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## Within-plant distribution of cotton aphid (Hemiptera: Aphididae) in cotton cultivars with colored fibers

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### ABSTRACT

We describe the vertical and horizontal distribution of the cotton aphid *Aphis gossypii* Glover within a cotton plant in two cotton (*Gossypium hirsutum* Linnaeus) cultivars (BRS Safira and BRS Rubi) with colored fiber over the time. Measurements of aphid population dynamics and distribution in the cotton plants were recorded in intervals of seven days. The number of apterous or alate aphids and their specific locations were recorded, using as a reference point the location of nodes on the mainstem of the plant and also those on the leaves present on branches and fruit structures. The number of apterous aphids found on the cultivar BRS Safira (56,515 aphids) was greater than that found on BRS Rubi (50,537 aphids). There was no significant difference between the number of alate aphids found on the cultivars BRS Safira (365 aphids/plant) and BRS Rubi (477 aphids/plant). There were interactions between cotton cultivar and plant age, between plant region and plant age, and between cultivar and plant region for apterous aphids. The results of this study are of great importance in improving control strategies for *A. gossypii* in the naturally-colored cotton cultivars BRS Safira and BRS Rubi.

**Key words:** *Aphis gossypii*, behavior, cotton with colored fibers, distribution.

### INTRODUCTION

The cotton plant (*Gossypium hirsutum* Linnaeus) presents major environmental and economic benefits, as its naturally-colored cotton fibers do not need to be dyed using industrial processes. It thus does not demand the use of chemical products that are harmful to human health if not used appropriately. It also reduces water and electricity consumption and cuts down on effluent output. The chemicals used to dye fabric are harmful and often carcinogenic.

Naturally colored cottons are unique because they do not require dyeing in the fabric manufacturing process. In traditional processing cotton fibers are bleached and then colored with dyes that often contain heavy metals. The processing produces significant amounts of contaminated waste water. Processing naturally-colored cotton uses less water and energy. Accordingly, the use of cotton with naturally-colored fiber could be an interesting strategy to help reinvigorate the cotton industry in the Northeast region of Brazil.

One of this crop's limiting factors in Brazil is the attack by insect pests. The cotton, aphid *Aphis gossypii* Glover (Hemiptera: Aphididae) is

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a phytophagous, cosmopolitan (Celini and Vaillant 2004) and polyphagous (Oliveira et al. 2008) species that is found during the development phase of cotton plants. *A. gossypii* is the main cotton pest in Brazil (Ramalho 1994) and various other countries (Leclant and Deguine 1994, Wu and Guo 2003). High densities of this pest can have negative impacts on cotton production. In Brazil, losses caused by cotton aphid vary from 24% to 40% of cotton lint production (Calcagnolo and Sauer 1954).

Colonies of *A. gossypii* are generally located on the ventral parts of leaves; however, nymphs and adults can also be found on the dorsal parts of leaves (Gonzaga et al. 1991). Apterous and alate individuals may be found on a single leaf; however, the alate individuals occur more frequently in high-density infestations, where competition for food is greater (O'Brien et al. 1993). Their reproduction is parthenogenetic, with a reproductive period from five to 10 days, in which a female can produce up to 40 nymphs (Van Steenis 1992).

The abundance of aphids is generally seasonal, and may vary from year to year. Population fluctuation patterns for an aphid species may also differ among geographic regions, among different populations that have developed in the same region for some years, and among neighboring populations that have developed simultaneously (Cividanes and Santos 2003).

Knowledge concerning the vertical and temporal distribution of insect pests in the host plant is of great importance in developing integrated pest-management programs (Trichilo et al. 1993) and cutting the time and costs required to monitor the pest without negatively affecting the reliability of results (Wilson et al. 1982). Aphids are generally found in the upper and middle parts of the plant possibly due to the softness of the leaf tissue, which substantially facilitates the carbohydrate extraction by aphids (Weathersbee and Hardee 1994, Fernandes et al. 2001). According to Gonzaga et al. (1991), the vertical distribution of *A. gossypii* in cotton plants varies with the age of the plant. The

aphid development in the host plant depends on two main factors: the plant's characteristics and climate conditions (Ghovlanov 1976). The influence of the host plant on the success of a phytophagous insect species can be measured from three aspects: stimuli that lead insects to locate and choose the plant; plant conditions that lead to the initiation and maintenance of feeding; and finally the nutritional characteristics of the plant, which enable the development of the insect and its progeny (Ghovlanov 1976). Sucrose is the only sugar found in the cotton phloem sap (Tarczynski et al. 1992) and *A. gossypii* converts most of the sucrose it ingests into oligosaccharides. Carbohydrate concentration and content vary with the age of the plant (Wells 2002).

A lot of research has been conducted on the distribution of arthropods in cotton plants (Kuehl and Fye 1972, Wilson et al. 1983, 1984, Fernandes et al. 2003); there is, however, little information about the vertical and horizontal distribution of *A. gossypii* according to the age of colored-fiber cotton. Knowledge on the vertical and horizontal distribution of *A. gossypii* in naturally-colored cotton plants according to age may help to improve the decision-making process in integrated management programs for this pest. Accordingly, the aim of this study was to describe the vertical and horizontal distribution of the cotton aphid, *A. gossypii* within a cotton plant in two cotton cultivars (BRS Safira and BRS Rubí) with colored fiber over the time.

## MATERIALS AND METHODS

The study was carried out at in Experimental Station of the Embrapa Algodão, Campina Grande, Paraíba State, Brazil. The cultivars BRS Safira and BRS Rubí were planted in March 2009. The seeding rate varied between 17 - 19 seeds per m of row in 100 cm of row spacings, and row direction was E-W. The fertilizer was applied immediately before planting at 33.6 kg N/ha in dryland plots. A randomized block experimental design was used, with two treatments

composed of colored-fiber cotton cultivars BRS Safira and BRS Rubí, distributed in five replications, with each experimental unit composed of 25 plants.

Measurements of aphid population dynamics and distribution in the cotton plants were taken in intervals of seven days, from the moment of plant emergence until the appearance of the first open bolls. The number of apterous or alate aphids and their specific locations were recorded, using as a reference point the location of nodes on the mainstem of the plant (from node zero until the last node) and also those on the leaves/nodes of vegetative/fruitlet branches from inside leaf toward outside.

The numbers of apterous and alate aphids recorded per plant were tested for normality (Kolmogorov D: normal test) and homogeneity

of variance (Bartlett's test), and square root of ( $x + 0.5$ ) transformation was used when necessary; however, untransformed means are presented in tables and figures.

The mean numbers of apterous and alate aphids recorded on the first leaves originated from nodes on the mainstem were submitted to three-way analysis of variance (ANOVA) (cotton cultivar, cotton age and plant region) and Student-Newman-Keuls tests, with  $P < 0.05$ .

Each plant was divided into three regions: bottom (the lowest 1/3 of the plant), middle (the middle 1/3), and top (the upper 1/3 of the plant).

The percentages of apterous and alate aphids were recorded in relation to the nodes' vertical position on the plant (the lowest node = 1 and the highest = 20) or the leaf's position on

**TABLE I**  
Number of apterous aphids per plant (mean $\pm$ se) found on the leaf<sup>1</sup> of two cotton cultivars with colored fibers (BRS Safira and BRS Rubí) in function of age and cotton cultivar (F<sub>Cotton cultivar by age (13, 332)</sub> = 16.28;  $P < 0.0001$ ).

Plant age (day)	Cotton cultivars <sup>2</sup>	
	BRS Safira	BRS Rubí
1	0.00 $\pm$ 0.00 aA	0.00 $\pm$ 0.00 aA
7	0.00 $\pm$ 0.00 aA	0.00 $\pm$ 0.00 aA
14	0.56 $\pm$ 0.09 aA	0.00 $\pm$ 0.00 aA
21	14.65 $\pm$ 9.02 bAB	0.00 $\pm$ 0.00 aA
28	2.07 $\pm$ 1.01 aA	0.00 $\pm$ 0.00 aA
35	0.81 $\pm$ 0.04 aA	0.03 $\pm$ 0.01 aA
42	4.60 $\pm$ 2.01 aA	0.29 $\pm$ 0.09 aA
49	19.72 $\pm$ 10.20 bAB	1.96 $\pm$ 0.12 aA
56	37.27 $\pm$ 18.98 bBC	7.07 $\pm$ 1.98 aA
63	89.48 $\pm$ 22.76 bDE	23.33 $\pm$ 9.81aB
70	125.67 $\pm$ 31.12 bE	49.28 $\pm$ 17.99 aCD
77	89.08 $\pm$ 20.88 aE	74.28 $\pm$ 20.12 aD
84	51.37 $\pm$ 12.71 aCD	42.03 $\pm$ 18.09 aBC
91	49.28 $\pm$ 14.78 aCD	138.23 $\pm$ 40.12 bE

<sup>1</sup> First leaves come from mainstem nodes.

<sup>2</sup> Means with the same lower case letter within rows and means with a common upper case letter within columns do not differ significantly by the Student-Newman-Keuls test ( $P = 0.05$ )

the branches, using PROC REG (Sas Institute 2006). Furthermore, to test the hypothesis that the behavior of the aphid's vertical distribution on the plant varies according to the cultivar, the linear portion of fitted models was compared. Thus, the linear slopes of fitted models (i.e., first- or second-order models) of percentage of aphids per vertical (node on mainstem or leaf on branches) or horizontal (leaves and reproductive structures) structure or per horizontal were compared among cotton cultivars using PROC MIXED to test the equality of linear slopes (Sas Institute 2006).

### RESULTS

The results of this study show that the number of apterous aphids found on the cultivar BRS Safira (56,515 aphids) was significantly greater than that found on BRS Rubí (50,537 aphids) ( $F_{(1, 332)} = 183.83$ ,  $P < 0.0001$ ). However, there was no significant

difference among the number of alate aphids of the cultivars BRS Safira (365 aphids) and BRS Rubí (477 aphids) ( $F_{(1, 332)} = 2.55$ ,  $P > 0.1114$ ).

Considering the vertical distribution of apterous ( $F_{(26, 332)} = 1.82$ ,  $P > 0.1201$ ) and alate aphids ( $F_{(26, 332)} = 1.60$ ,  $P > 0.1010$ ) on the plants, no significant interactions were observed among cultivar, plant age and plant region. However, there were interactions between cotton cultivar and plant age ( $F_{(13, 332)} = 22.39$ ,  $P < 0.0001$ ) (Table I), between plant region and plant age ( $F_{(26, 332)} = 11.57$ ,  $P < 0.0001$ ) (Table II), and between cultivar and plant region ( $F_{(2, 332)} = 17.17$ ,  $P < 0.0001$ ) (Fig. 1) for apterous aphids.

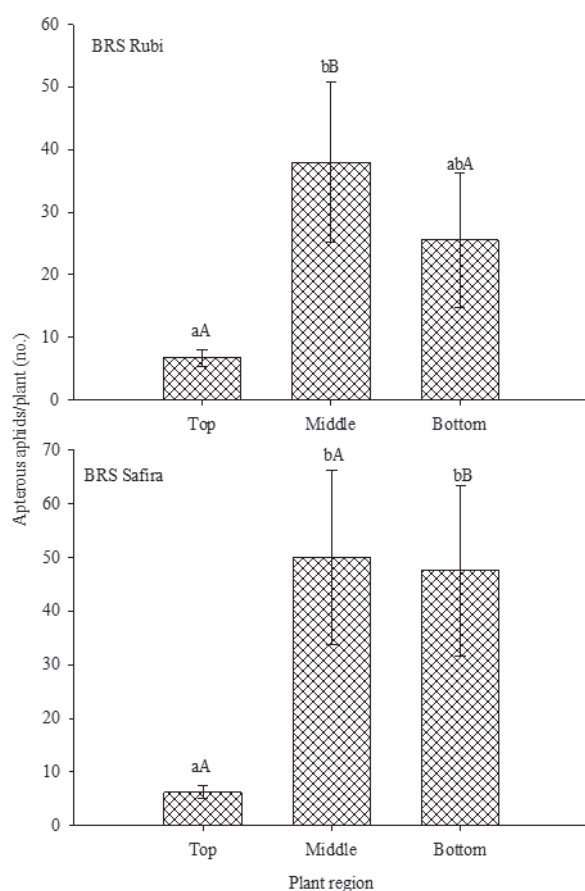
Similar results were observed for alate aphids, for which there was interaction between cotton cultivar and plant age ( $F_{(13, 332)} = 16.45$ ,  $P < 0.0001$ ) (Table III), between plant region and plant age ( $F_{(26, 332)} = 4.42$ ,  $P < 0.0001$ ) (Table IV), and between cultivar and plant region ( $F_{(2, 332)} = 6.59$ ,  $P < 0.0016$ ) (Fig. 2).

**TABLE II**  
Number of apterous aphids (mean±se) found on leaf<sup>1</sup> of two cotton cultivars with colored fibers (BRS Safira and BRS Rubí) in function of age and plant region ( $F_{\text{Region by age (26, 332)}} = 15.25$ ;  $P < 0.0001$ ).

Plant age (day)	Plant region <sup>2</sup>		
	Top	Middle	Bottom
1	0.00±0.00 aA	0.00±0.00 aA	0.00±0.00 aA
7	0.00±0.00 aA	0.00±0.00 aA	0.00±0.00 aA
14	0.36±0.14 aA	0.32±0.13 aA	0.16±0.02 aA
21	11.68±2.48 aAB	9.10±1.89 aAB	1.20±0.50 aA
28	1.50±0.98 aAB	1.26±0.32 aA	0.34±0.10 aA
35	0.02±0.01 aA	0.50±0.10 aA	0.70±0.20 aA
42	0.08±0.01 aA	5.64±1.99 aAB	1.62±0.65 aA
49	3.47±1.28 aAB	20.68±10.58 aAB	8.36±2.99 aA
56	3.52±1.08 aAB	32.40±11.79 bB	30.58±9.98 bB
63	8.40±2.01 aAB	99.36±20.79 bC	61.46±13.98 cC
70	20.84±9.18 aB	119.94±34.86 bCD	121.64±38.48 bD
77	15.86±8.42 aB	137.06±41.80 cD	92.12±21.01 bD
84	18.12±7.99 aB	33.30±8.48 aB	88.69±19.48 bD
91	20.88±8.10 bB	155±.68±40.79 bD	104.70±30.49 aD

<sup>1</sup> First leaves come from mainstem nodes.

<sup>2</sup> Means with the same lower case letter within rows and means with a common upper case letter within columns do not differ significantly by the Student-Newman-Keuls test ( $P = 0.05$ )



**Fig. 1** - Number of apterous aphids (mean±se) found on the leaves<sup>1</sup> located in the top, middle and bottom regions of two cotton cultivars with coloured fibers (BRS Safira and BRS Rubi) ( $F_{\text{Cultivar by region}}(2, 332) = 17.17$ ;  $P < 0.0001$ ). <sup>1</sup>First leaves come from mainstem nodes. <sup>2</sup>Bars with the same lower case letter within each cotton cultivar and bars with a common upper case letter within each plant region do not differ significantly by the Student-Newman-Keuls test ( $P = 0.05$ ).

The apterous aphids produced population peaks during the season, at 70 (BRS Safira) and 91 (BRS Rubi) days of plant age (Fig. 3), while population peaks of alate aphids were produced at 70 (BRS Safira) and 84 (BRS Rubi) days of plant age (Fig. 3). In addition, for both cotton cultivars, during the peak occurrences of apterous and alate aphids, the highest proportional quantities of apterous and alate aphids were observed on nodes in the plants' bottom regions, except for the BRS Rubi cultivar, where the occurrence of alate aphids was proportionally highest in the middle region of the cotton plant.

The highest percentages of apterous aphids were found on nodes 1 to 10 of the BRS Safira (89.1%) and BRS Rubi (69.4%) cultivars (Fig. 4). In BRS Safira, 99.5% of alate aphids were found on nodes 1 to 12, while in BRS Rubi, 86.1% of alate aphids were found on nodes 5 to 16 (Fig. 5). Given that the apterous and alate aphids were found to concentrate in the bottom and middle nodes, quadratic models were the best fit to represent the decrease in percentage of apterous (BRS Safira:  $y = 7.73 + 0.47x - 0.05x^2$ ,  $R^2 = 0.69$ ,  $F_{(2,15)} = 16.89$ ,  $P < 0.0007$  and BRS Rubi:  $y = 0.66 + 1.70x - 0.10x^2$ ,  $F_{(2,17)} = 32.57$ ,  $R^2 = 0.79$ ,  $P < 0.0001$ ) (Fig. 4) or alate (BRS Safira:  $y = 7.65 + 0.50x - 0.06x^2$ ,  $F_{(2,15)} = 12.81$ ,  $R^2 = 0.63$ ,  $P < 0.0006$  and BRS Rubi:  $y = -1.89 + 1.94x - 0.10x^2$ ,  $F_{(2,17)} = 19.82$ ,  $R^2 = 0.70$ ,  $P < 0.0001$ ) aphids per node from bottom to top of plants (Fig. 5). The pattern for apterous (PROC MIXED of Sas for equality of linear coefficient:  $t_{(1, 332)} = 10.08$ ,  $P < 0.0018$ ) or alate (PROC MIXED of Sas for equality of linear coefficient:  $t_{(1, 332)} = 15.12$ ,  $P < 0.0006$ ) aphids was different comparing the linear coefficients of the models between BRS Safira and BRS Rubi cultivars.

Proportionally more apterous aphids (BRS Safira: 88.2% and BRS Rubi: 87.4% (Fig. 6) and alate aphids (BRS Safira: 92.3% and BRS Rubi: 81.1%) (Fig. 7) were found in the structures produced by positions 1 and 2 of the vegetative and fruit branches when compared to the other positions of the cotton cultivars. Since the occurrence of apterous (BRS Safira:  $y = 92.34 - 37.08x + 3.51x^2$ ,  $F_{(2,4)} = 16.67$ ,  $R^2 = 0.96$ ,  $P < 0.0151$  and BRS Rubi:  $y = 86.36 - 33.46x + 3.09x^2$ ,  $F_{(2,4)} = 41.15$ ,  $R^2 = 0.97$ ,  $P < 0.0030$ ) (Fig. 6) and alate (BRS Safira:  $y = 98.05 - 20.26x - 3.87x^2$ ,  $F_{(2,4)} = 117.54$ ,  $R^2 = 0.93$ ,  $P < 0.0062$  and BRS Rubi:  $y = 79.06 - 29.63x + 2.69x^2$ ,  $F_{(2,4)} = 31.94$ ,  $R^2 = 0.97$ ,  $P < 0.0048$ ) aphids (Fig. 7) was concentrated in branch positions 1 and 2, quadratic models were the best fit to represent the decrease in percentage of apterous or alate aphids found in structures produced by branch

**TABLE III**  
**Number of alate aphids per plant (mean±se) found on the leaf<sup>1</sup> of two cotton cultivars with colored fibers (BRS Safira and BRS Rubí) in function of age and cotton cultivar ( $F_{\text{Cotton cultivar by age (13, 332)}} = 12.69$ ;  $P < 0.0001$ ).**

Plant age (day)	Cotton cultivars <sup>2</sup>	
	BRS Safira	BRS Rubí
1	0.00±0.00 aA	0.00±0.00 aA
7	0.00±0.00 aA	0.00±0.00 aA
14	0.08±0.01 a	0.00±0.00 aA
21	0.00±0.00 aA	0.00±0.00 aA
28	0.00±0.00 aA	0.00±0.00 aA
35	0.00±0.00 aA	0.00±0.00 aA
42	0.04±0.01 a A	0.00±0.00 aA
49	0.24±0.09 aABC	0.00±0.00 aA
56	0.53±0.11 bABC	0.07±0.02 aA
63	0.97±0.16 bC	0.19±0.08 aA
70	0.91±0.32 aBC	0.48±0.11 aAB
77	0.59±0.17 aABC	1.52±0.82 aBC
84	0.05±0.01 aA	1.24±0.79 bC
91	0.04±0.01 aA	0.71±0.22 bABC

<sup>1</sup> First leaves come from mainstem nodes.

<sup>2</sup> Means with the same lower case letter within rows and means with a common upper case letter within columns do not differ significantly by the Student-Newman-Keuls test ( $P = 0.05$ ).



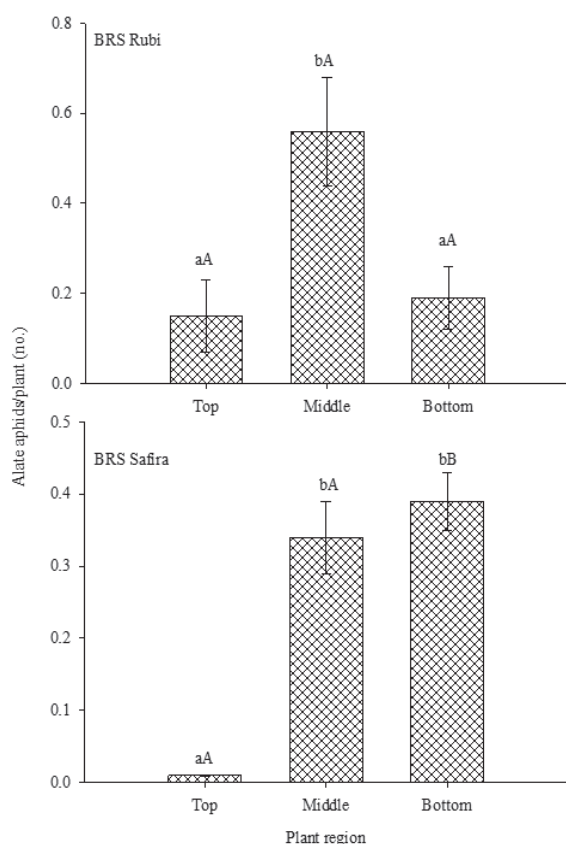
**TABLE IV**  
**Number of alate aphids (mean±se) found on the leaf<sup>1</sup> of two cotton cultivars with colored fibers (BRS Safira and BRS Rubi) in function of age and plant region (F<sub>Region by age</sub> (26, 332) = 3.74; P < 0.0001).**

Plant age (day)	Plant region <sup>2</sup>		
	Top	Middle	Bottom
1	0.00±0.00 aA	0.00±0.00aA	0.00±0.00 aA
7	0.00±0.00 aA	0.00±0.00 aA	0.00±0.00 aA
14	0.00±0.00 aA	0.06±0.09 aA	0.06±0.01 aA
21	0.00±0.00aA	0.00±0.00 aA	0.00±0.00 aA
28	0.00±0.00 aA	0.00±0.00 aA	0.00±0.00 aA
35	0.00±0.00 aA	0.00±0.00 aA	0.00±0.00 aA
42	0.00±0.00 aA	0.04±0.01 aA	0.02±0.00 aA
49	0.00±0.00 aA	0.30±0.09 aAB	0.06±0.02 aA
56	0.02±0.00 aA	0.42±0.12 aBC	0.46±0.29 aB
63	0.12±0.04 aA	0.68±0.23 bDE	0.94±0.32 bC
70	0.08±0.01 aA	0.82±0.34 bE	1.18±0.88 bD
77	0.24±0.09 aA	2.18±0.98 bG	0.74±0.44 bC
84	0.36±0.10 aA	1.22±0.78 bF	0.36±0.12 aB
91	0.30±0.09 aA	0.56±0.32 aCD	0.26±0.89 aAB

<sup>1</sup> First leaves come from mainstem nodes.

<sup>2</sup> Means with the same lower case letter within rows and means with a common upper case letter within columns do not differ significantly by the Student-Newman-Keuls test (P= 0.05)



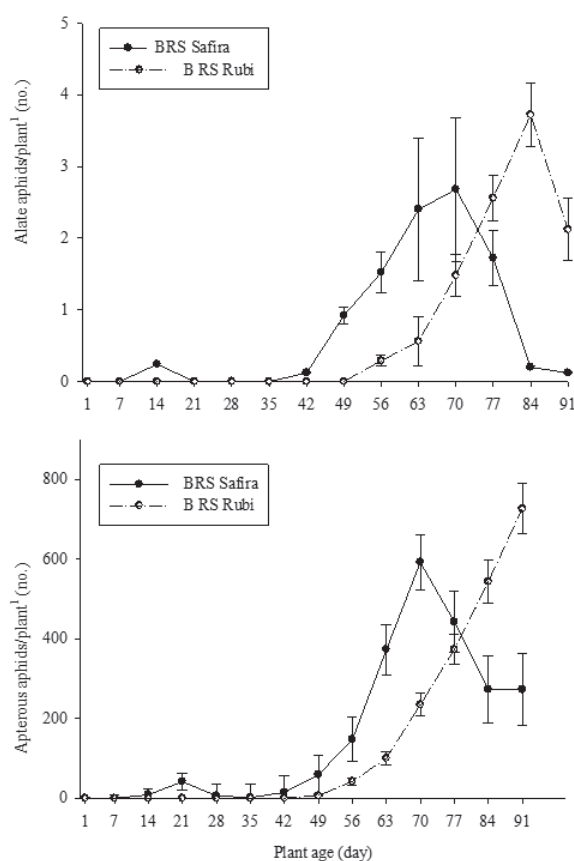


**Fig. 2** - Number of alate aphids (mean $\pm$ se) found on the leaves<sup>1</sup> located in the top, middle and bottom regions of two cotton cultivars with coloured fibers (BRS Safira and BRS Rubi) (F<sub>Cultivar by region</sub> (2, 332) = 6.59;  $P < 0.0016$ ). <sup>1</sup>First leaves come from mainstem nodes. <sup>2</sup>Bars with the same lower case letter within each cotton cultivar and bars with a common upper case letter within each plant region do not differ significantly by the Student-Newman-Keuls test ( $P = 0.05$ ).

positions beginning in the inside part of plants and extending to the outside part. The pattern of the horizontal distribution on branches was similar for apterous (PROC MIXED of Sas for equality of linear coefficient:  $t_{(1, 243)} = 1.12$ ,  $P > 0.1018$ ) or alate (PROC MIXED of Sas for equality of linear coefficient:  $t_{(1, 243)} = 0.912$ ,  $P > 0.1029$ ) aphids comparing the linear coefficients of the models between BRS Safira and BRS Rubi cultivars.

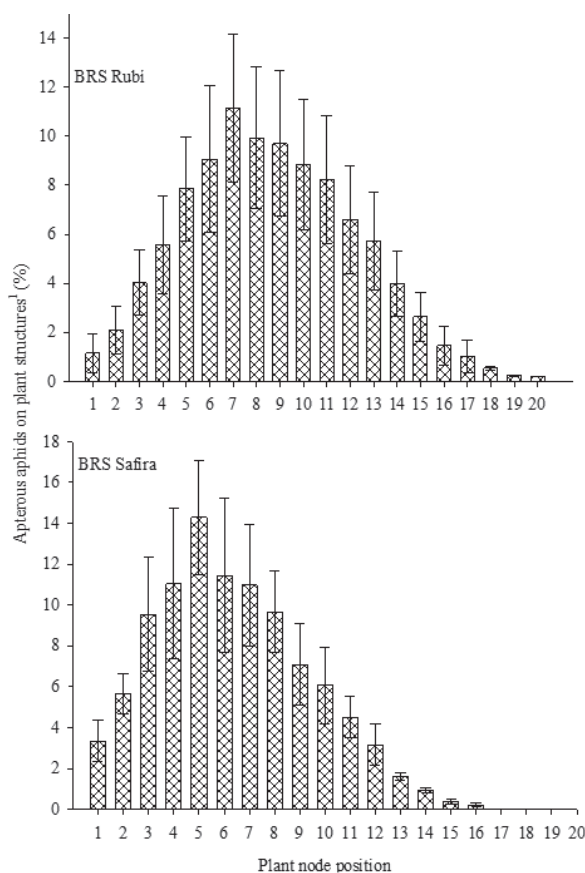
### DISCUSSION

The difference in the number of apterous aphids found in the colored-fiber cotton cultivars is

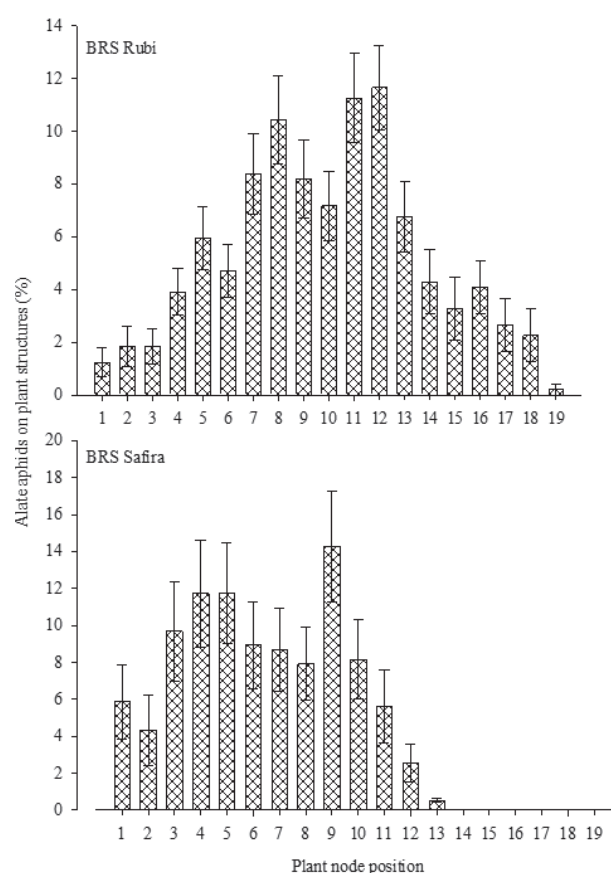


**Fig. 3** - Dynamics of apterous and alate aphids within 2008 season in cotton cultivars (BRS Safira and BRS Rubi) with coloured fibers. <sup>1</sup>All plant structures (leaves, squares, flowers and bolls).

possibly related to the individual aggregation model. It may be explained by chemical or physical attraction exercised by the host plant, with different nutritional support or wavelengths produced differently by different cultivars. In this study a significant difference was not found in the number of alate aphids of *A. gossypii* between the cultivars used. Cividanes (2002) believes that the appearance of alate aphids in crops in their initial development phase may be influenced by factors such as the host plant's odor, the quality of the light spectrum reflected by the crop and local temperature. It is probable that differences in such factors in the cotton crops studied were not great enough to establish significant differences for colonization by alate aphids of *A. gossypii*.



**Fig. 4** - Vertical distribution (%) of apterous aphids on nodes within BRS Safira ( $y = 7.73 + 0.47x - 0.05x^2$ ,  $R^2 = 0.69$ ,  $F_{(2, 15)} = 16.89$ ,  $P < 0.0001$ ) and BRS Rubi ( $y = 0.66 + 1.70x - 0.10x^2$ ,  $R^2 = 0.79$ ,  $F_{(2, 17)} = 32.57$ ,  $P < 0.0001$ ) cotton plants based on plant node position from bottom (node 1) to plant apex (node 20). <sup>1</sup>All plant structures (leaves, squares, flowers and bolls).

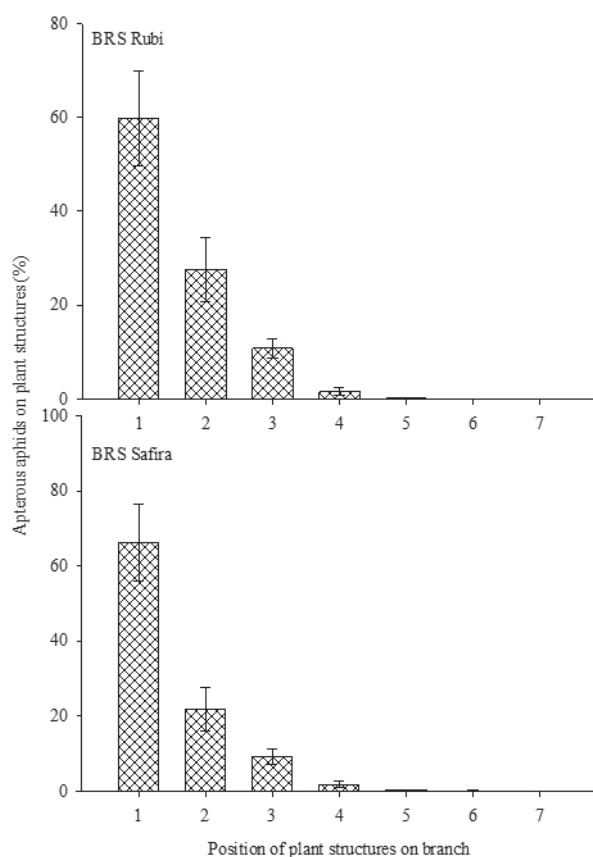


**Fig. 5** - Vertical distribution (%) of alate aphids on nodes within BRS Safira ( $y = 7.65 + 0.50x - 0.06x^2$ ,  $R^2 = 0.63$ ,  $F_{(2, 15)} = 12.81$ ,  $P < 0.0006$ ) and BRS Rubi ( $y = -1.89 + 1.94x - 0.10x^2$ ,  $R^2 = 0.70$ ,  $F_{(2, 17)} = 19.82$ ,  $P < 0.0001$ ) cotton plants based on plant node position from bottom (node 1) to plant apex (node 20). <sup>1</sup>All plant structures (leaves, squares, flowers and bolls).

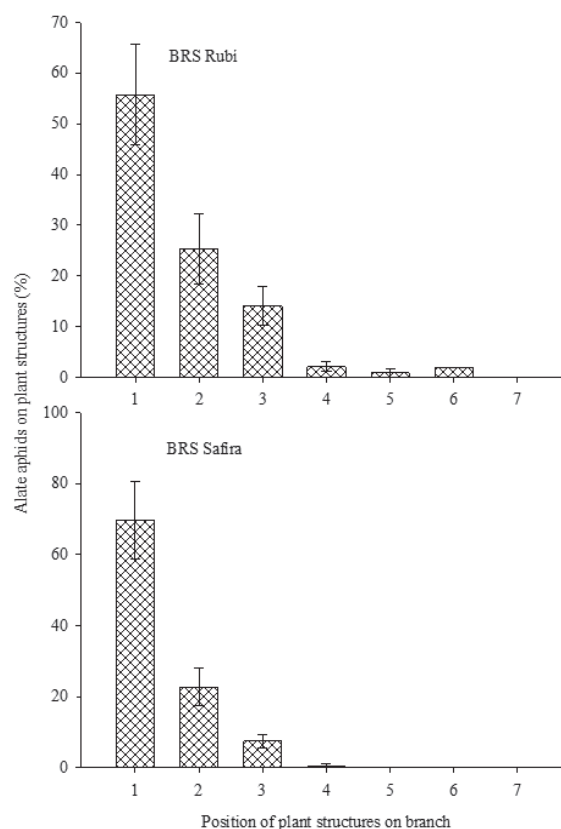
The interaction between cultivars and plant age and also between plant region and plant age reflects variation in the leaf area, the number of leaves, the age of the leaves, the level of nutrients, amino acid concentration, levels of secondary metabolites, and the number of nodes per mainstem. These factors consequently affect patterns of vertical distribution of apterous and alate aphids in the plants. The effects of these physiological factors on aphids depend on the plant's age, with a different behavior over the course of the plant's development (Cividanes and Santos 2003). The interactions observed between cotton cultivars and plant age, between plant region and plant age, and between cultivars and plant

region regarding to the distribution of apterous or alate aphids on the plants may also be explained by factors such as leaf size, the number of nodes per stem, the number of leaves, the leaves' age, and the relative concentration of amino acids in the plant. In terms of levels of amino acids, studies carried out by Auclair (1976) revealed that the performance of *Acyrtosiphon pisum* (Harris) is not only affected by the total concentration of amino acids, but also by the relative concentration of different amino acids that may contribute to a possible nutritional balance and/or reduced phagostimulation.

The population peak of apterous aphids at 70 (BRS Safira) and 91 (BRS Rubi) days of plant age



**Fig. 6** - Horizontal distribution (%) of apterous aphids within BRS Safira ( $y = 92.34 - 37.08x + 3.51x^2$ ,  $F_{(2, 4)} = 16.67$ ,  $R^2 = 0.96$ ,  $P < 0.0151$ ) and BRS Rubi ( $y = 86.36 - 33.46x + 3.09x^2$ ,  $F_{(2, 4)} = 41.15$ ,  $R^2 = 0.97$ ,  $P < 0.0030$ ) cotton plants based on the position of plant structures<sup>1</sup> on the branch from the inside leaf (leaf 1 including bud) toward the outside cotton plants. <sup>1</sup>All plant structures (leaves, squares, flowers and bolls)



**Fig. 7** - Horizontal distribution (%) of alate aphids within BRS Safira ( $y = 98.05 - 20.26x - 3.87x^2$ ,  $F_{(2, 4)} = 117.54$ ,  $R^2 = 0.93$ ,  $P < 0.0062$ ) and BRS Rubi ( $y = 79.06 - 29.63x + 2.69x^2$ ,  $F_{(2, 4)} = 31.94$ ,  $R^2 = 0.97$ ,  $P < 0.0048$ ) cotton plants based on the position of plant structures<sup>1</sup> on the branch from the inside leaf (leaf 1 including bud) toward the outside cotton plants. <sup>1</sup>All plant structures (leaves, squares, flowers and bolls)

(Fig. 3) or alate aphids at 70 (BRS Safira) and 84 (BRS Rubi) days of plant age (Fig. 3) are similar to the results found by Celini and Vaillant (2004), who observed that population growth curves for *A. gossypii* in cotton plants of similar physiological ages present similar behavior. Resende et al. (2004) also recorded a population peak of alate *A. gossypii* when cauliflower plants (*Brassica oleracea* Linnaeus) were 77 days old. On the other hand, Pinto et al. (2000) found that green peach aphid (*Myzus persicae* (Sulzer)) tends to present a single population peak during the crop cycle of the potato (*Solanum tuberosum* Linnaeus). However,

Kindlmann and Dixon (1996) explained that aphid population dynamics are not characterized by defined patterns, but instead are considered highly variable over the course of the year, particularly when a comparison is made among these insects' mechanisms, which enable their population dynamics to follow either a similar or distinct path.

In terms of the peak occurrences of alate or apterous aphids, the highest proportions of apterous or alate aphids were found on nodes in the bottom region of the cotton plant, except in the BRS Rubi cultivar, where the proportionally highest occurrence of alate aphids was observed in the

middle region of the plant. The results for the BRS Safira cultivar agree with those found by Leite et al. (2007), who found more apterous individuals of *A. gossypii* in the bottom region of the plant than in the middle and top regions by studying okra crops (*Abelmoschus esculentus* (Linnaeus)). On the other hand, Cividanes and Santos (2003), who studied apterous aphids of the species *Brevicoryne brassicae* (Linnaeus) in cauliflower plants, found the highest proportion on the leaves of the middle region of the plants and the lowest proportion on the leaves of the top region of the plants. According to Gonzaga et al. (1991), the distribution of *A. gossypii* in 93-day-old cotton plants grown in field conditions is weighted towards the top region of the plant rather than the middle and bottom regions. On the other hand, Fernandes et al. (2001) found that neither the cotton cultivars (CNPA 7H, CNPA Precoce 1, and CNPA Precoce 2) nor the plant region had an effect on the number of *A. gossypii* found in cotton plants. However, our study showed that the distribution of *A. gossypii* in cotton plants does indeed vary according to cultivars.

Insect species belonging to the order Homoptera are classified in different groups in line with their feeding area in the host plant: some establish themselves predominantly on the stems, some prefer branches and leaves, while others settle throughout the plant (Kozár 1976). This study found the highest proportions of apterous aphids (BRS Safira: 88.2% and BRS Rubí: 87.4%) (Fig. 6) or alate aphids (BRS Safira: 92.3% and BRS Rubí: 81.1%) (Fig. 7) on the structures produced by positions 1 and 2 of the vegetative and fruit branches in the cotton cultivars. As the occurrence of apterous or alate aphids was concentrated in positions 1 and 2, a quadratic model was deemed most appropriate to represent the percentage decline in aphids found in structures produced by branch positions beginning in the inside part of plants and extending until their outside part. Comparing the model linear coefficients between BRS Safira and BRS Rubí, it was found that the

horizontal distribution pattern for apterous aphids throughout the vegetative and fruit branches was similar between the cultivars. The distribution of apterous or alate aphids within the cultivars BRS Safira and BRS Rubí was proportionally greatest on leaves rather than on the squares, flowers and bolls. These results are in line with those of Akhtar et al. (2004), which showed that the majority of aphids found on wheat plants (*Triticum aestivum* Linnaeus) were on leaves rather than on other structures. On the other hand, Rondon et al. (2005) found that the majority of apterous aphids of the species *A. gossypii* observed on strawberry plants (*Fragaria vesca* Linnaeus) were on small leaves rather than on large leaves.

The concentration of aphids on leaves, and particularly at positions 1 and 2 of the plants may be related to the availability of glucose, fructose and sucrose. However, sucrose production depends on the concentration of glucose plus fructose, establishing an inversely proportional relationship, and consequently altering total sugar content in aphids (Slosser et al. 2004). A study conducted by Gomez et al. (2006) showed that sugar levels found in cotton leaves are affected by the daylight period. This is mainly due to non-structural daily variations in carbohydrate levels and photosynthesis rates in the host plants (Gomez et al. 2006). They also found that the amount of sucrose produced by aphids varies throughout the day. Fructose is produced in large scale by aphids, while glucose and sucrose account for the lowest amounts in honeydew (Gomez et al. 2006). The aphids preferentially select host plants or feeding sites that are nutritionally superior, on which their rate of growth and reproduction and their survival are highest (Auclair 1976). Under natural conditions, the act of selection of host plants, but more probably the selection of specific feeding sites on a particular plant, and eventually the establishment of aphid colonies of economic importance, are influenced markedly, among other things, by the nutritional superiority of the host, in which amino acids may contribute significantly.

The results of this study are of great importance in improving control strategies for *A. gossypii* in the naturally-colored cotton cultivars BRS Safira and BRS Rubí. They may prove to be useful in sampling programs for this pest, as well as in forecasting outbreaks and population peaks of *A. gossypii* and in taking related decisions. They may also help to reduce costs and save time spent on pest monitoring and control activities.

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#### RESUMO

Nós descrevemos a distribuição vertical e horizontal do pulgão do algodoeiro *Aphis gossypii* Glover dentro da planta de algodão (*Gossypium hirsutum* Linnaeus), em dois cultivares com fibras coloridas (BRS Safira and BRS Rubí) ao longo do seu desenvolvimento. Medidas de dinâmicas de populações e distribuição de *A. gossypii* nas plantas de algodão foram registradas em intervalos de sete dias. O número de afídeos ápteros ou alados e suas localizações específicas foram registrados, usando-se como ponto de referência a localização do nó no caule principal da planta e também aqueles presentes nas folhas de ramos e estruturas frutíferas. O número de afídeos ápteros encontrados na cultivar BRS Safira (56.515 afídeos) foi maior do que o encontrado na BRS Rubí (50.537 afídeos). Não houve diferença significativa entre o número de afídeos alados encontrados na BRS Safira (365 afídeos/planta) e na BRS Rubí (477 afídeos/planta). Ocorreram interações entre cultivar de algodão e idade da planta, entre região da planta e idade da planta e entre cultivar e região da planta para pulgões ápteros. Os resultados obtidos neste estudo são de grande importância na melhoria das estratégias de controle de *A. gossypii* nas cultivares de algodão com fibras coloridas BRS Safira e BRS Rubí.

**Palavras-chave:** *Aphis gossypii*, comportamento, algodão com fibras coloridas, distribuição.

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