, 2000. Patron de emergencia, longevidad, parasitismo y proporción sexual de Telenomus remus (Hymenoptera: Scelionidae) con relacion al cogollero del maíz. Bioagro, 12: 47-54.

Morales, J., S.G.C. Jose. Vásquez and Y. Ríos, 2001. Respuesta funcional de Telenomus remus (hymenoptera: Scelionidae) a los huevos de Spodoptera Frugiperda (Lepidoptera: Noctuidae). Bioagro, 13: 49-55.

Morales-Pérez, A., 1982. Cría masiva del parásito Telenomus sp. usando como huesped huevecillos de Spodoptera exigua. Proceedings of the 10th Reunion Nacional de Control Biologico. Grupo Sectorial Agropecuario y Forestal, pp: 7-7.

Oliveira-de-Freitas-Bueno, R.G., T. Rodrigues-Carneiro, A. de-Freitas-Bueno, D. Pratissoli and O.A. Fernández et al., 2010. Parasitism capacity of Telenomus remus Nixon (Hymenoptera: Scelionidae) on Spodoptera Frugiperda (Smith) (Lepidoptera: Noctuidae) eggs. Brazilian Archives Biology Technol., 531: 133-139.

Oliveira-de-Freitas-Bueno, R.G., T. Rodrigues-Carneiro, D. Pratissoli, A. de-Freitas-Bueno and O.A. Fernández, 2008. Biology and thermal requirements of Telenomus remus reared on fall armyworm Spodoptera Frugiperda eggs. Ciência Rural, 381: 1-6.

PASW Statistics, 2009, IBM Corporation.

Powell, W., 1986. Enhancing parasitoid activity in crops. Proceeding of the 13th Symposium of the Royal Entomological Society of London, Sept. 18-19, Academic Press, London.

Risch, S.J., 1981. Insect herbivore abundance in tropical monocultures and polycultures: an experimental test of two hypotheses. Ecology, 62: 1325-1340.

Rojas, L. and F. García, 1995. Comportamiento parasitico de Telenomus spen Spodoptera Frugiperda. Revista Colombiana de Entomología, 214: 191-197.

Root, R.B., 1973. Organization of a plant-arthropod association in simple and diverse habitats: The fauna of collards (Brassica oleracea). Ecological Monographs, 43: 95-124.

Rothschild, G.H.L., 1970. Parasites of rice stemborers in sarawak (Malaysian borneo). Biocontrol, 15: 21-51. DOI: 10.1007/BF02371624

Sankaran, T., 1974. Natural enemies introduced in recent years for biological control of agricultural pests in India. Indian J. Agricultural Sci., 447: 425-433.

Schwartz, A. and D. Gerling, 1974. Adult biology of Telenomus remus [Hymenoptera: Scelionidae] under laboratory conditions. 19: Biocontrol, 483-492. DOI: 10.1007/BF02372784

Sifuentes, A.J.A., 1967. Oviposicion de palomillas de cogollero y daño de las larvas en plántulas de maíz y sorgo, en invernadero. Agricultura Técnica en México, 11: 311-314.

Silva, C.J., 1977. Plagas del cultivo de maíz en el Estado de Chiapas.

Waddill, V.H. and W.H. Whitcomb, 1982. Release of Telenomus remus Hymenoptera: Scelionidae against Spodoptera Frugiperda Lepidoptera: Noctuidae in Florida, USA. Florida Entomol., 65: 350-354.

Wojcik, B., W.H. Whitcomb and D.H. Habeck, 1976. Host range testing of Telenomus remus (Hymenoptera: Scelionidae). Florida Entomologist, 59: 195-198. DOI: 10.2307/3493972

Yassen, M., F.D. Bennett and R.M. Barrow, 1981. Introduction of exotic parasites for control of Spodoptera Frugiperda in Trinidad.