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Seasonality of Violet-winged grasshopper (*Tropidacris collaris*) (Stoll, 1813) (Orthoptera: Romaleidae) in the dwarf cashew

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Abstract

Tropidacris collaris (Stoll, 1813) is a polyphagous pest, found throughout the South American continent.It has recently been reported to cause damage to cashew trees. The aim of this study was to evaluate the population dynamics of *T. collaris* in the dwarf cashew, the effects of climate variables on the population dynamics of *T. collaris*, and the population dynamics of *T. collaris* in relation to the phenological stages of the dwarf cashew. Violet-winged grasshopper was collected in a clonal garden with 35 dwarf cashew clones (*Anacardium occidentale* L.) in Pacajus, Ceará, Brasil. The specimens were randomly captured using an entomological net in two collectors spaced 10 m apart. The collections were made between 09:00 and 11:00, in two 45-min shifts separated by an interval of 15 min. In the laboratory, the insects were separated and weighed, and the females dissected to assess the degree of maturation of the ovaries (I, II and III) and classify the ovipositor valves. A greater abundance of adults was found in December 2017 and June 2018. The number of females with mature ovaries (type III) showed a positive correlation with ovipositors with open valves, such ovaries being registered in December 2017, and in January and July 2018. Wind speed, evapotranspiration and relative humidity showed a significant correlation with the nymph population of *T. collaris*. The greatest peaks in the nymph population were stimulated by the leaf fall/leaf flux phenological stages of the dwarf cashew. In this study we show some of the phenological aspects of *T. collaris* under field conditions, correlated with climatic and phenological variables of the cashew tree. These results may help in decision-making about the application of methods to control *T. collaris* in tropical regions, as this insect is polyphagous, and its large size has great potential for damage to several crops.

Keywords: *Anacardium occidentale*, abiotic factors, giant grasshopper, population dynamics, behavior.

Introduction

Tropidacris collaris (Stoll, 1813) (Orthoptera: Romaleidae), also known as the violet-winged or giant grasshopper, is an insect found throughout the South American continent. Despite having a preference for the leaves of woody plants, it is characterised as a polyphagous species and is of great economic importance for attacking several crops, such as sugar cane, cotton, olive trees, jojoba, maize, soya and wheat (Barrera and Paganini, 1975). *Tropidacris collaris* is considered one of the largest species of grasshopper, with adult males and females measuring 101 mm to 126 mm, respectively. Juveniles are gregarious and voracious, causing intense defoliation in plants (Pelizza et al., 2012).
In Brazil, *T. collaris* is considered an emergent pest in the cashew (*Anacardium occidentale* L.), since the insect can be found in large populations, with adults and nymphs causing severe damage to the plants (Lhano et al., 2019). There are no registered products for management of the insect in the cashew (MAPA, 2020), and there is still no information on the population dynamics or reproductive habits of *T. collaris*.

To implement strategies for controlling *T. collaris*, it is necessary to understand some of the factors intrinsic to the insect, such as population dynamics, that affects the biology of the insect to be controlled (Kishimoto-Yamada and Itioka, 2015). In addition, fluctuations in the availability of food resources (Kishimoto-Yamada and Itioka, 2015) and climate change are extrinsic factors that cause changes in the behaviour of the insect (Nufio and Buckley, 2019). Furthermore, such characteristics as morphology, development and reproductive potential, are also affected by abiotic factors, resulting in an increase or decrease in the insect population (Figueira et al., 2000; Karpakakunjaram et al., 2002; Nufio and Buckley, 2019).

The aim of this study, therefore, was to evaluate a) the population dynamics of *T. collaris* in the dwarf cashew, b) the effects of climate variables (solar radiation; maximum, minimum and mean temperature; relative humidity; wind speed; and reference evapotranspiration) on the population dynamics of *T. collaris*, and c) the population dynamics of *T. collaris* in relation to the phenological stages of the dwarf cashew.

Results and discussion

Population dynamics of Tropidacris collaris and climatic variables

Over the 14 months of sampling, 134 individuals were collected. Adults and nymphs occurred at different periods, with nymphs recorded only from February to May 2018, a period in which there were no adults. A greater abundance of adults was found in December 2017 and June 2018 (Fig. 1).

Among the climate variables under evaluation, only wind speed, evapotranspiration and relative humidity influenced the nymph population of *T. collaris* (Fig. 1). There was a significant negative correlation between wind speed and population ($r = -0.7003$ $P = 0.0053$) and the weight of the nymphs (g) ($r = -0.6166$ $P = 0.0189$). Likewise, the population ($r = -0.5503$ $P = 0.0160$) and weight of the nymphs (g) ($r = -0.6287$ $P = 0.0415$) were negatively correlated with the reference evapotranspiration. In contrast, the nymph population showed a positive correlation with relative humidity ($r = 0.5950$ $P = 0.0248$).

The phenological study of *T. collaris* showed that the species is present in the field during most months of the year, with the exception of September 2018 and January 2019, at low density, which did not cause significant damage to the cashew trees. However, in recent years, this species has been documented as causing damage to cashew orchards (Lhano et al., 2019), and is considered a pest of the eucalyptus (MAPA, 2020). In addition, it has a history of damage caused to economically important crops in the country, such as the mango (*Mangifera indica* L.) and coconut (*Cocus nucifera* L.) (Chagas et al., 1995). The appearance of *T. collaris* nymphs in February, followed by a peak in May, may have been caused by the occurrence of rain, as rainfall favours eclosion (Lecoq and Pierozzi, 1994). The occurrence of *T. collaris* nymphs during this period suggests that this is the most appropriate time to carry out control, as it will prevent the appearance of a new generation of adults over the following months (June/July), a critical period during which the dwarf cashew enters the flowering stage. A lack of control of the insect, and the consequent growth of the adult population, can lead to losses in cashew production. In Brazil, there are no products registered with the Ministry of Agriculture, Fisheries and Supply (MAPA, 2020) for the management of *T. collaris*, however in other countries, studies using biological control have proved to be promising, for example, the fungi *Paranosema locustae* (Canning, 1953) (Lange, 2010) and *Beauveria bassiana* (Balsamo) Vuillemin, 1912 (Pelizza et al., 2012) in Argentina, as well as nematodes of family Mermithidae in Canada (Attard et al., 2008).

Among the climate variables under evaluation, wind speed, evapotranspiration and relative humidity were significantly correlated with the nymph population, however, no variable was correlated with the adult population. Likewise, Braga et al. (2011) found no significant correlation between abiotic factors and the population of *Cornops aquaticum* (Bruner, 1906) (Orthoptera: Acrididae) in the central Amazon. Despite the phenology of grasshoppers often being linked to abiotic factors (Nufio and Buckley, 2019), in the present study, the population dynamics of *T. collaris* was not strongly influenced by such factors.

Phenological aspects of Tropidacris collaris

Overall, the values for mean fresh weight in the females were higher, followed by the males and nymphs (Table 2). The highest values for adult mean fresh weight (MFW) occurred in December 2017, January 2018 and December 2018, which corresponded to the months with the highest values for female MFW (Table 2). The nymphs stood out in February 2018 with the lowest recorded values for MFW. The mean fresh weight of the males ranged from 3.5 to 4.5 during the months they occurred (Table 2).

In the *T. collaris* population, immature ovaries (type I) occurred for each month in which females were collected, except January 2018 (Table 2). In contrast, the presence of mature ovaries (type III) was seen in December 2017, and in January and July 2018. Maturing ovaries (type II) occurred only in December 2017 (Table 2).

The number of females with mature ovaries showed a positive correlation with ovipositors with open valves ($r = 0.669$ $P = 0.009$ $n = 14$). However, during the collection period, females were seen with both immature ovaries and open valves (Table 2).

Ovary maturation in *T. collaris* varied during the period under evaluation, indicating the possible reproductive period of the population. Mature ovaries (type III) occurred more frequently at the beginning of the year (December/January), showing that *T. collaris* was in the reproductive phase, since this precedes the period of greatest leaf abundance in the dwarf-cashew (March-May), guaranteeing the survival of the offspring. This period also coincides with the following period of eclosion (February/March), evidenced by the appearance of nymphs.

The presence of nymphs for only four months of the year suggests that the population of *T. collaris* reproduces once a year, since even with mature ovaries (type III) being found in July, no nymphs were seen after this period. In contrast, Silva et al. (2010), studying the phenology of grasshoppers of species *C. aquaticum*, noted continuous reproduction from the presence of nymphs throughout the year, together with the presence of mature ovaries (type III) for almost every month they evaluated. The result found in the present study corroborates that of Carbonell (1986) and Duranton et al. (1987), who state that *T. collaris* is univoltine. Knowledge of their voltinism allows for greater certainty in synchronising the ideal moment for applying the control method with the most susceptible development phase of the insect. In general, there are differences in the life cycle of Orthoptera, which vary

Table 1. Classification of the phenological stages of the cashew, adapted from Mesquita et al. (2002), and Adiga et al. (2019).

Month	Phenological stages of the cashew plant	Abbreviation
January	Inflorescence senescence	IS
February	Leaf fall	LF
March	Leaf fall/Leaf flux	LF.LFL
April	Leaf fall/Leaf flux	LF.LFL
May	Leaf fall/Leaf flux	LF.LFL
June	Flowering	FLW
July	Flowering	FLW
August	Fruit and pseudo-fruit development	FPD
September	Fruit and pseudo-fruit development	FPD
October	Fruit and pseudo-fruit maturation	FPM
November	Fruit and pseudo-fruit maturation	FPM
December	Fruit and pseudo-fruit maturation	FPM

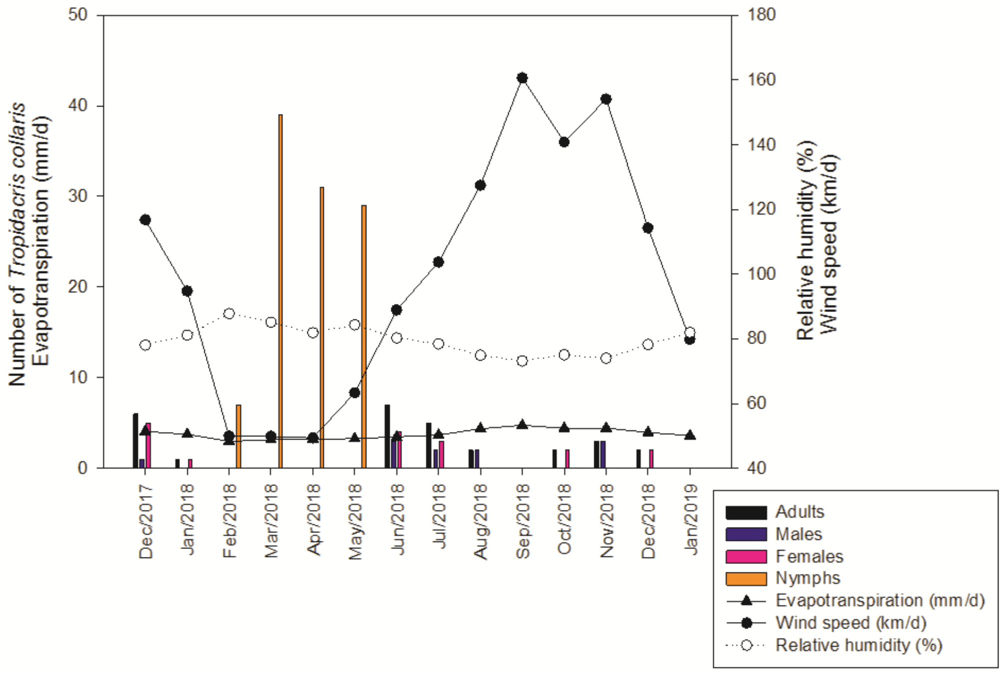

Fig. 1 Number of adults and nymphs of *Tropidacris collaris*, evapotranspiration (mm/d), relative humidity (%) and wind speed (km/d) in the Pacajus experimental area, Ceará, Brazil, from December 2017 to January 2019.
model with Poisson distribution.

Table 2. Mean adult (males and females) and nymph fresh weight, degree of ovary maturation and position of the valves in *Tropidacris collaris* in Pacajus, Ceará, Brazil. December 2017 to January 2019.

	Mean Fresh Weight *Tropidacris collaris* (g)				Ovipositor valve		Ovary		
Month	Adults (n*)	Males (n)	Females (n)	Nymphs (n)	Open	Closed	I	II	III
December	9.36±1.10 (6)	4.37±0.00 (1)	10.36±0.58 (5)	-	4	1	2	2	1
January	15.56±0.00 (1)	-	15.56±0.00 (1)	-	1	-	-	-	1
February	-	-	-	0.33±0.09 (7)	-	-	-	-	-
March	-	-	-	8.01±5.45 (39)	-	-	-	-	-
April	-	-	-	8.98±2.19 (31)	-	-	-	-	-
May	-	-	-	12.88±8.91 (29)	-	-	-	-	-
June	5.84±0.69 (7)	4.46±0.56 (3)	6.87±0.83 (4)	-	-	4	4	-	-
July	6.06±1.34 (5)	3.625±0.63 (2)	7.68±1.62 (3)	-	1	2	2	0	1
August	3.94±0.00 (2)	3.935±0.00 (2)	-	-	-	-	-	-	-
September	-	-	-	-	-	-	-	-	-
October	7.24±0.69 (2)	-	7.24±0.69 (2)	-	-	2	2	-	-
November	4.18±0.29 (3)	4.18±0.29 (3)	-	-	-	-		-	-
December	13.89±3.61 (2)	-	13.89±3.61 (2)	-	2	-	2	-	-
January	-	-	-	-	-	-	-	-	-

*n= number of individuals.

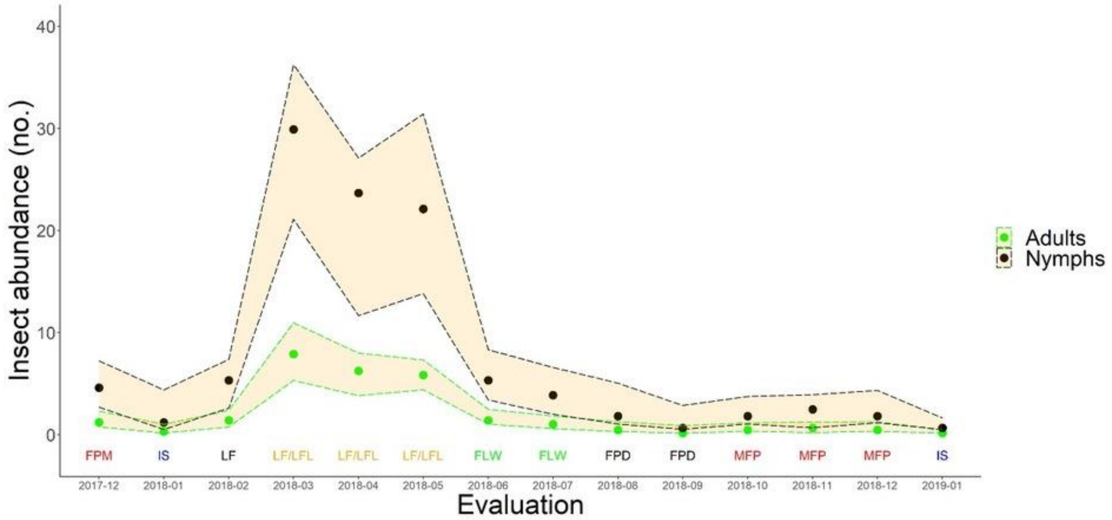

Fig. 2 Population dynamics of *T. collaris* (adults and nymphs) for the phenological stages of the cashew in Pacajus, Ceará, Brazil, from December 2017 to January 2019. Estimated confidence regions (coloured areas) based on the generalised linear mixed.

depending on the species and time of year (Squitier and Capinera, 2003).

Dwarf cashew tree phenology and seasonality of Tropidacris collaris

The generalised linear mixed predictive model showed that the phenological stage of the cashew trees with the highest probability of *T. collaris* nymph and adult occurrence is the Leaf fall/leaf flux stage (LF.LFL) (Fig. 2), albeit with a nymph infestation significantly greater than the adult infestation. This same trend is seen in the flowering stage (FLW) (Fig. 2). For the other stages there are overlaps of the confidence intervals predicted by the model, thereby showing no significant difference between the nymph and adult stages.

The mean fresh weight of *T. collaris* varied over time as a function of the development stage of the insect. Higher values for MFW in *T. collaris* were obtained in January 2018 due to the population including a greater number of adult insects. After that month, nymphs were sampled in the early stages of development, and over the following months the immature insects progressed to more advanced stages, as evidenced by the increase in nymph MFW. It should be noted that this change in phase in the grasshoppers collected in the field coincided with the end of the phenological stages of fruit and pseudo-fruit development and maturation, inflorescence senescence, and the start of leaf flux. The increase in nymph MFW and the greater probability of their occurring compared to adults during the phenological stage of leaf fall/leaf flux, were probably caused by the large amount of dwarf-cashew foliage for feeding during this period. The presence of leaves makes this habitat more suitable for the nymphs to develop, as they have no wing structures to search for food in environments far from their birthplace. On the other hand, adults, as they have wings, are well able to fly, thereby having access to larger areas for foraging. In addition to the plant phenology, environmental conditions can also interfere with the insect-plant relationship (Baldin and Bentivenha, 2019).

Despite the low population density of *T. collaris* seen in the dwarf cashew throughout the collection period, such behaviour is not a sporadic occurrence, indeed it shows the constant presence of these insects in the area, since this orthoptera has been detected in areas of cashew in previous years (Lhano et al., 2019). Furthermore, Duranton et al. (1987) classify this species as an "occasional and localised ravager" that is present in low abundance; although any change in environmental factors can lead to high population growth due to the biotic potential and voracious habit of the insect (Pelizza et al., 2012), and cause possible damage to crops, as shown in earlier records of the species (Chagas et al., 1995; Lhano et al., 2019). In fact, populations of *T. collaris* have already been recorded in the Amazon region (Carbonell, 1984). The appearance of grasshopper clouds is due to changes in abiotic factors, especially rainfall and temperature (Lecoq, 1991). Anthropogenic action can also modify the environment, favouring the grasshoppers and creating new environments which are conducive to populations of certain previously harmless species (Lecoq, 1991). However, the management strategies adopted for controlling each species are determined based on the particularities of its bioecology (Lecoq, 1991).

The seasonality and population dynamics of *T. collaris* in the dwarf cashew as described here comprise extremely important information that should be considered for an assertive management of *T. collaris*.

Materials and methods

Study area

The study was carried out in an orchard of dwarf cashew (*A. occidentale*), 1.3 ha in size, of the cashew genetic improvement program of Embrapa Agroindústria Tropical, located in Pacajus, Ceará (4°11' S, 38°30' W, altitude 79 m) from December 2017 to January 2019. According to the Köppen climate classification (Kottek et al., 2006), the local climate is classified as equatorial savanna with dry winters, located in a region of arid climate, with a rainy season concentrated in February and March. Climate data were recorded at a weather station of Embrapa Agroindústria Tropical located close to the experimental area. During the experiment, no phytosanitary treatments were carried out on the plants. Cropping treatments were given following the recommendations for commercial plantations of the dwarf cashew under rainfed cultivation (Barros et al*.,* 1993). The phenology of the cashew tree was classified by Adiga et al. (2019) (Table 1).

***Tropidacris collaris* collection protocol**

The specimens were randomly captured using an entomological net in two collectors spaced 10 m apart. The collections were made between 09:00 and 11:00, in two 45-min shifts separated by an interval of 15 min. The collected insects were placed in plastic boxes and transported live to the Entomology Laboratory of Embrapa Agroindústria Tropical, Fortaleza, Ceará.

In the laboratory, the specimens of *T. collaris* were stored in a freezer for 72 hours to avoid damaging their structure; males, females and nymphs were then weighed to obtain the mean fresh weight (MFW). The adult females were dissected with a cut made along the dorsal surface (Youdeowei, 1974) to analyse the ovaries and determine the degree of maturation using the classification proposed by Franceschini et al. (2007): stage I (immature), represented by small, white, threadlike ovarioles with no content; stage II (maturing), the presence of eggs in the ovarioles, albeit small and without any yellow colouration; and stage III (mature), the presence of large yellow eggs in the ovarioles. The presence of ovipositors with open or closed valves was also recorded.

Statistical analysis

The relationship between the climate variables (solar radiation; maximum, minimum and mean temperature; relative humidity; wind speed; and reference evapotranspiration) (annexed) and the population data for *T. collaris* (males, females and nymphs; male weight (g), female weight (g) and nymph weight (g); ovaries [I, II and III], and open and closed valves, as well as the relationship between mature ovaries and open valves) was analysed by means of the Pearson correlation coefficient at a significance level of 5%, using the PAST v 4.03 software (Hammer et al., 2001). A generalised linear mixed model with Poisson distribution was fitted to the data for the population dynamics of *T. collaris*. The model was programmed using the *glmer* function of the *lme4* package (Bates et al., 2015) of the R software (R Core Team 2020), where the phenological stage of the plant was considered a random effect, while the insect stage was considered a fixed effect. The fit of the model to the data was confirmed by means of a simulated half-normal envelope using the *hnp* package (Moral et al., 2017) of the R software (R Core Team 2020). The data predicted by the model were obtained by means of a bootstrap based on mixed models, using the *bootMer* function of the *lme4* package (Bates et al., 2015) of the R software (R Core Team 2020).

Conclusion

The population dynamics of *Tropidacris collaris* varies throughout the year, whose increase in nymph population is affected by climate variables such as wind speed, evapotranspiration and relative humidity, with the greatest peaks in the nymph population being stimulated by the leaf fall/leaf flux phenological stages of the dwarf cashew.

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References

Adiga JD, Muralidhara BM, Preethi P, Savadi S (2019) Phenological growth stages of the cashew tree (*Anacardium occidentale* L.) according to the extended BBCH scale. Ann Appl Biol. 175:246–252.

Attard LM, Carreno RA, Paré JA, Peregrine AS, Dutton CJ, Mason TR (2008) Mermithid nematode infection in a colony of blue-winged grasshoppers (*Tropidacris collaris*). J Zoo Wildl Med. 39:488–492.

Baldin ELL, Bentivenha JF (2019) Fatores que afetam a expressão da resistência. In: Baldin ELL, Vendramim JD & Lourenção AL (ed) Resistência de plantas a insetos: fundamentos e aplicações, 1st edn. Piracicaba, São Paulo. 1.

Barrera M, Paganini IH (1975) Acridios de Tucumán: notas bioecológicas. Acta Zool Lilloana. 31:107–124.

Barros LDM, Pimentel CRM, Correa MPF, Mesquita ALM (1993) Recomendações técnicas para a cultura do cajueiro anão precoce. Embrapa Agroindústria Tropical.

Bates D, Maechler M, Bolker BM, Walker S (2015) Fitting linear mixed-effects models using lme4. J Stat Softw. 67:1–48.

Braga CE, Nunes-Gutjahr AL, De Morais JW, Joachim ADIS (2011) Fenologia de (Orthoptera: Acrididae) associado a *Eichhornia crassipes* (Pontederiaceae) em um Lago de Várzea na Amazônia Central, Brasil. Rev Soc Entomol Argent. 70:185–196.

Carbonell CS (1984) Nomenclature and systematics of Tropidacris et Eutropidacris (Orthoptera, Acrididae, Romaleidae). Not Nat Acad Nat Sci Philadelphia. 461:11.

Carbonell CS (1986) Revision of the Neotropical Genus Tropidacris (Orthoptera, Acridoidea, Romaleidae, Romaleinae). Proc Acad Nat Sci Phila. 138:366–402.

Chagas M, Moreira M, Barreto MFP (1995) Biological aspects of *Schistocerca pallens*, *Stiphra robusta* and *Tropidacris collaris* grasshoppers species at Rio Grande do Norte State, Brazil. Acta Hortic. 370:83–88.

Duranton JF, Launois M, Launois-Luong MH, Lecoq M (1987) Guia prático de luta contra as gafanhotos devastadores no Brasil. FAO.

Figueira LK, Carvalho CF, Souza B (2000) Biologia e exigências térmicas de *Chrysoperla externa* (Hagen, 1861) (Neuroptera: Chrysopidae) alimentada com ovos de *Alabama argillacea* (Hubner, 1818) (Lepidoptera: Noctuidae). Ciênc Agrotec. 24:319–326.

Franceschini MC, Adis J, Poi De Neiff A, De Wysiecki M (2007) Fenologia de *Cornops aquaticum* (Orthoptera: Acrididae) en un camalotal de *Eichhornia azurea* (Pontederiaceae) en Argentina. Amazoniana. 19:149–158.

Hammer O, Harper DAT, Ryan PD (2001) Paleontological Statistics Software Package for Education and Data Analysis. Palaeontol Electronica. 4:1-9.

Karpakakunjaram V, Kolatkar MD, Muralirangan MC (2002) Effects of abiotic factors on the population of an acridid grasshopper, *Diabolocatantops pinguis* (Orthoptera: Acrididae) at two sites in southern India: a three-year study. J Orthoptera Res. 11:55–62.

Kishimoto-Yamada K, Itioka T (2015) How much have we learned about seasonality in tropical insect abundance since Wolda (1988)? Entomol Sci. 18:407–419.

Kottek M, Grieser J, Beck C, Rudolf B, Rubel F (2006) World map of the Köppen-Geiger climate classification updated. Meteorol Z. 15:259–263.

Lange CE (2010) *Paranosema locustae* (Microsporidia) in grasshoppers (Orthoptera: Acridoidea) of Argentina: Field host range expanded. Biocontrol Sci Technol. 20:1047–1054.

Lecoq M (1991) Gafanhotos do Brasil. Natureza do problema e bibliografia/ Les criquets du Brésil. Nature du probtème et bibtiographie. EMBRAPA/NMA e CIRAD/PRIFAS.

Lecoq M, Pierozzi JRI (1994) *Rhammatocerus schistocercoides* (Rehn, 1906), criquet ravageur de l'état du Mato Grosso (BRESIL): essai de synthèse bibliographique. CIRAD-PRIFAS.

Lhano MG, Serrano LA, Vidal-Neto FC, Dias-Pini NS (2019) *Tropidacris collaris* (Orthoptera: Romaleidae) expands its damage in orchards of the dwarf cashew, Anacardium occidentale (Anacardiaceae). Entomol Sci. 22:151–156.

MAPA. Ministério da Agricultura, Pecuária e Abastecimento. Availablein: <http://agrofit.agricultura.gov.br/agrofit_cons/principal_agrofit_cons> Acessed in: 17 nov. 2020.

Moral RA, Hinde J, Demétrio CGB (2017) Half-normal plots and overdispersed models in R: The hnp package. J Stat Softw. 81:1-23.

Nufio CR, Buckley LB (2019) Grasshopper phenological responses to climate gradients, variability, and change. Ecosphere. 10:2866.

Pelizza SA, Eliades LA, Saparrat MCN, Cabello MN, Scorsetti AC, Lange CE (2012) Screening of Argentine native fungal strains for biocontrol of the grasshopper *Tropidacris collaris*: relationship between fungal pathogenicity and chitinolytic enzyme activity. World J Microbiol Biotechnol. 28:1359–1366.

R Core Team R (2020) A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria, 2020. Available in: <https://www.R-project.org/> Acessed in: 14 april. 2020.

Silva FR, Marques MI, Battirola LD, Lhano MG (2010) Fenologia de *Cornops aquaticum* (Bruner) (Orthoptera: Acrididae) em *Eichhornia azurea* (Pontederiaceae) no Norte do Pantanal de Mato Grosso. Neotrop Entomol. 39:535–542.

Squitier JM, Capinera JL (2003) Habitat associations of Florida grasshoppers (Orthoptera: Acrididae). Fla Entomol. 85:235–244.

Youdeowei A (1974) Dissection of the variegated grasshopper. Oxford University Press.