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# Population parameters as a way to evaluate the risk of attack of *Aphis craccivora* (Hemiptera: Aphididae) on cowpea

## *Parâmetros populacionais como forma de avaliar os riscos de ataque de* **Aphis craccivora** *(Hemiptera: Aphididae) em feijão-caupi*

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**ABSTRACT:** The objective of this research was to develop fertility life tables in order to estimate the population parameters of black aphid (*Aphis craccivora* Koch) in cowpea (*Vigna unguiculata*) varieties, aiming to propose a risk scale for its use. The experiment consisted of six treatments and six replicates (five varieties plus the cultivar VITA 7 as a susceptible control). A cohort was formed with six adult females distributed in six replicates of each genotype, and the insects were observed daily. Based on the data, fertility life tables were drawn for each variety and the population parameters were estimated. The different values of the finite growth rate (λ) were considered to propose a risk scale for the use of the genotypes. The results obtained give the dimension of the variability of *V. unguiculata* in respect to the character, resistance to *A. craccivora*, with antibiosis as the main mechanism of resistance. Considering all the results, the varieties studied can be classified according to their suitability as a plant favorable to the development of the black aphid as follows: VITA 7 > CE-13 > CE-51 > CE-08 = CE-07. The proposal of a risk scale for the use of *V. unguiculata* genotypes against the *A. craccivora* population, based on the finite growth rate (λ) values, was adequate to discriminate the varieties studied.

**KEYWORDS:** *Vigna unguiculata*; cowpea aphid; antibiosis; integrated pest management.

**RESUMO:** Objetivou-se nesta pesquisa elaborar tabelas de vida de fertilidade com o intuito de estimar os parâmetros populacionais de pulgão-preto (*Aphis craccivora* Koch) em variedades de feijão-caupi (*Vigna unguiculata*), visando propor uma escala de risco para o seu uso. O experimento constituiu-se em seis tratamentos (cinco variedades mais o cultivar VITA 7 como padrão de suscetibilidade) com seis repetições. Formou-se uma coorte com seis fêmeas adultas distribuídas em cada genótipo, sendo todos os indivíduos observados diariamente. De posse dos dados, foram elaboradas tabelas de vida de fertilidade para cada variedade e estimados os parâmetros populacionais. Para propor uma escala de risco de uso de genótipos, ponderou-se sob os diferentes valores da razão finita de crescimento (λ). Os resultados obtidos dão a dimensão da variabilidade de *V. unguiculata* com relação ao caráter da resistência a *A. craccivora*, sendo a antibiose o principal mecanismo de resistência associado. Considerando-se todos os resultados, foi possível hierarquizar as variedades estudadas segundo sua aptidão como planta favorável ao desenvolvimento ao pulgão-preto conforme segue: VITA 7 > CE-13 > CE-51 > CE-08 = CE-07. A proposta de uma escala de risco do uso de genótipos de *V. unguiculata* frente à população de *A. craccivora*, baseada nos valores da razão finita de crescimento (λ), foi adequada para discriminar as variedades estudadas.

**PALAVRAS-CHAVE:** *Vigna unguiculata*; pulgão-preto; antibiose; manejo integrado de pragas.

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## INTRODUCTION

The cowpea [*Vigna unguiculata* (L.) Walp.] stands out as an important crop for people that inhabits the tropical and subtropical regions of the world (TORRES et al., 2015). In Brazil, this plant is traditionally grown in the North and Northeast regions, and it is considered important as food and cash crop to the poorest populations in these regions. However, with the beginning of its exploitation in the Brazilian Cerrado, the cowpea, as other crops, started to be part of productive systems in large areas and, due to the continuous supply of food substrate, it favors the appearance of a pest complex of agricultural importance. This leads to an increasing in the demand for control inputs (FREIRE FILHO et al., 2011).

The black aphid, *Aphis craccivora* Koch, 1854 (Hemiptera: Aphididae), is considered a key pest of this crop (YADAV et al., 2015), having a short period of time among generations, high fertility and a high reproductive potential during its cycle (KLINGLER et al., 2001). In addition, it is responsible for causing direct damage by sap suction, such as plant depletion, and indirect damage by the transmission of viruses (OLIVEIRA et al., 2012; SILVA et al., 2012).

Right after the sowing of the crop in the field, species considered r-strategists, such as the black aphid, are the first to colonize the crop. In the absence of anthropic actions, they are mainly regulated by climatic conditions, although sometimes they can easily reach the pest status (BELL et al., 2007). However, within agroecosystems, integrated pest management (IPM) has been encouraged in order to keep the pest population below the economic damage level in a sustainable economical way; in this aspect, genetic plant resistance has been one of the main explored tools.

In several countries, mainly in the African continent, IPM for cowpea is a reality, with programs that involve consolidated management strategies that allow farmers to predict population outbreaks and, consequently, apply more appropriate control measures. A similar fact does not occur in Brazilian territory, with most studies focusing on common beans, *Phaseolus vulgaris*.

The study of fertility life tables is often used as a method for projecting the growth and population dynamics of different species of arthropods pests (OBOPILE; OSITILE, 2010; LA ROSSA et al., 2013; PEDRO NETO et al., 2013), because it provides useful estimates such as the period of development, survival and fertility rates in addition to other parameters that will help in planning a pest management program.

In Brazil, in recent years, research has been carried out to find genotypes of cowpea resistant to black aphid (SILVA; BLEICHER, 2010; SILVA et al., 2012; BANDEIRA et al., 2015; MELVILLE et al., 2016; NERE, 2016). However, there are still no reports on studies that assess the risks of *Aphis craccivora* population outbreaks resulting from the use of a specific variety or cultivar. Thus, the objective of this research was to elaborate fertility life tables in order to estimate the population parameters of *Aphis craccivora* Koch in cowpea varieties, aiming to propose a risk scale to be used in IPM.

## MATERIAL AND METHODS

The research was carried out in a greenhouse with sides covered with an anti-aphid screening and covered with a 200 µ thick plastic film, located in the experimental area of the Centro de Ciências Agrárias (3°40’24” S and 38°34’32” W at 12 m altitude) of the Universidade Federal do Ceará, in Fortaleza, Ceará, Brazil, at room temperature.

In this study, five local varieties that came from the Active Germoplasm Bank of the Universidade Federal do Ceará were used. They are: Roxão-1 (CE-13), selection within Roxão-1 (CE-51), Enrica Pobre (CE-36), Ritinha (CE-08) and Das Almas (CE-07). The cultivar VITA 7 from the International Institute of Tropical Agriculture (IITA) was used as a susceptibility pattern to *A. craccivora* (SILVA; BLEICHER, 2010).

Two seeds of each genotype were sown in a 300 mL polystyrene pot containing a substrate composed of sandy-clay soil, earthworm humus and vermiculite at 6:3:1 proportion. Five days after planting, thinning was carried out, leaving only one plant per pot. The most vigorous plants with similar height and canopy volume were selected to compose the experiment, being infested on the twelfth day after sowing with five/six-day old adult insects, from a colony of aphids of the same age group. Then, the plants were arranged equidistantly on benches and covered with anti-aphid cages (1.0 × 1.0 × 0.50 m).

In the morning, after a three-hour infestation, the adult insects and part of the nymphs were removed, leaving only two of them at places easily located. After a period of 24 h, the nymph best positioned in the plant was selected and the surplus was eliminated. In this way, a cohort was formed with six individuals, distributed in six replicates of each genotype, which were observed daily, taking note of mortality, number of offspring (which was then removed at each evaluation) and longevity of each insect within the cohort.

Using the daily average number of offspring and survival in the cohort for each age group, fertility life tables for the varieties were elaborated and the population parameters were estimated according to SILVEIRA NETO et al. (1976). The life tables made possible to verify survival at the time of the first offspring in the cohort (S $1^{st}$ O); gross reproduction rate (GRR), which, according to HOQUE et al. (2008), represents the total average number of nymphs produced per female during its life; and the relationship between Ro/GRR, in which the value close to 1.0 indicates no adverse effect of the genotype as food for the insect. They were also estimated:

The net reproduction rate: $Ro=\Sigma(x.l_x.m_x)$
The average interval between generations: $T=\Sigma(x.l_x.m_x)/\Sigma(l_{x.m_x})$
The intrinsic rate of increase: $(r_m)=r_{m=ln(R_0)/T}$
The finite rate of increase: $(\lambda)=exp^{rm}$.

Where: $l_x$ represents the percentage of living individuals in each age group $x$, and $m_x$ represents the average progeny in the cohort in this same age group.

The use of the different lambda values (λ) presented by SILVEIRA NETO et al. (1976) (Table 1) was considered to propose a risk scale for the use of *V. unguiculata* genotypes against the attack of *A. craccivora* at field conditions. Thus, considering that the finite rate of increase is represented by an exponential model, different values of λ will represent different population density curves and outbreak risk associated to them.

The finite rate of increase values estimated for the genotypes used in this research as well as the values found for the cultivar VITA 7 widely used in the world (SINGH et al., 2002) and other varieties were used to verify the usefulness of this scale.

## RESULTS AND DISCUSSION

The results presented in Table 2 indicate that the evaluated genotypes influenced the population parameters of *A. craccivora*. For the varieties Ritinha (CE-08) and Das Almas (CE-07), it was not possible to estimate any population parameter, as the aphids allocated on their plants died before reaching the reproductive state, showing a high degree of resistance to *A. craccivora* and suggesting antibiosis as the main associated mechanism of resistance.

**Table 1.** Values of λ presented by SILVEIRA NETO et al. (1976) and the proposed risk associated with them.

| Values of λ | Risk Scale |
|---|---|
| < 1.0 | Absence of risk |
| 1.1 – 1.25 | Low risk |
| 1.26 – 1.5 | Medium risk |
| 1.51 – 1.75 | High risk |
| > 1.75 | Extreme risk |

The percentage of survival in the cohort at the time of the birth of the first offspring (S 1st O) showed that only the cultivar VITA 7 kept the cohort intact, that is, all nymphs produced have reached adulthood and have been bred without any type of interference from the plant. While on the Roxão-1 variety (CE-13), the cohort had lost 50% of its population, on CE-51 (selection within Roxão-1) and Enrica Pobre (CE-36), only 16% of cohort remained, which indicates that the survival of the nymphs on these genotypes was seriously compromised (Table 2). Antibiosis also directly influenced the gross reproduction rate (GRR), varying from 0 to 48.60 nymphs per female (Table 2). According to PANIZZI; PARRA (2009) and LA ROSSA et al. (2013), the nutritional quality may vary depending on the host type, as well as the presence of substances of the secondary metabolism, these conditions could cause a decrease or increase in the insect's reproductive capacity.

From the RO values, which represent the number of times that individuals in the population will increase at each generation (HOQUE et al., 2008), it is possible to estimate whether this population will be able to grow (RO > 1), decrease (RO < 1) or remain stable (RO = 1) (MEDEIROS et al., 2017). For the varieties studied, RO values of 44.6 were obtained in 'VITA 7', 16.5 in Roxão-1 (CE-13), 0.64 for Enrica Pobre (CE-36) and 0.32 in CE -51 (Table 2). Based on these values, it is expected that the population in the last two genotypes will decrease at each generation and will not be established in the cultivation areas.

The correlation between RO/GRR, on the other hand, represents a value that the closer to the 1.0 unit, the greater the suitability of the host as food. In this case, the genotype 'VITA 7' (0.92) seems to have been the most favorable host. In contrast, the other genotypes, with the exception of Roxão-1 (CE-13), showed to be the least palatable food for aphids (Table 2).

Observing the data on the average interval between generations (T), the following values were obtained: 7.47 days for

**Table 2.** Survival on the first descendant (S 1 ° D), gross reproduction rate (GRR), net reproduction rate (RO), RO/GRR ratio, Mean interval among generations (T), intrinsic rate of increase ($r_m$), and finite rate of increase (λ) of *A. craccivora* in cowpea genotypes. Fortaleza, Ceará, 2015.

| Genotypes | S 1º D (%) | GRR | $R_0$ | $R_0$/GRR | T | $r_m$ | λ |
|---|---|---|---|---|---|---|---|
| 'VITA 7' | 100 | 48.60 | 44.60 | 0,92 | 7.47 | 0.51 | 1.66 |
| Roxão 1 (CE-13) | 50 | 43.30 | 16.50 | 0,38 | 13.33 | 0.23 | 1.26 |
| Seleção do CE-13 (CE-51) | 16 | 2.00 | 0.32 | 0,16 | 13.50 | -0.08 | 0.92 |
| Enrica Pobre (CE-36) | 16 | 4.00 | 0.64 | 0,16 | 13.75 | -0.05 | 0.95 |
| Ritinha (CE-08) | 0 | 0.00 | -(*) | - | - | - | - |
| Das Almas (CE-07) | 0 | 0.00 | - | - | - | - | - |

(*) Data not estimated due to the mortality of individuals before reaching reproductive age.

'VITA 7', 13.33 days for Roxão-1 (CE-13), 13.5 days for CE-51 and 13.75 days for Enrica Pobre (CE-36) (Table 2). The T value of 7.47 days for 'VITA 7', the 100% survival of individuals in the cohort at the time of the first descendant, and the RO/GRR ratio corroborate the fact that this genotype does not affect the biology of *A. craccivora*. On the other hand, Roxão-1 (CE-13), CE-51 and Enrica Pobre (CE-36) must have harmful substances that need to be metabolized and thus increase the generation time. VAN LENTEREN; NOLDUS (1990) state that a shorter development time and a greater number of descendants reflect the plant's suitability for the insect.

Values related to the intrinsic rate of increase ($r_m$) that estimates the multiplication capacity of the population in one generation varied according to the type of host (between 0.05 and 0.51 (Table 2). The cultivar VITA 7 showed a higher $r_m$ value (0.51). It is worth noting that MESSINA et al. (1985), using this same cultivar and insect over 30 years ago, in the United States of America, found a similar value for $r_m$, that is, 0.576.

DE LA PAVA; SEPÚLVEDA-CANO (2015), using a landrace, in Colombia, found $r_m$ of 0.30 and 0.32 for two cohorts of *A. craccivora*; therefore, lower than those reported here for 'VITA 7', indicating that this cultivar used by Colombian farmers has some resistance. Likewise, a $r_m$ of 0.23 for Roxão-1 (CE-13) provides similar information. On the other hand, negative $r_m$ values for CE-51 (-0.08) and Enrica Pobre (CE-36) (-0.05) indicate that the mortality rate exceeds the birth rate and, in this case, the invading population would not establish itself (SILVEIRA NETO et al., 1976).

Another very important parameter is the finite rate of increase (λ) that represents the number of times the population will multiply per unit of time. The λ values were quite different for the genotypes evaluated in this study, obtaining a higher value for the cultivar VITA 7 (1.66) and lower in the CE-51 genotype (0.92) (Table 2). For this parameter, the values below the unit (1.0) indicate that the population as a whole will decrease. Values close to the unity are indicative of a stable population.

The set of results presented in Table 2 gives a dimension of the variability of *V. unguiculata* in relation to the resistance to *A. craccivora*. Therefore, the finite rate of increase (λ) among them can be used in breeding programs for this plant species to avoid the release of highly susceptible cultivars or at least to signal the possible adverse effects of its use, at field conditions, taking in consideration the attack of the black aphid.

Thus, when comparing the value of λ for the cultivar VITA 7, it appears that it would be classified in the high-risk level, considering the proposed scale (Table 1). On the other hand, MESSINA et al. (1985), when estimating the value of λ for this same cultivar, obtained a value of 1.78 for the conditions in which the experiment was carried out, indicating a probable environmental effect or occurrence of a local biotype.

Based on the proposed scale, the variety Roxão-1 (CE-13) with λ of 1.26 would be in the medium risk category, whereas CE-51 (selection of Roxão-1) and Enrica Pobre (CE-36) with λ of 0.92 and 0.95, respectively, in the absence of risk category (Table 1). The varieties Ritinha (CE-08) and Das Almas (CE-07), as previously seen, would not allow the development of the black aphid, classified under the category of no risk.

OBOPILE; OSITILE (2010) and MACHACHA et al. (2012), using the cultivar Blackeye as a susceptibility pattern and aphids obtained from Botswana/Africa, observed λ values of 1.43 and 1.4 respectively. Similarly, DE LA PAVA; SEPÚLVEDA-CANO (2015), testing a landrace and aphids obtained in Santa Marta, Colombia, had values of λ of 1.34 and 1.38 for two cohorts, in the same genotype and in simultaneous studies. It appears that both in the case of Botswana and Colombia these genotypes would be in the medium risk category. On the other hand, when estimating the value of λ for the cultivar VITA 7 in aphids from the research carried out by MESSINA et al. (1985), a value for λ of 1.78 was obtained, classifying the cultivar in the category of extreme risk in that environment.

The proposed scale can become a valuable tool for the use of IPM with *A. craccivora* in cowpea, being able to warn about the consequences of launching certain cultivars classified in the extreme risk category. For example, if it is a material that has desirable agronomic and culinary qualities, it may be decided whether to launch it or not. In this case, knowing the possibility of black aphid population outbreaks, a management plan can be made with measures that may restrict the damages caused by this pest, such as refuge areas, sowing crop areas contrary to the direction of the wind, polyculture systems or intercropping with other crops, use of resistant plants, and, if necessary, use of insecticides. In the latter case, it is also necessary to warn of measures for the management of resistance to insecticides, in order to prevent the selection pressure within the population from causing the development of an aphid biotype tolerant to the agrochemical used. On the other hand, it can also be inferred that, although the cultivar is susceptible, but with other qualities of interest, it may be part of a genetic improvement program, being able to receive aphid resistance genes and still preserve its agronomic and culinary characteristics.

The cultivar VITA 7 is within the high-risk category, and, due to its agronomic qualities, was distributed by the IITA to several countries: Burkina Faso, Costa Rica, Democratic Republic of Congo, Brazil, Central Africa, Peru, South Yemen and Liberia (SINGH et al., 2002). This cultivar has been used as a susceptibility pattern to *A. craccivora* (SILVA; BLEICHER, 2010) and even so it was widely cultivated, sometimes requiring the use of agrochemicals, indicating that, although the genotypes occupy the risk range, they are still possible to be cultivated, provided the appropriate management strategies are used.

To released cultivars that fall into the medium risk category, the same previous guidelines may be considered. However, they must be cultivated in small areas, with refuge areas for natural enemies and preferably in mixed systems.

It is believed that cultivars in the low risk range cause a delay in increasing the population density of aphids, allowing colonization by natural enemies within the cultivated areas, thus reducing the possibility of an outbreak of the pest, and it may not be necessary to interfere with insecticides or be required in less quantity. In the latter case, more selective products should always be chosen.

Cultivars classified in the risk-free range, i.e. $\lambda < 1$, could be considered ideal, although there is a possibility of selection pressure on the population and consequent selection of a resistant biotype to the genotype. In this case, unlike high-risk cultivars, the selection would be exercised by the chemical substances inherent to the plant. According to ALIYU; ISHIYAKU (2013), it is not clear how a parthenogenetic species, such as cowpea aphid, suddenly produces biotypes; however, rare mutations, chromosomal rearrangements and mitotic recombinations can give rise to new individuals with specific characteristics.

Therefore, as already mentioned, the probable appearance of biotypes, both for the overuse of agrochemicals and for varieties highly resistant to aphids, should be part of the daily research in this area, as well as the constant search for genotypes with resistance characteristics, to face this constant threat of new biotypes for the different cowpea producing regions. Alerts in this regard have already been given by MESSINA et al. (1985), SILVA; BLEICHER (2010) and SOULEYMANE et al. (2013).

DOGIMONT et al. (2010) report the durability of resistance genes in different plant families to aphids of various species. These authors affirm that the resistance break is quite erratic, while for some species of aphid and plants the resistance lasted 10 or 20 years to be broken, there are examples of resistance break in 2 to 5 years, probably, evidencing, a huge range of variables involved and not yet clarified.

## CONCLUSION

The population parameters studied gives the dimension of genetic variability between the studied genotypes. The use of the finite rate of increase ($\lambda$) seems to be adequate to confirm a risk scale to be used in launching a new cultivar. The data set points to antibiosis as a probable type of resistance by *Vigna unguiculata*.

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