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Performance and Preference of *Chinavia erythrocnemis* (Berg) (Heteroptera: Pentatomidae) on Reproductive Structures of Cultivated Plants

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Abstract

Laboratory studies with the stink bug *Chinavia erythrocnemis* (Berg) (Hemiptera: Pentatomidae) were conducted to evaluate the effect of reproductive structures of cultivated plants, on nymph and adult performance, and adult preference. Results indicated that nymphs were able to complete the development on all plants evaluated. Nymph developmental time was significantly shorter on immature soybean pod [*Glycine max* (L.) Merrill], compared with immature green bean pod (*Phaseolus vulgaris* L.), immature siliques of canola (*Brassica napus* L. var. *oleifera*), and immature ear heads of wheat (*Triticum aestivum* L.). Nymph survivorship was superior on soybean (60%), decreasing on the remaining food sources (< 38%). Fresh body weight of females and males at adult emergence was higher on green bean and on soybean, compared with wheat and canola. Survivorship of adults after 40 days was highest on soybean (80%) and on green bean (65%), and lowest on canola (25%). Females of *C. erythrocnemis* reproduced on all food sources tested, except on canola, on which no female laid eggs. The fecundity and longevity of adults were significantly higher on green bean and on soybean compared with wheat and canola. In general, adults gained weight over time when fed on green bean (18%), followed by soybean (3.4%). On wheat and on canola, the bugs lost weight over time (− 14.9% and − 27.4%, respectively). In general, soybean pod was preferred compared with green bean, canola, and wheat; green bean was preferred over wheat and canola; and canola was preferred to wheat.

Introduction

The family Pentatomidae is one of the largest family within Heteroptera, including almost 5000 species in more than 800 genera, worldly distributed, especially in the Tropical Region (Panizzi & Grazia 2015). The majority of species are phytophagous, feeding on a wide range of plants, including several cultivated plants (Panizzi *et al* 2000).

The genus *Chinavia* Orian, until recently reported as genus *Acrosternum* Fieber, is one of the most diverse within Pentatomidae including 84 described species and is widely distributed on different regions of the world (Schwertner & Grazia 2006). The most common species is *Chinavia hilaris* (Say), with a wide distribution in the Nearctic Region (McPherson 1982), colonizing mostly soybean plants (McPherson *et al* 1988). In Brazil, 32 species of *Chinavia* have been identified; of which, 18 are endemic (Schwertner & Grazia 2007).

Species of the genus *Chinavia*, in general, show a medium-to-large body size and greenish color, popularly known as green stink bugs; they are frequently confused with another green stink bug, *Nezara viridula* L, because they share similar coloration and morphology. *Chinavia* species are exclusively phytophagous and polyphagous and are reported as minor components of the stink bug complex pest of several crops (Panizzi *et al* 2000).

In the Neotropical Region, species of *Chinavia* have been associated with at least 51 different plant species from 24 botanical families (Schwertner & Grazia 2007); among those plants, most are cultivated (e.g., soybean, common bean, rice, cotton), where they eventually reach pest status (Panizzi *et al* 2000). The species *Chinavia erythrocnemis* (Berg) occurs in Southern Brazil, predominantly in Rio Grande do Sul state; it was also reported in Argentina and Uruguay (Rolston 1983; Schwertner & Grazia 2007). This stink bug species was recorded on seven different plant species, including soybean, from six different botanical families (Schwertner & Grazia 2007).

Although reports published about morphological description of adults and immatures (Matesco *et al* 2006; Schwertner & Grazia 2007), no data is available on the performance and preference of nymphs and adults of *C. erythrocnemis* on different food sources. The knowledge of the insect performance is essential to understand its interaction with different plants, aiming to identify its host plants, as well as predicting possible damage to cultivated plants (Panizzi *et al* 2018). Therefore, in this study, the performance of nymphs and adults and preference of adults of *C. erythrocnemis* on reproductive structures of different cultivated plants was investigated.

Materials and Methods

Establishment of stink bug colonies and cultivated plants

Adults of *C. erythrocnemis* were field-collected on plants of canola (*Brassica napus* L. var. *oleifera*) and soybean [*Glycine max* (L.) Merrill], at the Embrapa Trigo Research Center located in Passo Fundo, RS, Brazil (28°15′S, 52°24′W). Adults were taken to the Laboratory of Entomology and placed into plastic cages (25 × 20 × 20 cm) lined with paper to established a colony; a cotton wad and a piece of toilet paper were also placed inside the cage to serve as substrate for oviposition. The cages were kept inside a climate room at 25 ± 1°C, 65 ± 10% UR, and 14 h of photophase.

A natural diet composed of fresh green bean pod (*Phaseolus vulgaris* L.), mature soybean seed, and raw shelled peanut (*Arachis hypogaea* L.) was provided as food source, and replaced twice a week. The egg masses obtained from the rearing cages were placed into clear plastic cages (11 × 11 × 3.5 cm), lined with filter paper, containing the same foods mentioned above, with wet cotton on a plastic lid (2 cm diameter) to provide water and to keep the humidity to obtain nymphs and adults. The cages were kept in a climate chamber at 25 ± 1°C, 65 ± 10% UR, and 14 h of photophase.

To obtain the reproductive structures of the cultivated plants, seeds of soybean cv. "BRS 5601," wheat cv. "BRS Reponte," and canola cv. "Hyola 575 CL" were seeded twice per month in plastic pots (2 L) in a greenhouse from June 2018 to February 2019. Fresh green bean pods of unknown cultivar were obtained in local grocery stores. For the experiments, soybean pods were used at the R5 stage (pod-filling stage) (Fehr *et al* 1971); wheat ear head were used at the R11.1 stage (milk grain stage) (Large 1954); and canola siliques were used at the R5 stage (grain filling stage) (Edwards & Hertel 2011).

Nymphal development study on different food sources

Nymphs obtained from the laboratory colony were carefully separated, on the first day of the 2nd instar (first instars stay grouped and do not feed), and placed inside clear plastic cages (11 × 11 × 3.5 cm) lined with a filter paper, and containing one of the four food sources tested: fresh green bean pod, soybean pod, wheat ear head, and canola siliques. To keep the plant tissue turgid and to prevent desiccations, the green bean pod or the plant stems/branches bearing pods/ear head/siliques were wrapped with wet cotton and placed inside a Petri dish (6.0 × 1.0 cm). For each food source, 5 nymphs were placed inside each cage and replicated ten times, totalizing 50 nymphs per food evaluated. The food and filter paper in each box were changed twice per week.

The plastic cages were placed randomly in an environmental chamber maintained at 25 ± 1°C and 65 ± 10% RH and 14 h of photophase. Daily observations were made to check for nymph survivorship and instar change; data were used to calculate the nymph developmental time and percent mortality from 2nd instar to adult. The day nymphs reached the adult stage, males and females had their fresh body weights measured using a precision electronic balance (Mettler Toledo MS 3002S/A01, Barueri, SP, Brazil).

Adult development study on different food sources

Adults on the day of emergence, obtained from the stink bug colonies, were carefully separated; female + male pairs had their fresh body weight individually taken using a precision electronic balance, and then, placed inside a plastic cage (11 × 11 × 3.5 cm) lined with a filter paper, and containing one of the four food sources tested (n = 10 pairs per each food): fresh green bean pod, soybean pod, wheat ear head, and canola silique. To prevent the tissue desiccation, the green bean pod or the plant stem/branch bearing pods/ear heads/siliques were wrapped with wet cotton and placed inside a Petri dish (6.0 × 1.0 cm). The cages were placed randomly in an environmental chamber maintained at 25 ± 1°C and 65 ± 10% RH with a photoperiod of 14L:10D hours.

Daily observations were made to determine the following biological parameters: females and males' survivorship up to 40 days, longevity, and reproduction (% females that laid eggs, preoviposition time, number of egg masses, and total eggs laid per female). In addition, males and females had their fresh body weight taken weekly during 4 weeks to calculate the body weight change per week (%), and over the total time (4 weeks). The fresh body weight change was calculated considering both males and females together, because the low number of replicates on some food sources.

Adult preference on different food sources

To check *C. erythrocnemis* adult preferences for different reproductive structures, two different tests (methodology) were carried: olfactometer test and cages (*bugdorm* type) test. At both tests, six different combinations (comparisons one by one) were evaluated: soybean pod vs. wheat ear head; soybean pod vs. canola silique; soybean pod vs. fresh green bean pod, wheat ear head vs. fresh green bean pod, wheat ear head vs. canola silique, and fresh green bean pod vs. canola silique. Fresh green bean pods and stems/branches carrying reproductive structures of the plants tested (immature soybean pod, immature wheat ear head, and canola siliques) were placed inside small glass jars (100 mL) containing water, and then used in the bioassays.

Olfactometer test

This test is based on the stimuli of volatiles released by plants on stink bug preference. For that, a two-choice "Y" type olfactometer was used, which is composed by two arms with 20 cm long and 3 cm diameter with a 60-angle between them and a leg (20 cm and 3 cm diameter). In the two arms, an air tube was connected and this one was connected individually in a glass chamber where the plant to be tested was placed. The insect was individually released in the beginning of the leg (release point), where another air tube, linked with a vacuum pump (MA-057/1, Marconi Equipamentos para Laboratório, SP, Brazil), was connected. Charcoal-filtered humidified air was drawn through the system at a flow rate of 0.8 L/min regulated by acrylic flowmeters (Key Instruments, PA, USA). Observations were made in a closed room maintained at 25 ± 2°C with continuous artificial light.

Adults *C. erythrocnemis* (female and males) were separated from the laboratory colony and starved for 24-h prior to the tests. After that, a single adult (either female or male) was carefully placed into the release point of the Y-tube using an artist's paint brush. At each comparison, at least, 50 replicates (insects) were assessed (each insect was tested only once). Each comparison was conducted in a day period, starting at 9 AM. Insect choices were recorded up to 10 min after its release, and it was considered a positive answer when the bug moved at least 5 cm past the Y junction marked in the arms of the Y-tube. After each comparison, the apparatus was cleaned with neutral liquid soap, rinsed thoroughly with water, alcohol 99% and acetone and then dried in a heat chamber at 70°C to be used again.

Cages (bugdorm type) test

In this test, *C. erythrocnemis* adults were released inside a plastic cage (30 cm × 30 cm × 30 cm) (*bugdorm*, MegaView Science Co., Ltd., Taiwan) lined with filter paper, containing the different food sources tested. At each cage, four vials (i.e., two for each food source tested), containing water and plant cuts (stems/branches) carrying reproductive structures of the plants (soybean pods, wheat ear head, and canola siliques) or fresh green bean pods, were placed. The vials were placed alternatively in the corners of each cage. Two *C. erythrocnemis* adults (either female or male) were released in the center of each cage. After 24 h, twice observations were taken daily (9:00 AM and 5:00 PM) during 7 days, and the location of the bugs on one of the food sources was recorded. Each dual comparison totalized 56 observations (2 cages × 2 insects × 2 observations × 7 days). The percentage values of the preferences for the reproductive structures tested were calculated.

Statistical analysis

The analyzed variables for nymphs and adults were previously submitted to the Bartlett test using the "Bartlett.test" function in R software (R Development Core Team 2016) to determine the homogeneity of variances and then transformed as necessary, to fulfill the normality distribution requirement prior to the ANOVA, using an appropriate transformation for each case (indicated in figure/table legends).

Dataset from each analyzed variable was fit in a one-way analysis of variance model using the "aov" function in R, which the dependent variable was the analyzed variable and the independent variable was the food sources tested. When applicable, mean separations were done using the Tukey's test ($P < 0.05$) using the "TukeyC" package (Faria *et al* 2018).

Data on the bugs preference using the olfactometer test and cages (*bugdorm*) test for reproductive structures of plants were separated using the Pearson's chi-square test (χ^2) using the "chisq.test" function in R.

Results

Nymphal development study

Nymphs of *C. erythrocnemis* were able to complete their development when fed on all food sources provided, ranging from 31 to 43 days. Nevertheless, the total developmental time to reach adulthood was significantly (F = 13.69, df = 3, 65, P < 0.001) higher for nymphs fed on immature wheat ear head than on immature soybean pod; an intermediate time was observed for nymphs fed on immature canola silique, and on immature green bean pod (Fig 1). Nymph survivorship (n = 50) was superior on soybean pod (60%), decreasing on green bean pod (38%), on canola silique (25%), and on wheat ear head (20%).

At the first day of adult life, fresh body weight of both females and males show statistical differences (females, F = 14.27, df = 3, 38, P < 0.001; males, F = 21.42, df = 3, 23, P < 0.001) among foods provided. For females, the highest fresh body weights were observed on green bean pod (173.1 mg; n = 15) and on soybean pod (157.3 mg; n = 17), which they did not significantly differ; on those both foods, body weight was significantly greater than on canola silique (113.7 mg; n = 6) and on wheat ear head (109.5 mg; n = 4) (Fig 2). For males, a similar situation was observed, green bean pod allowed a higher fresh body weight (162.7 mg; n = 4) compared with wheat ear head (104.2 mg; n = 6); on soybean pod (n = 13) and canola silique (n = 4), stink bugs showed an intermediate fresh body weight, on which they did not significantly differ from each other (Fig 2).

Adult development study

Feeding on reproductive structures of cultivated plants, *C. erythrocnemis* females and males presented a variable survivorship. In general, passed 40 days, females and males showed a similar survivorship on each food source, except on canola silique, where males showed a higher survivorship than females. The value of survivorship (%) of adult females and males together was highest on soybean pod (80%), followed by green bean pod (65%) (Fig 3); by contrast, on wheat ear head and on canola silique, survivorship decreased over time, reaching only 25% on canola after 40 days of adult life (Fig 3).

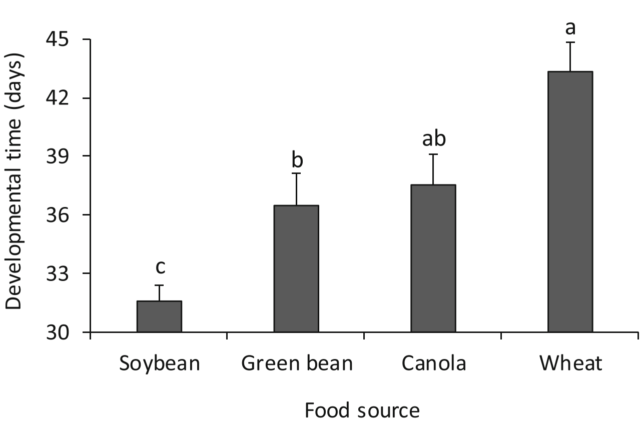

Fig 1 Developmental time of nymphs *Chinavia erythrocnemis* feeding on reproductive structures of different cultivated plants in laboratory conditions. Means (± SE) followed by the same letter are not significantly different using Tukey's test, P < 0.05.

Females of the stink bug *C. erythrocnemis* were able to reproduce on all food sources provided, except on canola silique, on which no female laid eggs. The percentage of females that oviposited ranged from 20% (wheat hear head) to 100% (soybean pod) (Table 1). No statistical difference was observed on preoviposition time (F = 2.63, df = 2, 15, P = 0.11); however, the number of egg masses was significantly higher on green bean pod (ca. 6X) compared with wheat ear head (F = 4.59, df = 2, 15, P < 0.05); soybean was intermediate do not differing from green bean and wheat. Regarding the total number of eggs laid, a significant difference was also observed (F = 4.89, df = 2, 5, P < 0.05), where green bean and soybean pods allowed the highest values (> 9X) compared with wheat ear head (Table 1).

The longevity of females and males were significantly different (females, F = 4.71, df = 3, 36, P < 0.01; males, F = 2.97, df = 3, 36, P < 0.05) among food sources tested, ranging from 30 to 56 days and 32 to 59 days for females and males, respectively. For female, immature green bean pod and soybean pod allowed the highest longevity compared with immature canola silique; in an intermediate position were females fed on immature ear heads of wheat (Fig 3). For males, again soybean and green bean pod allowed the highest values of longevity, followed by silique of canola and ear head of wheat; green bean did not differ statistically from wheat and canola (Fig 3).

Fresh body weight change of adults (female + male) *C. erythrocnemis* showed significant differences during all weeks tested, except on the 4th week (1st week, F = 20.15, df = 3, 76, P < 0.001; 2nd, F = 9.71, df = 3, 72, P < 0.001; 3rd, F = 3.23, df = 3, 61, P < 0.05; 4th, F = 0.76, df = 3, 52, P = 0.52) (Table 2). During the 1st and 2nd weeks, adults significantly gained weight when fed with green bean and soybean pods, whereas on silique of canola and on wheat ear head, adults lost weight (Table 2). On the 3rd week, a slight weight gain was observed to stink bugs feeding on wheat ear head and on green bean pod, whereas on soybean pod and canola silique, bugs lost weight. On the 4th week, no significant differences were observed; adults tended to gain weight on canola and to lose weight on the other food sources (Table 2).

In summary, fresh body weight gain of adults (female + male) showed significant differences (F = 21.21, df = 3, 52, P < 0.001) after the total time evaluated (4 weeks). In general, adults gained weight over time, particularly when fed on immature green bean pod (> 18%), followed by adults fed with immature soybean pod, which showed a slight gain (3.4%). On the other hand, on immature wheat ear head

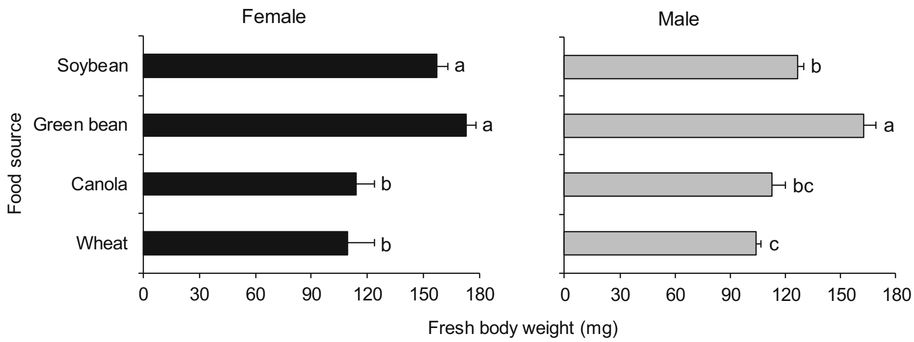

Fig 2 Fresh body weight of females and males *Chinavia erythrocnemis* at the first day of the adult life feeding on reproductive structures of different cultivated plants in laboratory conditions. Means (± SE) followed by the same letter in each gender are not significantly different using Tukey's test, $P < 0.05$.

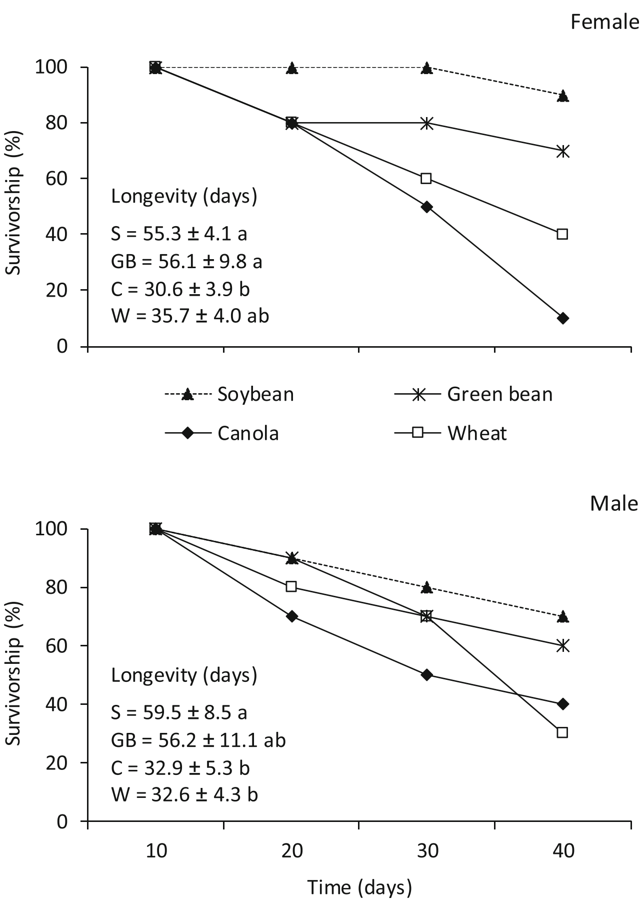

Fig 3 Survivorship (%) up to 40 days and longevity (days ± SE) of adult females and males *Chinavia erythrocnemis* feeding on reproductive structures of different cultivated plants in laboratory conditions. S, soybean pod; GB, green bean pod; C, canola siliques; and W, wheat ear head. Means (± SE) of longevity followed by the same letter in each gender are not significantly different using Tukey's test, $P < 0.05$. Original data presented for longevity of females and males (for analysis, data were transformed to $\sqrt{x}$)).

and on canola silique, adults lost weight over time (wheat, − 14.9%; canola, − 27.4%) (Fig 4).

Adult preference

The tests used to assess the *C. erythrocnemis* adult preferences for different plants showed significant differences and, in general, they produced similar results. In the olfactometer test, stink bugs showed a high and significant preference for immature soybean pod compared with reproductive structures of green bean (χ^{2calc} = 36.0; $P < 0.001$), canola (χ^{2calc} = 16.0; $P < 0.001$), and wheat (χ^{2calc} = 16.0; $P < 0.001$). In addition, the stink bug significantly preferred green bean pod compared with canola silique (χ^{2calc} = 8.49; $P < 0.01$), and wheat ear head (χ^{2calc} = 7.84; $P < 0.01$); canola silique was preferred compared with wheat ear head (χ^{2calc} = 36.0; $P < 0.001$) (Fig 5A).

In the *bugdorm* cage test, stink bugs showed a significant preference for soybean pod compared with canola silique (χ^{2calc} = 4.84; $P < 0.05$) and wheat ear head (χ^{2calc} = 36.0; $P < 0.001$); however, it did not differ from immature green bean pod (χ^{2calc} = 0.27; $P = 0.60$). Again, bugs showed significant preference for green bean pod compared with ear head of wheat (χ^{2calc} = 54.76; $P < 0.001$), but silique of canola was more preferred compared with green bean pod (χ^{2calc} = 4.0; $P < 0.05$); no difference was observed between ear head of wheat and canola silique (χ^{2calc} = 0.34; $P = 0.56$) (Fig 5B).

Discussion

Species of the genus *Chinavia* are considered pests on many legumes (Fabaceae) plants around the world. In North America, the most common species, *C. hilaris*, is reported as a major pest of soybean (McPherson *et al* 1988). Besides

Table 1 Reproductive performance of adults *Chinavia erythrocnemis* feeding on reproductive structures of different cultivated plants in laboratory conditions.

Food source	% females laying eggs	Preoviposition time (days)[2]	Egg masses	Total number of eggs[2]
Soybean	100 [10][1]	13.8 ± 1.2 a	7.1 ± 1.1 ab	76.8 ± 12.2 a
Green bean	60 [6]	16.0 ± 2.6 a	9.3 ± 1.8 a	85.8 ± 19.4 a
Wheat	20 [2]	25.5 ± 10.5 a	1.5 ± 0.5 b	8.5 ± 1.5 b
Canola	0 [0]	0	0	0

Means (± SE) followed by the same letter in columns (except for % females laying eggs) are not significantly different using Tukey's test, $P < 0.05$.

[1] Value within brackets indicates the number of females that laid eggs.

[2] Original data presented (for analysis, data were transformed in √(x)).

legumes, other cultivated plants are colonized such as peaches and cotton. *Chinavia marginatum* (Palisot de Beauvois) is found on soybean and common bean crops in the Americas, and *Chinavia armigera* (Stål) is reported on soybean in South America (Panizzi 1997 and references there in).

In the neotropics, several other species of *Chinavia* are considered secondary pests of soybean, occurring and competing simultaneously with other stink bugs species more abundant, mostly *Euschistus heros* (F.), *Dichelops* spp., and *Piezodorus guildinii* (Westwood) (Panizzi *et al* 2000). The Netropical species *C. erythrocnemis* occurs predominantly in Southern Brazil, and it was found associated with seven different plant species, including soybean (Schwertner & Grazia 2007).

The laboratory studies with *C. erythrocnemis* demonstrated its great preference for legumes (Fabaceae), in this case, immature pods of soybean and green bean. On these foods, both nymphs and adults showed a great performance, whereas on immature silique of canola (Brassicaceae) and ear head of wheat (Poaceae), they showed poor performance.

Nymphs of *C. erythrocnemis* were able to complete the development on all food sources, but on soybean and green bean, developmental time was shorter compared with that of the other tested food sources. Compared with other species, *C. erythrocnemis* presented a similar developmental time on green bean (for example, *Chinavia pengue* (Rolston), ca. 33 days, Matesco *et al* 2007); for other species, this time was shorter on this food (for example, *Chinavia longicorialis* (Breddin), ca. 28 days, Matesco *et al* 2009, and *Chinavia bellum* Rolston, 29 days, Avalos & La Porta 1996). However, in general, these species presented a low rate of survivorship on green bean pod, as observed in our study for *C. erythrocnemis*.

The majority (≥ 65%) of *C. erythrocnemis* adults survived past 40 days of adult life; they were able to lay eggs and gained body weight when fed with immature pods of soybean and green bean. On this last food, similar or even higher fecundity was also reported to other *Chinavia* species (Avalos & La Porta 1996, Matesco *et al* 2007, 2009).

Chinavia erythrocnemis is not reported to occur on graminaceous (Poaceae) plants, but other species of *Chinavia* were recorded on these plants in the Neotropical Region, such as, *Chinavia armigera* and *Chinavia impicticornis* (Stål) on rice, and *Chinavia nigrodorsata* (Breddin) on rice and on wheat (see references on Schwertner & Grazia 2007). On canola plants, Bianchi *et al* (2019) found seven different species of this genus associated with this crop in Southern Brazil, where *C. erythrocnemis* was the second most abundant among them. Compared with legumes tested

Table 2 Fresh body weight change (%) of adult (female + male) *Chinavia erythrocnemis* feeding on reproductive structures of different cultivated plants in laboratory conditions.

Food source	1st week	2nd week[2]	3rd week[2]	4th week
Soybean	6.8 ± 4.1 a [20][1]	7.2 ± 3.0 a [20]	− 5.2 ± -1.9 b [19]	− 6.3 ± − 3.0 a [18]
Green bean	16.5 ± 3.5 a [20]	2.3 ± 2.3 ab [18]	1.7 ± 3.8 ab [17]	− 3.2 ± − 3.3 a [15]
Canola	− 17.5 ± − 2.6 b [20]	− 12.7 ± − 1.4 c [19]	− 6.8 ± − 2.4 b [13]	0.5 ± 5.3 a [10]
Wheat	− 12.8 ± − 4.0 b [20]	− 5.2 ± − 3.9 bc [19]	3.1 ± 3.8 a [16]	− 1.1 ± − 2.4 a [13]

Means (± SE) followed by the same letter in the columns are not significantly different using Tukey's test, $P < 0.05$.

[1] Value within brackets indicates the number of adults (female + male).

[2] Original data presented (for analysis, data were transformed in arcsine √(x/100)).

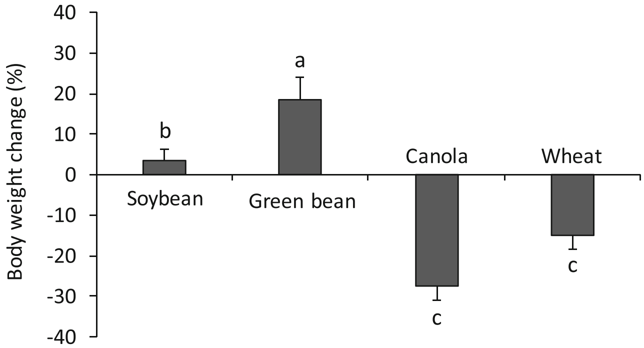

Fig 4 Fresh body weight change (%) of adult (female + male) *Chinavia erythrocnemis* after four weeks of adult life feeding on reproductive structures of different cultivated plants in laboratory conditions. Means (± SE) followed by the same letter are not significantly different using Tukey's test, $P < 0.05$.

(soybean and green green), on wheat and on canola (although bugs were found on canola in the field), nymphs showed the longest developmental time and the lowest fresh body weight gain at adult emergency. In addition, adults also had negative result on those foods, with few females laying eggs (on wheat) or even not laying eggs (on canola), a short period of longevity and a significant loss of weight over time. In fact, canola and wheat were less preferred by adults compared with soybean and green bean pods in the preference tests.

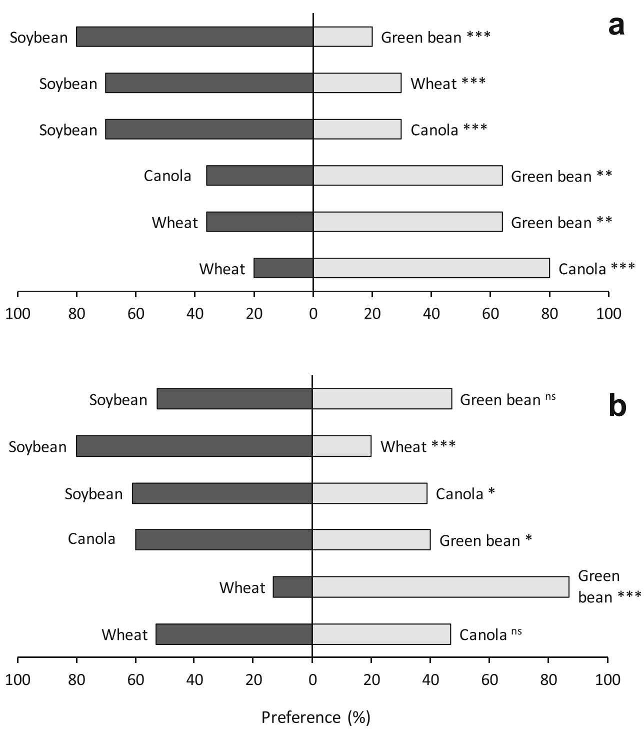

Fig 5 Preference ratios (%) of adults *Chinavia erythrocnemis* on different combinations among reproductive structures of cultivated plants in laboratory conditions. Bioassays conducted using the olfactometer (A); and using plastic cages (*bugdorms*) (B) for dual comparisons. *significantly different ($P < 0.05$); ** significantly different ($P < 0.01$); ***significantly different ($P < 0.001$); and ^{ns} non-significant different using Pearson's chi-square test (χ^2).

In summary, these laboratory studies indicate that legumes (soybean and green bean), during the reproductive period, allow *C. erythrocnemis* nymphs and adults to perform well, demonstrating that these food sources are suitable and play an important role to their phenology. Canola and wheat are considered less suitable, perhaps because these food sources may have detrimental factors or poor nutritional quality. However, our results do not fully explain the reason for the poor performance, and additional studies are needed to clarify it. Nevertheless, on these plants, stink bugs may feed to obtain nutrients/water enough to keep them alive during unfavorable periods, which is reported for other pentatomid species (see more details in Smaniotto & Panizzi 2015, and Panizzi & Lucini 2017). *Chinavia erythrocnemis* does not seem to have reached economically damaging levels on canola and on wheat. This fact indicates that these food sources serve as alternative food source, mostly to sustain insects, during the unfavorable period (e.g., later autumn-winter) that will colonize summer crops afterwards, such as soybean or common bean, where the stink bugs showed a better performance and more likely will attain pest status.

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Author Contributions TL co-planed, analyzed, and co-wrote the manuscript; ARP co-planed and co-wrote the manuscript; MAS co-planed and conducted lab work; ALMJ co-planned and co-wrote the manuscript.

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Compliance with Ethical Standards Research activity was registered at the Sisgen databank under number AA93702 and at the Publication Committee of Embrapa Trigo under number 21205.002249/2019-41.

References

Avalos DS, La Porta NC (1996) Biología de *Acrosternum bellum* Rolston, 1983 (Hemiptera, Pentatomidae). Agriscientia 13:25–30

Bianchi FM, Marsaro AL Jr, Grazia J, Pereira PRVS, Panizzi AR (2019) Diversity of stink bugs (Pentatomidae) associated with canola: looking for potential pests. Neotrop Entomol 48:219–224

Development Core Team R (2016) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna

Edwards J, Hertel K (2011) Canola growth & development. PROCROP Series, NSW Department of Primary Industries, Australia, 90

Faria JC, Jelihovschi EG, Allaman IB (2018) TukeyC: Conventional Tukey test package: R package. Available from: https://cran.r-project.org/web/packages/ /TukeyC (Accessed 08/30/2019)

Fehr WR, Caviness CE, Burmood DT, Pennington JS (1971) Stage of development descriptions for soybeans, *Glycine max* (L.) Merrill. Crop Sci 11:929–931

Large EC (1954) Growth stages in cereals. Illustration of the Feekes scale. Plant Path 3:128–129

Matesco VC, Schwertner CF, Grazia J (2006) Descrição dos estágios imaturos de *Chinavia erythrocnemis* (Berg) (Hemiptera, Pentatomidae). Neotrop Entomol 35:483–488

Matesco VC, Schwertner CF, Grazia J (2007) Descrição dos estágios imaturos e biologia de *Chinavia pengue* (Rolston) (Hemiptera, Pentatomidae). Rev Bras Entomol 51:93–100

Matesco VC, Schwertner CF, Grazia J (2009) Morphology of the immatures and biology of *Chinavia longicorialis* (Breddin) (Hemiptera: Pentatomidae). Neotrop Entomol 38:74–82

McPherson JE (1982) The Pentatomoidea (Hemiptera) of northeastern North America with emphasis on the fauna of Illinois. Southern Illinois University Press, Illinois, 240

McPherson RM, Zehnder GW, Smith JC (1988) Influence of cultivar, planting date, and row width on abundance of green cloverworms (Lepidoptera: Noctuidae) and green stink bugs (Heteroptera: Pentatomidae) in soybean. J Entomol Sci 23:305–313

Panizzi AR (1997) Wild hosts of pentatomids: ecological significance and role in their pest status on crops. Annu Rev Entomol 42:99–122

Panizzi AR, Grazia J (2015) Introduction to true bugs (Heteroptera) of the neotropics. In: Panizzi AR, Grazia J (eds) True bugs (Heteroptera) of the neotropics. Springer, Dordrecht, pp 3–20

Panizzi AR, Lucini T (2017) Host plant-stink bug (Pentatomidae) relationships. In: Čokl A, Borges M (eds) Stink bugs biorational control based on communication processes. CRC Press, Boca Raton, pp 31–58

Panizzi AR, McPherson JE, James DG, Javahery M, McPherson RM (2000) Stink bugs (Pentatomidae). In: Schaefer CW, Panizzi AR (eds) Heteroptera of economic importance. CRC Press, Boca Raton, pp 421–474

Panizzi AR, Lucini T, Possebom T (2018) Development of *Dichelops furcatus* (Hemiptera: Heteroptera: Pentatomidae) reared on spring cereals versus soybean. J Insect Sci 18(17):1–7

Rolston LH (1983) A revision of the genus *Acrosternum* Fieber, subgenus *Chinavia* Orian in the Western Hemisphere (Hemiptera, Pentatomidae, Pentatomini). J New York Entomol Soc 91:97–176

Schwertner CF, Grazia J (2006) Descrição de seis novas espécies de *Chinavia* (Hemiptera, Pentatomidae, Pentatominae) da América do Sul. Iheringia 96:237–248

Schwertner CF, Grazia J (2007) O gênero *Chinavia* Orian (Hemiptera, Pentatomidae, Pentatominae) no Brasil, com chave pictórica para os adultos. Rev Bras Entomol 51:416–435

Smaniotto LF, Panizzi AR (2015) Interactions of selected species of stink bugs (Hemiptera: Heteroptera: Pentatomidae) from leguminous crops with plants in the neotropics. Fla Entomol 98:7–17