ECOLOGY, BEHAVIOR AND BIONOMICS

Geographical Distribution of Genetically Determined Types of *Nezara viridula* (L.) (Heteroptera: Pentatomidae) in Brazil

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Distribuição Geográfica de Tipos Geneticamente Determinados de *Nezara viridula* (L.) (Heteroptera: Pentatomidae) no Brasil

RESUMO - *Nezara viridula* (L.) é um pentatomídeo cosmopolita e polimórfico. Vários tipos geneticamente determinados têm sido descritos devido à variação de coloração de adultos. Com o objetivo de mapear a distribuição geográfica dos tipos no Brasil, foram feitos levantamentos em 2001 e 2002 em 13 estados. Os percevejos do tipo G (*smaragdula* – totalmente verde) foram mais comuns e apresentaram distribuição ampla, ocorrendo de norte a sul do país (latitude 2º 49'N a 31º 46' S), exceto na Região Centro-Oeste. Os percevejos do tipo O (*torquata* - corpo verde com os lobos laterais e medianos da cabeça e margem anterior do pronoto de cor amarela), menos abundantes que o anterior, restringiram-se a locais com latitudes maiores que 23º18' S e temperaturas médias anuais < 20,8ºC (Região Sul). Percevejos do tipo Y (*aurantiaca* - totalmente amarelo ou alaranjado), de ocorrência esporádica, foram coletados somente na Região Sul. O tipo *N. viridula* (*smaragdula*) foi coletado em apenas um local na Região Norte (Boa Vista, RR, latitude 2º 49' N). Não se observou correlação da abundância dos tipos mais comuns *smaragdula* e *torquata* com a altitude.

PALAVRAS-CHAVE: Insecta, percevejo verde, tipo polimórfico

ABSTRACT - *Nezara viridula* (L.) is a cosmopolitan and polymorphic pentatomid. Several genetically determined types have been described due to body color variation in adults. A survey covering 13 Brazilian states was conducted during 2001 and 2002 to determine the geographical distribution of the main types. Type G (*smaragdula* - body entirely green), the most common, showed a wide distribution, from south to north (latitude 2º 49' N to 31º 46' S), except in the Central-West Region. Type O (*torquata* – body green with lateral and median lobes of the head and anterior margin of the pronotum yellow), less abundant than the former, was more frequent at latitudes > 23º18' S and mean annual temperatures < 20.8ºC (Southern Region). Type Y (*aurantiaca* – body entirely gold or orange), which is rare, was collected only in the Southern Region. *N. viridula* (*smaragdula*) was captured in only one place in the Northern Region (Boa Vista, RR, latitude 2º 49' N). The abundance of the two most common types, *smaragdula* and *torquata*, was not correlated with altitude.

KEY WORDS: Insecta, southern green stink bug, polymorphic type

Nezara viridula (L.) is a cosmopolitan and polymorphic pentatomid. Of the nine polymorphic types of *N. viridula* described, the three main types are: type G = *smaragdula* Fabricius – body entirely green; type O = *torquata* Fabricius – body green with lateral and median lobes of the head and anterior margin of the pronotum yellow; and type Y = *aurantiaca* Costa – body entirely yellow or orange (Yukawa & Kiritani 1965).

In Brazil, of the nine polymorphic types of *N. viridula,* only the three more common types, G, O, and Y, are present, mostly in the Southern Region. However, two other types derived from the basic types G and O, having a yellowish-green background instead of green, were recently collected; the G-yellowish type was obtained from the field in Londrina, PR (latitude 23º18' S), and the O-yellowish type was obtained in the laboratory (Vivan & Panizzi 2002). It is known that different intermediate morphs of *N. viridula* originating from the basic types might be obtained in the laboratory by crossing

(Ohno & Alam 1992), but this also occurs in the field.

N. viridula is more adapted to the cooler temperatures of southern Brazil (Panizzi & Corrêa-Ferreira 1997). However, recently it has expanded toward the warmer regions with lower latitudes, such as northeast Brazil (Panizzi 2002), probably following the expansion of its preferred host plant, soybean, *Glycine max* (L.) Merrill. Little is known about the biology and ecology of the genetically determined types of *N. viridula*, how they are distributed and how they are impacted by natural enemies and pesticides. Answers to these questions are important in order to design effective integrated management systems against the pest. Therefore, this study was conducted in order to learn the geographical distribution of the three main types of *N. viridula*, in the traditional and in the expanding regions of its occurrence.

Material and Methods

Localities of survey. During January-March 2001 and 2002, *N. viridula* adults were surveyed, each year, in 19 localities of 13 different states out of the 26 states of the country. The latitude and altitude of each place were recorded (Table 1).

Host plants examined. In general, bugs were collected from soybean plants. This is a preferred host, widely cultivated in Brazil. Plants examined were, in general, in the reproductive period, which is the time when bugs move from alternate hosts to feed on soybeans' fruiting structures (pods). Other host plants examined included cabbage, *Brassica oleracea* L. (Cruciferae), common bean, *Phaseolus vulgaris* L. (Leguminosae), pigeonpea, *Cajanus cajan* (L.) Millsp., and okra, *Hibiscus esculentus* L. (Malvaceae).

Insect sampling and storage. From each locality, 10 samples were taken at random, using either a sweep net or a beat cloth, depending on the type of plants available. Usually on soybean and greenbean, the beat cloth was used. The samples consisted of beating soybean plants over the

Table1. Collection localities of *N. viridula* of different types in Brazil, in 2001 and 2002.

State[1]	Locality	Latitude	Altitude (m)	T(°C)[2]	Sampling dates
RS	Pelotas	31°46' S	17	18.1	03/19/01; 03/25/02
	Cruz Alta	28°39' S	452	18.4	03/20/01; 04/03/01; 03/26/02; 04/17/02
	Passo Fundo	28°15' S	687	17.8	03/21/01; 03/27/02
SC	Chapecó	27°07' S	674	19.8	03/22/01; 03/28/02
PR	Ponta Grossa	25° 05' S	969	21.8	03/23/01; 03/30/02
	Mariópolis	26°21' S	879	21.7	03/24/01; 03/29/02
	Palotina	24°17' S	333	21.8	03/24/01; 03/29/02
	Campo Mourão	24°02' S	585	22.4	03/12/01; 03/19/02
	Londrina	23°18' S	585	22.7	01/25/01; 02/15/01; 02/21/01; 02/26/01; 03/06/01; 02/15/02; 02/18/02; 02/22/02; 03/02/02; 03/05/02; 03/09/02; 03/10/02
SP	Assis	22°37'S	546	23.1	01/18/01; 02/05/01; 02/23/01; 03/06/02; 03/12/02
MS	Dourados	22°14' S	430	___	___[3]
GO	S.anta Helena de Goiás	17°47' S	562	___	___[3]
MT	Rondonópolis	16°29' S	227	___	___[3]
BA	Barreiras	12°06' S	452	___	___[3]
AC	Rio Branco	09°58' S	153	___	___[3]
PE	Petrolina	09°23' S	376	___	___[3]
MA	Balsas	07°36' S	247	26.7	01/20/01; 02/07/02
RR	Boa Vista	02°49' N	85	28.4	01/04/01; 01/10/02
PA	Belém	01°32' S	10	___	___[3]

[1] RS = Rio Grande do Sul; SC = Santa Catarina; PR = Paraná; SP = São Paulo; MS = Mato Grosso do Sul; GO = Goiás; MT = Mato Grosso; BA = Bahia; AC = Acre; PE = Pernambuco; MA = Maranhão; PA = Pará; RR = Roraima

[2] Annual mean temperature of the last 10 years.

[3] One sample was taken each year, but no exact dates are available.

beat cloth 20 times. On the other host plants the sweep net was used, sweeping the plants 20 times. Adults of *N. viridula* captured were killed, using killing jars, and were pinned and stored in the Insect Collection of Embrapa Soja, in Londrina, PR.

Statistics. The total number of adults of each type was recorded and the percentage of adults calculated for each place where the samples were taken. Data on the number of adults *N. viridula* of the main two types (*smaragdula* and *torquata*) obtained in each place were submitted to the analyses of regression, to examine the relationship between the number of insects captured and the latitude, the temperature (annual mean temperature of last 10 years), and the altitude. These analyses were performed using the program Statistical Analysis Systems (SAS 1997).

Results

Of the 13 states surveyed, in 19 localities, *N. viridula* was captured in eight states, in 14 localities, in particular in the southern states of Rio Grande do Sul, Santa Catarina, and Paraná, where all three basic types were collected (Fig. 1). *N. viridula* was not collected in the western states of Mato Grosso do Sul (Dourados - 22º 14' S), and Mato Grosso (Rondonópolis - 16º 29' S), the central state of Goiás (Santa Helena de Goiás - 17º 47' S), the northern state of Pará (Belém - 1º 32' S), and the north-western state of Acre (Rio Branco - 9º 58' S). Type G (*smaragdula*) was present in all 13 states, showing a greater distribution and adaptability to a wide range of environments. Types O (*torquata*) and Y (*aurantiaca*) were restricted to the three states of the South Region, around or below the Tropic of Capricorn (latitude 23º 30' S) (Fig. 1).

During 2001, 3,406 adults of *N. viridula* were collected, 100% of the specimens belonging to type G (*smaragdula*) in the northern locality of Boa Vista, RR (latitude 2º 49' N); in the northeastern localities of Barreiras, BA (12º 06' S), Petrolina, PE (9º 23' S), and Balsas, MA (7º 36' S); and in the southern localities of Assis, SP (22º 37' S) and Palotina, PR (24º 17' S) (Fig. 2 A). Over 95% of the bugs of type G were obtained in Londrina, PR (23º 18' S) and in Campo Mourão, PR (24º 02' S). In localities with latitudes > 27º S, in general, less than 90% of the bugs were of type G; the lower values were observed in Chapecó, SC (27º 07' S) (84.0%) (Fig. 2 A).

The second most abundant type (O - *torquata*) occurred in eight of the 14 localities where *N. viridula* was collected,

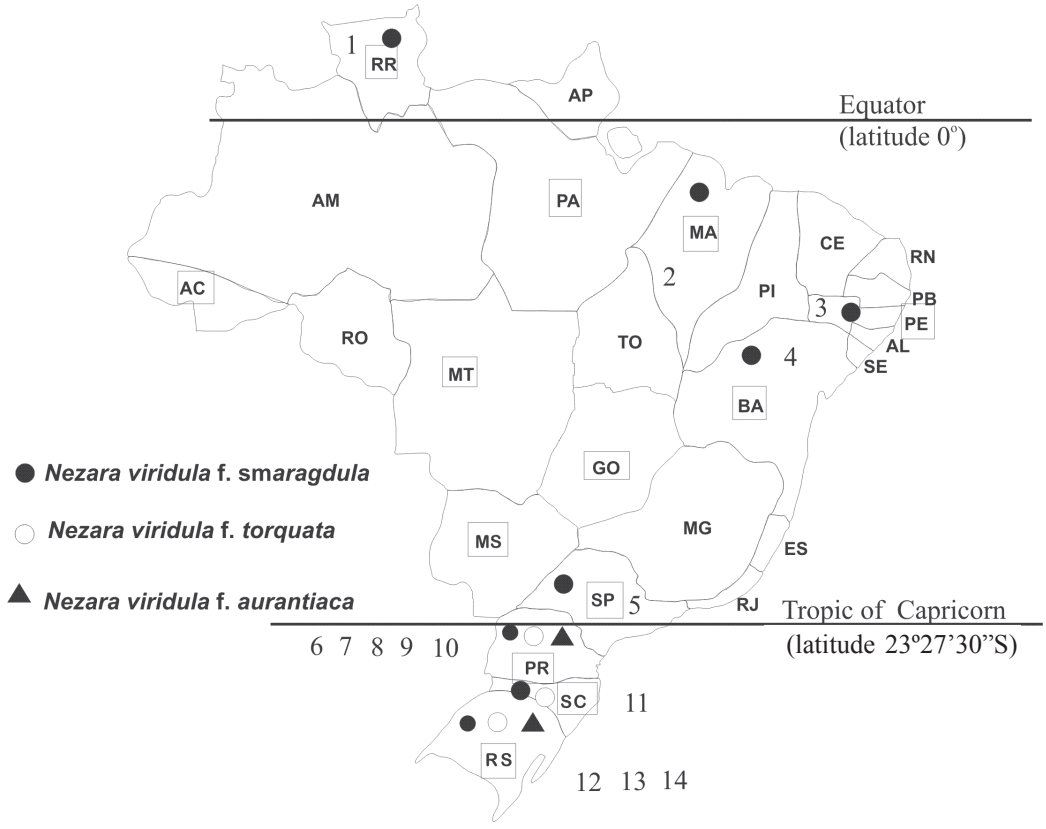

Fig. 1. Geographical distribution of different types of the southern green stink bug, *N. viridula*, in Brazil, January-March 2001 and 2002. Localities where bugs were intercepted: 1 = Boa Vista, RR; 2 = Balsas, MA; 3 = Petrolina, PE; 4 = Barreiras, BA; 5 = Assis, SP; 6 = Londrina, PR; 7 = Campo Mourão, PR; 8 = Ponta Grossa, PR; 9 = Palotina, PR; 10 = Mariópolis, PR; 11 = Chapecó, SC; 12 = Passo Fundo, RS; 13 = Cruz Alta, RS; and 14 = Pelotas, RS. G = *N. viridula* f. *smaragdula*, O = *N. viridula* f. *torquata*, Y = *N. viridula* f. *aurantiaca*.

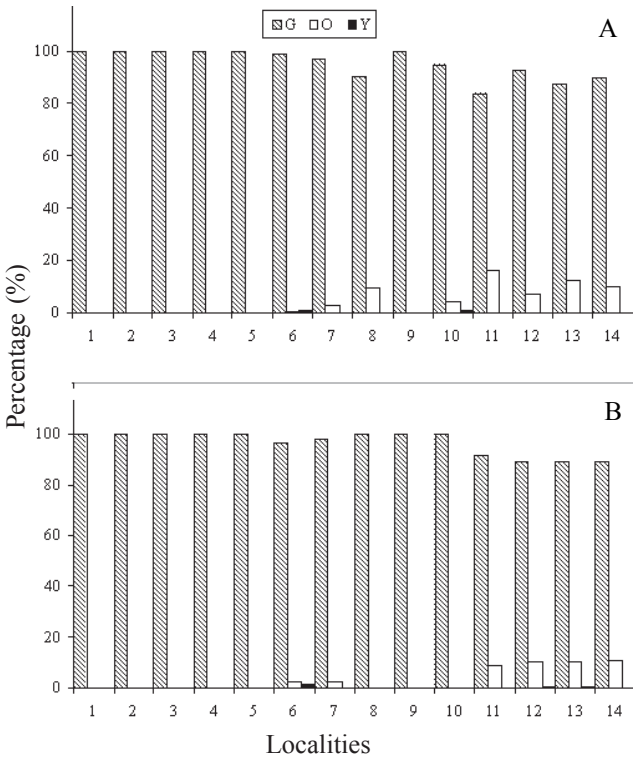

Fig. 2. Percentage of the number of adult southern green stink bug, *N. viridula*, captured in several different locations of different geographical regions of Brazil, during January-March 2001 (A) and 2002 (B) (latitude and altitude in parentheses). 1 = Boa Vista (02°49'N/85 m), 2 = Balsas (07°36'S/247), 3 = Petrolina (09°23'S/376), 4 = Barreiras (12°06'S/452), 5 = Assis (22°37'S/546), 6 = Londrina (23°18'S/585), 7 = Campo Mourão (24°02'S/585), 8 = Ponta Grossa (25°05'S/969), 9 = Palotina (24°17'S/333), 10 = Mariópolis (26°21'S/879), 11 = Chapecó (27°07'S/674), 12 = Passo Fundo (28°15'S/687), 13 = Cruz Alta (28°39'S/452), and 14 = Pelotas (31°46'S/17). G = *N. viridula* f. *smaragdula*, O = *N. viridula* f. *torquata*, Y = *N. viridula* f. *aurantiaca*.

restricted to the southern states of Paraná, Santa Catarina, and Rio Grande do Sul (Fig. 2 A). The values varied from 0.4% in Londrina, PR to 16.0% in Chapecó, SC, relatively high values (7.5 -12.5%) occurring in the localities of the southernmost state, Rio Grande do Sul. The rare type Y (*aurantiaca*) was collected only in Paraná state, in Londrina (0.7%) and Mariópolis (1.0%) (Fig. 2 A).

During the summer of 2002, results followed in general those from the previous year. No bugs were captured in Belém, Rio Branco, Dourados, Santa Helena de Goiás, and Rondonópolis, confirming the results obtained in 2001. In the remaining localities, the total of 2,828 specimens were collected, and 100% were of the type G (*smaragdula*) in all the same six localities as in 2001, plus Mariópolis and Ponta Grossa, both in Paraná state in the south (Fig. 2 B). In the other six remaining locations, the percentage of G types decreased to approximately 97% in Campo Mourão and Londrina, to 92% in Chapecó, and to approximately 89% in the three localities of Rio Grande do Sul state, Cruz Alta, Passo Fundo, and Pelotas (Fig. 2 B). In 2002, type Y (*aurantiaca*) was recorded in three locations in the South Region, namely Londrina (1.2%), Cruz Alta (07%), and Passo Fundo (0.2 %).

The regression analysis comparing the number (%) of *N. viridula* of the two main types, G (*smaragdula*) and O (*torquata*), with latitude indicated that as the latitude increased, the percentage of type G collected decreased, and the % of type O increased (Fig. 3). Although the data obtained in 2001 only show a tendency for this trend (for type G, F = 4.40; P = 0.0465; for type O, F = 4.26; F = 0.0498) (Fig. 3 A), in 2002, the data do yield a significant coefficient of determination (R^2) with the approximate value of 0.7 (for type G, F = 8.08; P = 0.0098; for type O, F = 9.53; F = 0.0060) (Fig. 3 B), indicating that, in fact, the O type increases in abundance to the south and greater latitudes.

Regarding the relation between types G and O of *N. viridula* and temperature, the regression analyses indicated that as temperatures increased the number of the G types collected also increased (2001, F = 5.88; P = 0.0232; 2002, F = 45.20, P = 0.0001), in contrast to the O type, which was less abundant in areas with increasing temperatures (2001,

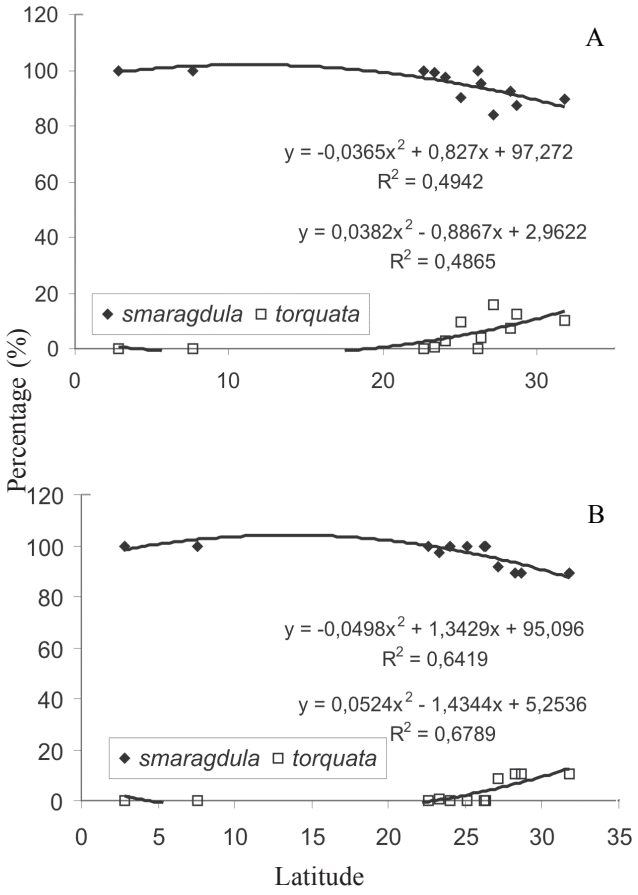

Fig. 3. Regression analysis of the percentage of the number of adult southern green stink bug, *N. viridula* f. *smaragdula* and f. *torquata* captured in several different locations in different geographical regions of Brazil, during January-March 2001 (A) and 2002 (B) and the respective latitudes.

F = 5.88; P = 0.0232; 2002, F = 63.65, P = 0.0001) (Fig. 4 A,B).

Considering the altitude (m), no relationship was found between this parameter and the number of bugs of types G (*smaragdula*) (2001, F = 0.07, P = 0.7912; 2002, F = 0.59, P = 0.4588) and O (*torquata*) (2001, F = 0.03, P = 0.8623; 2002, F = 0.67, P = 0.4334) (Fig. 5 A,B). The coefficients of determination (R^2) values were very low and not significant in either year. The suspicion that with an increase in altitude, temperatures will be lower and will favor type O, and, in consequence, decrease the percentage of individuals of type G, was not confirmed.

Discussion

These extensive surveys indicate that the southern green stink bug, *N. viridula*, is broadly distributed in Brazil, and that type G (*smaragdula*) is the most widespread, covering a wide range of latitudes from 31° 46' to 2° 49' S. This type is believed to have greater ability to adapt to different environments than the others (Kiritani 1970). Despite this ability, it seems that *N. viridula* is unable to thrive in the areas of the Central-West Brazil, where it was not intercepted, confirming data from former studies that have not reported its presence in this region in the past (Corrêa *et al.* 1977), and more recently (Borges 1992). This could be due to several factors such as the impact of high temperatures during most of the year, a greater impact of natural enemies such as tachinid flies (Corrêa-Ferreira 1984) and egg parasitoids (Corrêa-Ferreira & Moscardi 1995) active year round, and stronger competition with other pentatomids, such as *Euchistus heros* (Fabricius) and *Piezodorus guildinii* (Westwood), which are prevalent in this area on soybean plantations (Panizzi 1997). At this point, however, there is no clear explanation of why *N. viridula* does not occur or is rare in the Central-West.

The wide range of distribution of *N. viridula* confirms recent studies that report its increasing expansion towards Northeast Brazil (Panizzi 2002). It seems that this pentatomid is spreading in other areas of the world too, such as northward in Japan, due to climate warming (Musolin & Numata 2003).

The fact that type O (*torquata*) is present only in the

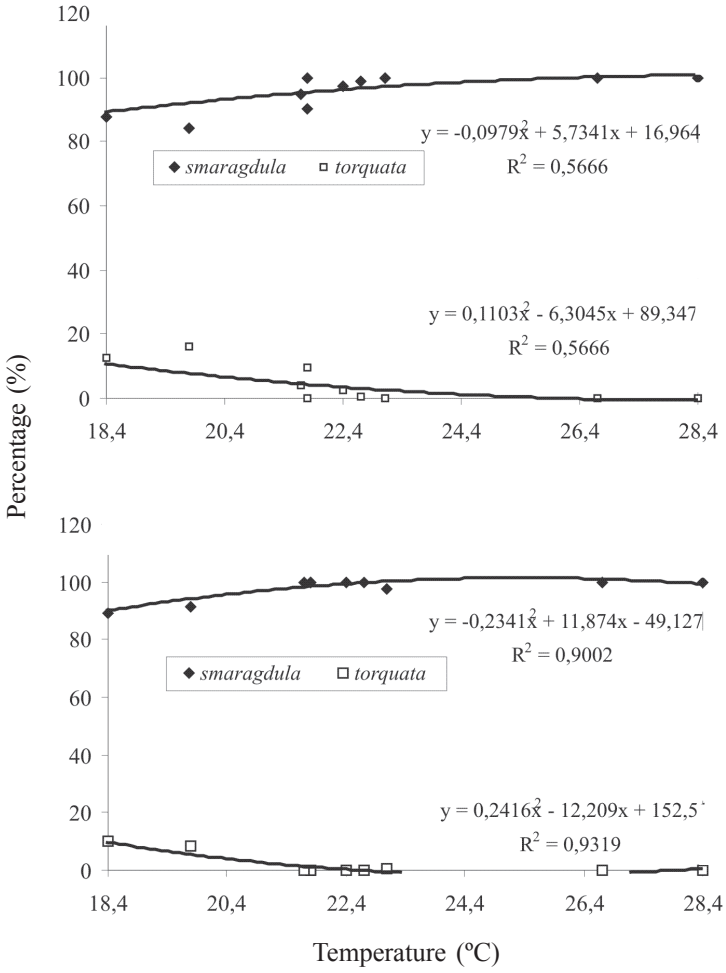

Fig. 4. Regression analysis on the percentages of adult southern green stink bug, *N. viridula* f. *smaragdula* and f. *torquata*, captured in several different locations in different geographical regions of Brazil, during January-March 2001 (A) and 2002 (B) and the respective temperatures (annual mean temperature of last 10 years).

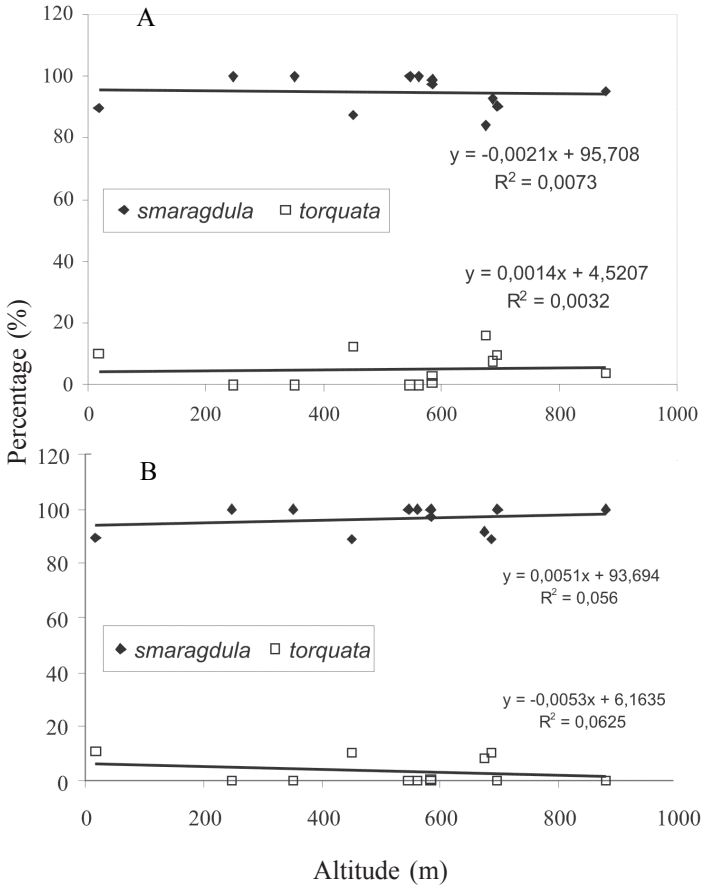

Fig. 5. Regression analysis on the percentage of the number of adult southern green stink bug, *N. viridula* f. *smaragdula* and f. *torquata*, captured in several different locations in different geographical regions of Brazil, during February-March 2001 (A) and 2002 (B) and the respective altitudes.

South Region, and, within this area, is more abundant toward southern locations of higher latitudes, indicates that this type is better adapted to cooler temperatures. Data on nymph biology and adult reproduction of type O in the laboratory, comparing different temperatures, demonstrate its better adaptability to lower temperatures than the most common type G (Vivan & Panizzi 2005).

The proportions among the types found in Brazil, the type G being much more abundant than the others, and type Y being rare, are in accordance with data in the literature for other regions of the world. For example, in a survey conducted in Macau (China), 85% of the specimens were of type G, 13% of type O, and less than 0.2% of type Y (Easton & Pun 1997). Hokkanen (1986) reported one specimen of type Y of 203 individuals (0.5%) in the United States. Because this last type was rare, no relationship of its occurrence with the latitude or temperature can be done.

The capture of *N. viridula* in the North Region in Boa Vista, RR (latitude 02º49' N) is a new record of its distribution in Brazil, and it means that the bugs are present at least in some localities of this area where soybean is being introduced, since they were not captured in Belém, PA (latitude 1º 32' S) nor in Rio Branco, AC (latitude 9º 58' S) toward the west, where the crop is absent. Very probably *N. viridula* is already present in these two last states, feeding on wild legumes, but no records of its presence are available.

The significant positive correlation of latitude and negative correlation of temperature with the occurrence of type O (*torquata*) demonstrates that this type is more adapted to areas with lower mean temperatures, and during the summer with longer days and during the winter shorter days.

In conclusion, the data from these surveys indicate that *N. viridula* is widespread in Brazil and that type G (*smaragdula*) is the best adapted to colonize different environments. Type O (*torquata*) is favored by the conditions in the South Region, which allow the gene(s) responsible for the polymorphism to be expressed.

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