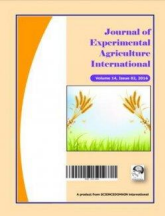

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Meroncidius intermedius (Orthoptera: Tettigoniidae): Incidence and Analysis of Fruits Attacked in Banana Crops in the State of Espírito Santo, Brazil

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Authors' contributions

This work was carried out in collaboration with all authors. Authors PAB and JLFJ designed the study and managed the writing of the manuscript. Author JRC performed the statistical analysis. Authors FZM, ADBG, DP and LP managed the writing of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The objective of this study was to evaluate the influence of abiotic factors on the incidence of the damage caused by *Meroncidius intermedius* on Prata cv. Pacovan banana fruits and whether such damage interferes in the development and commercialisation of the fruits. The experiment was conducted in two stages. The first one was carried out at Fazenda Bonadiman, municipality of Iconha ES, Brazil, in an area of 02 hectares cultivated with Pacovan banana, Prata variety, in a spacing of 3 m x 3 m, between the months of June 2016 and May 2017, where the incidence of damage was monitored in the monthly harvested fruits. The second stage was carried out at the Federal Institute of Education, Science and Technology of Espírito Santo - Santa Teresa *campus*, in

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May of 2018, the measurements of the fruits and the sensory analysis and intention to buy damaged fruits being carried out. As a result, it was obtained that the ambient temperature influenced the incidence of pests in the banana crop, being favoured by mild temperatures, while higher temperatures disadvantage the insect causing a lower incidence. From June to October 2016, the highest incidences were observed, with population peaks in September and October, decreasing in December, where the increase in temperature was also reported. The precipitation variable did not present a correlation with the incidence, thus not influencing it. Although the visual quality is impaired, making the fruit infeasible for commercialization *in natura*, the morphological and sensory characteristics are not jeopardized by the damage, so the fruits can be used for other purposes, such as agroindustry processing.

Keywords: Musa cv. Pacovan; pest; damage; dynamics.

1. INTRODUCTION

Banana farming occupies the eighth place among the most important species in the world, cultivated in almost all tropical countries, being more or less the most important among the less developed countries [1,2]. The fruit has great acceptance, due to its sensory aspects and nutritional values, possessing important vitamins such as A, B1, B2, C, D, high potassium, minerals and carbohydrates content and no cholesterol. In addition, the banana can be consumed mature, green, raw or processed [3,4].

Nowadays, its cultivation is spread all over the world, being a source of income for producers and merchants. Banana cultivation stands out for being ranked first in the world fruit ranking, with Brazil producing approximately seven million tons of the fruit in an area of 489,937 hectares [5]. The state of Espírito Santo has characteristics essential to its cultivation, such as climate and soil, which allows it to be a privileged state in cultivation, becoming a major producer of the fruit [6].

However, the challenges faced by banana producers, ranging from the devaluation of the product in commercialization to the diseases and pests that attack the crop, are great. Among the main pests that affect cultivation are:*Cosmopolites sordidus,* Germar, *Metamasius hemipterus* L., *Opogona sacchari* (Bojer) and *Frankliniella brevicaulis* Hood [7,8,9,10]. In addition to those cited, the *Meroncidius intermedius* Brunner von Wattenwyl (Orthoptera: Tettigoniidae) is cited as a new crop pest, causing economic losses to producers [11].

M. intermedius is popularly known as banana-brown-hopper, has a masticating mouthpiece, which when feeding upon the fruit of the banana causes scratches on its bark that can reach the pulp. The nymphs and adults are sheltered in the bunches, below the first leaf that covers the nest or between the leaves of the pseudostem during the day, and they go out at night to feed. Adults are usually found in isolation, while nymphs are found in small groups [12].

When the insect causes damage on the bark of the banana fruit, it renders them unsuitable for commercialisation, and a single damaged fruit causes loss of the whole bunch. However, according to the reports of producers, the fruits that present damage remains on the properties, being used in the feeding of the family and for animal feed.

Considering that *M. intermedius* has reached plague *status* in banana plantations in the state of Espírito Santo and that there is scarce information about this insect, it is necessary to study the influence of abiotic factors on the incidence of attacks of this species, in order to substantiate possible strategies minimising future losses. In view of this problem, this study aims to evaluate the influence of climatic variables on the attack of *M. intermedius on* banana cultivation, to investigate the effect of injury on the development of damaged fruits and their sensory aspects.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The study was conducted in two stages, the first of which monitored the incidence of damage caused by M. intermedius correlating with meteorological variables, was conducted between June 2016 and May 2017 (totaling 12 months), in a commercial Prata cv. Pacovan banana cultivation, located in the municipality of Iconha, Espírito Santo (latitude: 20º47'38 " S;

longitude: 40º48'37" W), with a spacing of 3 x 3 m.The predominant relief is plateau (ranging from 0 to 1000 m), a clay soil, with an average maximum temperature of 32.3°C and average minimum temperature of 14.9°C.The highest occurrence of rainfall is from October to January, with an average rainfall of approximately 1200 mm.

The second stage was carried out at the Federal Institute of Education, Science and Technology (IFES) - Santa Teresa campus, with the sensorial analysis, purchase intension tests and evaluation of the effect of the damage on the development taking in place during May, 2018.IFES is located in the district of Santo Antônio de Canaã, in the municipality of Santa Teresa, Espírito Santo, with an average temperature of 23.1ºC, average annual rainfall of 1004 mm and an altitude of 155 m.

2.2 Monitoring of the Incidence of the Damage Caused by *M. intermedius* and Correlation of Meteorological Variables

The experimental area has 2 ha of banana cultivation. The fruits of 20 plants were randomly sampled at random to account for the incidence of damage caused by *M. intermedius*. The collection of the fruits with damage was performed at the time of harvest.

The monthly averages of the meteorological variables (maximum, average and minimum temperatures and rainfall) were used to correlate with the incidence of the observed damage. The meteorological data were obtained from the Meteorological Station of the Capixaba Institute for Research, Technical Assistance and Rural Extension - INCAPER of the municipality of Alfredo Chaves, ES, Brazil, located approximately 40 km from the experimental areal.

2.3 Evaluation of the Effect of Damage on Fruit Development

In order to determine the effect of the damage on the development of the fruit, the fruits that showed excoriation caused by *M. intermedius* were selected at the time of harvest. The mass (g), length (cm) and diameter of the median portion (cm) were measured. The variables measured were compared with that of healthy fruits.

2.4 Sensory Analysis and Intention to Purchase Damaged Fruits

The fruits were grouped according to the degree of damage in three classes: low (up to 33% of damage present in the fruit peel), moderate (from 33% to 66% of damage present in the fruit peel) and high (above 66% of damage present in the bark of the fruit). In order to determine the consumer's acceptance of the different degrees of damage present in the fruit's peel, the intention to buy test was performed using a five-point structured scale (5 = certainly would buy, 1 = certainly not buy) [13]. To carry out this study, 50 people were interviewed, students and professors at IFES,using simple random sampling to make it possible to compensate for sample errors [14].

The sensory analysis was performed in the Agroindustry of the Federal Institute of Espírito Santo Santa Teresa *campus* - IFES. The attributes of aroma, colour, flavour and texture of *in natura* fruit pulp with and without damage caused by the insect were evaluated. In order to perform this test, a rating sheet was used in a structured hedonic scale of nine points (9 = I liked it very much, 1 = I disliked it very much), proposed by the Adolfo Lutz Institute (2008). The samples were exposed to the tasters in slice format with a thickness of approximately 1.5 cm. The sensory panel consisted of 50 untrained judges, who appreciated the product, made up of IFES students and professors.

2.5 Statistical Analysis

The influence of the meteorological variables on the incidence of damage caused by the pest was verified by the Pearson correlation analysis ($p \leq 0.05$).

The data of the quantitative variables, circumference, diameter and mass of the fruits were submitted to the one-way variance analysis and later to the Bartlett ($p \leq 0.05$) and Shapiro-Wilk ($p \leq 0.05$) tests to verify the homogeneity of the residual variances and normality, respectively.

Because they were scale categories, purchase intent was analyzed by the Kruskal-Wallis test ($p \leq 0.05$) and later by the Dunn test ($p \leq 0.05$) to compare the medians. The sensory variables measured were analyzed by the Mann-Whitney test ($p \leq 0.05$).

All analyses were performed in the R software [15].

3. RESULTS AND DISCUSSION

3.1 Monitoring the Incidence of Damage Caused by *M. intermedius*

The incidence of *M. intermedius* damage varied throughout the sampling period (Fig. 1A). There was a reduction in the percentage of damage during the analyzed months, with a larger decrease after the month of November. The observed fluctuation of damage incidence was negatively affected by maximum, average and minimum temperatures (Fig. 1B and Table 1). Despite the variation observed for rainfall, it did not present a significant correlation on the incidence of damage in fruits.

Table 1. Pearson correlation between meteorological variables and incidence of damage caused by *M. intermedius*

Meteorological variables	ρ[1]	p-value
Average temperature	-0.7651734	0.0008
Minimum temperature	-0.7218982	0.0024
Maximum temperature	-0.7803070	0.0006
Rain	0.1846169	0.5101

[1] *Pearson correlation coefficient*

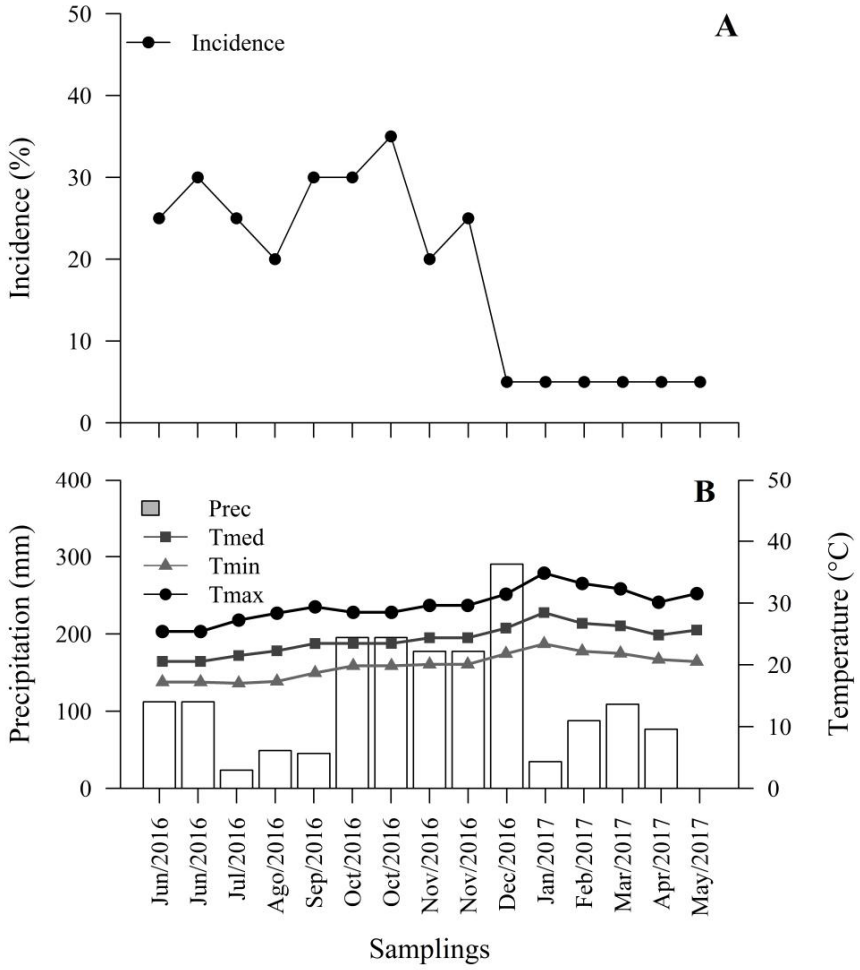

Fig. 1. Incidence of *M. intermedius* (A) and meteorological variables (rainfall and maximum, average and minimum temperatures) (B) from June 2016 to May 2017 in commercial banana plantations in the municipality of Iconha, ES, Brazil

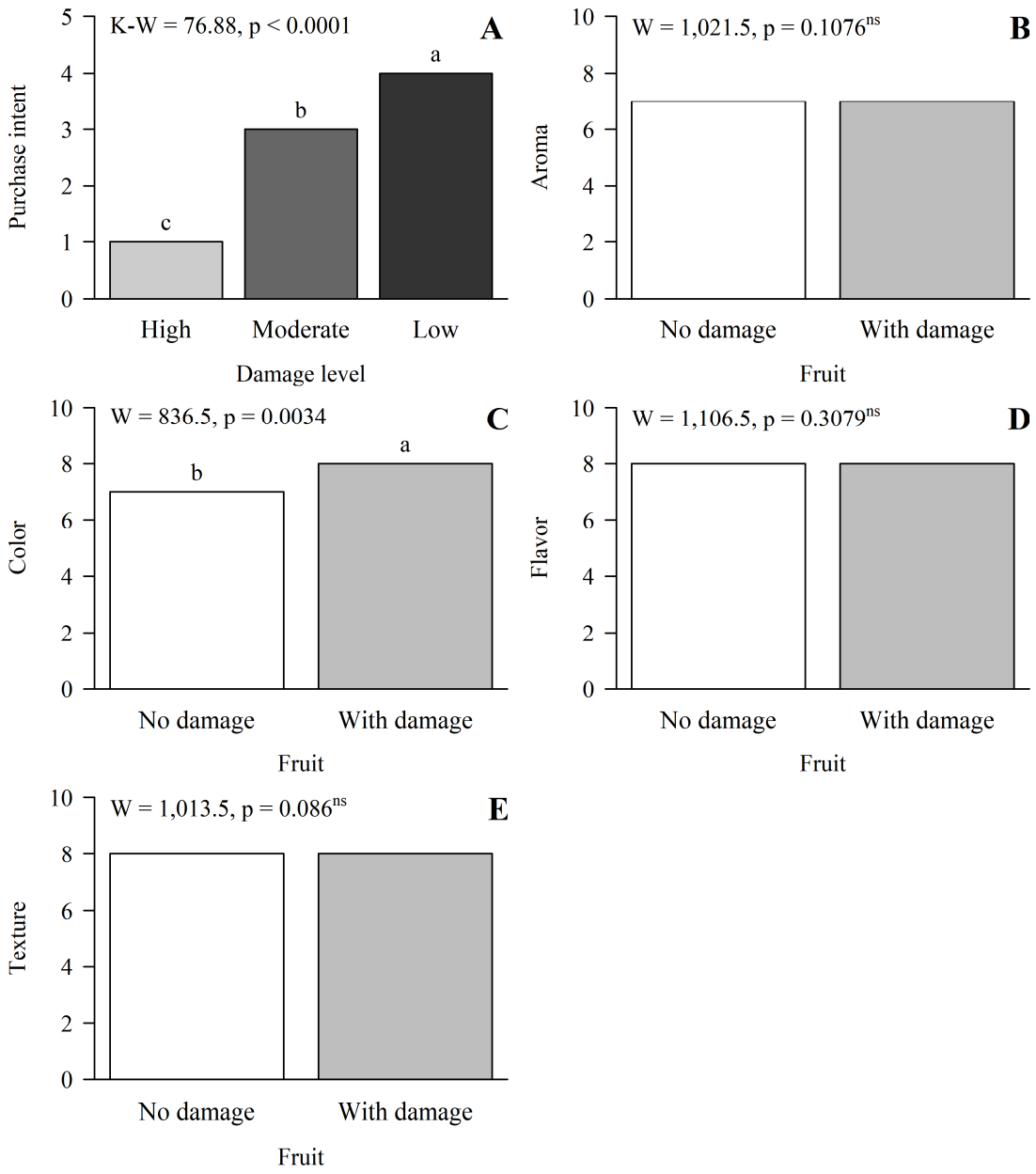

Fig. 2. Purchase intention (A) and sensory analysis: aroma (B), colour (C), flavour (D) and texture (E); of banana fruits with damage caused by *Meroncidius intermedius* (Orthoptera: Tettigoniidae). Bars (Medians) accompanied by the same letter do not differ among themselves by the Dunn test (p <0.05). ns Not significant by the Mann-Whitney test (p>0.05)

Banana production occurs every month in the study region. However, we verified that even with food supply variation occurred in the incidence of banana leaf damage. A similar variation was observed by Zanuncio Junior (2015), although no probable cause was indicated for the phenomenon.

The absence of damage present in the fruits between the months of December 2016 and May 2017 may be directly related to the increase in temperature and possibly associated with the reduction of rainfall. Although the rain did not present a significant correlation with the presence of damage, the increase of air humidity may allow the occurrence of a favourable micro-

climate, possibly minimising the effect of temperature. Abiotic variables, such as temperature and rainfall, may have direct and indirect effects on the population dynamics of insects, affecting their development, feeding, reproduction and mortality [16,17,18,19,20,21, 22,23].

However, the temperature variable is a prime factor in the biological processes of living beings [24,25] and in the face of climate change and insect complexity, such a response may not be so easily measurable [26,27,28,29]. Studies of population dynamics commonly carried out with agricultural pests usually show the insects under study, being favoured by months with higher temperatures [30,31,32]. Faced with this, studies are needed that contemplate bio-ecological aspects about organisms of interest, seeking to understand their relationships.

3.2 Evaluation of the Effect of Damage on Fruit Development

The external characteristics of the fruit were not affected by the damage present in the bark (Table 2), it is noticed that the circumference, the length and the mass of the fruits that presented the damage obtained averages similar to the healthy fruits.

Table 2. Morphometry and mass of fruits (average ± standard error) that presented injuries and healthy fruits

Variables	Damaged fruits	Healthy fruits
Circumference (cm)^{ns}	13.05±0.09	13.33±0.12
Length (cm)^{ns}	17.82±0.19	17.86±0.09
Mass (g)^{ns}	111.38±4.31	112.55±2.38

^{ns}*Not significant by the ANOVA F test (p > 0.05)*

In banana crops for commercialisation, the fruits are harvested at the physiological maturation point, where it presents a high content of starch and polysaccharides, providing high firmness. In a study on the characterisation of ripening Prata banana, the firmness presented was 15.12 Newtons after two days of fruit harvest, and it decreases as ripening occurs [33]. Thus, the damage caused by the insect's oral apparatus are carried out in fruits until harvest, that is, when the bark is still rigid, damaging it only superficially, not interfering with the morphological development of the fruit.

3.3 Sensory Analysis and Intention to Purchase Damaged Fruits

The purchase intention for fruits with damage varied (Fig. 2A). The fruits that presented the moderate and low amount of damage were the most preferred, even though, they presented a significant difference between them.

The sensory analysis made it possible to verify that, regardless of the presence of the damage in the peels, the fruits presented similar characteristics to the fruits free of damage (Figs. 2 B-E). However, although the staining parameter was deferred, the scores attributed to both were high (Fig. 2C).

As regards the morphological and sensory aspects verified in the damaged fruits, it was observed that these, except for the colour of the fruit, were similar to those of fruits without damage. This is an important factor, because even if these damaged fruits do not have an acceptance for the trade *in natura*, due to the appearance [34], it may be possible to be exploited in the agroindustry sector. It is worth noting that processed banana products have a high consumer acceptance, as well as a longer shelf life [35,36], whether large-scale or artisanal, and can contribute to farmers' incomes.

4. CONCLUSION

Based on the present study, we verified that the incidence of damage caused by *M. intermedius* was higher in the period between June and November, with temperature being the factor that contributed most to this observation.

The absence of discrepant characteristics (morphological and sensory) implies that the damage caused by *M. intermedius* do not affect the quality of the pulp and, consequently, it can be used for other purposes. This may represent a positive factor for the banana industry's production chain, since it is possible to minimise losses by allocating the banana to the industrial or artisanal processing of products.

However, we emphasise the need for studies that allow the understanding of bioecological aspects of *M. intermedius*, since this insect has been highlighted as a potential pest for banana culture, seeking to assist in the implementation of integrated management strategies.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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