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CROP SCIENCE

Diagrammatical scale to quantify herbivory severity on feijoa leaf caused by *Paraulaca dives* (Coleoptera: Chrysomelidae)

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Abstract: The aims of this work were to characterize the damage caused by *Paraulaca dives* in feijoa (*Acca sellowiana*) and develop a diagrammatic scale to evaluate the severity of herbivory. The evaluations were carried out in a feijoa progenies orchard with eight-year-old. The beetles caused damage mainly on leaves, from October to December (spring season). The distribution of beetles in the orchard occurred randomly, not following a defined pattern of incidence. The diagrammatic scale of herbivory severity was represented by seven levels (1%, 3%, 5%, 7%, 15%, 32%, and 55% of the leaf area consumed). The use of this diagrammatic scale significantly increased the precision and accuracy of severity estimates by inexperienced evaluators. This can help in strategies to control this pest to expand the cultivation of feijoa in Brazil.

Key words: *Acca sellowiana*, insect herbivory, pest georeferencing, population fluctuation.

INTRODUCTION

Feijoa [*Acca sellowiana* (O. Berg), Burret, Myrtaceae)] is a fruit plant grown in different parts of the world (Moretto et al. 2014), largely due to its adaptation to wide climatic ranges (Fischer 2003) and its characteristics organoleptic properties and bioactive properties of the fruits (Amarante et al. 2017, Phan et al. 2019). Although the species is native of Southern Brazil, the largest production occurs in Colombia, New Zealand, and the United States (Santos et al. 2017).

In Brazil, the research with feijoa started about three decades ago, supporting the incipient process of domestication. There was an evolution in the plant breeding, with the introduction of new cultivars, tested in the conditions of the center of origin, above 900 m altitude (Ducroquet et al. 2007, 2008, Santos et al. 2017). In environments where the species occurs at lower altitudes, *on farm* management and selection has been proposed (Santos et al. 2018, Donazzolo et al. 2020, Saifert et al. 2020). In a progenies test of feijoa conducted in the Southwest of Paraná (500-700 m a.s.l.) (Donazzolo et al. 2019), intense defoliation caused by the beetle *Paraulaca dives*, was detected (Germ., 1824, Coleoptera: Chrysomelidae). This insect is cosmopolitan and polyphagous, and considered a secondary pest of feijoa (Hickel & Ducroquet 1992).

The aims of this work were to characterize the damage caused by *Paraulaca dives* in feijoa (*Acca sellowiana*) and develop a diagrammatic scale to evaluate the severity of herbivory.

MATERIALS AND METHODOS

The work was developed in an feijoa orchard with eight-year-old, composed of five progenies resulting from crosses between Alcântara, Helena (Ducroquet et al. 2007) and Nonante (Ducroquet et al. 2008) cultivars. The orchard is in Pato Branco, Paraná, Brazil (26 ° 10'34.3 "S, 52 ° 41'09.0" W, 730 m a.s.l.). There are 60 plants in total, arranged in four rows of 15 plants (three plants by progeny), spaced 4.5 x 3.0 m, and managed with annual pruning. Insecticides were not used for pest control. The soil is classified as Dystroferric Red Latisol (Embrapa 2013) with humid subtropical climate - Cfa (Alvares et al. 2013).

The damage caused by the beetle on leaves, flowers, and fruits was recorded by photographs. To assess population fluctuation, were counting the number of adult beetles of 20 feijoas from the orchard (four from each progeny). This assessment was made weekly, over a year, in the highlighted branches. To determine the infestation pattern and the spatial distribution of *P. dives* in the orchard, the total value of the number of beetles collected and the location of the plants, represented by Cartesian coordinates (X, Y), were used. Semivariograms and spatial distribution models were generated by the Inverse Distance Weighting (IDW) method (Weber et al. 2018).

Leaves exhibiting signs of *P. dives* herbivory were scanned and the severities estimated using the software ImageJ (Schneider et al. 2012). The standard area diagram (SAD) was developed with seven levels. For the validation of the SAD, eight people, without experience, made estimates for 82 random images without and with the proposed SAD. The images set (625 pictures), of known severity, were inserted into the DiseasePlan spreadsheet, which performs the randomization of images, estimate recording and agreement statistics (Sachet et al. 2017). It was evaluated the precision, accuracy, deviations from the ideal projection, Lin`s concordant correlation coefficient (Nicoli et al. 2015) and the smallest difference detectable value based on the random effect of the one-way ANOVA, corresponding to the least significant difference (DMS, p = 0.05). All statistical analyzes were performed in R (R Core Team 2019).

RESULTS

The herbivory caused by *P. dives* beetles was concentrated on feijoa leaves, both tender and fully expanded leaves, causing perforations throughout the limbus (Figure 1a, b). The occurrence of beetles on flowers was also observed, consuming mainly the petals (Figure

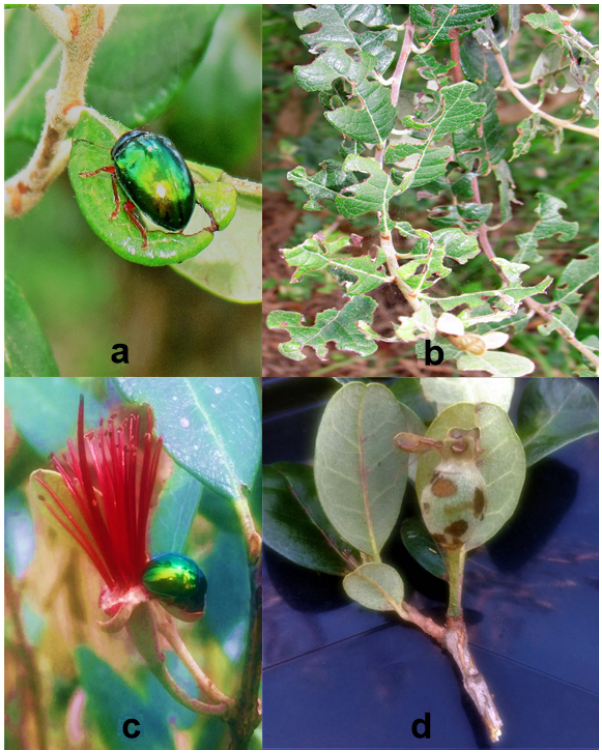

Figure 1. Damages caused by the beetle *Paraulaca dives* (Coleoptera: Chrysomelidae) on feijoa (*Acca sellowiana*). a) Beetle feeding a young leaf. b) Damage in fully expanded leaves. c) Beetle feeding a petal of flower. d) Damage in fruits.

1c) and scraping the epicarp of the fruits (Figure 1d).

The occurrence of *P. dives* in the feijoa orchard was monitored over the year. However, they just were found in October, November and December, with respectively 43.4%, 53.6% and 3.0% of occurrences (Figure 2).

The spatial distribution of *P. dives* in the feijoa orchard occurred in a random manner, as can be visualized in the analysis of the semivariogram, which showed a pure nugget effect with 80 variance (Figure 3). Similarly, no significant association (chi-square test, $p = 0.91$) between the number of beetles per plant and the five progenies evaluated in the orchard.

The average of herbivory severity in 625 leaves analyzed was 16%, ranging from 0% to 55%. The standard area diagram (SAD) was

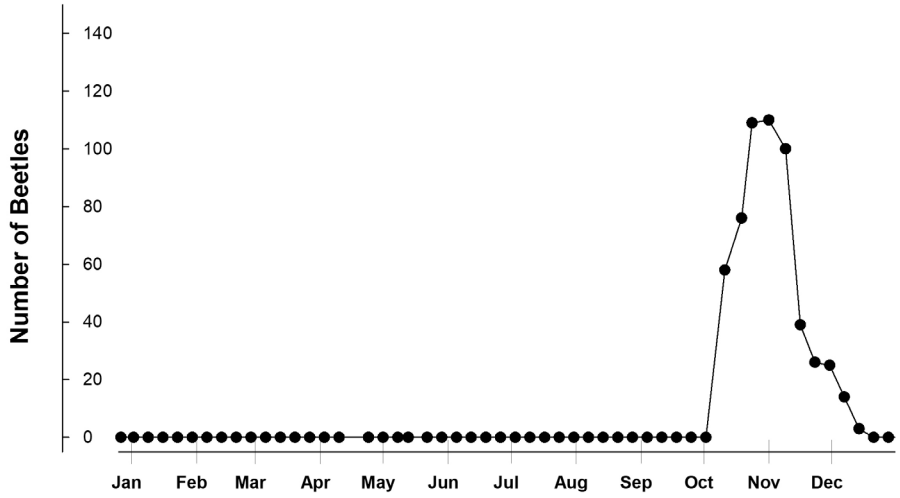

Figure 2. Fluctuation of the population of *Paraulaca dives* (Coleoptera: Chrysomelidae), in the feijoa orchard (*Acca sellowiana*), from January to December.

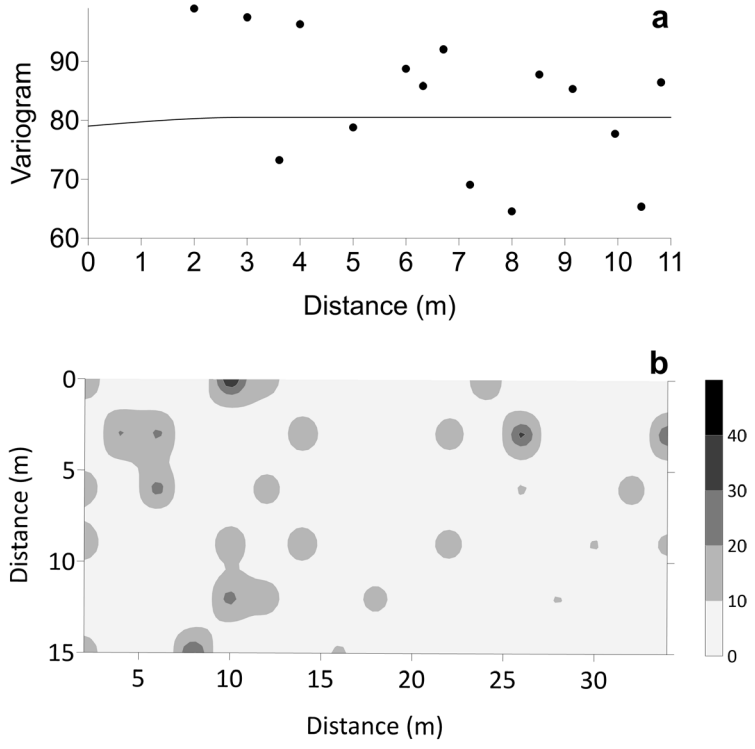

Figure 3. Spatial distribution of *Paraulaca dives* (Coleoptera: Chrysomelidae) in the feijoa orchard (*Acca sellowiana*). a) Semivariogram of the relationship between the variance of the data and the distance between the points of occurrence. The horizontal line in semivariogram represents pure nugget effect of 80. b) Dispersion map of the insect generated by Inverse Distance Weighting method.

developed with seven levels: 1, 3, 5, 7, 15, 32 and 55% (Figure 4).

The use of SAD increased significantly ($p \leq 0.05$) the accuracy (0.812 to 0.996) and concordant correlation coefficient (0.716 to 0.919), in relation to severity assessment without SAD. The estimated *u* values (difference between the line of regression and the concordant line) approached zero (ideal value) with the use of SAD (-0.032), while for assessments without SAD it was 0.497. The precision remained high (0.922 and 0.883), not differed with using the SAD ($p > 0.05$). Raters began to demonstrate greater ability to estimate the real severity of herbivory level with the aid of SAD, since the SDD was lower with SAD than without (11.57% and 18.60% respectively), reducing the lower value from which it can be stated that there was a difference between observations (Table I).

DISCUSSION

The damage caused by *P. dives* beetles on feijoa orchard was mainly in the leaves. This was also verified in feijoa by Hickel & Ducroquet (1992), in guabiroba (*Campomanesia xanthocarpa*, Myrtaceae) by Luckmann et al. (2015) and in ingá (*Inga edulis*, Fabaceae) by Menezes et al. (2018), which makes obvious the given name "defoliating beetle". Although, the attack on flowers and fruits was also observed in our work. This damage makes the fruit visually defective,

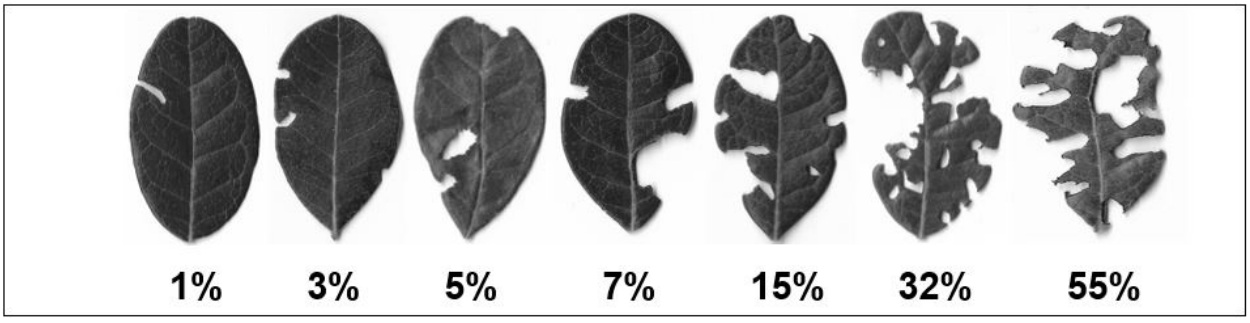

Figure 4. Feijoa (*Acca sellowiana*) leaves representing the percentage of leaf consumption caused by *Paraulaca dives* (Coleoptera: Chrysomelidae) of the seven levels of the generated diagrammatic scale.

Table I. Proposed standard area diagram (SAD) set on the visual estimate performance of leaf herbivory by *Paraulaca dives* (Coleoptera: Chrysomelidae) on feijoa leaves (*Acca sellowiana*).

Statistics	With SAD	Without SAD	MD	CI (95%)
r	0.922 (0.028)	0.883 (0.042)	0.04 (0.058)	-0.002 to 0.08^{ns}
C_b	0.996 (0.003)	0.812 (0.057)	0.185 (0.058)	0.144 to 0.225*
u	-0.032 (0.055)	0.497 (0.056)	-0.529 (0.084)	-0.587 to -0.471*
υ	0.966 (0.052)	1.583 (0.211)	-0.617 (0.182)	-0.743 to -0.491*
ρ_c	0.919 (0.027)	0.716 (0.057)	0.203 (0.056)	0.164 to 0.242*
SDD	11.575 (1.942)	18.606 (3.633)	-7.031 (3.038)	-9.137 to -4.926*

Means and standard error of mean in parenthesis (n = 8 raters). r: correlation coefficient between estimated and real severity (i.e. precision); C_b: a correction factor that measures how far away the adjusted line is in relation to concordant line (i.e. accuracy); *u*: difference between the line of regression and concordant line; *υ*: difference in the inclination between regression and concordant lines; ρ_c: Lin`s concordant correlation coefficient. SDD: Small detectable difference; MD: Mean Difference between each evaluation with mean standard error in parenthesis. CI: Confidence interval at 95% probability. Interval including zero, the difference is not significant (^{ns}), unlike, the difference is significant (*).

decreasing the market potential (Fischer 2003), which reinforces the importance of controlling this insect.

The infestation by *P. dives* in the feijoa orchard occurred in the spring season (from Oct to Dec), coinciding with the period of rising rain and temperatures after winter in Southern Brazil. In the other months of the year there was no presence of the insect in the orchard. The end of the infestation in December occurred as a result of the beetle migration to the near beans crop that we visually perceived. The beans are the suitable host of *P. dives* (also named *Iphimeis dives*), as detected by Alves et al. (2016).

The spatial distribution of *P. dives* in the feijoa orchard occurred in a random manner. This means that nearby plants showed high heterogeneity with the number of beetles, while plants distant from each other showed similar numbers of insects (Weber et al. 2018). There was also no significant association between the number of beetles per plant and the progenies in the orchard. These results indicate that there is no clear preference of the insect for a given genotype and that the monitoring and control of this pest should be carried out over the entire orchard.

The standard area diagram (SAD) was developed with seven levels, with 55% the maximum of severity observed. At the highest level, the leaf fibrous portion and necrotic tissues predominates. The SAD presented here was shown to be easy to use, applicable under a wide variety of conditions and provided reliable results. Representative signs of the herbivory were identified, and the maximum and minimum severity in the field was ascertained. Thus, the adoption of the SAD proposed in this paper to evaluate *P. dives* herbivory in feijoa leaves, can reduce the subjectivity of the estimates and provided better information for entomological studies (Nicoli et al. 2015).

CONCLUSIONS

The damage caused by *P. dives* beetles on feijoa orchard was mainly in the leaves, during the spring season.

The standard area diagram (SAD) with seven levels was efficient to evaluate the severity of *P. dives* herbivory in feijoa leaves.

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REFERENCES

ALVARES CA, STAPE JL, SENTELHAS PC, GONÇALVES JLM & SPAROVEK G. 2013. Köppen's climate classification map for Brazil. Meteorol Z 22: 711-728.

ALVES AL, NUNES M, DA COSTA ACT, DUARTE JÚNIOR JB & PIETROWSKI V. 2016. *Iphimeis dives* (Crysomelidae) beetle occurrence in beans in western Parana State, Brazil. Afr J Plant Sci 10: 39-42.

AMARANTE CVT, DE SOUZA, AG, BENINCÁ, TDT & STEFFENS CA. 2017. Phenolic content and antioxidant activity of fruit of Brazilian genotypes of feijoa. PAB 52: 1223-1230.

DONAZZOLO J, STEFENON VM, GUERRA MP & NODARI RO. 2020. On farm management of *Acca sellowiana* (Myrtaceae) as a strategy for conservation of species genetic diversity. Sci Hortic 259: 108826.

DONAZZOLO J, TURRA EC, VOSS LC, DANNER MA, CITDIN I & NODARI RO. 2019. Reproductive biology and flowering of feijoa (*Acca sellowiana* (Berg) Burret) in areas of marginal occurrence. J Agric Sci 11: 156-164.

DUCROQUET JPHJ, NUNES EC, GUERRA MP & NODARI RO. 2008. Novas cultivares brasileiras de goiabeira serrana: SCS 414-Mattos e SCS 415-Nonante. RAC 21: 79-82.

DUCROQUET JPHJ, SANTOS KL, ANDRADE ER, BONETI JI, BONIN V & NODARI RO. 2007. As primeiras cultivares brasileiras de goiabeira serrana: SCS 411 Alcântara e SCS 412 Helena. RAC 20: 77-80.

EMBRAPA - EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA. 2013. Sistema brasileiro de classificação de solos. 3° ed.

Brasília: Embrapa Serviço de Produção de Informação, 353 p.

FISCHER G. 2003. Ecofisiología, crecimiento y desarrollo de la feijoa. In: FISCHER G, MIRANDA D, CAYÓN G & MAZORRA MM (Eds), Cultivo, poscosecha y exportación de la Feijoa (*Acca sellowiana* Berg.). Bogotá: Produmedios, p. 9-26.

HICKEL ER & DUCROQUET JPHJ. 1992. Entomofauna associada à goiabeira serrana (Feijoa sellowiana Berg.). Rev Bras de Frutic 14: 101-107.

LUCKMANN D, POTRICH M, LOZANO ER & WAGNER JÚNIOR A. 2015. Ocurrence of *Paraulaca dives* (Coleoptera: Chrysomelidae) in *Campomanesia xanthocarpa* (Myrtaceae), in Paraná state, Brazil. Appl Res & Agrotech 8: 99-103.

MENEZES CWG, CARVALHO GA, SOARES MA, PINTO DR, SILVA WM, TAVARES WS & ZANUNCIO JC. 2018. *Iphimeis dives* (Coleoptera: Chrysomelidae): First report on *Inga edulis* (Fabaceae) in Brazil and data on its biology. Flo Ent 101: 345-347.

MORETTO SP, NODARI ES & NODARI RO. 2014. A Introdução e os Usos da Feijoa ou Goiabeira Serrana (*Acca sellowiana*): A perspectiva da história ambiental. Front J Soc, Technol Environ Sci 3: 67-79.

NICOLI A, DA COSTA RV, COTA, LV, DA SILVA DD, ZAMBOLIM L, LANZA FE, GUIMARÃES, PEREIRA D & LANDAU EC. 2015. Diagrammatic scale validation to quantify the severity of anthracnose stalk in corn. Cienc Rural 45: 1-7.

PHAN ADT, CHALIHA M, SULTANBAWA Y & NETZEL ME. 2019. Nutritional characteristics and antimicrobial activity of Australian grown Feijoa (*Acca sellowiana*). Foods 8: 1-15.

R CORE TEAM. 2019. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available in: https://www.R-project.org/.

SACHET MR, CITADIN I, DANNER MA, GUERREZI MT & PERTILLE RH. 2017. Aplicativo de planilha para treinamento de avaliadores de doença e para auxiliar o desenvolvimento de escalas diagramáticas. Cienc Rural 47: 1-3.

SAIFERT L, SÁNCHEZ-MORA FD, BORSUK LJ, DONAZZOLO J, COSTA NCF, RIBEIRO HN & NODARI RO. 2020. Evaluation of the genetic diversity in the feijoa accessions maintained at Santa Catarina, Brazil. Crop Sci 60: 345-356.

SANTOS KL, CIOTTA MN & NODARI RO. 2017. Melhoramento genético da goiabeira-serrana (*Acca sellowiana*) em Santa Catarina. RAC 30: 40-42.

SANTOS KL, DONAZZOLO J, GURIES RP, PERONI N & NODARI RO. 2018. Participatory research with *Acca sellowiana*: Stimulating the breeding process for a native fruit species. Agroecol Sustain Food Syst 42: 432-447.

SCHNEIDER CA, RASBAND WS & ELICEIRI KW. 2012. NIH Image to ImageJ: 25 years of image analysis. Nat Methods 9: 671-675.

WEBER AC, DEGRANDE PE, DE SOUZA EP, AZAMBUJA R & FERNANDES MG. 2018. Spatial Distribution of *Euschistus heros* (Hemiptera: Pentatomidae) in Cotton (*Gossypium hirsutum* Linnaeus). An Acad Bras Cienc 90: 3483-3491.

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**In memoriam*

Author contributions

GCCC carried out the experiment, and wrote the previous manuscript. GCCC, MRS and JRRC performed the statistical analyses. GSA, IC, AR, JD, and MAD concept and design the experiment, reviewed and edited the manuscript. All authors read and approved the final version of the manuscript.