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NATURAL CONTROL OF INSECT-PESTS IN THE RICE AGROECOSYSTEM, IN PANAMA AND THE COMPLEX OF EGG PARASITOIDS

Zachrisson B.[1]*, Polanco P.[2], Osorio P.[1]

1. Biological Control Laboratory, Institute of Agricultural Research of Panama (IDIAP), Chepo, Panama, Panama.

2. Entomology Master Program, University of Panama, Panama, Panama

ABSTRACT: The present study highlights the importance of basic elements of the bioecology of insect pests, which are fundamental to guarantee the success of insect pest management programmes for rice cultivation. We related the bioecology of insect pests to alternate hosts, among other aspects. In the last decade, several insect pest species have colonized, established, and adapted, such as: *Hydrellia* sp.; *Lissorhoptrus* sp., *Tibraca limbativentris*; and, recently, *Euschistus nicaraguensis*. Other commonly known species, such as *Tagosodes orizicolus* and *Oebalus insularis*, with wide distribution in the American continent, stand out as key insect pests in rice cultivation. The producers will be able to implement strategies that may reduce the population of these insects according to the biological and reproductive characteristics of the production areas. Insect pest management based on a dynamic and multidisciplinary context should be carried out in a holistic manner, thus promoting the profitability of the crops. For this reason, the integration of the information presented for the definition of an insect pest management programme suggests the consideration of variables, such as the cultivar planted, location, and the relationship between the population dynamics of the insect pests and egg parasitoids, taking into consideration natural control as an appropriate short-term management measure.

KEYWORDS: Natural control, Eggs parasitoids, Platygastridae, Rice, *Oryza sativa.*

***Corresponding Author: Dr. Zachrisson B.** Ph.D.

Biological Control Laboratory, Institute of Agricultural Research of Panama (IDIAP), Chepo, Panama

* Email Address: bazsalam@gmail.com

1. INTRODUCTION

The Republic of Panama has a land area of 75,517 km^2. The metropolitan region covers about 16,777.50 km^2 and the rest of the country that corresponds to rural regions and suburban cities has an area of 58,739.50 km^2. The basis of Panama's rural economy is the agri-food sector, because it generates employment for 14% of the economically active population. The conventional agricultural production model has encouraged research and development programmes to implement innovative insect pest management strategies that promote the sustainability of agricultural crops. These strategies were specifically targeted at the cultivation of rice (*Oryza sativa* L.), which is considered one of the main agricultural products in Panama and around the world. Rice contributes to food security of half of the world population (FAO, 2006). In addition, this food item provides 50% of the total calories in the Panamanian diet (Puga et al., 2009). A reduction of 12% in the performance of these crops is attributed to the incidence of insect pests (Vivas and Notz, 2011). For this reason, the use of biotic resources, in this case the beneficial entomofauna, for efficient and rational insect pest management in the rice agroecosystem is a priority. The use of sustainable alternatives, based on economic and environmental parameters, is a choice against the excessive use of insecticides in agricultural ecosystems. In this way, natural biological control is one of the viable management variables for reducing insect pest populations in these crops. The information collected allowed identifying and knowing the bioecology of oophagous parasitoids in different rice fields. The role of oophagous parasitoids in the agroecosystems of annual crops lies in the reduction of insect pest populations during the egg stage, prior to the damage that immature stages and adults can cause. The efficiency and profitability of this control measure stand out, because it is consistent with integrated pest management (IPM) and (ICM)integrated crop management. Knowledge of the bioecology of oophagous parasitoids reported for the rice agroecosystem, related to climatic or abiotic factors, such as temperature, relative humidity, and solar radiation, among others, is specific to each production area. In this way, the biology, ecology, and behaviour of the parasitoid species reported provided valuable information for the implementation of multiplication programs for mass rearing of egg parasitoids of the key insects in these crops. The specificity of the insect-parasitoid relationship is a determining factor in the success of biological control programmes for insect pests. In addition, it is essential to consider the development stage of the insects that offers comparative advantages in terms of management, as technical input for the natural biological control of insect pests in this agricultural area. The results of the studies conducted in the last decade have been focused on identifying the species and assessing the important bioecological parameters for the colonization, establishment, and adaptation stages of insect pests, considering the direct relationship with the increase in the population of egg parasitoids. This chapter reports the progress and projections, in this line of research, with medium and long term projection, for establishing protocols for the multiplication of these natural control agents, with the purpose of releasing them in the productive areas. The reduction of insect pest populations below the level of economic damage is fundamental to the profitability of the production. Integrated insect pest management in rice fields has been mainly targeted at *Tagosodes orizicolus* and *Oebalus insularis*, which are considered key insect pests in Panama (Table 1) (Zachrisson, 2009 and Zachrisson et al., 2014a). However, there are other species that can cause damage to the different structures of the plant at different phenological stages, among them stand out *Lissorhoptrus* sp. (rice water weevil), *Hydrellia* sp. (Leaf miner), *Diatraea tabernella* (Sugarcane borer), *Diatraea saccharalis* (Sugarcane borer), e) *Rupela albinella* (White stem borer), f) *Spodoptera frugiperda* (Fall armyworm), *Panoquina* sp. (Long-winged skipper) and *O. insularis* (Rice stink bug). The dynamic population of these insect-pests depends on the abiotic conditions and the regulation of the biocontrol agents. Some species of family Pentatomidae, such as *Tibraca limbativentris* and *Euschistus nicaraguensis*, have exhibited a recent population increase, which has coincided with high temperatures resulting from climate change. However, the interaction of these insects with natural control agents mainly depends on the phenological stage susceptible to the attack and the reproductive strategy of the insects. Due to the reproductive capacity of parasitoids as *Telenomus rowani*, *Trichogramma pretiosum*, and *Telenomus podisi*, they are considered efficient control agents for *R. albinella*, *S. frugiperda,* and *O. insularis,* respectively (Table 2). Despite having moderate importance, the management of the insect pest species mentioned largely depends on the rate of natural parasitism in the production areas. Currently, in the production areas of Coclé, Panama, *R. albinella*, *T. oryzicolus*, and *O. insularis* are responsible for the significant reduction in the profitability of rice cultivation (Zachrisson, 2009). The high rate of natural parasitism of *T. rowani* and *T. podisi*, associated with *R. albinella* and *O. insularis*, indicates a high degree of control in the areas assessed (Zachrisson, 2009). In addition, other species of family Pentatomidae, such as *Tibraca limbativentris* (Zachrisson et al., 2014b) and *Euschistus nicaraguensis*, were recently reported in extensive areas of rice cultivation in different locations, such as Juan Hombrón and Río Hato, Coclé, Panama (Table 3).

INSECT-PLANT INTERACTION

The agroecosystem, which is the basic unit for insect pest management, integrates the abiotic and biotic factors that influence the trophic interactions. For this reason, the success of biological control programs, among them the natural biological control, largely depends on the knowledge of the ¨parasitoid-insect-plant¨ relationship (Plate 1). This way, it is necessary to know the biological and reproductive aspects of the insect pests of economic importance and their natural enemies. Some authors have stressed the influence of the variety selected, the sowing density, and the crop phenology, which are considered the variables that may affect the efficiency in insect parasitism (Botelho, 1995 and Hassan et al., 1988). Some studies have suggested that the architecture of the plant, depending on the variety and sowing density, influence the parasitism rate of species of the families Platygastridae and Trichogrammatidae, which include *T. podisi* and *T. pretiosum*. In addition, other aspect to be taken into consideration is the effect of secondary metabolites which, depending on the variety of the crop and the plant phenological stage, may also influence the parasitism rate of these species. The natural control of insect pests in rice by means of rational management of this agroecosystem stands out due to the reduction of these arthropods population. The relationship between egg parasitoids, as biological agents for insect pest control, should be taken into consideration when choosing alternative methods for the rational management of the agroecosystem. The insect pest bioecology, which include biological and reproductive parameters, are related to the different phenological stages of the crops, depending on the development of the seedling, and the vegetative, reproductive, and maturation stages. In this way, the regulation of insect pests during the various phenological stages, by means of egg parasitoids, will determine the extent of the damage caused in the plants and the effect on the development of the crops. In addition, the synchronization between natural enemies and insect-pests, determined by abiotic conditions that promote balance in the agroecosystem, should be taken into consideration (Hassan et al., 1988).

Biology and Behaviour Of The Key And Emerging Insect Pests In Rice Cultivation

a) *Tagosodes orizicolus* (Homoptera: Delphacidae)

Tagosodes orizicolus is considered to be one of the key insect pests in rice cultivation due to the mechanical damage that it causes by the injection of toxins in the plant and the transmission of phytopathogens, as is the case of the ¨Rice Hoja Blanca Virus¨ (RHBV). The recommended management for the populations of this vector insect is aimed at the mechanical damage and the transmission of viruses, varying in accordance with the economic damage levels and action thresholds. The situations described, determine the management strategies considering the use of this viruses (RHBV) resistant varieties (Galvis et al., 1982). The populations that transmit the virus diseases of this vector insect can be potential for vertical transmission, also known as transovarian transmission (Galvis et al., 1982). The natural control of eggs by *Anagrus* sp. (Mymaridae) is sporadic and reduced in areas cultivated with the variety ¨Costa Rica-1113¨ (CR-1113) in the eastern region of Panama. The recommended management for the populations of the vector insect that causes mechanical damage and transmits the virus is mainly aimed at the use of RHBV, resistant varieties and selective insecticides for sucking insects. The initial damage features perforations or incisions in the mesophyll of the leaves for feeding or oviposition. The eggs of *T. orizicolus* are oval shaped and white in colour. The number of eggs can vary and 200 eggs of *T. orizicolus* per leaf oviposited during a period of three days have already been reported. The nymphal stage of the insect, which usually consists of five instars, can vary depending on the temperature (Galvis et al., 1982). The nymphs of *T. orizicolus* exhibit brown dorsal longitudinal stripes, which persist in the adult stage (Galvis et al., 1982). Adult specimens have membranous wings, which are yellow in female specimens and always clearer than those of male specimens. The size of male specimens is two to three millimetres, always smaller than the size of female specimens. The longevity of adult specimens varies from 14 to 24 days for males, and 24 to 36 days for females. This is a reproductive behaviour that favours the increase in the oviposition rate.

b) *Oebalus insularis* (Heteroptera: Pentatomidae)

Oebalus insularis, known as rice stink bug, is one of the most important insect pests in rice fields of Panama and Central America (Cherry and Nuesly, 2010, Rodríguez et al., 2006 and Vivas and Notz, 2010). The inoculation of toxins and phytopathogens occurs during the milky stage of grain development through the insertion of the stylet of *O. insularis* nymphs and adults when they feed on the plants (Rodríguez et al., 2006). This phenomenon, known as "grain discoloration", is directly related to *O. insularis* infestation, since more than 0.7 insects/panicle affect qualitatively and quantitatively crop yields (Vivas and Notz, 2011). Currently, there are no reports of varietal resistance to this insect. Therefore, it is difficult to control it through genetic improvement. This fact promotes the viability of biological control during the egg stage of *O. insularis* by means of *T. podisi*, which is considered the most viable proposal for the management of this insect (Rodríguez et al., 2006) (Plate 2). This way, a protocol for the multiplication of this parasitoid has been developed and depend of the production of *O. insularis* eggs and their subsequent release in rice fields (Zachrisson, 2014). The nutritional adaptation of *O. insularis* to various weed species as an alternative source of food can influence the biological and reproductive performance of this specie (Zachrisson, 2014 and Naresh and Smith, 1983). In Latin America, *Echinochloa colona* is the main alternative host of *O. insularis* and responsible for the early migration of this insect in rice fields (Naresh and Smith, 1983 and Rashid et al., 2005) (Plate 3). In addition to *E. colona*, other weed species, such as *Echinochloa crus-galli*, *Paspalum conjugatum*, and *Paspalum virgatum*, are associated with the feeding and reproduction of other *Oebalus* species (Rashid et al., 2005).

c) *Rupela albinella* (Lepidoptera: Pyralidae)

This insect is found in the crops between 35 and 40 days after germination during the vegetative stage. The damage is caused by first instar larvae that penetrate the stem and feed on the xylem and phloem, causing the yellowing of the leaves in the top region of the plant. Eggs of *R. albinella* are oviposited in the upper face of leaves and they appear grouped and overlapping, covered by a cottony mass and parasitised with *T. rowani* (Plate 4). The parasitism rates of eggs of this insect found in the different areas of rice fields, such as the eastern region of Panama, located in Juan Hombrón, Río Hato, was ranged between 79 and 88%. However, the indiscriminate use of broad-spectrum insecticides, reduced the population of natural enemies, such as *T. rowani*, considered to be the main agent control for this insect.

d) *Tibraca limbativentris* (Heteroptera: Pentatomidae)

The rice stalk stem bug *T. limbativentris* (Heteroptera: Pentatomidae) is considered a potential specie present in the main rice fields in Panama, with a relative abundance of 2.7% (Zachrisson et al., 2014b). This insect belongs to family Pentatomidae, insert its stylet into the stem and injects toxins that cause the sterility of the stem in the formation stage. The population increased between 2009 and 2012, reaching higher levels than nine insects per sweep net. This phenomenon gave rise to the use of insecticides in production fields located in the eastern region of Panama (Zachrisson et al., 2014b).The intensive use of chemical control, unilaterally aimed at the reduction of the populations of *T. limbativentris* poses the need of other control alternatives, such as biological control during the egg stage. However, the reduced information about the association between parasitoids and *T. limbativentris* is restricted to the eggs of species of family Pentatomidae (Margaría et al., 2009). The presence of *Oencyrtus submetallicus*, *T. podisi*, and *Trissolcus urichi* was reported for the first time in the State of Maranhão, Brazil (Maciel et al., 2007). In addition, the parasitoids *T. podisi* and *T. urichi* were reported as potential biological control agents in the State of Santa Catarina, Brazil (Riffel et al., 2010). The association between *T. limbativentris* and *T. urichi*, among other species, emphasises the need of understanding the ¨parasitoid-pest-crop¨ interaction for the implementation of biological control programs (Riffel et al., 2010). In Panama, the parasitism rates reported were higher than 80%. *T. podisi* was the only species reported in the experimental areas in which insecticides were not being used (Table 3). This report confirmed the high natural parasitism potential of *T. podisi*, considered a promising biological control agent for *T. limbativentris*, corroborating the results obtained by different researchers (Zachrisson et al., 2014b, Maciel et al., 2007 and Riffel et al., 2010).

The adaptation of *T. podisi* to the abiotic conditions of rice fields in the east of Panama confirmed the high parasitism rate of this parasitoid associated with the egg mass of *T. limbativentris*. It is worth noting that the association between *T. podisi* and *T. limbativentris* was the first report of this interaction in Panama, which also contributed to the strengthening of biological control programs for the species of family Pentatomidae in rice (Zachrisson et al., 2014b). The incorporation of management practices favourable to the conservation of *T. podisi* strengthens the holistic approach of integrated pest management programmes.

e) *Euschistus nicaraguensis* (Heteroptera: Pentatomidae)

The sub-family Pentatominae, which includes *E. nicaraguensis*, has 116 genera and approximately more than 667 species reported in the Neotropical region (Rolston, 1974). The geographic distribution of this species includes several countries in Central America between Panama and Honduras (Maes, 1994). It feeds on different weed species of this area, as well as rice (Maes, 1994 and Arismendi, 2002). Despite reports of the occurrence of *E. nicaraguensis* in rice fields in Panama (Maes, 1994 and Arismendi, 2002) (Plate 5), this species of Pentatomidae is sporadically found and its population is small. However, the colonization, adaptation, and biological development of *E. nicaraguensis* in weed species associated with the rice agroecosystem have been insufficiently studied. Similarly, the interaction between the natural control of this insect species and the population of biological control agents, specifically egg parasitoids, is considered a new association between *E. nicaraguensis* and *T. podisi*, defined as a key component in the integrated pest management of rice agroecosystems. The rate of *T. podisi* parasitism (85.5%) confirmed the regulation of this insect population found in an experimental rice field planted with the variety IDIAP-38 (Table 4). The parasitism of *E. nicaraguensis* eggs reported in weed species surrounding this area varied from 42.0 to 65.0% (Table 4). This fact indicated the reduction of the insect population in areas surrounding rice fields, which could be considered a reservoir of *T. podisi* during the sowing time.The incidence of *E. nicaraguensis* in weed species of families Asteraceae (*Eclipta prostrata*), Cyperaceae (*Cyperus rotundus* L.), Cyperaceae (*Fimbristylis littoralis* L.), and Poaceae (*Echinochloa colona* Link) in the rice fields in Panama requires a planning of integrated pest management (IPM) programs. The trophic interaction observed between *E. nicaraguensis*, as potential pest, and *T. podisi* provides relevant information for the implementation of natural biological control.

FUTURE PERSPECTIVE

The trophic interactions between the complex of insect pest and them eggs parasitoids, within the holistic vision of the rice agroecosystem management, provides basic information for the generation of technological innovations, focused to the strengthening of the augmentative biological control. So, the performance of insect pests and natural parasitism, specifically from the egg stage, provide subsidies for the massive multiplication of these species, in controlled abiotic conditions (Spechta et al., 2016). The use of natural and artificial diets of them insect pests, to produce high quantities of *Te. podisi*, *Tr. basalis* and *T. pretiosum*, is fundamental to the success of augmentative biological control programs (Valente et al., 2016 and Coelho et al., 2016). The knowledge of the nutritional requirements of the insect, depending on the phenological stage of the crop (Silva et al., 2016), which serves for the development of the artificial diet. In addition, in this interaction trophic, influences the release of volatile compounds in the natural parasitism of these insect pests (Signoretti et al., 2012).

The information obtained strengthens augmentative biological control, starting from the establishment of the diversity of species of parasitoids of the eggs of the insect-pest complex.

2. CONCLUSION

The natural biological control of insect pests in the rice agroecosystem by means of oophagous parasitoids is a successful management measure, which can be strengthened through the rational use of selective insecticides for the species of natural enemies. The results of the studies conducted in the rice fields in Coclé and others locations of the eastern region of the province of Panama, suggest the sustainable and rational management of this complex of insect-pests. The conservation of natural reservoirs composed by weed species will promote the natural parasitism of species such as *T. rowani* and *T. podisi,* which regulate the population of *R. albinella* and *O. insularis*, respectively. The high potential of *T. rowani* and *T. podisi* in tropical agroecosystems, associated with the specific features of the crops, such as the duration of the cycle of the recommended varieties and secondary metabolites, will define the ¨plant-insect-parasitoid¨ interaction. This aspect deserves to be further studied taking into consideration trophic interactions present in the rice agroecosystem.

Trophic interactions are relevant dynamic processes for the implementation of natural biological control programs, highlighting the relevance of new insect-parasitoid association. However, the increase in temperature during the last decade in the main rice fields in Panama confirms the need of performing periodic sampling of insects and natural enemies indicating their population density at different phenological stages of the crops. This way, it will be possible to select potential control agents, specifically egg parasitoids with the biological and reproductive performance to adapted in the rice agroecosystem. The egg parasitoid *T. podisi* is considered a promising agent for the reduction of the *O. insularis* population, among other emerging species of family Pentatomidae. The biological and reproductive parameters of the insect-pest and the parasitoid will strengthen the implementation of natural biological control programs in rice fields.

CONFLICT OF INTEREST

The authors have no conflict of interest.

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REFERENCES

1. Arismendi N. Pentatomidae en Honduras: Listado, distribución y biología de especies. B.Sc. thesis, Escuela Agrícola Panamericana, El Zamorano, Honduras, Hn, 2002.
2. Botelho PSM. Eficiência de *Trichogramma* em campo. Edn, *Trichogramma* e o Controle Biológico, 1995, pp. 303-318.
3. Cherry R, Nuesly G. Establishment of a new stink bug pest, *Oebalus insularis* (Hemiptera: Pentatomidae), in Florida rice. Florida Entomologist. 2010; 93: 291-293.
4. Coelho Jr A, Rugman-Jones PF, Reigada C, Stouthamer R, Parra JRP. Laboratory Performance Predicts the Success of Field Releases in Inbred Lines of the Egg Parasitoid *Trichogramma pretiosum* (Hymenoptera: Trichogrammatidae). PLOSONE, January 5, 2016. http://dx.doi.org/10.1371/journal.pone.0146153
5. FAO, ¨Seguimiento del mercado del arroz, Roma,¨. [Accessed: 18 July 2014]. Available: http://www.ftp.fao.org/docrep/fao/009/ag068s00.pdf. 2006.
6. Galvis Y, Gonzalez J, Reyes J. Descripción y daño de los insectos que atacan al arroz, en América Latina, CIAT, 1982.
7. Gutiérrez A, Meneses R, Arias A, Hernández M, Amador M. La chinche del arroz en Cuba. Arroz en las Américas. 1991; 12:2-4.
8. Hassan S, Kolher E, Rost WM. Mass production and utilization of *Trichogramma*: 10. Codling moth, *Cydia pomoella* and the summer fruit tortrix moth *Adoxopphyes orana* (Lepidoptera: Tortricidae). Entomophaga. 1988; 3:413-420.
9. Maes JM. Catálogo de los Pentatomoidea (Heteroptera) de Nicaragua. Print-León, León, Nicaragua, 1994; Vol. 28:1-19.

10. Maciel AA, De Lemos RNS, De Souza JR, Costa V, Barrigossi JAF, Das Chagas EF. Parasitismo de ovos de *Tibraca limbativentris* Stål (Hemiptera: Pentatomidae) na cultura de arroz no Maranhão. Neotropical Entomology. 2007; 36:616-618.
11. Margaría CB, Loiácono MS, Lanteri AA. New geographic and host records for scelionid wasps (Hymenoptera) parasitoids of insects pests in South America. Zootaxa. 2009; 2314:41-49.
12. Naresh JS, Smith CM. Development and survival of rice stink bugs (Hemiptera: Pentatomidae) reared on different hosts plants at four temperatures. Environmental Entomology. 1983; 12:1496-1499.
13. Puga PEB. 2009. Programa nacional de granos básicos, en el cultivo de arroz mecanizado, secano y riego. Informe final (2008-2009), Ministry of Agricultural Development, Panamá.
14. Rashid T, Johnson DT, Bernhardt JL. Feeding preference, fecundity and egg hatch of rice stink bug on artificial diet, rice and alternative host grasses. Southwestern Entomology. 2005; 30: 257-262, 2005.
15. Riffel CT, Prando HF, Boff MI. Primeiro relato de ocorrência de *Telenomus podisi* (Ashmead) e *Trissolcus urichi* (Crawford) (Hymenoptera: Scelionidae) como parasitoides de ovos de percevejos-do-colmo-do-arroz, *Tibraca limbativentris* (Stål) (Hemiptera: Pentatomidae), em Santa Catarina. Neotropical Entomology. 2010; 39:447-448.
16. Rodriguez PG, Navas D, Medianero E, Chang R. Cuantificación del daño ocasionado por *Oebalus insularis* (Heteroptera: Pentatomidae) en el cultivo del arroz (Oryzica-1) en Panamá. Revista Colombiana de Entomología. 2006; 32:131-135.
17. Rolston LH. Revision of the genus *Euschistus* in Middle America (Hemiptera: Pentatomidae, Pentatominae). Entomológica Americana. 1974; 48:23-25.

18. Signoretti AGC, Peñaflor MFGV, Bento JMS. Fall Armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), Female Moths Respond to Herbivore-Induced Corn Volatiles. Neotropical Entomology. 2012; 41:22–26. DOI 10.1007/s13744-011-0003-y

19. Silva TRSB, de Sousa Almeida AC, de Lima Moura T, da Silva AR, de Sousa Freitas S, Gonçalves JF. Effect of the flavonoid rutin on the biology of *Spodoptera frugiperda* (Lepidoptera: Noctuidae). Acta Scientiarum. 2016; 38:165-170.

20. Spechta DG, Montezano B, Sosa-Gómez DR, Paula-Moraes SV, Roque-Spechtd VF, Barros NM. Reproductive potential of *Spodoptera eridania* (Stoll) (Lepidoptera: Noctuidae) in the laboratory: Effect of multiple couples and the size. Brazilian Journal Biology. 2016; 76:526-530.

21. Valente ECN, Broglio SMF, dos Passos EM, de Lima AST. Desempenho de *Trichogramma galloi* (Hymenoptera: Trichogrammatidae) sobre ovos de *Diatraea* spp. (Lepidoptera: Crambidae). Pesquisa Agropecuaria Brasileira. 2016; 51:293-300.

22. Vivas LE, Notz A. Determinación del umbral y nivel de daño económico del chinche vaneador del arroz, sobre la variedad cimarrónen Calabozo estado de Guárico, Venezuela. Agronomía Tropical. 2010; 60:271-281.

23. Vivas LE, Notz A. Distribución espacial en poblaciones de *Oebalus insularis* Stal (Hemiptera: Pentatomidae) en el cultivo de arroz, estado Guárico, Venezuela. Revista Científica UDO Agrícola, 2011; 11: 109-125.

24. Zachrisson BA, Martínez O. Bioecologia de *Telenomus podisi* (Ashmead) y *Trissolcus basalis* (Wollaston) (Himenoptera: Scelionidae), parasitoides oófagos de *Oebalus insularis* (Kulghast) (Heteroptera: Pentatomidae). Tecnociencia. 2011; 13:65-76.

25. Zachrisson B, Avances en el control biológico de plagas de arroz (*Oryza sativa*), por medio de parasitoides oofagos, en Panamá. Agricultural Research Institute of Panamá, 2009, ISBN: 978–9962–8960–6–7.

26. Zachrisson B. Protocolo de multiplicación de *Oebalus insularis* Stal (Heteroptera: Pentatomidae), en condiciones abióticas controladas: Subsidio para la cría masiva de *Telenomus podisi* Ashmead (Hymenoptera: Platygastridae). IDIAP, 2014, Panama, Panama, ISBN: 978-9962-677-37-5.

27. Zachrisson B, Costa V, Bernal J. Incidencia natural de parasitoides de huevos de *Oebalus insularis* Stal (Heteroptera: Pentatomidae) en Panamá. IDESIA. 2014a; 32:119-121.

28. Zachrisson B, Margaría CB, Loiácono M, Martínez O. Parasitismo de huevos de *Tibraca limbativentris* (Hemiptera: Pentatomidae), en arroz (*Oryza sativa* L) en Panamá. Revista Colombíana de Entomología. 2014b; 40:189-190.

SUPPLEMENTARY FILES

Table 1. Degree of importance of the main insect pests that affect rice cultivation (Oryza sativa) in the production areas of Panama

Order	Family	Species	Phenological stage[2]	Degree of importance[1, 3]
Coleoptera	Cucurlionidae	*Lissorhoptrus* sp.	Establishment	2
		Hydrellia sp.	Vegetative	2
Hemiptera	Pentatomidae	*Tibraca limbativentris*	Vegetative-Reproductive	2
Homoptera	Delphacidae	*Tagosodes orizicolus*	Vegetative-Reproductive	1
Lepidoptera	Pyralidae	*Diatraea tabernella*	Vegetative-Reproductive	2
Lepidoptera	Pyralidae	*Diatraea saccharalis*	Vegetative-Reproductive	3
Lepidoptera	Pyralidae	*Rupela albinella*	Vegetative-Reproductive	2
Lepidoptera	Noctuidae	*Spodoptera frugiperda*	Vegetative-Reproductive	3
Lepidoptera	Hesperiidae	*Panoquina* sp.	Vegetative	3
Hemiptera	Pentatomidae	*Oebalus insularis*	Reproductive-Maturation	1
Hemiptera	Pentatomidae	*Euschistus nicaraguensis*	Reproductive-Maturation	2

Note 1 = important; 2 = moderately important; 3 = sporadically important.

Note 2=Phenological stage: Life cycle events and how these are influenced by seasonal and interannual variations in climate, as well as habitat factors.

Note 3=Reference that indicates the degree of importance of the insect pests (Galvis et al., 1982).

Table 2. Egg parasitoids of the families Platygastridae and Trichogrammatidae reported in rice cultivation (*Oryza sativa*) in Panama

Family	Insect pest	Family	Natural enemy	Location (Distribution)	Natural incidence of parasitoids
Pyralidae	*Diatraea saccharalis*	Trichogrammatidae	*Trichogramma pretiosum*	Chepo, Panama	H[1]
Pyralidae	*Rupela albinella*	Platygastridae	*Telenomus rowani*	Felipillo, Chepo	H
Noctuidae	*Spodoptera frugiperda*	Trichogrammatidae	*Trichogramma pretiosum*	Felipilllo, Pacora; Panamá	M
Delphacidae	*Tagosodes orizicolus*	Encyrtidae	*Anagrus* sp.	Chepo, Panama	L
Pentatomidae	*Oebalus insularis*	Platygastridae	*Telenomus podisi*	Juan Hombrón, Río Hato, Coclé; Chepo, Panama	H
Pentatomidae	*Tibraca limbativentris*	Platygastridae	*Telenomus podisi*	Chepo, Panama	M
Pentatomidae	*Euschistus nicaraguensis*	Platygastridae	*Telenomus podisi*	Juan Hombrón, Panama	M

Note 1= High (H) = 80-100%; Moderate (M) = 60-79%; low = below 50%.

Table 3. Percentage of *Tibraca limbativentris* (Hetroptera: Pentatomidae) eggs parasitised with *Telenomus podisi* (Hymenoptera: Platygastridae), collected in Chichebre and Paso Blanco, Panama

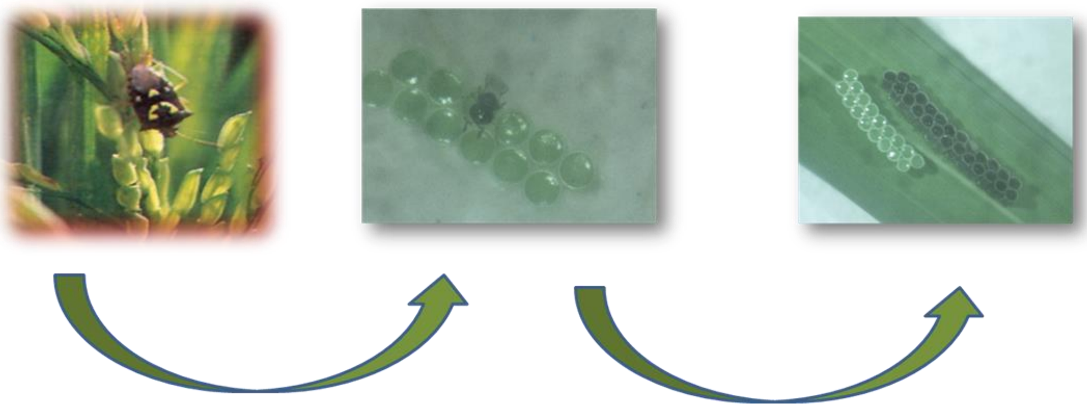
Location	Variety	Number of eggs collected	Number of emerging parasitoids	Parasitism rate (%)
Paso Blanco	IDIAP-L7	186	158	84.9
Chichebre	IDIAP-38	342	325	95.0
Total	**-------**	**528**	**483**	**91.5**

Table 4. Parasitism rate of *Euschistus nicaraguensis* (Heteroptera: Pentatomidae) eggs caused by *Telenomus podisi* (Hymenoptera: Platygastridae) in the rice agroecosystem of Juan Hombrón, Coclé, Panama

Species	Family	Total number of eggs collected/mass	Total number of parasitised eggs	Parasitism rate (%)
Oryza sativa	Poaceae	76 (3)[1]	58	82.9
Cyperus rotundus	Cyperaceae	49 (2)	22	44.9
Echinochloa colona	Poaceae	68 (3)	52	76.5

Note. 1= Number of egg masses.

(a) **(b)** **(c)**



Photograph: Bruno Zachrisson (2015)

Plate 1. Model of trophic interaction showing natural parasitism of eggs of *Oebalus insularis* (Heteroptera: Pentatomidae) (a) by the parasitoid *Telenomus podisi* (Hymenoptera: Platygastridae) (b) and eggs parasitized ¨black color¨ (c)

(a) (b)

Photograph: Bruno Zachrisson (2014)

Plate 2. Adult of *Telenomus podisi* (Hymenoptera: Platygastridae) (a) emerging from eggs of *Oebalus insularis* (Heteroptera: Pentatomidae); and males (♂) and females (♀) (b) of *Telenomus podisi* (Hymenoptera: Platygastridae)

(a) (b) (c)

Photograph: Pamela Polanco (2013)

Plate 3. Nymphs of *Oebalus insularis* (Heteroptera: Pentatomidae) (a) feeding on rice grains (*Oryza sativa*); *Echinochloa colona* (b); and *Eclipta alba* (c)

Photograph: Bruno Zachrisson (2012)

Plate 4. Egg mass of *Rupela albinella* (Lepidoptera: Pyralidae), parasitised with adult specimens of *Telenomus rowani* (Hymenoptera: Scelionidae)

(a) 

(b) 

Photograph: Pamela Polanco (2016)

Plate 5. (a) Eggs and (b) adults of *Euschistus nicaraguensis* (Heteroptera: Pentatomidae), collected in the rice agroecosystem