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ECONOMIC INJURY LEVEL OF CITRUS BLACK-FLY IN COMMERCIAL 'PERA-RIO' ORANGE AREA[1]

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ABSTRACT – Citrus black-fly (*Aleurocanthus woglumi*) has become an important pest in many citrus-producing regions in Brazil, causing direct and indirect damage to plants. Due to the lack of studies on the economic injury level (EIL) for this insect, control efficiency can be impaired. The objective of this research was to determine the EIL and the influence on the productivity of orange trees colonized by *A. woglumi* nymphs in an orchard located in the municipality of Capitao-Poço, Pará, using statistical analysis and damage prediction models through multivariate statistics. Population levels varied along the experiment. Infestation by *A. woglumi* nymphs negatively influenced orange production in Capitao-Poço with the highest population densities of the pest associated to lower plant productivity. The level of *A. woglumi* infestation on orange trees resulting in economic losses was, on average, 47.63% of infested plants, ranging from 22.75 to 89.92% and EIL is expressed by equation $Y = 97.39 - 8.43x$.

Index Terms: Aleyrodidae, *Aleurocanthus woglumi*, Citrus, nymphs, EIL.

NÍVEL DE DANO ECONÔMICO PARA MOSCA-NEGRA-DOS-CITROS EM ÁREA COMERCIAL DE LARANJA 'PÊRA-RIO'

RESUMO – A mosca-negra-dos-citros (*Aleurocanthus woglumi*) tem-se tornado praga importante em diversas regiões produtoras de citros no Brasil, provocando danos diretos e indiretos às plantas. Devido à ausência de estudos acerca do nível de dano econômico deste inseto (NDE), a eficiência de controle pode ser prejudicada. O objetivo desta pesquisa foi determinar o nível de dano econômico e a influência sobre a produtividade de laranjeiras colonizadas por ninfas de *A. woglumi* em pomar localizado na cidade de Capitão-Poço, Pará, usando análise estatística e modelos de previsão de danos através de estatística multivariada. Os níveis populacionais variaram ao longo do experimento. A infestação por *A. woglumi* influenciou negativamente a produção de laranja no município de Capitão-Poço, com as maiores densidades populacionais da praga associadas à menor produtividade das plantas. O nível de infestação de laranjeiras por *A. woglumi* que resultou em dano econômico foi de, em média, 47,63% de plantas infestadas, com variação de 22,75 a 89,92%, e o NDE é expresso pela equação $Y= 97,39 - 8,43x$.

Termos para indexação: Aleyrodidae, *Aleurocanthus woglumi*, ninfas, NDE.

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INTRODUCTION

Important for local economy, citriculture in the state of Pará has reached high growth rates in the last ten years. With the advances in this period, Pará started to assume a prominent position as the largest producer in the northern region, being among the seven largest orange producers in Brazil, with production of 200,000 tons in an approximate area of 12,000 ha. Much of this production is exported to the state of São Paulo (world's largest producer) and to the northeastern Brazil (IBGE, 2016).

Citrus black-fly (*Aleurocanthus woglumi* Ashby, 1915), (Hemiptera: Aleyrodidae), is an exotic pest that had its first occurrence report in the State of Pará in the year 2001 (SILVA, 2005), being currently found in most citrus producing regions of Brazil, with its last occurrence report in the state of Paraná (MOLINA et al., 2014). This insect can cause direct (sap suckling) and indirect damages (association with the *Capnodium sp.* fungus) in citrus plants, reducing production, leading to death at high infestations, finding in the Amazon region ideal conditions for fast development and life cycle (PENA et al. 2009a; SILVA et al., 2011 a,b).

Citrus growers argue that the cost of producing orange has increased with difficulties of pest control, including citrus black-fly, which decimated orchards and demanded more care, and that the prices of product are relatively low due to the great power that the concentrated orange juice industry is willing to pay. Based on the above, pest control based on chemical control deserves special attention to the pest density that actually causes economic losses.

In this sense, several researches have been conducted in order to adequately handle citrus black-fly in citrus farms. Among these, the studies of Maia (2008), Silva et al. (2011a) and Silva et al. (2014) stand out, who verified, among others, its population dynamics, spatial-temporal distribution, and sequential sampling plan. In this sense, studying the Economic Injury Level (EIL), in addition to presenting an additional step in pest management, is an important component for cost-benefit analysis in Integrated Pest Management (IPM), which is a fundamental necessity for the decision-making in the application of phytosanitary products (SHIPP et al., 2000).

Pest control is an agronomic and statistical decision and the state of Pará has the greatest potential to carry out studies on citrus black-fly due to its time of introduction and adaptability to the climatic conditions of the region. In this way, it is essential to know the EIL of *A. woglumi* to develop a future management plan for this pest in order to obtain better application and use of pesticides, with the objective of improving productivity, reducing production costs and environmental impacts caused by excess use of pesticides, subsequently, to spread this knowledge to other Brazilian regions, where this pest is present.

It is noteworthy that studies on citrus black-fly EIL are scarce. Thus, the aim of this study was to determine the EIL of citrus black-fly (A. woglumi) in a commercial orange area in the state of Pará.

MATERIAL AND METHODS

The experimental area is located in eastern Amazon, at Nova Citropar SA Farm, located in the geographical coordinates: 01º 48 '38' 'S, 47º 11' 38 '' W in the municipality of Capitão Poço, State of Pará, responsible for approximately 80% of the citrus production in the state (IBGE, 2016), distant about 200 km from the state capital, Belém, corresponding to the microregion of the Guamá, mesoregion of northeastern Pará.

The soil was classified as Alicate Yellow Latosol, medium texture (EMBRAPA, 2006) and climate as Ami Type, according to the Köppen classification (ALVARES et al., 2013), presenting the highest rainfall indexes from January to March and the lowest from July to November (MAIA, 2008; SILVA et al., 2011a). The selected block was composed of orange trees of the Pêra-Rio variety (Citrus sinensis [L.] Osbeck) grafted on a 13-year-old Cleopatra mandarin (Citrus reshni Hort. ex. Tanaka), consisting of 16 ha plantation, with 4,600 plants distributed in 40 rows of 115 plants with 5 x 7 spacing.

The experiment was arranged in a completely randomized design (CRD), with six treatments and 12 replicates, each containing plots with 5 trees, making a total of 360 plants. Citrus trees were selected in the planting line and marked with ribbons of different colors, in order to identify and differentiate plants belonging to the experiment from the other plants in the area, and different colors corresponded to different treatments. During the research period (January to October 2010), the orange orchard was maintained in accordance with standard fertilization and cultural treatment recommendations for the region, and the orange trees were not screened.

Different levels of infestation of *A. woglumi* nymphs were maintained in orange trees by applying different insecticide concentrations of imidacloprid active ingredient (a.i.) of neurotoxic action in the insect, in the entire plant. Concentrations of 0%

(water only), 20%, 40%, 60%, 80% and 100% were applied to reach different levels of nymph density, with the first dose as control and the last as that recommended for the pest (0.004% a.i.). The different concentrations were labeled with different ribbon colors (black, blue, yellow, white, orange and red) followed in the same order of concentrations above, according to methodology adopted by Hassani et al. (2009).

To simulate the application recommended by the manufacturer, even at lower concentrations, 7 liters of syrup were applied per plant, as it is recommended the application of 2000 liters of syrup per hectare. The application of the phytosanitary product was carried out by a turbo atomizer driven by a 90 HP tractor. In each of the evaluated plots, 10 leaves among fresh shoots and mature leaves that were randomly selected were collected from the mean height of each marked plant, where the number of nymphs was recorded and used to determine the number of nymphal days according to methodology proposed by Burts (1988), represented by:

$$ND = \frac{(N_1 + N_2)}{2\,x\,\mathrm{D}} \qquad [1]$$

where N1 is the number of nymphs in the first data count, N2 is the number of nymphs in the subsequent count to N1 and D is the interval of days between N1 and N2.

At the time of fruit harvesting in October, end of the orange production season in the region, each treated plot was harvested and weighed in order to determine its production. To calculate the estimated EIL for the crop described by Pedigo et al. (1986), it was necessary to perform the regression analysis that according to Andrade (2007) consists of the verification of the relationship between a dependent and an independent variable. This relation is represented by the following mathematical model:

$$\mathrm{Y} = \alpha + \beta\mathrm{x} + \varepsilon \qquad [2]$$

where α is the intercept, that is, the value that Y (orange production-kg) assumes when the line cuts (intercepts) the ordinate axis, when X (average number of nymph days) is equal to zero; *β* is a slope measure and Ɛ is the random error. This model is called a simple linear regression model, where a linear relationship between the dependent variable and the independent variable is defined.

After determining the slope of the regression curve expressed by the *β* value, it was used as part of the mathematical model to determine EIL, given by:

$$NDE = \frac{\mathrm{C}}{(\mathrm{V}\,x\,\mathrm{b}\,x\,\mathrm{K})} \qquad [3]$$

where C is the cost of control (cost of pesticide + cost of application), per production unit (R$ / ha), V is the crop market value (R$ / 20 kg box), b is the slope of the regression curve of the number of nymphs in the loss of productivity and K is the reduction of the injury by the treatment. In the mentioned work, the value of 80% of control efficiency was adopted because it is the criterion of efficiency required by the ministry of agriculture for the registration of insecticides for agricultural use in Brazil (MAPA).

In order to verify if the number of *A. woglumi* nymphs was related to the production of orange fruits, they were divided into categories so that the correspondence analysis technique could be applied, which according to Cunha Júnior (2000), consists of the association of categorical variables in a bivariate form (Simple Correspondence Analysis - AC), by means of a perceptual / intuitive map, in which it was verified whether there was proximity (similarity) of the proposed object from variables in a specific study. The perceptual / intuitive map was defined by Hair et al. (2009) as a visual representation of the perceptions of objects of an individual in two or more dimensions.

For the correspondence analysis to be effectively applied, the analyzed pair of variables should be submitted to the Chi-square test (x^2), given by:

$$x^2 = \sum_{\mathrm{i}} \sum_{\mathrm{j}} \frac{(O_{ij} - E_{ij})^2}{E_{ij}} \qquad [4]$$

where O_{ij} is the observed frequency and E_{ij} is the expected frequency. The significance of x^2 indicates significant deviations of the line profiles in relation to its centroid, with significance level, generally α = 0,05.

After performing the x^2 test, the second validation test is the criterion *β*, which indicates if the application of the correspondence analysis among variables is valid or not, that is, the resultant value of the test must present statistical significance. The calculation of the criterion *β* value is given by

$$\beta = \frac{x^2 - (l-1)(c-1)}{\sqrt{(l-1)(c-1)}} \qquad [5]$$

where χ2 is the chi-square value, l is the number of lines, c is the number of columns, O is the observed frequency, and E represents the expected frequency (4). If β> 3, variables are said to be associated with each other (dependent) at a risk less than and equal to 5% and, consequently, the correspondence analysis is applicable in the respective variables. It is recommended to perform the β criterion before the application of the technique, because if β is less than 3, the technique cannot be applied because the criterion indicates independence between variables.

After the performance of the chi-square and β criterion tests, it was necessary to perform the residue analysis in order to verify which categories actually had significant associations. The residue for each cross of categories of variables under study Z_{res} is given by:

$$Z_{res} = \frac{O_{ij} - E_{ij}}{\sqrt{E_{ij}}}, \quad i = 1, \cdots, l \quad \text{e} \quad j = 1, \cdots, c \qquad [6]$$

The respective confidence levels were calculated for each residue Z_{res} in order to determine the likelihood of association between categories of the variables under study.

$$\gamma = \begin{cases} 0, & \text{se } Z_{res} \leq 0; \\ 1 - 2 \times \left[1 - P\left(Z < Z_{res}\right)\right], & \text{se } 0 < Z_{res} < 3, \\ 1, & \text{se } Z_{res} \geq 3, \end{cases} \qquad [7]$$

In which Z_{res} is a random variable with standard normal probability distribution and for effect of significant statistical relation were considered $\gamma \geq 0{,}70$.

RESULTS AND DISCUSSION

The number of *A. woglumi* nymphs varied during the execution of the experiment, showing an efficiency of the gradient indices between the insecticide concentrations and the pest growth in the study area (Fig. 1).

Nymph densities increased and showed an increasing behavior in almost all treatments along the fruiting and maturation of orange fruits, even submitted to chemical treatment, agreeing with results observed by Maia (2008), Silva et al. (2011a) and Silva et al. (2014), which showed a natural growth of the insect in the same period of the year due to the decrease of rainfall and the increase of plants with new leaves, preferred by citrus black-fly nymphs.

There has been a reduction in the number of citrus black-fly nymphs, which demonstrates efficiency of chemical control when the area is in high infestation of the pest, even if the insect shows a growth in the course of treatment. According to Medeiros et al. (2009) and Silva et al. (2011a), citrus black-fly occurs in all months of the year with population peaks, concentrating on periods of low rainfall, a fact observed in the period from August to October 2010 in the municipality of Capitão Poço. These results favor the planning and execution of operational measures that are more feasible and safe for the control of these aleyrodidae within the principles of integrated pest management (IPM).

Based on the values of orange production and number of nymphs / day, the adjusted regression model was linear, where negative and significant relationship between number of nymphs / day and plot production in the different treatments was verified (Fig. 2).

For the application of the multivariate correspondence analysis (AC), the number of nymphs was classified as Low for amounts of nymphs from 126 to 586; Intermediate from 587 to 1047 and High from 1048 to 1509 nymphs / 10 citrus leaves. Production levels were classified as: Low for production volume from 7.41 to 26.01 kg; Intermediate from 26.02 to 44.61 and High from 44.62 to 63.23 kg / plant. The analysis of the relationships between the categories of variables was carried out from the calculation of the residues, presented in Table 1.

The increase in the mean number of nymphs / day has an inverse relation to orange production. As the angular coefficient value (b = 0.675) is negative, it is concluded that the production decreases with high infestation by *A. woglumi* nymphs, because when feeding on the plant, the pest removes organic products affecting fruiting, interfering with orange production (RAGA et al., 2013).

The values highlighted in bold in Table 1 show the confidence level, in which, for statistical effect, was equal to and greater than 70%. Figure 3 shows the perceptual map of these relations, showing that the inertia percentages of dimensions 1 and 2 restore 100% of the information. Thus, the analysis focuses on these two main component dimensions.

Other analyses were performed considering the values used in the municipality of Capitão Poço due to the sale price of a 20 kg orange box, which has its market value ranging from R$ 3,80 to R$ 8,00 due to the quality of the orange offered, and the operating costs, which oscillate between R$ 57,00 and R$ 107,00 (values at the time of the experiment). Thus, it was found that the number of approximately 13 to 15 boxes per hectare was necessary to pay for the product application.

With the results from the application of the correspondence analysis evidenced in Table 1, it was verified that citrus black-fly nymphs and production are associated with each other, so they are dependent and have interaction, at a risk lower than and equal to 5% of significance. Orange trees with high levels of nymphs are associated with low production level, with level of confidence of 77%, that is, orange trees with high numbers of nymphs are associated with low orange production. It was also verified that the average level of nymphs is associated to intermediate production level, at the level of confidence of 70%, thus, orange trees with intermediate number of nymphs are associated with intermediate production. Finally, it was found that orange trees with low nymph level are associated with the high production level, at the level of confidence of 87%, indicating that orange trees with low number of nymphs were not incisively affected, affecting orange production.

The EIL values were calculated and expressed as a percentage, necessary to cause critical loss of production. These values were obtained based on the cost of insecticide application and market value of the 20 kg orange box. The calculated EIL interval for *A. woglumi* nymphs varied between 22.75 and 89.92% of plants infested by citrus black-fly nymphs (Table 2).

EIL values had mean value of 47.63% and ranged from 22.75 to 89.92% of citrus black fly infested plants, which shows a large amplitude in the amount of *A. woglumi* nymphs, necessary to interfere with orange production, a fact that may be associated with plant vigor that tolerates large amounts of insect or the density of citrus black fly's natural enemies present in the area, a fact observed by Pena et al. (2009b) and Raga et al. (2013) in their studies, with the entomopathogenic fungus of the species *Aschersonia* cf. *aleyrodis* Webber (Deuteromycotina: Hyphomycetes), and natural enemies (predators and parasitoids) that present efficient controls of *A. woglumi*.

These EIL values are influenced by the orange price along with the cost of control, which can also by influenced by the fruit supply and demand, labor, value of insecticide and fuel, since application is carried out with agricultural machinery. Observations by Agostinetto et al. (2005) demonstrated that the increase of variables included in the EIL calculation increases the values obtained.

Although the EIL values are influenced by variables, market value and application cost; the market value is a determinant variable for EIL because it presents a smaller amplitude of values when it is fixed, especially when the value paid by the 20 kg box is R$ 8,00. Even when the application cost values increase, the infestation density required to cause economic loss is not much influenced, thus denoting the importance of the market value. EIL is an important conceptual and practical tool for decision making in IPM programs (HIGLEY; PEDIGO, 1996).

From Table 2 of EIL, analysis of variance (Table 3) was performed to determine if the linear regression model was appropriate to generate a mathematical model that could estimate EIL for any market value.

The lack of adjustment was not significant at 5% probability level, which implies the appropriation of the linear regression model adopted. The calculated F value was significant at 5% probability level, which implies that the market value affects EIL, causing it to decrease with the increase in the orange market value.

The mathematical model generated by the regression analysis was given by: $Y = 97.39 - 8.43x$ where Y is the EIL value and X is the market value of a 20 kg orange box. From the regression model adjusted to estimate EIL, it could be inferred about both EIL and the market value, since with the formula, it is possible to estimate the EIL value for any market value paid for the 20 kg orange box in the current market, thus facilitating the farm manager to apply the chemical control only when necessary, avoiding waste of product when there is no need of application and reducing the cost of control in the orchard.

Thus, there is no fixed value of the number of nymphs that can cause economic damage to the crop, but rather an estimate of the number of nymphs. This information can be considered by farm managers as a first-order guideline for the management of the citrus black-fly, a potential pest for citriculture, helping decision-making to apply the product to the control of the insect, in order to reduce costs with pesticides, increase profitability and contribute to protect the environment due to the rational use of agrochemicals, using them only when necessary.

TABLE 1 - Residues and confidence levels resulting from the correspondence analysis of the levels of citrus black-fly nymphs (*Aleurocanthus woglumi* Ashby) versus levels of orange production in the municipality of Capitão Poço, PA, 2010 harvest.

Nymphs	Orange production		
	Low	Intermediate	High
Low	-0.54 (0%)	0.08 (6%)	1.52 **(87%)**
Intermediate	-0.27 (0%)	1.04 **(70%)**	-1.21 (0%)
High	1.20 **(77%)**	-1.40 (0%)	-0.99 (0%)

TABLE 2 - Economic injury level (%) for citrus black-fly nymphs (*Aleurocanthus woglumi* Ashby) in orange trees in the municipality of Capitão Poço - PA, 2010 harvest.

	Cost of application of imidacloprid insecticide (R$/ha)				
Market value (R$/ 20 kg orange box)	**57**	**67**	**87**	**97**	**107**
3,8	47,91	56,30	73,12	81,52	89,92
4,4	41,37	48,63	63,13	70,39	77,65
5,0	36,40	42,78	55,56	61,96	68,34
5,6	32,51	38,21	49,61	55,32	61,01
6,2	29,37	34,51	44,82	49,96	55,11
6,8	26,76	31,47	40,85	45,56	50,25
7,4	24,59	28,92	37,54	41,85	46,18
8,0	22,75	26,75	34,73	38,71	42,72

TABLE 3 - Analysis of variance of data from Table 2.

Variation coefficient	**g.l.**	**SQ**	**QM**	**Fcal***	**Ftab****
Regression	1	5379.10	5379.10	35.78	4.15
Lack of adjustment	6	249.89	41.65	0.28	2.40
Treatments	7	5628.99	103.16	0.69	2.31
Residues	32	4811.41	150.36		
Total	39	10440.40			

***F calculated**
**** F table**

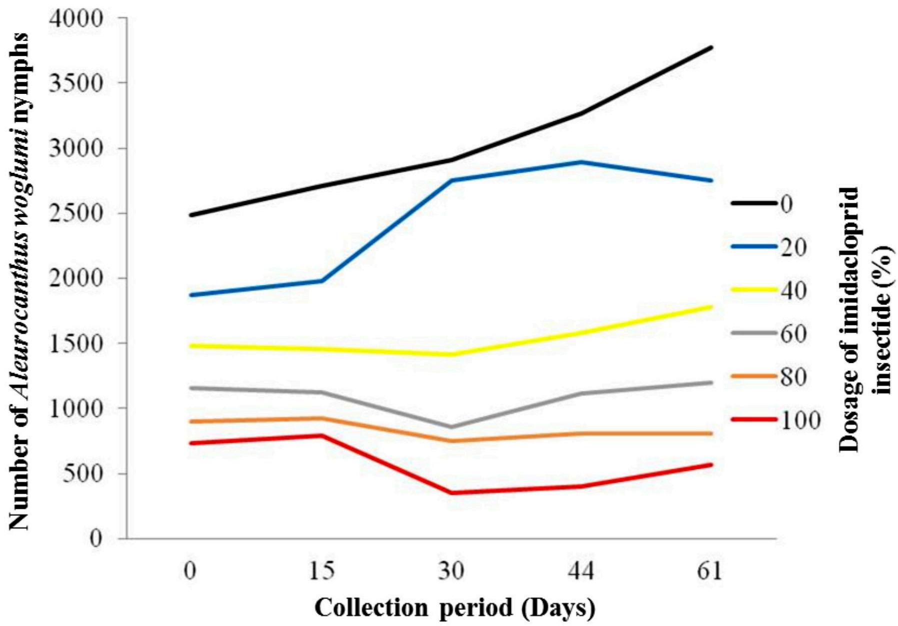

FIGURE 1-Number of citrus black-fly nymphs (*Aleurocanthus woglumi* Ashby) at different levels of chemical treatments in the orange crop, Pêra Rio variety, in the municipality of Capitão Poço - PA, 2010 harvest.

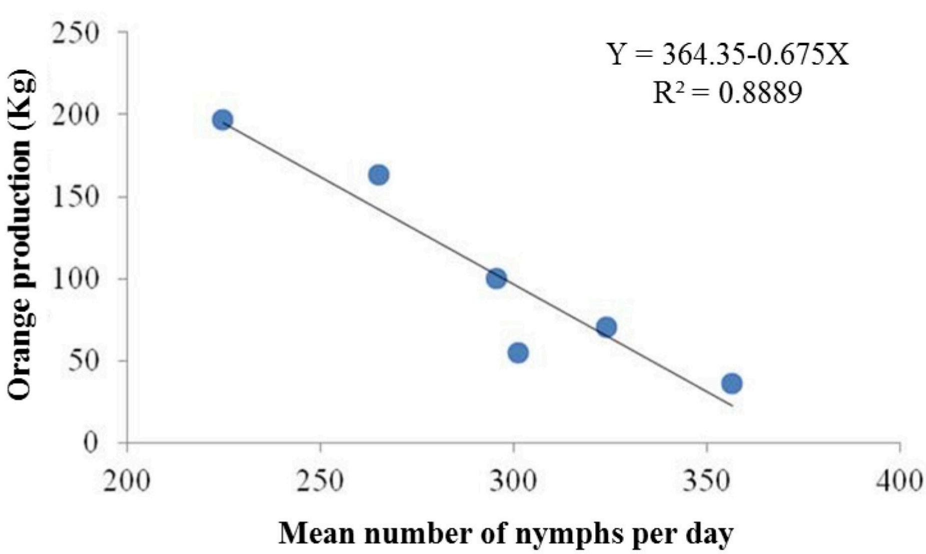

FIGURE 2 - Relationship between the mean number of nymphs / day (*Aleurocanthus woglumi* Ashby) and orange production in the municipality of Capitão Poço, PA, 2010 harvest.

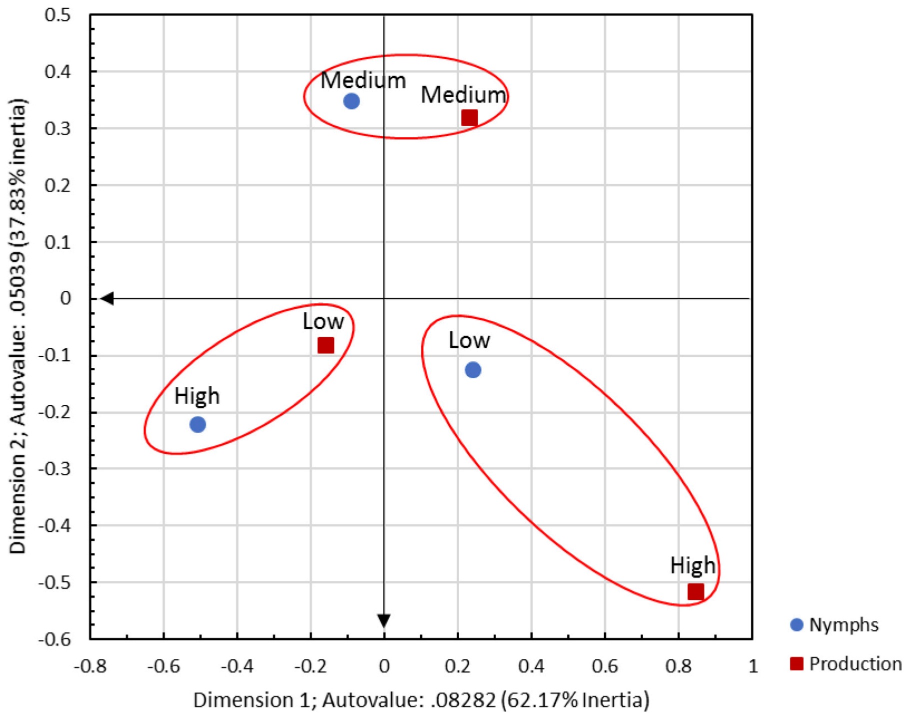

FIGURE 3- Perceptual map resulting from correspondence analysis applied to orange production (kg) variables and number of citrus black-fly nymphs (*Aleurocanthus woglumi* Ashby), in the municipality of Capitão Poço - PA, 2010 harvest.

CONCLUSIONS

Citrus black-fly negatively influences orange production in the municipality of Capitão Poço / PA.

High black fly nymph density is associated with low production level; intermediate nymph density is associated with intermediate orange production and low density is associated with the high production level.

The estimation of *A. woglumi* EIL for orange in the municipality of Capitão Poço / PA has average infestation of 47.63% and variation from 22.75 to 89.92% of infested plants per hectare and EIL is equal to Y = 97.39 - 8.43x, where variables in any value paid by the 20 kg orange box allow identifying EIL.

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