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Hormetic Responses of a Stinkbug Predator to Sublethal Doses of Pyrethroid

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Abstract Stressors can affect reproduction and longevity by impacting endocrine and immune systems but they may increase life span and stimulate reproduction. The effects of sublethal doses of permethrin topically applied on third instar nymphs of *Podisus distinctus* (Heteroptera: Pentatomidae) was evaluated. The weight of females survival of nymph and adults, number of eggs and nymphs/females of *P. distinctus* were higher when exposed to lower doses of permethrin. On the other hand, the exposition to the 0.131, 1.315 and 13.15 ppb showed positive effects on the oviposition periods, number of egg masses and longevity of *P. distinctus* females.

Keywords Asopinae · Predatory bugs · Stresses · Sublethal effects · Xenobiotic

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Chemical control of pests may result in problems for pest management such as resistance to insecticides, resurgence of insects and mite pests, outbreaks of secondary pests, elimination of natural enemies and residues in food (Morse 1998; Medeiros et al. 2004).

Knowledge of total effect of an insecticide is a challenge for ecotoxicologists, because these products may cause lethal and sublethal effects on non-target organisms (Desneux et al. 2007). On the other hand, low doses of poisons can stimulate the performance of organisms, including effects on growth rate and on different physiological responses in bacteria, fungi, invertebrates and plants (Calabrese and Baldwin 2000). Sublethal effects of insecticides have been studied in insects that can respond positively to these stressors (Haynes 1988; Zanuncio et al. 2005). These effects are consistent with the hypothesis of hormesis, first termed hormoligosis (*hormo* = excites e *oligo* = small amount) (Southam and Ehrlich 1943), where reduced doses of stressors may be beneficial for an organism (Townsend and Luckey 1960; Morse 1998). Hormesis (*hormaein* = to excite) is a biphasic phenomenon, where the response of the organism is stimulated by low doses of a compound, but inhibited by higher doses of it (Calabrese and Baldwin 2001; Turturro et al. 2001; Calabrese 2004).

Pyrethroid insecticides are selective for predatory bugs (Picanço et al. 1997; Zanuncio et al. 1998, 2003, 2005).

Permethrin is selective for *Podisus maculiventris* (Say) (Heteroptera: Pentatomidae), with a mortality of 13% due to the low rate of penetration into the cuticle and increased metabolism of this insecticide by the insect (Yu 1987, 1988). In addition, the low absorption and metabolism of this insecticide by predatory bugs can trigger hormesis phenomenon in the field, as evidenced in the laboratory (Zanuncio et al. 2005) which is desirable for the integration of biological and chemical control.

Predatory bugs as *Podisus distinctus* (Stål), *Brontocoris tabidus* (Signoret), *Podisus nigrispinus* (Dallas), *Podisus rostralis* (Stål) and *Alcaeorrhynchus grandis* (Dallas) (Heteroptera: Pentatomidae) are important in biological control in reforested areas and agricultural cultures (Azevedo et al. 2007; Zanuncio et al. 2008; Lemos et al. 2009; Ribeiro et al. 2010).

Podisus distinctus (Stal) (Heteroptera: Pentatomidae), found throughout South America (Thomas 1992) is an agent of biological control of pest in homogeneous eucalyptus forests in Brazil (Zanuncio et al. 2000, 2004). The reproductive biology, predatory capacity and susceptibility to chemical compounds used in integrated pest management should be evaluated because they may affect the success of biological control (Stapel et al. 2000; Tavares et al. 2010). Therefore, this study evaluated the impact of topical application of five sublethal doses of permethrin on the development and reproduction of *P. distinctus*.

Materials and Methods

Individuals of *P. distinctus* were obtained from the mass rearing of the Biological Control Laboratory of the Insectary of the Federal University of Viçosa (UFV) in Viçosa, Minas Gerais State, Brazil.

The experiment was conducted in the laboratory of Biological Control at the Institute of Biotechnology Applied to Agriculture (BIOAGRO) of the UFV at 25 ± 1°C, 12 h photophase and 75 ± 5% relative humidity. *P. distinctus* eggs were placed in ten Petri dishes (9.0 cm diameter), with 100 eggs per plate, until the eclosion of the nymphs. From the beginning of the second instar, the nymphs of this predator received *Tenebrio molitor* L. (Coleoptera: Tenebrionidae) pupae ad libitum (Zanuncio et al. 2000).

Five hundred and forty nymphs of the same age at the second instar of *P. distinctus* were placed in groups of ten individuals per Petri dish and fed on *T. molitor* pupae. One day after molting to third instar, these nymphs were individually placed in transparent plastic flasks (50 mL), whose cover tops had a cylindrical tube of 2.5 mL for water supply to this predator (Zanuncio et al. 2000).

Technical grade permethrin insecticide was dissolved in acetone for concentrations of 10^{-2}–10^{-6} mg/mL. Then, permethrin doses of 0.131, 1.315, 13.15, 131.5 and 1,315 ppb were applied on third instar nymphs of *P. distinctus*. Control was performed with topical application of acetone. This application was made with a 1 µL microsyringe onto the scutellum of each *P. distinctus* nymph.

Mortality, weight within 24 h after molting and duration of nymph period were recorded. Three days after emergence adults were mated, with one couple per 500 mL transparent plastic flask, receiving water and *T. molitor* pupae. Mortality, weight within 24 h after emergence of adult, preoviposition period, number of ovipositions, eggs and longevity of this predator were recorded. The eggs of this predator were collected daily and placed in Petri dishes with a cotton moistened ball with distilled water to observe incubation periods, egg viability and number of eggs per oviposition of *P. distinctus*.

The experimental design was completely randomized with six treatments [five permethrin doses and the control group (acetone)]. For each treatment tree replications were used with 30 nymphs each totaling 90 nymphs/treatment. Regression analysis was performed with the procedure SAS PROC REG (SAS Institute 2002) and the model that best explained the relationship between the variables was chosen.

Results and Discussion

Increase survival and weight of nymphs and the larger number of eggs and nymphs per female of *P. distinctus* with the lowest doses of permethrin and reduced values with higher doses of this stressor show the hormesis phenomenon, as reported for insects and mites with sublethal doses of insecticides (Morse 1998; Marcic 2003). Sublethal doses of stressors can increase reproduction (Forbes 2000) with decreased longevity (Molina-Rugama et al. 1998; Wittmeyer and Coudron 2001; Hoffmann 2009).

The decrease of natural enemies populations caused by insecticides may be the cause for pest resurgence together to hormetic response of insect pests when exposed to sublethal doses of insecticides (Bartlett 1968; Morse 1998), although hormesis had not been reported for insect pests exposed to permethrin. However, exposure of the maize weevil *Sitophilus zeamais* Mots. (Coleoptera: Curculionidae) to sublethal doses of deltametrin increase some population parameters of this insect pest (Guedes et al. 2010). In the same way, the insecticide imidacloprid increases the fertility of the insect pests *Myzus persicae* (Sulzer) (Hemiptera: Aphididae) and *Tryporyza incertulas* (Walker) (Lepidoptera: Pyralidae) as well as the mite *Tetranychus urticae* (koch) (Acari: Tetranychidae) (Sclar et al. 1998; Wang et al. 2005; Cutler et al. 2009; Yu et al. 2010).

Duration of third and fourth instars and that of the nymph stage of *P. distinctus* was shorter with the permethrin doses of 0.131, 1.315 and 13.15 ppb than in the control and longer with 1,315 ppb (Fig. 1a, b, d). On the other hand the duration of fifth ínstar was proportional to the increase of the permethrin doses (Fig. 1c). The lower survival of nymphs (Fig. 2a, b, c), adults (Fig. 3h) and longer period of pré-oviposition (Fig. 3a), oviposition (Fig. 3b), egg masses per female (Fig. 3d) longevity de adults (Fig. 3f) and females (Fig. 3g) of *P. distinctus* with the longer dose of permethrin (1,315) demonstrate a possible allocation of energy for reproduction rather than survival, which is known as the principle of allocation (Calow and Sibly 1990).

The higher weight of the nymphs (Fig. 2d, e, f) exposed to lower doses of permethrin confirms the hormetic effect as reported for other organisms exposed to low levels of xenobiotics (Calabrese and Baldwin 1998; Calabrese 1999; Zanuncio et al. 2005). Hormetic effect for the weight is important, because the number of ovipositions, eggs and descendants are positively correlated with these parameters for predatory bugs which is important in pest management programs (Evans 1982; Zanuncio et al. 2002).

The increase in weight and survival of *P. distinctus* nymphs exposed to lower permethrin doses (0.131 and 1.315 ppb) can facilitate the adaptation of this predator to the environment. Typically, when such effect takes place in more than one biological parameter, such as reproduction and survival, the energy for the organism to adapt to this stress condition needs to be optimized, which can lead to energetic exchanges between competitive physiological processes (Forbes 2000).

Increase in survival and weight of the nymphs and better reproductive performance of *P. distinctus* subjected to low permethrin doses shows hormesis and agrees with higher survival and life expectancy of nematodes (Butov et al. 2001) and aphids (Cutler et al. 2009) subjected to stressor agents. The connection between oxidative stress and aging process or longevity was shown for the nematode *Caenorhabditis elegans* (Rhabdtida: Rhabditidae), based on the hypothesis that the increased resistance to stress also increases reproduction and longevity (Johnson et al. 2001). This indicates that exogenous stresses can be replaced by endogenous ones that, in general, results in different patterns of endogenous metabolism (Finkel and Holbrook 2000; Johnson et al. 2001).

Longest preoviposition of *P. distinctus*, with the higher dose of 1,315 ppb, shows that females of this predator can reduce energy consumption destined to reproduction, until environmental conditions become more adequate. This demonstrates, once again, the occurrence of the principle of resource allocation between different physiological processes (Forbes 2000), but it may be due to deleterious action of the insecticide on the reproductive tract, such as, in the ovarioles of this insect (Lemos et al. 2010). Therefore, morphological studies of reproductive structures of

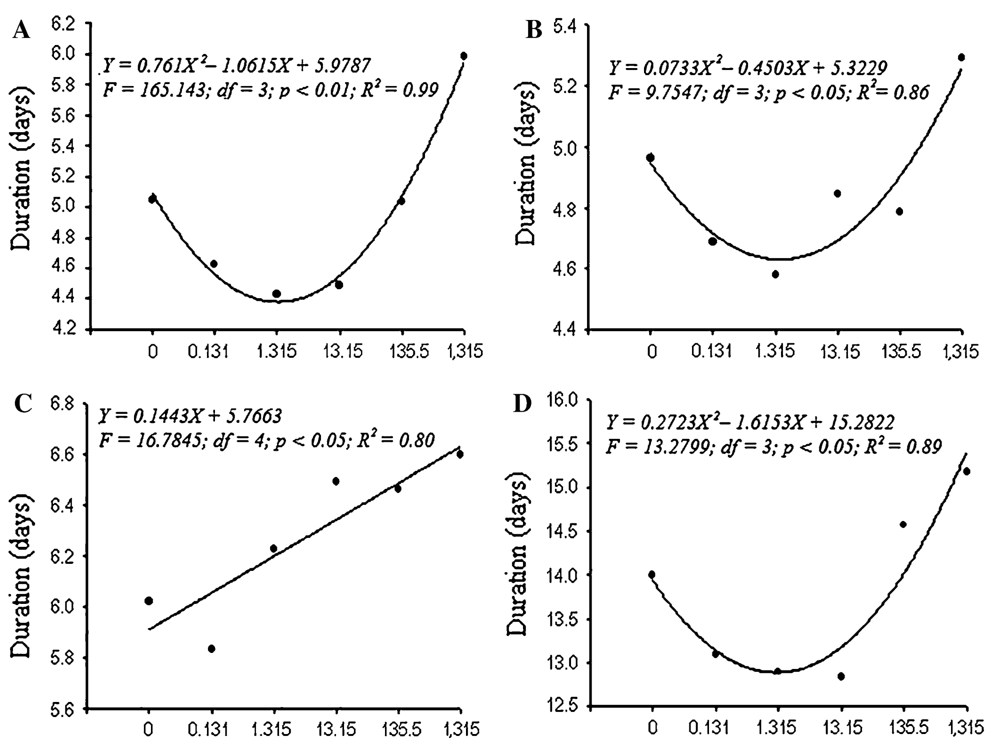

Fig. 1 Duration of third (**a**), fourth (**b**) and fifth (**c**) instars and of the nymph stage (**d**) of *Podisus distinctus* (Heteroptera: Pentatomidae) after topic application of the sublethal doses of permethrin, 0.131; 1.315; 13.15; 131.5, 1,315 ppb or acetone in the control (0)

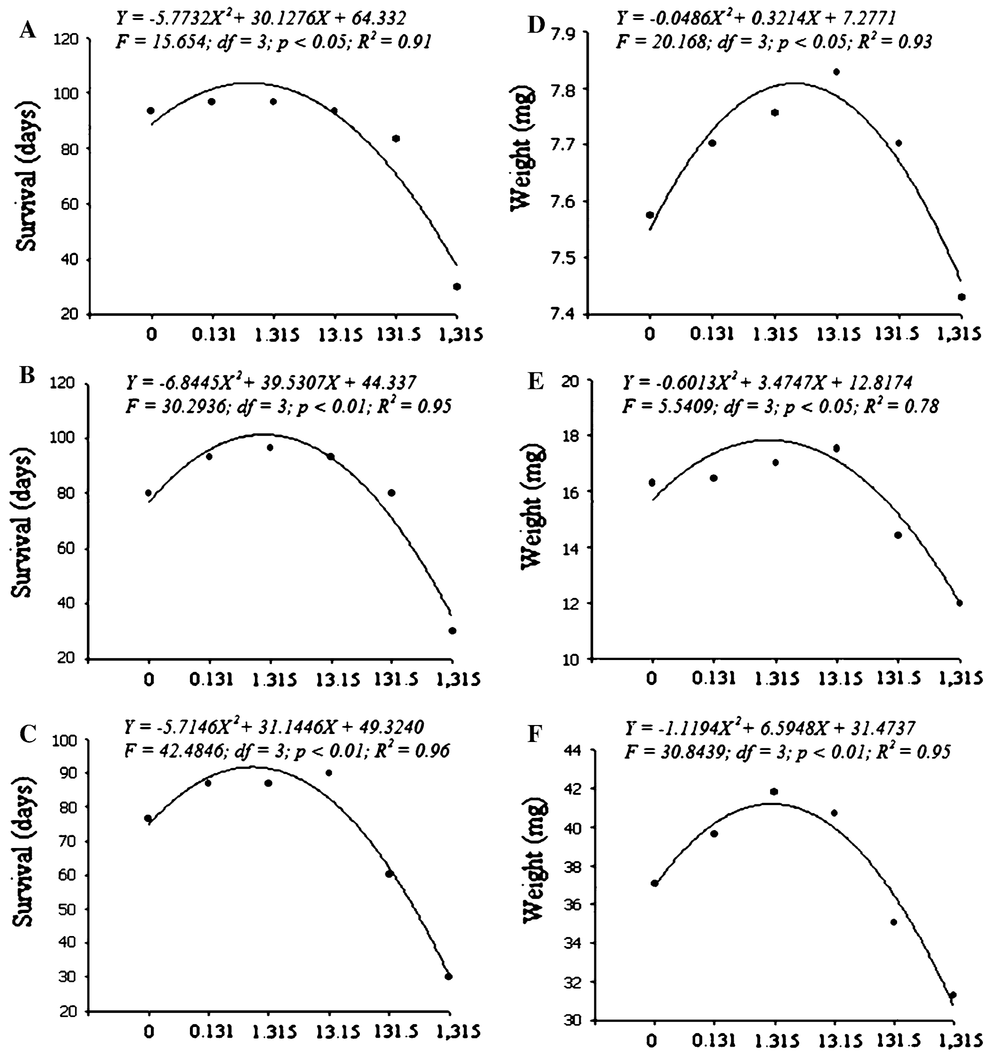

Fig. 2 Survival in the third (**a**), fourth (**b**) and fifth (**c**) instars and during the nymph stage and weight of third (**d**), fourth (**e**) and fifth (**f**) instars nymphs of *Podisus distinctus* (Heteroptera: Pentatomidae) after topic application of the sublethal doses of permethrin 0.131; 1.315; 13.15; 131.5, 1,315 ppb or acetone in the control (0)

predatory bugs are suggested, since *P. distinctus* females with higher preoviposition period showed lower weight and survival and longer duration of immature instars with the permethrin doses of 131.5 and 1,315 ppb. Similar pattern of duration of the preoviposition period was reported for *Supputius cincticeps* (Stal) (Heteroptera: Pentatomidae) females (Zanuncio et al. 2003, 2005) and *P. maculiventris* females (Mohaghegh et al. 2000) with longer preoviposition period after exposition to the deltamethrin.

The similar number of eggs (Fig. 3c) and nymphs (Fig. 3e) per famale of *P. distinctus* with most permethrin doses and in the control, except for the lowest value with 1,315 ppb, showed that individuals of this predator exposed to this dose may have allocated energy for other parameter, through greater longevity of surviving females. This may be related to the principle of resource allocation and represents a compensation for the destabilization in homeostasis (Calow and Sibly 1990; Forbes 2000. Calabrese and Baldwin 2001; Hoffmann 2009).

Higher mortality of *P. distinctus* adults with increasing permethrin doses differs from results for *Geocoris pallens* Stål (Heteroptera: Lygaeidae), which adults survived the applications of insecticides without deleterious effect (Yokoyama and Pritichard 1984). The number of fertile eggs of this predator was also higher after the exposition to acifluorfen and bentazon herbicides (Farlow and Pitre 1983). Female originated from fifth instar nymphs of *P. maculiventris* had shorter longevity and oviposition, following the exposition to sublethal doses of diflubenzuron and pyriproxyfen (De Clercq et al. 1995).

Hormesis depends on heterogeneity and population size, and is commonly detected in more homogeneous populations (Hoffmann 2009; Michalski and Yashin 2002), such as that of *P. distinctus* maintained in the laboratory.

Low doses of the permethrin insecticide increased the weight and survival of nymphs and reproduction of adults, and reduced the duration of nymph stage of *P. distinctus*. These effects were reduced by the higher doses of the

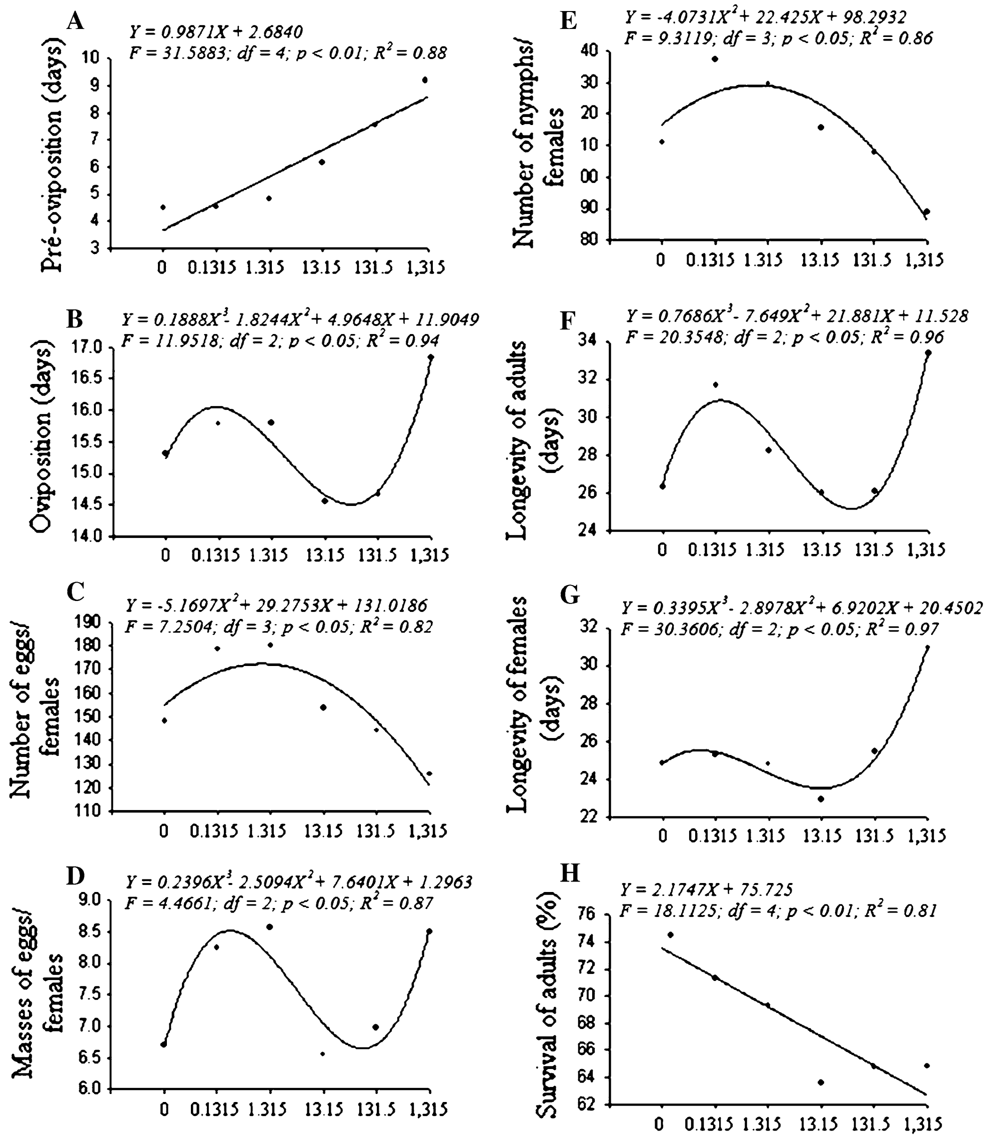

Fig. 3 Duration of the pré-oviposition (**a**) and oviposition periods (**b**), number of eggs (**c**), egg masses (**d**) and nymphs per female (**e**), longevity of adults (**f**) and females (**g**) and survival of adults (**h**) of *Podisus distinctus* (Heteroptera: Pentatomidae) after topic application of the sublethal doses of permethrin, 0.131; 1.315; 13.15; 131.5, 1,315 ppb or acetone in the control (0)

stressor, which demonstrated the hormesis phenomenon. This insecticide can be used in sublethal doses as a stimulating agent for the predator *P. distinctus* within integrated pest management programs.

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References

Azevedo DO, Zanuncio JC, Zanuncio Júnior JS, Martins GF, Silva SM, Sossai MF, Serrão JE (2007) Biochemical and morphological aspects of salivary glands of the predator *Brontocoris tabidus* (Heteroptera: Pentatomidae). Braz Arch Biol Tech 50: 469–477

Bartlett BR (1968) Outbreaks of two spotted spider mites and cotton aphids following pesticide treatment. I. Pest stimulation vs. natural enemy destruction. J Econ Entomol 61:297–303

Butov A, Johnson T, Cypser J, Sannikov I, Volkov M, Sehl M, Yashin A (2001) Hormesis and debilitation effects in stress experiments using the nematode worm *Caenorhabditis elegans*: the model of balance between cell damage and HSP levels. Exp Geront 37:57–66

Calabrese EJ (1999) Evidence that hormesis represents an "overcompensation" response to a disruption in homeostasis. Ecotoxicol Environ Safe 42:135–137

Calabrese EJ (2004) Hormesis: from marginalization to mainstream. A case for heresies as the default dose response model in risk assessment. Toxicol Appl Pharm 197:125–136

Calabrese EJ, Baldwin LA (1998) Hormesis as a biological hypothesis. Environ Health Perspect 106:357–362

Calabrese EJ, Baldwin LA (2000) The marginalization of hormesis. Hum Exp Toxicol 19:32–40

Calabrese EJ, Baldwin LA (2001) Hormesis: U-shaped dose responses and their centrality in toxicology. Trends Pharmacol Sci 22:285–291

Calow P, Sibly RM (1990) A physiological basis of population processes: ecotoxicological implications. Funct Ecol 4:283–288

Cutler GC, Ramanaidu K, Astatkie T, Isman BM (2009) Green peach aphid, *Myzus persicae* (Hemiptera: Aphididae), reproduction during exposure to sublethal concentrations of imidacloprid and azadirachtin. Pest Manag Sci 65:205–209

De Clercq P, Tirry L, Vinñela E, Degheele D (1995) Toxicity of diflubenzuron and pyriproxyfen to the predatory bug *Podisus maculiventis*. Entomol Exp Appl 74:17–22

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

Evans EW (1982) Consequences of body size for fecundity in the predatory stinkbug, *Podisus maculiventris* (Hemiptera: Pentatomidae). Ann Entomol Soc Am 75:418–420

Farlow RA, Pitre HN (1983) Bioactivity of the post emergent herbicides acifluorfen and bentazon on *Geocoris punctipes* (Say) (Hemiptera: Lygaeidae). J Econ Entomol 76:200–203

Finkel T, Holbrook J (2000) Oxidants, oxidative stress and the biology of aging. Nature 408:239–247

Forbes VE (2000) Is hormesis an evolutionary expectation? Funct Ecol 14:12–24

Guedes NMP, Tolledo J, Corrêa AS, Guedes RNC (2010) Insecticide-induced hormesis in an insecticide-resistant strain of the maize weevil, *Sitophilus zeamais*. J Appl Entomol 134:142–148

Haynes KF (1988) Sublethal effects of neurotoxic substances on the behavioral responses of insects. Annu Rev Entomol 33:149–168

Hoffmann GR (2009) A perspective on the scientific, philosophical, and policy dimensions of heresies. Dose-Response 7:1–51

Johnson TE, Castro E, Castro SH, Cypser J, Henderson S, Tedesco P (2001) Relationship between increased longevity and stress resistance as assessed through gerontogene mutations in *Caenorhabditis elegans*. Exp Geront 36:1609–1617

Lemos WP, Zanuncio JC, Ramalho FS, Serrão JE (2009) Fat body of the zoophytophagous predator *Brontocoris tabidus* (Het.: Pentatomidae) females: Impact of the herbivory and age. Micron 40:635–638

Lemos WP, Zanuncio JC, Ramalho FS, Zanuncio VV, Serrão JE (2010) Herbivory affects ovarian development in the zoophytophagous predator *Brontocoris tabidus* (Heteroptera, Pentatomidae). J Pest Sci 83:69–76

Marcic D (2003) The effects of clofentezine on life-table parameters in two-spotted spider mite *Tetranychus urticae*. Exp Appl Acarol 30:249–263

Medeiros RS, Silva AMC, Zanuncio JC, Ramalho FS (2004) Oviposition pattern of the predator *Podisus nigrispinus* (Dallas) (Heteroptera: Pentatomidae) under different temperatures. Biocontrol Sci Tech 14:487–498

Michalski AI, Yashin AI (2002) Detection of hormesis effect in longevity: simulation approach for heterogeneous population. Math Biosci 175:57–66

Mohaghegh J, De Clercq P, Tirry L (2000) Toxicity of selected insecticides to the spined soldier bug, *Podisus maculiventris* (Heteroptera: Pentatomidae). Biocontrol Sci Tech 10:33–40

Molina-Rugama A, Zanuncio JC, Zanuncio TV, Oliveira MLR (1998) Reproductive strategy of *Podisus rostralis* (Stal) (Heteroptera: Pentatomidae) females under different feeding intervals. Biocontrol Sci Tech 8:583–588

Morse JG (1998) Agricultural implications of pesticide-induced heresies of insects and mites. Hum Exp Toxicol 17:266–269

Picanço MC, Ribeiro LJ, Leite GLD, Zanuncio JC (1997) Seletividade dos inseticidas a *Podisus nigrispinus* predador de *Ascia monuste orseis*. Pesq Agrop Bras 32:369–372

Ribeiro RC, Lemos WP, Bernardino AS, Buecke J, Müller AA (2010) Primeira ocorrência de *Alcaeorrhynchus grandis* (Dallas) (Hemiptera: Pentatomidae) predando lagartas desfolhadoras do dendezeiro no Estado do Pará. Neotrop Entomol 39:131–132

SAS (2002) User's manual, version 9.1. SAS Institute, Cary, NC

Sclar DC, Gerace D, Cranshaw WS (1998) Observation of population increases and injury by spider mites (Acari: Tetranychidae) on ornamental plants treated with imidacloprid. J Econ Entomol 91:250–255

Southam CM, Ehrlich J (1943) Effects of extracts of western red-cedar heartwood on certain wood-decaying fungi in culture. Phytopathology 33:517–524

Stapel JO, Cortesero AM, Lewis WJ (2000) Disruptive sublethal effects of insecticides on biological control: Altered foraging ability and life span of a parasitoid after feeding on extrafloral nectar of cotton treated with systemic insecticides. Biol Control 11:175–183

Tavares WS, Costa MA, Cruz I, Silveira RD, Serrão JE, Zanuncio JC (2010) Selective effects of natural and synthetic insecticides on mortality of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) and its predator *Eriopis connexa* (Coleoptera: Coccinellidae). J Environm Sc Heal B 45:1–5

Thomas DB (1992) Taxonomic synopsis of the Asopinae Pentatomidae (Heteroptera) of the Western Hemisphere. The Thomas Say Foundation, USA

Townsend JF, Luckey TD (1960) Hormoligosis in pharmacology. J Am Med Assoc 173:44–48

Turturro A, Hass B, Hart RW (2001) Does caloric restriction induce hormesis? Nutrition 17:78–82

Wang AH, Wu JC, Yu YS, Liu JL, Yu JF, Wang MY (2005) Selective insecticide induced stimulation on fecundity and biochemical changes in *Tryporyza incertulas* (Lepidoptera: Pyralidae). J Econ Entomol 4:1143–1149

Wittmeyer JL, Coudron TA (2001) Life table parameters, reproductive rate, intrinsic rate of increase and estimated cost of rearing *Podisus maculiventris* (Heteroptera: Pentatomidae). J Econ Entomol 94:1344–1352

Yokoyama VY, Pritichard J (1984) Effect of pesticides on mortality, fecundity and egg viability of *Geocoris pallens* (Hemiptera: Lygaeidae). J Econ Entomol 77:876–879

Yu SJ (1987) Biochemical defense capacity in the spined bug (*Podisus maculiventris*) and its lepidopterous prey. Pestic Biochem Physiol 28:216–223

Yu SJ (1988) Selectivity of insecticides to the spined soldier bug (Heteroptera: Pentatomidae) and its lepidopterous prey. J Econ Entomol 81:119–122

Yu Y, Shen G, Zhu H, Lu Y (2010) Imidacloprid-induced hormesis on the fecundity and juvenile hormone levels of the green peach aphid *Myzus persicae* (Sulzer). Pest Biochem Physiol 98: 238–242

Zanuncio JC, Batalha VC, Guedes RNC, Picanço MC (1998) Insecticide selectivity to *Supputius cincticeps* (Stål, 1860) (Heteroptera: Pentatomidae) and its prey *Spodoptera frugiperda* (Lepidoptera: Noctuidae). J Appl Entomol 122:457–460

Zanuncio JC, Zanuncio TV, Guedes RNC, Ramalho FS (2000) Effect of feeding on three *Eucalyptus* species on the development of *Brontocoris tabidus* (Het.: Pentatomidae) fed with *Tenebrio molitor* (Col.: Tenebrionidae). Biocontrol Sci Tech 10: 443–450

Zanuncio JC, Molina-Rugama AJ, Santos GP, Ramalho FS (2002) Effect of body weight on fecundity and longevity of the stinkbug predator *Podisus rostralis*. Pesq Agrop Bras 37:1225–1230

Zanuncio TV, Serrão JE, Zanuncio JC, Guedes RNC (2003) Permethrin-induced hormesis on the predator *Supputius cincticeps* (Stal, 1860) (Heteroptera: Pentatomidae). Crop Prot 22: 941–947

Zanuncio JC, Lacerda MC, Zanuncio Junior JS, Zanuncio TV, Silva AMC, Espindula MC (2004) Fertility table and rate of population growth of the predator *Supputius cincticeps* (Heteroptera: Pentatomidae) on one plant of *Eucalyptus cloeziana* in the field. Ann Appl Biol 144:357–361

Zanuncio TV, Zanuncio JC, Serrão JE, Medeiros RS, Pinon TBM, Sediyama CAZ (2005) Fertility and life expectancy of the predator *Supputius cincticeps* (Heteroptera: Pentatomidae) exposed to sublethal doses of permethrin. Biol Res 38:31–39

Zanuncio JC, Silva CAD, Lima ER, Pereira FF, Ramalho FS, Serrão JE (2008) Predation rate of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) larvae with and without defense by *Podisus nigrispinus* (Heteroptera: Pentatomidae). Braz Arch Biol Tech 51: 121–125