SPATIAL DISTRIBUTION OF *COSMOCLOPIUS NIGROANNULATUS* STAL (HEMIPTERA: REDUVIIDAE) IN A CULTURE OF *NICOTIANA TABACUM.*

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RESUMEN

La presencia de depredadores en agroecosistemas puede garantizar la estabilidad de la población de insectos fitófagos minimizando sus daños en las plantas. La distribución espacial influye en la dinámica de las poblaciones y su conocimiento es esencial para determinar la función de fitófagos y enemigos naturales en un programa de control biológico. Se estudió la distribución espacial vertical (interplanta) y horizontal (intraplanta) de una población de *Cosmoclopius nigroannulatus* Stal (Hemiptera: Reduviidae) en un cultivo de tabaco. Se observaron 270 plantas en un área experimental del Departamento de Fitossanidade de la Faculdade de Agronomia de la Universidade Federal do Rio Grande do Sul – UFRGS, desde agosto de 1999 hasta abril del 2000. Las plantas se identificaron por coordenadas alfanuméricas, las hileras por letras y las plantas en cada línea por números. La distribución vertical en las plantas se evaluó considerando los tercios inferior, mediano y apical. Se anotaron la coordenada y localización en la planta de los adultos de *C. nigroannulatus* capturados en cada muestreo y la estructura (tallo, cara adaxial o abaxial de las hojas) en la que los insectos eran encontrados. De un total de 62 muestreos, el 52% de los resultados de distribución espacial entre plantas de los adultos se ajustaron a los modelos matemáticos Poisson y el 42% a la Binomial Negativa. Los índices de Dispersión se calcularon por la Ley de Potencia de Taylor y por el Índice de Iwao. El valor de ß (ß = 1,1624) obtenido por la regresión de Iwao no fue significativamente mayor que 1, indicando que no hay agregación. El valor estimado de b = 1,18 de la regresión de Taylor, aunque distinto, se acerca al 1, indicando un agregado débil en la mayoría de las densidades. La ocurrencia del estándar agregado en algunas ocasiones, se debe posiblemente al comportamiento reproductivo de cortejar y copular. En la primera generación, la región media presentó la mayor concentración de individuos y, en la segunda, el tercio apical. En todas las generaciones, la mayoría de los adultos se encontraron en la cara adaxial de las hojas.

Palabras clave: Distribución espacial, Harpactorinae, Reduviidae, *Nicotiana tabacum*, tabaco.

ABSTRACT

Presence of predators in agriculture systems may guarantee stability of phytophagous insect populations, minimizing their damage to plants. Spatial distribution influences population dynamics and its knowledge is essential to determine the function of phytophaga and natural enemies in a biological control program. Vertical (interplant) and horizontal (intraplant) spatial distribution of a population of *Cosmoclopius nigroannulatus* Stal (Hemiptera: Reduviidae) were studied on a tobacco crop. A total of 270 plants were observed at an experiment area of the Departamento de Fitossanidade, Faculdade de Agronomia, Universidade Federal do Rio Grande do Sul – UFRGS, from August 1999 through April 2000. Plants were identified by alphanumeric coordinates, the rows with letters, and plants on each line by numbers. Vertical distribution on the plants was evaluated in the lower, medium and apical thirds. Coordinates and location on the plants of adult *C. nigroannulatus* captured on each sampling, and plant structure were insects were found (stem, adaxial or abaxial leaf face) were annotated. From a total 62 samplings, 52% of the results of interplant spatial distribution of adults adjusted to the Poisson mathematical model, and 42% to the Negative Binomial. Dispersion index were calculated through Taylor Power Law and by the Iwao index. The value of ß = 1.1624 obtained by the Iwao regression was not significantly greater than one, indicatin that there is no aggregation. The estimated value of de b = 1.18 by Taylor's regression, although distinct, nears 1, indicating a weak aggregate in most densities. The occurrence of the standard aggregated in some occasions, is due possibly to the reproductive behavior of courtship and mating. In the first generation, the medium third had the greatest concentration of individuals, and in the second, the apical portion. In all generations, most adults were found on the upper side of the leaves.

Key words: Harpactorinae, Reduviidae, *Nicotiana tabacum*, tobacco, spatial distribution.

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INTRODUCTION

The spatial distribution of a population is the position that individuals occupy in relation to others in a given environment and on a certain moment (Southwood, 1978; Ricklefs, 1996). Different reactions to biotic or abiotic environmental stimuli make populations use space in distinct ways (Krebs, 1985).

The distribution pattern influences the dynamics of populations. Differences in the impact of several agents may occur in function of spatial variations in the proximity of individuals within a population (Heads & Lawton, 1983; Hassell, 1987). Thus, the spatial distribution pattern identification is a fundamental aspect for the understanding of the population ecology. It also supplies subsides which could help to detect which are the main factors that determine numeric oscillations and even persistence in natural environments (Berryman & Gutierrez, 1999).

The majority of insects seldom disperse at random in their natural environment, since few environments are homogenous and the behaviors producing insect dispersion are usually specific and non random. Aggregation in insects, as well as in other animals, seems to be a fundamental characteristic originated from a great variety of ecological effects: (1) responses to physical factors of the environment; (2) responses to the host plants; (3) reproduction behavior; (4) mutual attraction with other individuals of the same species; and (5) interaction with other organisms (Waters, 1959).

In the specific case of predatory species, the spatial distribution may be directly related to prey distribution. Variations in insect population densities may affect economic interests, mainly when they are associated to agricultural activities. There are not many studies on the spatial distribution of insects in agroecosystems. Vickerman & Sunderland (1975) studied in USA the vertical distribution of many predatory arthropods of aphids in cereal crops. They distinguished the ones found on the ground from those present on the plant, during the day and at night. Funderburk & Mack (1989) carried out a survey of the spatial distribution patterns of predators of the Nabidae family in soybean crops, in Florida and Alabama, USA in search for data on the impact these predators had upon pests of this crop. Shipp *et al.* (1992) determined the pattern of intra and interplant distribution of two *Orius* species (Hem., Anthocoridae) in greenhouse-grown sweet pepper, in Canada. In the Hubei province, China, Zhang *et al.* (1994) studied the spatial distribution of *Orius similis* Zheng and its interaction with *Pectinophora gossipella* Saunders (Lep., Gelechiidae), a pest of cotton.

In an experimental tobacco area in Porto Alegre, RS, Canto-Silva (1999) evaluated the pattern of spatial distribution of eggs, nymphs, and adults of *Spartocera dentiventris* (Berg) (Hem., Coreidae) and estimated the mortality of immature phases. An aggregated pattern was observed for immature phases and a random pattern for adults. The action of natural enemies, especially *Cosmoclopius nigroannulatus* Stal (Hem., Reduviidae) was found as the main factor of the nymphs' mortality. Parseval (1937), Silva *et al.* (1968) and Caldas (1998) have also indicated this species as a predator of *S. dentiventris* in tobacco crops.

In a laboratory study Fallavena (1993) observed that *C. nigroannulatus* accepts a great variety of prey, among them three chrysomelids associated to the tobacco culture: *Diabrotica speciosa* Germar, *Epitrix fasciata* Blatchley and *Cerotoma arcuata* Bechyné. Furthermore in a pilot-study carried out in an experimental tobacco plot in Porto Alegre, RS, *C. nigroannulatus* was observed predating, in addition to nymphs of *S. dentiventris*, also aphids, *E. fasciata*, *C. arcuata* and *D. speciosa.*

Since *C. nigroannulatus* is a very promising biocontrol agent the present work has aimed at determining the vertical spatial (intraplant) and horizontal (interplant) distributions of the egg and adult phases of a population of *C. nigroannulatus* in tobacco culture.

MATERIAL AND METHODS

Fieldwork was carried out on a tobacco crop, at the experimental area of the Department of Fitossanidade of the Federal University of Rio Grande do Sul (UFRGS), Porto Alegre (30° 01'S and 51° 13'W), Brazil. In the beginning of August 1999, 270 tobacco seedlings of *Nicotiana tabacum* L. (Solanaceae) were planted in ten rows. The distance between rows was 1m, and 0.8m between seedlings. No phytosanitary measures were taken.

All plants were identified with alphanumeric coordinates. Letters identified rows (A to J) and

numbers identified plants in each line. (1-27). The spatial distribution of *C. nigroannulatus* adults was evaluated by daily inspection of all the plants in the plot from August 3rd to December 15th, 1999 and three times a week until April 5th, 2000. All adult individuals of *C. nigroannulatus* found were registered, accordingly to the sex. Males and females could be distinguished by an abdominal shalow beige grove that only females have in the 8th abdominal segment.The vertical distribution on the plant was evaluated, considering three regions: inferior, middle, and apical third. The portion of the plant where the adults were found was also identified: stem, abaxial or adaxial surface of the leaves. All plants were inspected and every time an adult was found its code number plant coordinate and position in the plant was registered. After this procedure each individual was returned to the plant at the same location where it was found.

For spatial distribution analysis, it was considered only those occasions when the number of individuals captured was equal or higher than 8 because the tests for spatial distribution are sensitive to the size and number of sampling units and to the frequency of zeros of the sample (Krebs, 1989), so, small samples may disguise the results Data fitting to Poisson distribution were tested by dispersion index I (Krebs, 1989), which evaluates the relation between sample mean and variance through the formula: $I = s^2 / x$, where s^2 = variance; x = arithmetic mean. Goodness-of-fit was tested by (Krebs, 1989): $\chi^2 = I$ (n-1), where χ^2 = chi-squared calculated; I = dispersion index; n=number of sample units.

Data fitting to Negative Binomial were tested by the U test of Mann-Whitney, which considers the difference between the estimated variance of the sample in relation to variance expected in a Negative Binomial, according to the formula: $U = s^2 - (x + x^2 / k)$, where k = index of dispersion of the Negative Binomial (Elliot, 1983). The acceptance of fitting of the Negative Binomial was calculated by the standard error of U (SE(U)), through the equation:

$$EP(U) = \sqrt{\frac{1}{n}\left\{2\bar{x}(\bar{x}+a)(b)\left[\frac{(b^2)(\log_e b)-a(1=2a)}{(b)(\log_e b)-a}\right]+c\right\}}$$

$a = \bar{x}/k$; $b = 1+a$; $c = \{ba^4 / [b(\log_e b)-a]^2\} \{b^{(1+\bar{x}/a)} - (\bar{x}+b)\}$

The dispersion indexes were calculated through Taylor's Power Law and the Dispersion Index of Iwao. Taylor's Power Law expresses the relation between variance (s^2) and mean ($\bar{x}$). The linear regression between the mean and variances of the data series was calculated using transformed data: $\log(\bar{x}+1)$ and $\log(s^2+1)$ respectively. Through this way, we obtained the values of *b* and log *a* from the regression line: $\log y = bx + \log a$, where *a* is the function of the sample size, and *b* is the index of aggregation that describes a continuous gradient of distributions (Elliot, 1983). Iwao Regression relates the accumulated mean ($\bar{x}^* = \bar{x} + [(s^2/\bar{x}) - 1]$) and the mean ($\bar{x}$), using the linear regression: $x = \beta x + a$. The intercept (α) is the basic aggregation index and the inclination of the line (ß) gives the aggregation coefficient. (Elliot, 1983)

Vertical distribution, intraplant, and in different plant structures, of adults was tested by the χ^2 test.

The software Microsoft Excel 7.0 and Bioestat 2.0 were used for calculations.

RESULTS AND DISCUSSION

In the inspections realized, in 107 of them, individuals were registered, however in only 62 of them 8 or more adults of *C. nigroannulatus* were registered. In those sampling occasions (Table 1), spatial distribution was better described by Poisson model (58.06%). This mainly random spatial distribution, seems to reflect the predator behavior, which tries to distribute all over the area, searching for preys. It should be pointed that the main prey of *C. nigroannulatus* (nymphs of *S.dentiventris*) presents an aggregated distribution pattern (Canto-Silva, 1999). In fact, along the present experiment it was observed the existence of nymphs' aggregates of *S. dentiventris* in certain plants. Despite of this, adults of *C. nigroannulatus* did not concentrate in these places. This kind of pattern could be expected because predators and preys show different spatial scales for habitat occupation. According to Roos *et al.* (1998) prey usually occur in patches and migrate few between them, otherwise predators generally are distributed homogeneously among the patches and shows a foraging behavior in a large scale and also great

dispersion. Besides this aspect, the registered pattern may be a consequence of the high mobility presented by individuals of this predatory species.

Mean values of k, close to zero, indicate a strong aggregation in those occasions fitted to the Negative Binomial distribution. In the first generation, although most of the data adjusted to the Negative Binomial (57.14%), a mean k value higher than the others indicates a weaker aggregation, in other words, the clumps are small or with a low number of individuals. This dispersion pattern becomes clear when further tests are presented.

Spatial distribution patterns observed in *C. nigroannulatus* were similar to those found in other predatory insects. Funderburk & Mack (1989) working with damsel bugs registered random distributions in most occasions. The aggregated pattern was found in only 25% of sampling occasions. In the same way, the spatial pattern of adults of two *Orius* species was random in an experiment carried out by Shipp *et al.* (1992) in sweet pepper grown in greenhouses. Ruf & Kehr (1995), studying the spatial distribution of *Pelocoris* (*P.*) *binotulatus nigriculus* Berg in lake shores, in Argentina, registered a random pattern in 64% of sampling occasions.

In those occasions when the spatial distribution fitted the Negative Binomial, revealing an aggregated pattern, it seems to be strongly connected to the reproductive behavior of the species. Groot (2000) comments that many "heteropteran" produce sexual pheromones to attract individuals of the opposite sex, which act at long distances. In pentatomids the emission of acoustic signals to attract a partner at shorter distances has been registered (Tood, 1989). In the present study, 87% of the cases when ·two individuals were found in the same plant, they were of different sexes. In plants where three or four individuals were found, there were one female and two or three males, indicating a probable competition for mating. Waters (1959) considers that the reproductive behavior may cause an aggregated pattern in the population.

Figure 1 presents a graphic representation of some sampling days. The visual analysis of this representation seems to indicate a random distribution in all occasions. However, on December 13th 1999, December 29th 1999, January

12th 2000, and March 27th 2000 the data adjusted to the Negative Binomial distribution. It should be observed (Fig. 1), that aggregates are small (two or three individuals), which reinforces the idea that this pattern depend on sex of aggregated individuals.

Another important aspect is that, although we have not computed data of the immature phase, we observed that nymphs, including the first instars presented a great mobility. In several occasions, we observed that nymphs of the same eggs batches did not remain in the plant they came from. Brewe & Story (1987) considered that the increasing randomness during the development could be due to a greater dispersion ability of the final phases. In this sense, rarely we registered the recruitment of two or more adult individuals in the same plant and in the same occasion. This reinforces the assumption that clumps are not large.

The ß value (ß= 1.1624) obtained for adults of *C. nigroannulatus*, by the Iwao regression (Fig. 2a) was not significantly higher than 1 (t=0.27; df=61; P>0.05). This value and the low value of the determination coefficient (r^2=0.06) indicate that there is no aggregation, and the individuals are distributed at random. In the same way, a low coefficient of determination points that there is not much fitting of data in the line, evidenced by the great dispersion of points in relation to the line. These results corroborate those obtained by the fitting of mathematical models of distribution (see Table 1), since most of the times, distribution of adults of *C. nigroannulatus* followed a random pattern.

The estimated value for *b* (*b* = 1.18) of Taylor regression for the whole sampling period was significantly higher than 1 (t = 4.12; df = 61; P<0.05) and the coefficient of determination value was high (r^2 = 0.92), indicating a good data fit (Fig. 2 b). The *b* value is close to 1, indicating a weak aggregated in most of densities. Zhang *et al.* (1994) found a similar result when studying the spatial distribution of the predator *O. similis* registering a pattern close to random but with a weak aggregation, since the *b* index was equal to 1.05 and very close to 1.

When each· generation is compared independently, values of *b* obtained through the Taylor regression were not significantly higher than 1 (colonizing generation: *b* = 0.6045; r = 0.297; (t

= -1.47; df= 13; P>0.05)); (first generation: b = 1.19; r = 0.8879; (t=1.58; df= 13; P>0.05)) and (second generation: b = 1.09; r=0.8641 (t=1.24; df= 33; P>0.05)) (Fig. 3 a, b and c). In this case, the mathematical effect upon the Standard Error of each generation possibly results in this difference. The fact that separated generations show not-aggregated distributions strengthens the idea that, for the whole period, the aggregation is weak.

In relation to intraplant distribution (vertical stratum), in the period corresponding to the colonizing generation, plants do not allow a clear distinction among strata, therefore this generation is not considered in this analysis. Data of the first and second generations show significant difference among different strata (χ^2=140.07; df=10; P=0.05). In the period corresponding to the second generation in the area and to the senescence of plants (from the end of March) the higher concentration of individuals occurred in the apical third of the plant. This register may be reflecting that, in many plants, only leaves of the apical third have conditions for housing preys and therefore to attract predators to this region (FEALQ, 1992; Gallo *el al.,* 2002).

The distribution was not random with respect to the structure of plants (χ^2=50.31; df=15; P<0.05). The adaxial surface of leaves presented the highest number of individuals at all periods relative to the stem and abaxial surface of leaves. The preference for the adaxial leaf surface may be due to the fact, among others, this place provides individuals a wider visualization field of their preys as well as make it easier to start a flight.
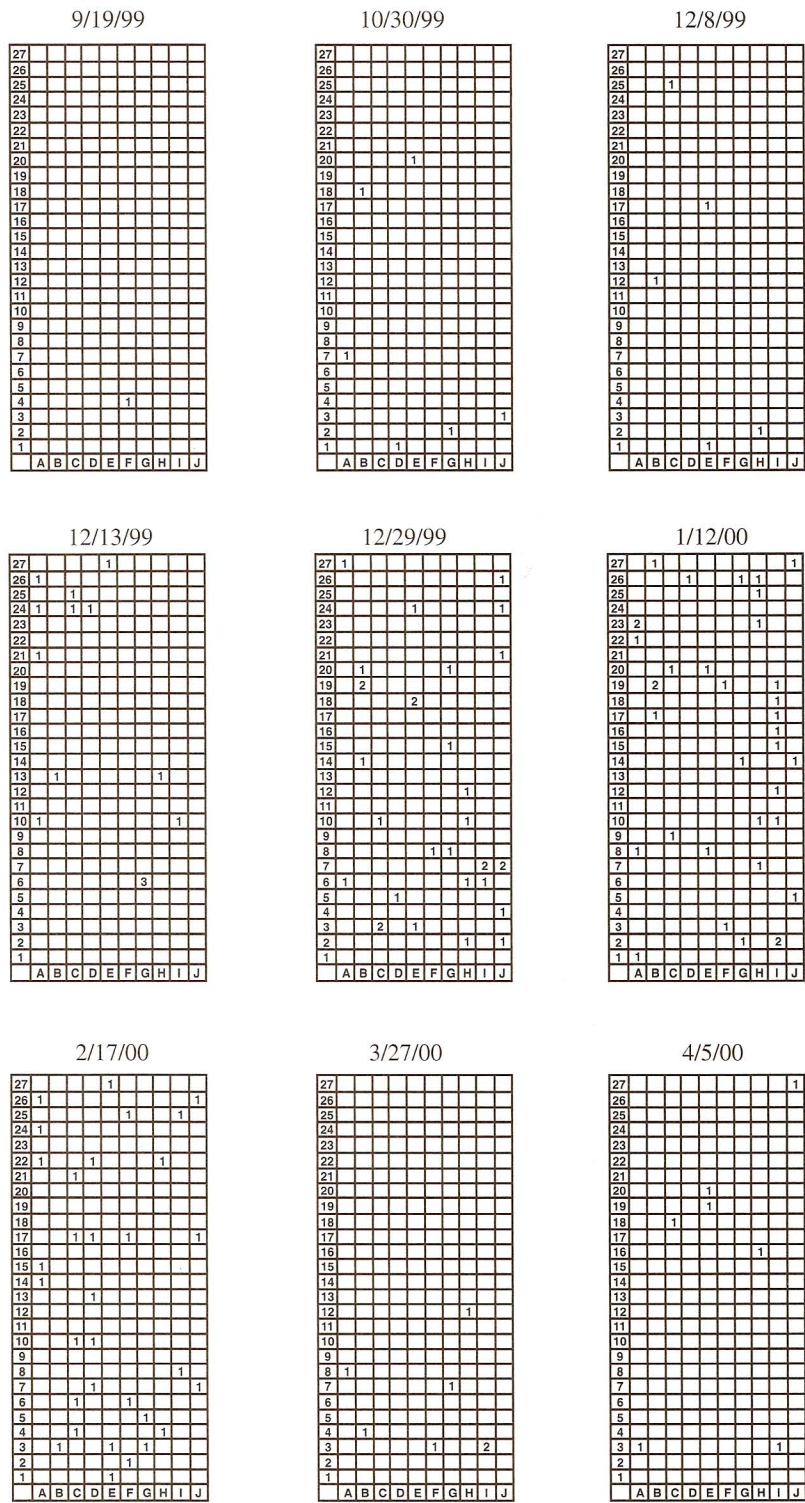
The characteristics of spatial distribution of *C. nigroannulatus*, indicate that this predator covers efficiently the whole area and, consequently make a good use of the available resources. This aspect is important from the agricultural point of view and strengthens the hypothesis that this species may be useful in biological control programs.

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Generation	Total number of sampling occasion	Poisson		Neg bin.		Mean k
		n°	%	n°	%	
Colonizing	14	7	50	7	50	0.133
1st	14	6	42.86	8	57.14	0.431
2nd	34	23	67.65	11	32.35	0.77
Total	62	36	58.06	26	41.94	0.286

Table 1 - Number of sampling occasions where *Cosmoclopius nigroannulatus* adults' spatial distribution was evaluated, number and percentage of occasions in which distribution adjusted to Poisson and Negative Binomial and mean values of aggregation index k of Negative Binomial. Porto Alegre (30° 01'S 51° 13' W), RS. (9/19/99 to 4/5/00).

Figure 1. Representative diagram of tobacco experimental plot with the spatial distribution of *Cosmoclopius nigroannulatus* adults by plant, registered in 9 different sampling occasions. Porto Alegre (30 01'S 51 13' W), RS.
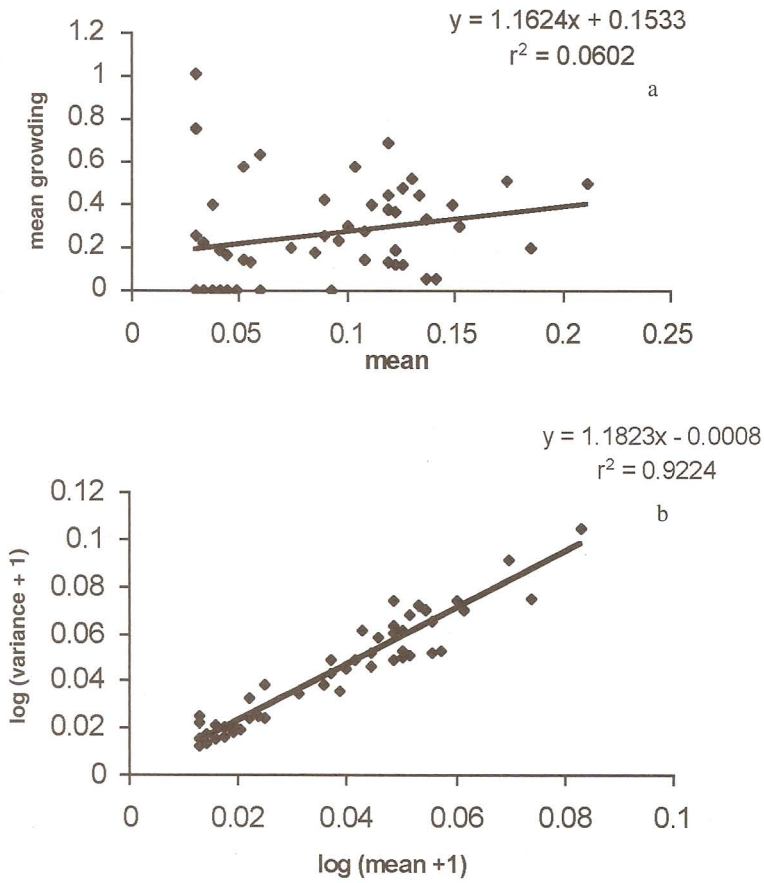
Figure 2. Regression of mean number of adults of *Cosmoclopius nigroannulatus* by plant by its variance in each sampling occasion according to Iwao regression (a) and the Taylor Power Law (b). Porto Alegre (30° 01'S 51° 13' W), RS. (9/19/99 to 4/5/00).
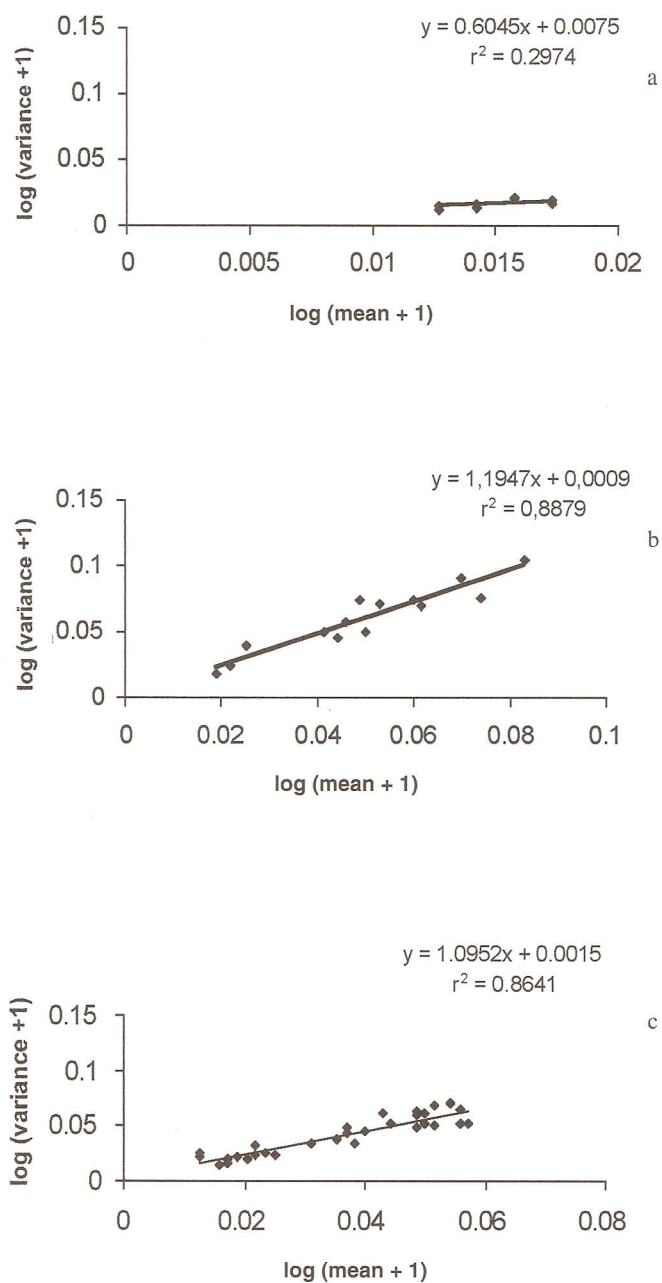
Figure 3. Regression between the mean number of adults of *Cosmoclopius nigroannulatus* in a plant by its variance for each sampling occasion, according to the Taylor Power Law, colonizing generation (a) first generation (b) and second generation (c). Porto Alegre (30° 01'S 51° 13' W), RS. (9/19/99 to 4/5/00).

REFERENCES

BERRY MAN, A. A. & A. P. GUTIÉRREZ, 1999. Dynamics of insect predator-prey interactions. In: Huffaker, C. B.& P. Gutierrez, Ecol. Entomol. 2. Ed. New York: John Wiley & Sons, p. 389-417.

BREWER, M. J. & R. N. STORY, 1987.Larval spatial patterns and sequential sampling plan for pickleworm, *Diaphania nitidalis* (Stoll) (Lepidoptera: Pyralidae), on summer squash. Environ. Entom.,*16*: 539-544.

CALDAS, B. C., 1998. Ciclo biológico de *Corecoris dentiventris* Berg, 1884 (Heteroptera, Coreidae) em cultura de fumo e morfologia das fases juvenis. Porto Alegre, 1998. 93 f. Dissertação (Mestrado) – Programa de Pós-Graduação em Fitotecnia. Faculdade de Agronomia. Universidade Federal do Rio Grande do Sul, Porto Alegre.

CANTO-SILVA, C. R. 1999. Aspectos da dinâmica populacional e distribuição espacial de *Corecoris dentiventris* em cultivo de *Nicotiana tabacum*. Porto Alegre, 1999. 167 f. Dissertação (Mestrado em Ecologia) – Universidade Federal do Rio Grande do Sul, Porto Alegre.

ELLIOTT, J. M., 1983. Some methods for the statistical analysis of samples of benthic invertebrates. 2. ed., Freswater Biological Association, 176p.

FALLAVENA, M.T.B., 1993. Aspectos biológicos e morfológicos de *Cosmoclopius nigroannulatus* (Stal, 1860) (Hemiptera, Reduviidae, Zelinae) Porto Alegre, 1993. 96 f. Dissertação (Mestrado em Zoologia) – Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre.

FEALQ. 1992. Curso de entomologia aplicada à agricultura. Piracicaba, FEALQ, 760p.

FUNDERBURK, J. E. & T. P. MACK, 1989.Seasonal abundance and dispersion patterns of damsel bugs (Hemiptera: Nabidae) in Alabama and Florida soybean fields. J. Entomol Sci. *24*: 9-15.

GALLO, D.; O. NAKANO; S. SILVEIRA NETO; R.P.L. CARVALHO; G.C. DE BAPTISTA; E. BERTI FILHO; J.R.P. PARRA; R.A. ZUCCHI; S.B. ALVES; J.D. VENDRAMIM; L.C. MARCHINI; J.R.S. LOPES Y C. OMOTO. 2002. Entomologia Agrícola. Piracicaba, FEALQ, 920p.

GROOT, A. T., 2000. Sexual behavior of the green capsid bug. Wageningen, 2000. 156p. Tese de doutorado - Wageningen University, Wageningen, Netherlands.

HASSELL, M. P., 1987. Detecting regulation in patchily distributed animal population. J. Anim. Ecol., Oxford, *56*: 705- 713.

HEADS, P. A. & J. H. LAWTON, 1983. Studies on the natural enemiy complex of the holly leaf-miner: the effects of scale on the detection of aggregative responses and the implications for biological control. Oikos, Copenhagen, *40*: 267-276.

KREBS, C. J. 1985. Ecology: the experimental analysis of distribution and abundance. 4. ed. New York: Harper Collins, 801p.

KREBS, C. J. 1989. Ecological metodology. New York: Harper & Hall, 654p.

PARSEVAL, M. von. 1937. As pragas do fumo do Rio Grande do Sul. Chácaras e Quintais, *56*: 489-494.

RICKLEFS, R. E. 1996. A economia da natureza. 3. ed. Rio de Janeiro: Guanabara/Koogan, 470p.

ROOS, A.M.; E. MCCAULEY & W. G. WILSON. 1998. Pattern formation and the spatial scale of interaction between predators and their prey. Theoretical Populations Biology, *53*: 108-130.

RUF, M. L. y A. I. KEHR, 1995. Dispersión espacial y temporal de una poblacion de *Pelocoris (P.) binotulatus nigriculus* Berg (Heteroptera, Limnocoridae). Rev. Brasil. Biol., *55* (1): 141-146.

SHIPP *et al*. 1992. Spatial patterns of sampling methods for *Orius* spp. (Hemiptera: Anthocoridae) on greenhouse sweet pepper. Can. Ent. , *124* : 887-894.

SILVA, A. G. D. A. *et al*. 1968. Quarto catálogo dos insetos que vivem nas plantas do Brasil, seus parasitos e predadores. Parte II, 1 tomo, Rio de Janeiro, Ministério da Agricultura, 622p.

SILVA, E.N.; T. M. SANTOS & F.S. RAMALHO, 1997. Consumo alimentar e crescimento do predador *Supputius cincticeps* (Stäl) (Heteroptera: Pentatomidae) alimentando-se de lagartas de Curuquerê-do-algodoeiro. An. Soc. Entomol. Bras., *26* (2): 439-357.

SOUTHWOOD, T. R. E. 1978. Ecological methods, with particular reference to the study of insect populations. 2ed. London: Chapman and Hall, 524p.

TOOD, J. W. 1989. Ecology and behavior of *Nezara viridula*. Ann. Rev. Entomol., *34*: 237-292.

VENNISON, S. J. & D. P. AMBROSE, 1990. Diversity of eggs and ovipositional behavior in Reduviids (Insecta, Heteroptera, Reduviidae) of south India. Mitt. Zool. Mus. Berl., *66* (2): 319-331.

VICKERMAN, G. P. & K. D. SUNDERLAND, 1975. Arthropods in cereal crops: nocturnal activity, vertical distribution and aphid predation. J. Appl. Ecol., *12* (3): 755-765.

WATERS, W. E., 1959. A quantitative measure of aggregation in insects. J. Econ. Entomol. , College Park, *52* (6): 1180-1183.

ZHANG,G. *et al*. 1994. Spatial distribution of the flower bug, *Orius similis*, and its interaction with the pink bollworm, *Pectinophora gossypiela*, in cotton fields. In. J. Pests Man., *40* (4): 309-312.