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EMERGENCE RATE OF THE MEXICAN BEAN WEEVIL IN VARIETIES OF BEANS FROM THE SOUTHWESTERN AMAZON[1]

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ABSTRACT - Common beans (*Phaseolus vulgaris* L.) are one of the most important protein sources worldwide. However, infestation by bruchids compromises the storage of these beans after harvest. The objective of this study was to determine the emergence rate of *Zabrotes subfasciatus* (Coleoptera: Chrysomelidae) in four *P. vulgaris* varieties (Carioca Pitoco, Enxofre, Gorgutuba Vermelho, and Rosinha) cultivated in the southwestern Amazon (State of Acre, Brazil). The grains from each variety were infested with 50 non-sexed adult *Z. subfasciatus*, and the insects were collected 13 days after initiating the bioassays. The adult progeny was collected from each plant variety on alternate days from the beginning to the end of the emergence period, and they were counted (number of insects/jar). The sum of emerged insects per day (SEd) was determined from the beginning of the emergence period, from which the accumulated emergence was calculated (SEa= ΣSEd, % day). There were differences in the emergence rates of *Z. subfasciatus* among the bean varieties, with the rates being lower in the Gorgutuba Vermelho variety. Although this bean variety had the lowest peak of adult insect emergence, the period of insect development was not of increased length in this variety compared to the other varieties. In general, the Gorgutuba Vermelho variety appears to be resistant to *Z. subfasciatus*.

Keywords: *Zabrotes subfasciatus*. *Phaseolus vulgaris*. Storage. Plant resistance.

AVALIAÇÃO DA TAXA DE EMERGÊNCIA DO CARUNCHO-DO-FEIJÃO EM VARIEDADES DE FEIJÃO ORIUNDAS DA AMAZÔNIA SUL-OCIDENTAL

RESUMO - O feijão comum (*Phaseolus vulgaris* L.) é uma das fontes proteicas mais importantes em todo o mundo. Todavia, o ataque de bruquídeos inviabiliza o armazenamento do produto após a colheita. O objetivo deste trabalho foi determinar a taxa de emergência de *Zabrotes subfasciatus* (Coleoptera: Chrysomelidae) em quatro variedades de feijão *P. vulgaris* (Carioca Pitoco, Enxofre, Gorgutuba Vermelho e Rosinha) cultivadas na Amazônia sul-ocidental (Acre, Brasil). Os grãos de cada variedade foram infestados com 50 adultos não-sexados e após 13 dias do início dos bioensaios, os insetos foram removidos. A progênie adulta obtida nas variedades foi contabilizada e removida em dias alternados, a partir da primeira emergência, até o final do período de emergência (n° de insetos/frasco). A soma da emergência de insetos foi acumulada a partir da emergência inicial e resultou na soma da emergência acumulada (SEa, % dia), calculada por SEa = ∑SEd. Foram constadas diferenças nas taxas de emergência de *Z. subfasciatus* entre as variedades de feijão, sendo que a variedade Gorgutuba Vermelho apresentou menor taxa de emergência. Embora esta variedade de feijão tenha apresentado menor emergência de adultos, o tempo de desenvolvimento dos insetos não se estendeu nesta variedade, em comparação com as outras variedades. Em geral, a variedade Gorgutuba Vermelho apresentou indícios de fontes resistência a *Z. subfasciatus*.

Palavras-chave: *Zabrotes subfasciatus*. *Phaseolus vulgaris*. Armazenamento. Resistência de plantas.

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INTRODUCTION

Common beans, *Phaseolus vulgaris* L. (Fabaceae), are one of the most widely used vegetables in the world due to their economic and nutritional importance. These beans are a source of essential nutrients for human consumption and provides income to small farmers in developing countries (MUTANGI et al., 2015; JONES; ALEXANDER; LOWENBERG-DEBOER, 2017). In the Amazon region, native bean varieties are grown and stored on the farm until the following crop cycle (LOPES et al., 2016). Landrace varieties are considered an important genetic source for pest resistance because these varieties have a broader genetic base and a greater proportion of distinct genes directly related to their large genetic diversity (ASFAW; BLAIR; ALMEKINDERS, 2009; TIGIST et al., 2018).

In Brazil, the bruchid *Zabrotes subfasciatus* (Coleoptera: Chrysomelidae) stands out as one of the main insect pests of the common bean (FARONI; SOUSA, 2006; COSTA et al., 2014; JAIROCE et al., 2016). The control of insect pests in stored products is traditionally achieved with pyrethroids, organophosphates, and the fumigant phosphine (PH_3) (CORRÊA et al., 2011; SOUSA; FARONI; FREITAS, 2014). However, the continuous and indiscriminate application of these products for pest control has been questioned worldwide, both for causing mortality in non-target organisms and for the residual insecticide levels remaining in the food and the consequent health risks to the consumers (COSTA et al., 2014; FREITAS; FARONI; SOUSA, 2016).

As an alternative to synthetic insecticides, the use of plant varieties resistant to bruchids has been recommended. The genetic resistance of plants has been widely studied and noted as one of the most efficient forms of pest and disease control, since it is compatible with any other method and does not cause health and environmental risks (APPLEBY; CREDLAND, 2004; KUSOLWA; MYERS, 2011).

Reserve proteins present in beans may limit the attack of bruchids, due to their toxic properties, which give the plants antibiosis resistance (EDUARDO et al., 2016). The reserve protein arcelin is homologous to lectin and has been identified in varieties of landrace beans resistant to *Z. subfasciatus*. This protein has been successfully reproduced in cultivated bean lines (CARDONA et al., 1990).

In view of the above and considering that Latin America is acknowledged as one of the genetic diversity centers of *P. vulgaris* (VELTEN et al., 2007; OLIVEIRA et al., 2013), the objective of this study was to determine the rate of emergence of *Z. subfasciatus* in four landrace varieties of *P. vulgaris* occurring in the Southwestern Amazon region and extensively grown in the Brazilian state of Acre.

MATERIAL AND METHODS

The bioassays were conducted at the Entomology Laboratory, Federal University of Acre, Rio Branco campus. The municipality of Rio Branco, Acre is located at latitude 9° 58' 29" (S) and longitude 67° 48' 36" (W), 153 m above sea level.

The stock colony was established from *Z. subfasciatus* specimens collected in a rural property located in the same municipality. The stock was maintained under constant temperature conditions of (27 ± 2 °C), relative humidity (70 ± 5%), and scotophase (24 h). The insects were reared in 1.5-L glass bottles containing beans of the Pérola variety with 13% moisture content, and the bottles had been previously cooled to -18 °C to avoid pre-infestation. The tenth generation offspring was used in the bioassays.

The rates of daily emergence and cumulative emergence of *Z. subfasciatus* were determined in the following bean varieties: Carioca Pitoco, Enxofre, Gorgutuba Vermelho, and Rosinha. These varieties are among the most commonly cultivated varieties in the Acre communities and are well-distributed in the Southwestern Amazon. The bioassays were conducted under the same environmental conditions referred to above for the multiplication of the stock colony.

The emergence bioassays were adapted from Trematerra, Fontona and Mancini (1996), and from Sousa et al. (2009). Plastic 350-mL jars with 150 g of beans from each variety were used. The beans were infested with 50 non-sexed adults, aged up to 48 hours. The insects were removed from the jars 13 days after the beginning of the bioassays, and the beans were stored until the emergence of the insect progeny. The adult progeny obtained was counted and removed every other day (1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23 days) from the first emergent insect to the end of the emergence period.

The normalized cumulative emergence rate was analyzed first. The sum of the emergence of insects was accumulated from the initial emergence, resulting in the cumulative emergence (SEa, % day), calculated as SEa = ÓSEd. The cumulative emergence data were analyzed because experimental errors are more likely if only the evaluation data of the emergence of insects on alternate days are considered due to the influence of the sampling times (TREMATERRA; FONTONA; MANCINI, 1996; SOUSA et al., 2009; LOPES et al., 2016).

The experimental design was completely randomized with four treatments (one for each variety) and four replications. The emergence data on alternate days and the cumulative emergence data were subjected to nonlinear modeling using SigmaPlot software.

RESULTS AND DISCUSSION

The three-parameter sigmoid model (y = a/1 + exp (–(x–b)/c)) was the best fit for the cumulative emergence of *Z. subfasciatus* adults ($P < 0.0001$; $R^2 = 0.99$; Table 1 and Figure 1). The cumulative emergence curves varied among varieties with an inflection point (maximum emergence rate) between 7 and 11 days (Table 1). The curve of the Carioca Pitoco variety presented the highest inflection point (11.72 ± 0.05 days), suggesting a later emergence, followed by Enxofre (9.57 ± 0.13 days), Gorgutuba Vermelho (8.79 ± 0.13 days), and Rosinha (7.82 ± 0.09 days) (Table 1).

Table 1. Summary of the non-linear regression analyzes of the *Z. subfasciatus* emergence.

Variable	Model	Variety	Estimated parameters (± SE)			F	R^2
			a	b	c		
Normalized Cumulative Emergence	y = a/1 + exp(–(x–b)/c)	Carioca Pitoco	99.52 ± 0.70	11.72 ± 0.05	0.89 ± 0.04	05673.33	0.99
		Enxofre	98.47 ± 1.43	9.57 ± 0.13	1.03 ± 0.11	41086.05	0.99
		Gorgutuba Vermelho	99.54 ± 1.25	8.79 ± 0.13	1.40 ± 0.11	11356.66	0.99
		Rosinha	99.17 ± 0.91	7.82 ± 0.09	1.01 ± 0.07	02093.62	0.99
Emergence	y = a exp(–0.5((x–b)/c)²)	Carioca Pitoco	339.77 ± 11.09	12.78 ± 0.06	1.38 ± 0.05	00461.73	0.99
		Enxofre	275.34 ± 24.29	10.18 ± 0.16	1.67 ± 0.18	01074.70	0.93
		Gorgutuba Vermelho	144.37 ± 13.85	9.66 ± 0.29	2.62 ± 0.29	01052.52	0.90
		Rosinha	293.49 ± 11.61	11.93 ± 0.09	2.01 ± 0.09	00327.65	0.98

Where normalized cumulative emergence (a = maximum value, b = inflection point, and c = curve shape); emergence (a = emergence peak, b = time in days when the emergence peak occurs, and c = standard deviation of parameter b); standard error of the mean (SE). All estimated parameters were significant at $P < 0.01$ by Student's *t*-test and all the models were significant at $P < 0.01$ by Fisher's F-test.

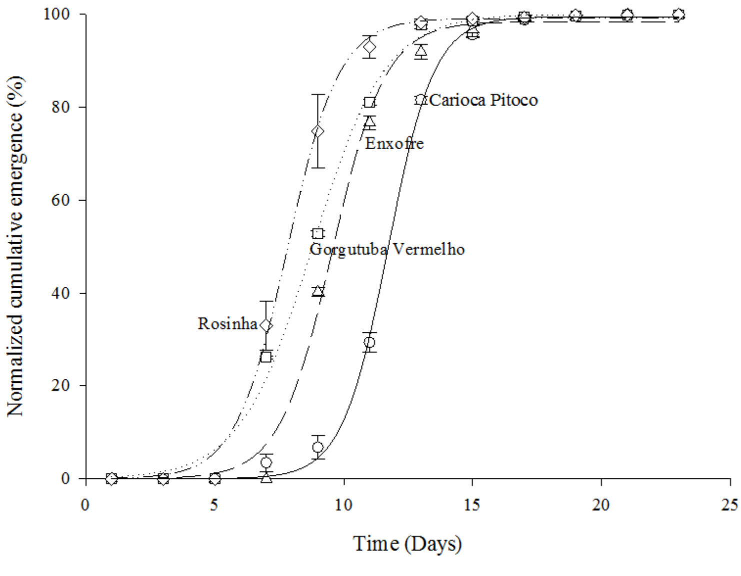

Figure 1. Normalized cumulative emergence of *Z. subfasciatus* in four landrace varieties of *P. vulgaris* (Carioca Pitoco (○), Enxofre (Δ), Gorgutuba Vermelho (□), and Rosinha (◊)). The symbols represent the means of the repetitions. The parameters of the equations are presented in Table 1.

The Gaussian model with three parameters ($y = a\ exp(-0.5((x-b)/c)^2)$) was the best fit for the emergence of *Z. subfasciatus* adults ($P < 0.0001$; $R^2 \geq 0.90$; Table 1 and Figure 2). There were obvious emergence rate differences among varieties; the lowest value was observed in Gorgutuba Vermelho, which reached the maximum emergence in 9 days (Figure 2 and Table 1).

The results indicate considerable variation in the emergence of *Z. subfasciatus* among the varieties of landrace beans tested. The Gorgutuba Vermelho revealed less susceptibility to bruchids. Changes in patterns of susceptibility to bruchids have been reported for different bean varieties from South America and the rest of the world (BALDIN; PEREIRA, 2010; EDUARDO et al., 2016).

Although the lowest emergence rate of *Z. subfasciatus* was recorded in Gorgutuba Vermelho, the normalized cumulative emergence was longer in Carioca Pitoco. This observation does not allow a relationship between the development period and the emergence rate in the varieties studied to be established. Similar results were obtained by Lopes et al. (2016), who did not find an association between the emergence rate and the development period in landrace varieties of beans attacked by *Z. subfasciatus*. However, other authors have observed that bruchid resistance is associated with prolonged population development, reduced insect emergence, and reduced mass loss (COSTA et al., 2013; BOIÇA JÚNIOR et al., 2015; EDUARDO et al., 2016).

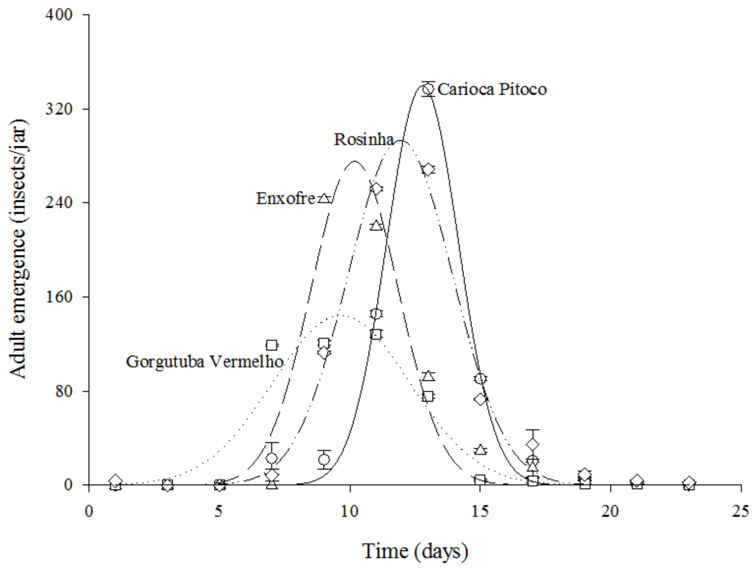

Figure 2. Emergence of *Z. subfasciatus* adults in four landrace varieties of *P. vulgaris* (Carioca Pitoco (○), Enxofre (Δ), Gorgutuba Vermelho (□), and Rosinha (◊)). The symbols represent the means of the repetitions. The parameters of the equations are presented in Table 1.

The genetic variability of *P. vulgaris* has been related to distinct diversity centers, known as the Mesoamerican gene pool and the Andean gene pool (OLIVEIRA et al., 2013). For decades, in these regions, farmers have cultivated complex mixtures of bean types as hedges against pests and diseases. This process produced a great genetic variability of color, texture, chemical composition, seed size, and resistance levels against bruchids (BONFIM et al., 2007). Hence, it is understandable that there are differences in both the normalized cumulative emergence rate and the adult emergence rate among the bean varieties studied (LOPES et al., 2016).

Antibiosis resistance in bean genotypes can be expressed in several ways; among these, defense proteins stand out (EDUARDO et al., 2016). The analysis of the chemical nature of these proteins may contribute to the elucidation of the causes of lower emergence of *Z. subfasciatus* in Gorgotuba Vermelho. Arcelin is a well-known protein with insecticidal properties that affect the larval development of bruchids, consequently reducing the number of emerged insects and their mass consumption (JANARTHANAN et al., 2008). Plant proteins with insecticidal properties have great potential in agricultural biotechnology, given that they are directly related to the development of a plant's resistant to pest attacks.

The prolonged development of bruchids in Enxofre and Carioca Pitoco, where a higher emergence of *Z. subfasciatus* was observed, may have unfavorable consequences for the insects under storage conditions. It is worth mentioning that with the extension of the larval stage, the insects become more susceptible to attack from natural enemies and to climatic extremes. This extended development also favors competition for essential resources to ensure their survival (GUEDES; GUEDES; SMITH, 2007; CRUZ et al., 2016).

The study of the susceptibility of varieties of landrace beans is of fundamental importance to integrated pest management and breeding programs targeted at resistance sources. In general, the emergence rate of *Z. subfasciatus* was lower in Gorgutuba Vermelho, which may be an indication of bruchid resistance. The recommendation to grow bean varieties less susceptible to the attack of *Z. subfasciatus* could allow the extension of the product's storage period, thereby enabling commercialization to take place when the net income is higher (LOPES et al., 2016).

CONCLUSIONS

Variations in the emergence of *Z. subfasciatus* indicate different patterns of insect susceptibility in the beans tested. The lowest daily emergence rate was recorded in the Gorgutuba Vermelho variety, but the normalized cumulative emergence was observed over a longer time period in the Carioca Pitoco variety. A relationship could not be established between the development period and the emergence rate in the varieties studied.

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