
VOL III
Estudos em Ciências Agrárias e Ambientais
Eduardo Spers
(Organizador)
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INTRODUÇÃO

O campo das Ciências Agrárias e Ambientais é vasto e dinâmico, abrangendo uma diversidade de abordagens, técnicas e inovações essenciais para o avanço da agricultura, da pecuária e do manejo dos recursos naturais. Em um mundo em constante mudança, em que a sustentabilidade e a busca por soluções eficientes para os desafios ambientais são cada vez mais urgentes, a contribuição dos profissionais das agrárias se torna fundamental para a construção de um futuro mais equilibrado e saudável.

O Volume III de **Estudos em Ciências Agrárias e Ambientais** reúne pesquisas de autores de diversas partes do mundo, contribuindo com uma série de investigações que exploram desde os fundamentos da agroecologia até as complexas interações entre os seres humanos e o meio ambiente. A primeira parte aborda questões cruciais relacionadas à sustentabilidade, desde a utilização de biopreparados como soluções ecológicas até a medição de emissões poluentes em processos produtivos, refletindo o compromisso com práticas agrícolas que buscam respeitar os ciclos naturais e minimizar impactos negativos no planeta.

Em seguida, somos conduzidos a uma viagem pelo campo da genética e do melhoramento de plantas, uma área essencial para garantir a segurança alimentar global e o uso mais eficiente dos recursos naturais. Através de uma análise detalhada, os estudos nos apresentam a diversidade genética e os avanços que permitem o desenvolvimento de culturas mais resilientes e produtivas.

O livro também nos convida a refletir sobre os diferentes aspectos do manejo de cultivos, abordando desde as propriedades físicas das madeiras tropicais até as técnicas agrícolas adaptadas a regiões semiáridas, sempre com o olhar atento para as melhores práticas agrícolas, que promovem uma integração harmoniosa entre o ser humano e a terra.

Por fim, encontramos uma seção dedicada à produção animal, que explora o papel fundamental da pecuária na alimentação e economia global, além das questões relacionadas à saúde animal. A conexão entre a produção e a saúde dos animais é uma chave para garantir a qualidade e a sustentabilidade dos sistemas produtivos, abrangendo desde práticas de manejo até o desenvolvimento de estratégias veterinárias inovadoras.

Através destes trabalhos, buscamos oferecer uma visão abrangente e integrada de diversos aspectos das ciências agrárias, com o objetivo de contribuir para o avanço do conhecimento, da pesquisa e da prática no campo. Este é um convite à reflexão sobre o papel fundamental que a ciência e a inovação desempenham na construção de um futuro agrícola mais sustentável, saudável e próspero para todos.

Desejo a todos uma proveitosa leitura!

Eduardo Eugênio Spers

SUMÁRIO

AGROECOLOGIA E SUSTENTABILIDADE

CAPÍTULO 9

BIOECOLOGY AND INTEGRATED MANAGEMENT OF ALIEN INVASIVE PEACH FRUIT *FLY BACTROCERA ZONATA* SAUNDERS (DITPTERA: TEPHRITIDAE) IN SUDAN

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ABSTRACT: Study of Bioecology and Integrated Management of Alien Invasive Peach Fruit Fly *Bactrocera zonata* Saunders (Ditptera: Tephritidae was conducted in Sudan during the period (2016-2018). The findings determined its spatiotemporal distribution, biology, host range, parasitoids, food attractants for mass trapping. In the study, the potency of *B. zonata* to compete and displace *B. doralis* in guava ecosystem was confirmed and the phenomenon of hybridization between the two species was demonstrated for the first time.
KEYWORDS: Bioecology of Bactrocera zonata. Invasive species management. Peach fruit fly. Spatiotemporal distribution. Hybridization of Bactrocera species.

1 INTRODUCTION

Sudan is the third largest country in Africa with an area of almost 1.88 million km^2 with diverse ecosystem, which avail production of several agricultural products all the year around. Sudan has a diversified large area; 40 per cent of the total area consists of pasture and forests (Stads and ElSiddig 2010), more than 50% of the remained area is cultivable land situated between the Blue Nile and the White Nile, and in the region between the Blue Nile and the Atbara River but only 25% of this area is cultivated (Mahgoub 2014). The agricultural sector contributes positively to Sudanese economy by 45% to national

GDP. Cotton, groundnuts (peanuts), sugarcane, sesame, vegetables and fruits as well as animal feed like alfalfa are the main cultivated cash crops under irrigation in Sudan while sorghum, millet, wheat, corn, barley and pulses like cowpeas and beans are cultivated as food crops. In addition to the subsistence crops, horticultural crops such as mango, citruses, banana and cucurbits represent the main exported commodities provide 12% of the national agricultural income (Idris 2006 and Mahgoub 2014).

Many obstacles hindering horticultural production in Sudan included fragmentation of lands, lack of financing, low-yield varieties, absence of quality control measures, high cost of transportation, and the incidence of pests and diseases (Elyas, 2008). Among pests and diseases, fruit flies are the main menace, causing severe losses to fruit production, which exceed 80% of guava and 30–50% of mango as reported from 2005 to 2008 (PPD 2008; Gesmallah et al. 2014).

Fruit flies belonging to the family Tephritide are the most serious insect pests that attack horticultural products causing severe damage leading to considerable quantitatively and qualitatively economic losses. The family Tephritide consisted of 5 genera but the genus Bactrocera is the largest of these approximately it contains 500 described species and most of them (40%) attacking fruits and vegetables and others attack stems and leaves. Among the genus *Bactrocera*, the peach fruit fly *Bactrocera zonata* Saunders which was added to the European Plant Protection Organization (EPPO) A1 quarantine pests list in 2002 and was transferred to the A2 List in 2015. *B. zonata* originates in South and South-East Asia and has spread to other parts of the world in the Near East including Egypt, Southern Iran, Israel in Rafah, south of Gaza strip, Oman, Saudi Arabia, Palestine and in 2012 it was reported in Sudan (Salah et al., 2012). The pest was known to attack more than 50 plant species including fruits, vegetables and wild plants. According to invasions to new territories, the host range of the pest is expanded. (Quilici et al. 2008).

2 FAUNA OF FRUIT FLY IN SUDAN

More than 39 fruit flies belonging to the family Tephritidae have been reported with their host plants at the Insect Taxonomy Unit of the Agricultural Research Corporation, Wad Medani, Sudan.

Since 1960th, different studies were conducted for many indigenous species of fruit flies reported in Sudan attacking various horticultural crops. The fauna of fruit fly includes the Mediterranean fruit fly or medfly (*Ceratitis capitata* (Weidmann), Mango fruit fly or Marula fruit fly (*C. cosyra* (Walker)), Rhodesian fruit fly (*C. quinaria* (Bezzi)), Cucurbit

fruit flies, *Dacus vertebratus* (Bezzi) and *D. ciliatus* Loew, apple of Sodom fly, *D. longistylus* (Wiedemann) and Jujube or Chinese date fruit fly, *Carpomya incompleta* (Schmutterer, 1969); Mahmoud et al. 2012; Beije et al. 1989 ; Venkatarman and El Khidir (1965); Abdellah and Mohammed 2010 and Mahmoud et al. 2020).

3 INVASION OF SUDAN BY ALIEN INVASIVE SPECIES OF FRUIT FLIES

In the last two decades, horticultural sector of Sudan was affected hardly by invasive species of fruit flies such as the Oriental fruit fly *Bactrocera dorsalis* (Hendel), formerly known as *B. invadens* Drew Tsuruta and White, in 2005 then melon fly *Zeugodacus cucurbitae* (Coquillett) and *Dacus punctatifrons* Karsch, (1887) (Gesmalla and Abdellah, 2011) and recently the peach fruit fly, *B. zonata* Saunders in 2012 (Salah et al. 2012).

After the invasion of the country by *B. dorsalis* in 2005 and *B. zonata in 2012,* the losses of fruits due to their attack was very severe affected income of small farmers and reflected directly on the economics of the country and returns of foreign currency.

Due to their seriousness, they caused (80%) economic losses to the produce. Plant Protection Directorate in Sudan upgrading *B. dorsalis and B. zonata* to the list of Sudan's national pests which controlled by the government. The government of Sudan controlled the both fruit fly species by distributing locally made traps equipped with wigs of cotton immersed in methyl eugenol; the male attractant, with malathion as killer. The traps were distributed free of charge. The invasion of *B. zonata* to Sudan, threatened other African neighboring countries include South Sudan, Kenya, Tchad, Eriteria, Ethiopia and Republic of Central Africa. To offer information on the new invader fruit flies to the continent, International Center of Insect Physiology and Ecology initiated a scientific project to collect basement data on bio-ecology and prospects of integrated management of alien invasive peach fruit fly *Bactrocera zonata* Saunders (Ditptera: Tephritidae) in Sudan. The project was collaborative research conducted by the Agricultural Research Corporation during the period 2014-2018. The objectives of the research were to determine, biology, temporal and spatial distribution, define host range and host preference, cataloging natural enemies and assessing their role in natural control, testing luring performance of some ready-made and locally-made attractants as well as to study the effect of spot application of Mazoferam and combined with spinosad in reduction of infestation levels of Peach Fruit Fly. Also the study included the study of the possibilities of competitive displacement between fruit fly species and the hybridization.

4 BIOLOGY OF *B. ZONATA*

Laboratory study was conducted at 25 °C temperature and 60% relative humidity to determine the developmental period and survival percentage of each stage of *B. zonata* on guava fruits. The whole period of the developmental stages of *B. zonata* was 18.8 days divided to 2.8± 0.2 days for egg, 6.9± 0.3days for larva and 9.1±1.1 days for pupa with survival percentages ca 82.9 ± 12.8, 90.2 ± 3.26 and 85.5 ± 14.4% for each stage respectively (Mahmoud et al., 2024).

5 SPATIAL DISTRIBUTION, RELATIVE ABUNDANCE AND LEVEL OF INFESTATION OF *B. ZONATA*

Surveys to determine the distribution, relative abundance and level of infestation of *B. zonata* was conducted including fruit production areas distributed in 18 states with several localities within the states. Lynfiled traps equipped with cotton wigs soaked in methyl eugenol with malathion (4:1) was used to determine the presence of the pest. Also rearing flies from the infested fruits was used to confirm the trapping results as well as to determine levels of infestation.

The results revealed wide spread of the peach fruit fly across the country with relative abundance fluctuated between 0.2–100% in different locations and the highest infestation level reached 648.7 flies/kg of fruits. The occurrence of the pest in all the country significantly threats neighboring countries and elsewhere if eradication programs aren't applied.

6 TEMPORAL DISTRIBUTION OF *B. ZONATA*

Torula yeast baited in Mcaphil traps was used in two guava orchards to determine temporal distribution of *B. zonata* and the compiled data of trapping coincided with rearing flies from guava fruits from the same orchards to assess the infestation levels of guava fruits. The result revealed abundance of *B. zonata* all around the year. The abundance of *B. zonata* attributed to the availability of the host. The population of *B. zonata* started in the 1st of November 2015 with 8.7 FTD and it was fluctuated in numbers less than 10 FTD during the period from 9th of November 2015 to 24th of October 2016. then the population of *B. zonata* increased rapidly from 9th of November 2016 with (35.5) FTD and crested with (39.6 and 40.9) FTD during the end of November and first week of December of 2016 respectively then it decreased to 18.5 FTD at the end of the study in 28th of December (Fig.1).

The infestation level of guava fruits by *B. zonata* started with (150 FF/Kg) of fruits for the period from 12th October to 12th of December 2015 and then altered from (200 FF/Kg) during the second third of December 2015 to (400 FF/kg) at the end of January 2016. During the period from February to April 2016, infestation level of guava by *B. zonata* decreased drastically to its lowest levels (2 and 38FF/kg) and started to increase gradually for the period from 18th May 2016 to 12th of June 2016 (86.3 to 428.6 FF/Kg) after that it was decreased to 125 FF/kg between 18th May 2016 and 12th of June 2016 then increased gradually to (335 FF/kg) for the period from 3rd of August 2016 up to the end of the study in 19thof December 2016 (Fig.2). In other study population of *B. zonata* peaked twice in Gezira states during 2014 and 2015 due to the fruiting season of mango trees, which bear fruits two times a year in Sudan (Mahmoud et al. 2016).

7 HOST PLANTS AND HOST PREFERENCE

Susceptibility of different fruits to *B. zonata* was determined through sampling from orchards from 18 states including fruits of some wild plants. Fruits of Guava, *Psidium guajava*; Mango, *Mangifera indica*; grape fruit, *Citrus × paradise*; cucumber, *Cucumis sativus*; date palm, *Phoenix dactylifera*; banana, Musa sp.; orange, *Citrus × sinensis* and lemon, Citrus × limon, to *B. zonata* were assessed in choice test. In addition to those fruits used in the choice test, Papaya, *Carica papaya*; sweet pepper, *Capsicum annuum*; hot pepper, *Capsicum annuum*; tomato, *Solanum lycopersicum*; eggplant, *Solanum melongena*; Sweet lemon *Citrus × limon*, were evaluated in no-choice test. Also, differential bioassay of susceptibility for cultivars of mango and cultivars of date palm to *B. zonata* was conducted in choice tests against *B. zonata.*

The results revealed that, mango, guava, grapefruit, oranges and papaya are the most susceptible host fruits to *B. zonata* in the field. Also it was reared from the wild host ivy fruit (*Coccina grandis*) and the Indian jujube) (*Ziziphus mauritiana*(. In the laboratory host preference choice test, *B. zonata* preferred guava, mango, banana, date palm and cucumber (Fig.3). In Non-choice test, guava was found to be the most susceptible host followed by cucumber, banana, sweet pepper, mango, sweet lemon, eggplant, papaya, tomato, date palm, orange and grape fruit. Elfons; mango cultivar, was found to be the most preferred cultivar to *B. zonata* followed by Genobia, Bezria, Temour, Abusamakah, Gabalia, Agoura, Sukariaas and Zibda. Four cultivars of date palm fruits namely, Barhey, Gargoura, Gundaila and Barakawi were found to be susceptible to *B. zonata* infestation while Meshrique and Wad Lagi were proved not to be susceptible to *B. zonata*.

8 PARASITOIDS ASSOCIATED WITH *B. ZONATA*

Study to determine natural enemies associated with *B. zonata* was carried out in an area completely dominated by the pest for one year around depending on rearing of flies from guava infested fruits. The results revealed three parasitoids associated with *B. zonata* viz., *Tetrastichus giffardianus* Silvestri (Eulophidae), Aganaspis sp. (Figitidae: Eucoilinae) and *Psyttalia* sp. (Braconidae Opiinae) (Fig. 4). *Tetrastichus giffardianus* was the most numerous parasitoid with 13.5% mean parasitism percentages and average of 3.2 parasitoids/puparia of *B. zonata* (Mahmoud et al., 2019).

9 MANAGEMENT OF *B. ZONATA* USING READY-MADE AND LOCALLY-DEVELOPED FOOD ATTRACTANTS

Performance of ready-made and locally attractants to lure *B. zonata* were evaluated in separate experiments using Mcaphil traps. All test attractants lured both sexes of *B. zonata* responded in high numbers to Mazoferm, Torula yeast and GF-120 as ready-made food attractants and were reacted positively to water extract of grinded maize, sorghum, millet and to diluted tomato catchup. For all tested materials the percentage of attracted females represented 70% of the total caught flies

Spray of Mazoferm (food attractant) combined with Spinosad significantly reduced population of *B. zonata* (FTD) population and suppressed infestation level of guava fruits (fruit flies/Kg of fruits). (Mahmoud et al., 2024).

10 DRAWBACKS OF APPLICATION OF METHYL EUGENOL WITH MALATHION TO CONTROL *B. ZONATA*

Plant Protection Directorate applied control campaigns all around the country since the declaration of *Bactrocera* sp as national pests in Sudan in 2008 after the country invaded by *B. dorsalis*. The campaigns depend mainly on using locally made traps equipped with Methyl Eugenol (male attractant) and Malathion (killer) in a proportion of 4:1 respectively. The technique participated positively in trapping huge number of males of *B. zonata* and *B. dorsalis* leading to decrease of infestation levels of fruits and increased the quantity of the exported products. After 10 years and according to the continuous use of Malathion as killer in the combination of lure and kill system, it was observed that *B. zonata* males were attracted to the Methyl eugenol but were not killed. A trial was conducted using other pesticides as killers in addition to the Malathion in the trapping system confirmed that, *B. zonata* resisted the killing action of Malathion.

11 COMPETITIVE DISPLACEMENT OF *B. ZONATA* TO *B. DORSALIS*

Previous studies mentioned that *B. dorsalis* was the dominant fruit fly that displaced *C. capitata*, *C. cosyra* (Mahmoud et al., 2012). In 2012 after the report of *B. zonata* as new fruit fly in Sudan, study to determine competitive displacement between the new invader and the dominant fruit fly *B. dorsalis* was conducted for more than one year in guava fruits in Gezira state, Sudan. Only *B. zonata* (99.6%) and *B. dorsalis* (0.4%) were reared out from guava fruits during the study period from November 2015 to December 2016. The mean of infestation level of *B. zonata* (204 FF/Kg) for the whole study period is higher than that caused by *B. dorsalis* (0.8 FF/Kg of fruits). The supremacy of *B. zonata* is credited to the high reproductively of the species, short life cycle compared to *B. dorsalis* ability to infest high numbers of plant species, and ability to develop resistance to several insecticides (Mahmoud et al., 2024).

12 HYBRIDIZATION BETWEEN *B. ZONATA* AND *B. DORSALIS*

As a phenomenon, cross mating between *B. zonata* and *B. dorsalis* was observed occurred naturally. Trials were conducted in laboratory to confirm the phenomenon using naïve adult flies from both sexes. The results approved phenomenon and determined the possibility of reproduction of several generations out of this relationship (Fig. 5) Unpublished data 2021.

13 TRAINING AND CAPACITY BUILDING

Training of trainers was conducted in 4 states of Sudan for stakeholders including pioneer farmers, extension officers, Plant Protection Directorate staff and postgraduate students.

Peer research papers were published in a recognized journals and knowledge was disseminated through mass media, Arabic books and brochures.

14 CONCLUSION

B. zonata is a serious insect pest invaded Sudan last decade, the pest within very short time dispersed in the country with abundance all around the year in the fruit orchard which threatened the neighboring countries and African Continent. The possibility of *B. zonata* to attack several fruit species including wild hosts coinciding with short developmental time increase its ability to displace other fruit flies especially the oriental fruit fly *B. dorsalis* which was used to be the most dominant fruit fly in Sudan.

The control campaigns depending on male attractant and one specific insecticide which conducted by Plant Protection Directorate complicated the situation by creating resistance of *B. zonata* to Malathion and give chance to the resurgence of displaced or/ and neglected fruit flies and promoted them to the class of primary pests. For that other control options are highly required. Part of solution of the resistance problem is come from the study which revealed the association of indigenous parasitoids with *B. zonata* with parasitism percentage ca 13% in addition to the luring efficiency of some locally-improved attractants. Incorporation of different control techniques including utilizing of identified parasitoids in this study, using food attractants, field sanitation and use of bio-rationale insecticides such as *Beauveria bassiana*, *Metarhizium anisopliae* and *Bacillus thurengensis.* To fulfill the study, future study should include assessment of competitive displacement phenomenon between *B. zonata* and *B. dorsalis. On other hand* detailed *behavioral* study for the aggressiveness of flies produced from the cross-mating between *B. zonata* and *B. dorsalis* should be conducted as well as determination of the genetic makeup of the progenies.

Fig 1. Mean No of *B. zonata* / Trap/Day at Fadasi site using Torula yeast Food bait attractant 9th Nov 2015 to 17th July 2017.

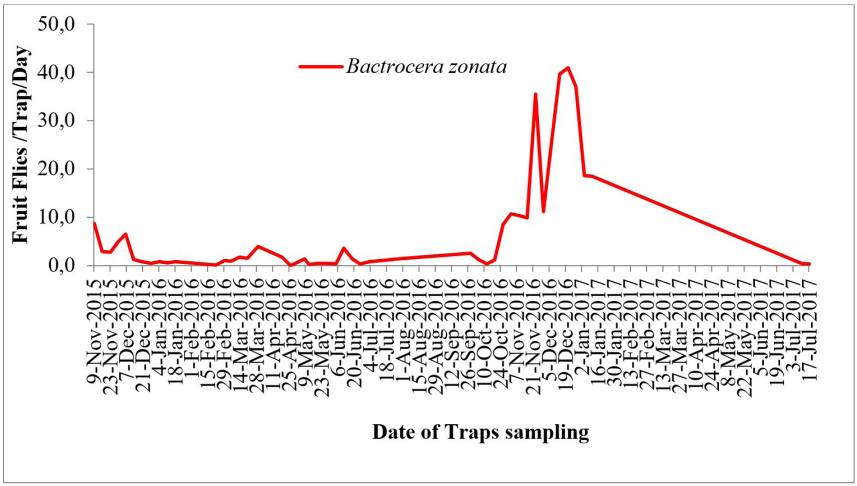


Fig 2. Infestation Levels of guava fruits (Fruit fly/Kg of fruits) by *B. zonata* and *B. dorsalis* at Fadasi site (1st Nov 2015 to 25th Dec 2017).

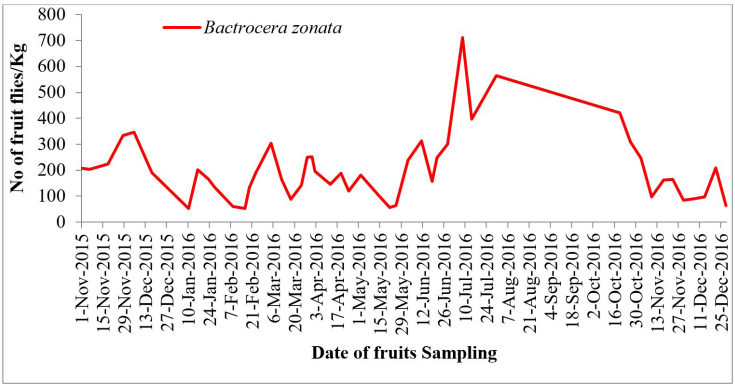


Fig 3. Attack of B. zonata to grapefruit, tomato, cucumber, pepper eggplant and Gentleman's toes (*Coccina grandis*).

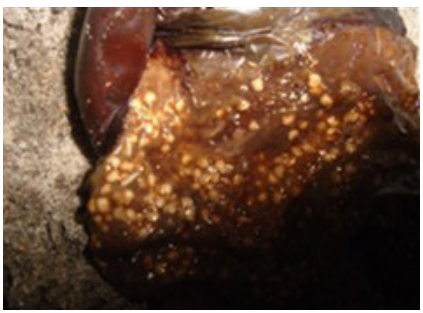


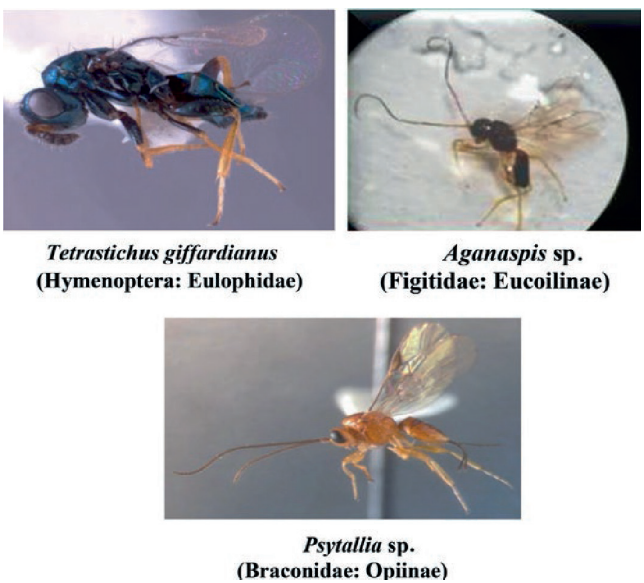
Table 1. Choice test to indicate susceptibility of some cultivars of date palm to infestation by *B. zonata*.

Date palm cultivar	**Mean of emerge pupae± Std error**
Gargoura	4.3±0.9
Meshrique	0
Wad lagai	0
Barhey	15.6±2.7
Gundaila	3.3±1.8
Barakawi	0.3±0.3
Total	3.9±1.4
F	19.7
Sig	0.001

Table 2. Evaluation of infestation of cultivar of mango by *B. zonata*.

Mango cultivar	Mean ± Std. Error of emerged pupae
Mistika	14.7±3.3
Mabrouka	66.0±12.3
Tomi atkins	0
Baladia	0
Total	20.2±8.6
F	24.068
Sig.	0.001

Fig 4. Parasitoids of *B. zonata*.



Tetrastichus giffardianus **(Hymenoptera: Eulophidae)**

***Aganaspis* sp.** **(Figitidae: Eucoilinae)**

***Psytallia* sp.** **(Braconidae: Opiinae)**

Fig 5. Hybridization between *B. zonata* and *B. dorsalis.*

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SOBRE O ORGANIZADOR

EDUARDO EUGENIO SPERS realizou pós-doutorado na Wageningen University (WUR), Holanda, e especialização no IGIA, França. Possui doutorado em Administração pela Universidade de São Paulo (USP). Foi Professor do Programa de Mestrado e Doutorado em Administração e do Mestrado Profissional em Comportamento do Consumidor da ESPM. Líder do tema Teoria, Epistemologia e Métodos de Pesquisa em Marketing na Associação Nacional de Pós-Graduação e Pesquisa em Administração (ANPAD). Participou de diversos projetos de consultoria e pesquisa coordenados pelo PENSA e Markestrat. É Professor Titular no Departamento de Economia, Administração e Sociologia, docente do Mestrado em Administração e Coordenador do Grupo de Extensão MarkEsalq no campus da USP/Esalq. Proferiu palestras em diversos eventos acadêmicos e profissionais, com diversos artigos publicados em periódicos nacionais e internacionais, livros e capítulos de livros sobre agronegócios, com foco no marketing e no comportamento do produtor rural e do consumidor de alimentos.

ÍNDICE REMISSIVO

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