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PLANT PROTECTION - Article

Impact of *Tetranychus ogmophallos* (Acari: Tetranychidae) on different phenological stages of peanuts

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ABSTRACT: Peanut red mite, or *Tetranychus ogmophallos* Ferreira and Flechtmann, is considered the major emerging pest of peanut in Brazil. Its impact on peanut farming is still unknown but can be harmful. Thus, it is essential to understand how this mite influences peanut for a successful pest management program. This study aimed to investigate the impact of *T. ogmophallos* on peanut plants at different growth stages in order to clarify whether or not it is worth controlling this pest throughout the peanut growing season. For that, four experiments were carried out in a greenhouse to evaluate the impact of *T. ogmophallos* infestation on peanut plants at different phenological stages. Results showed that peanut seedlings of up to 60 days emergence and infested with red mite did not complete the reproductive cycle. In addition, infestation at 90 days after seedling emergence (late season) led to considerable yield reduction. As a result, we may infer that infestation can significantly peanut yield, regardless of plant phenological stage. Thus, controlling this emerging pest is necessary even if infestations occur in the final stages of plant development. The adopted level of infestation is above the economic threshold given the importance of the impact on growth and yield of these plants. Because of this, establishing an economic threshold level at different plant developmental stage is crucial to determine when control measures should be taken.

Key words: peanut red mite, *Arachis hypogaea*, economic acarology, granoleico, fabaceae.

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INTRODUCTION

Peanut red mite, or *Tetranychus ogmophallos* Ferreira and Flechtmann (*Acari: Tetranychidae*), is considered the major emerging pest of peanut crops (*Arachis hypogaea* L.) in Brazil. This pest was first reported on cultivated peanut in 2001 and probably has been misidentified for years as *Tetranychus evansi* Baker and Pritchard (*Acari: Tetranychidae*) (Ferreira and Flechtmann 1997; Lourenção et al. 2001). As only reported in Brazil, *T. ogmophallos* is of quarantine importance to other countries (Bonato et al. 2000). This species has been reported to damage all peanut plant developmental stages. Feeding injuries may result in early leaf drop and retarding plant growth (Ferreira and Flechtmann 1997). Populations of peanut red mite develop better under low humidity and high temperatures.

Under field conditions, *T. ogmophallos* appears to be more aggressive and competitive than other mites on peanut plants, such as tetranychids (*Tetranychus urticae* Koch and *Mononychellus planki* [McGregor]), mainly by the capacity to produce abundant and dense silk webbing (Ferreira and Flechtmann 1997). The webs woven by mites prevent or hinder the establishment of other species (including some predatory mites) on the host plant (Mori and Saito 2004; Sarmento et al. 2001; Iwasa and Osakabe 2015).

Hypotheses suggested to explain the increased infestations of *T. ogmophallos*, in recent years, include frequent dry spells (Boyne and Hain 1983; Ahmed et al. 2012), changes in cropping systems (Smith and Mozingo 1983), and use of new varieties with characteristics favoring the mite development (Johnson et al. 1980). In addition, the aggressive polyphagous habit and the short generation times allow *T. ogmophallos* to reach damaging densities in a short period.

The impact caused by *T. ogmophallos* to peanut crops is still unknown but could reach high levels. Late-season infestations are common in peanut fields and there are doubts as to whether mite control is feasible at this stage. When control is deemed necessary, the main method adopted is spraying with acaricides, which is costly and may give rise to unintended side effects such as secondary pest outbreaks, pest resurgence, reduction on populations of natural enemies, environmental contamination, besides risks to human health (Cutler 2013; Guedes and Cutler 2014; Zhan et al. 2014; Guedes et al. 2016). Therefore, it is essential to understand the impact of this mite in order to the design a successful pest management program (Meck et al. 2013; Nyoike and Liburd 2013).

Given this background, this study was performed to investigate the impact of *T. ogmophallos* on peanut plants at different growth stages, so that clarifying whether its control is justifiable.

MATERIAL AND METHODS

Tetranychus ogmophallos colony

Tetranychus ogmophallos mites were collected from peanut fields in Jaboticabal city, Brazil. Afterward, these mites were reared on peanut plants (*A. hypogaea* cv. Granoleico) growing in 5-L pots inside a greenhouse. Severely damaged plants were replaced with new peanut plants every other week.

Experiments: Implementation and design

Four experiments were carried out from 25 May to 27 November 2014 in a greenhouse maintained at an average temperature of 22.9 °C (ranging from 10.7 °C to 35.1°C), and average relative humidity of 64.9% (ranging from 52.2% to 72.5%). Peanut plants (cv. Granoleico) were sown in 8-L pots containing a mixture of soil, sand, and bovine manure (2:1:1). Five seeds were sown per pot, leaving one seedling per pot after thinning. Plants were irrigated manually every other day or as needed.

All four experiments were arranged in a completely randomized design. Each experiment consisted of two treatments, non-infested plants (control) and plants infested with *T. ogmophallos*. In these experiments, each treatment had 20 replicates.

First, second, and third experiments

Infestations with *T. ogmophallos* were done at different stages in each experiment. In the first, it was at vegetative stage (V3), 15 days after seedling emergence (DAE). In the second, it was at reproductive stage (R1), 30 DAE. Moreover, in the third, plant infestation was done at reproductive stage (R5), 60 DAE (Boote 1982).

The evaluated variables in all experiments consisted of plant growth rate (cm·day^{-1}), plant height (cm), root length (cm), the number of leaflets (un), shoot dry mass (g), root dry mass (g), and total dry mass (g). The yield was not evaluated due to plant death after infestation with *T. ogmophallos*.

Fourth experiment

In this experiment, infestation with *T. ogmophallos* was done at reproductive stage (R7), 90 DAE, which is characterized by grain filling phase. The evaluated variables were the same for experiments 1-3, in addition to the number of pods per plant, the number of filled pods per plant, total grains per plant, the number of grain per pod, grain yield (%), the weight of ten grains (g), and plant yield (g·plant^{-1}).

Mite infestation

In each experiment, nearly 3.000 mites (all mobile stages) were transferred to each plant (400 mites per leaf) — infested plant treatment — using a single-bristle paintbrush under a stereoscopic microscope. Such number of mites was used because of the large populations found in the field as well as it is the number being used in similar studies conducted with twospotted-spider mite *T. urticae* (Oatman et al. 1981; Weihrauch 2003; Meck et al. 2013; Nyoike and Liburd 2013). To confirm whether the mites were established, we observed the plants the day after infestation using a hand magnifier (10× magnification). Due to a high webbing by peanut red mite, pots with infested plants were placed 80 cm apart from each other and 100 cm from the control plants, being examined daily to prevent the mites from migrating from one pot to another.

In the control treatment, acaricide fenpyroximate (Ortus 50 SC®) was applied at a dosage of 94 mL/100 L water to ensure the absence of *T. ogmophallos* on these plants. Spraying was done every two weeks with a backpack manual sprayer (PJH 20L – JACTO) equipped with an XR11002 (TeeJet) nozzle at a volume sufficient to provide complete coverage of the plants. For spraying, plants were temporarily taken to the outside of the greenhouse.

Measuring variables

Plant height and root length were measured as shown in Figure 1. Plant growth rate was obtained from the difference between the initial and final plant height divided by the time span between measurements. Shoot and root dry masses were obtained after placing the plant materials separately into paper bags (21.5 cm width × 12.0 cm depth × 47.5 cm height) and drying in a forced circulation oven (MA035 – Marconi) at 65 °C, until constant weight. Each sample was weighed in a precision balance (M5202 – Bel Engineering). At harvest time, yield components (pods per plant, total grains, grains per pod, grain yield, ten-grain weight, and total yield) were measured using grains at 9% moisture content, which was determined by a universal moisture meter (MD4 –105). Grain yield (%) was set based on the ratio between grain and pod masses. The assessments were carried out after detecting the death of infested plants, which was based on the ceasing of growth, by the time all leaves had dried.

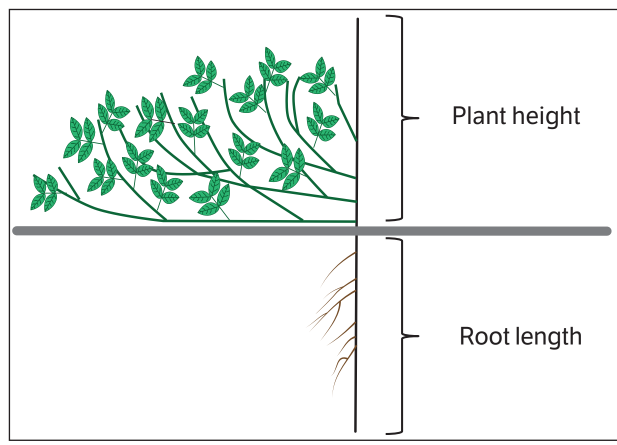

Figure 1. Schematic drawing of a peanut cultivar used in this study - Granoleico. The drawing shows the measurements site of plant height and root length.

Statistical analyses

Each experiment was analyzed individually. Data were first tested for normality (Kolmogorov-Smirnov's and Shapiro-Wilk's tests), homogeneity (Levene's test) and analyzed using a Student's pairwise t-test ($p > 0.05$) (SAS Institute 2002).

RESULTS

First, second, and third experiments

In the first experiment, plant growth could not be evaluated due to early plant death. As a result, infested plants had no differences from control plants in height

($F_{1,38}$ = 0.00; p = 0.9629), root length ($F_{1,38}$ = 0.00; p = 0.8399), number of leaflets ($F_{1,38}$ = 0.58; p = 0.0995), dry mass of aerial parts ($F_{1,38}$ = 0.00; p = 0.9848), root dry mass ($F_{1,38}$ = 0.00; p = 0.9848) and total dry mass ($F_{1,38}$ = 0.04; p = 0.834) (Figure 2).

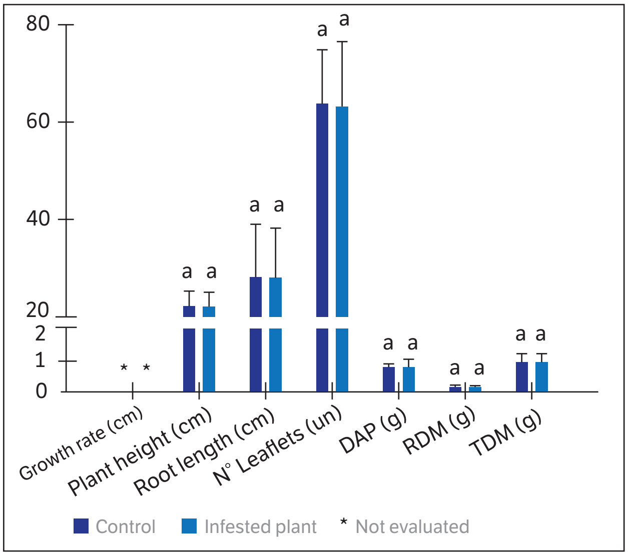

Figure 2. First experiment - Mean (± ES) growth rate (cm·day-1), plant height (cm), root length (cm), number of leaflets, dry mass of aerial parts - DAP (g), root dry mass - RDM (g) and total dry mass - TDM (g) of peanut plants non-infested (control) and infested with *Tetranychus ogmophallos* at V3 (15 DAE). Means followed by different letters differ significantly by Student's t-test (α = 0.05).

In the second experiment, there were significant differences in growth rate ($F_{1,38}$ = 28.39; p = < 0.0001) and root length ($F_{1,38}$ = 8.38; p = 0.0063), with roots of infested plants growing 6.6 cm more than those of control plants (Figure 3). In addition, control plants had 17.3 more leaflets than did infested plants, being this difference significant ($F_{1,38}$ = 6.16; p = 0.0176). Shoot dry mass was different among treatments, and the control showed a mass approximately 30% greater than those measured in the infested plants ($F_{1,38}$ = 10.30; p = 0.0027) (Figure 3). Root dry mass also differed; however, in this case, infested plants showed an increased gain of 0.2 grams compared to control plants ($F_{1,38}$ = 29.50; p< 0.0001). On the other hand, no difference was observed for plant height ($F_{1,38}$ = 3.60; p = 0.0654) (Figure 3). Furthermore, total dry mass was similar for all treatments ($F_{1,38}$ = 0.83; p = 0.3676) (Figure 3).

In the third experiment, plant growth rate differed among treatments, and control plants grew 24% more per day ($F1,38$ = 58.38; p < 0.0001) (Figure 4). The values obtained for plant height differed, and control plants grew on average 6.6 cm more than did infested plants ($F1,38$ = 67.70; p < 0.0001). Moreover, there were differences in the number of leaflets and, on average, control plants showed 217.6 more leaflets than did infested plants ($F1,38$ = 201.30; p < 0.0001) (Figure 4). Concerning to dry mass of aerial parts, both control plants and infested plants differed, among which

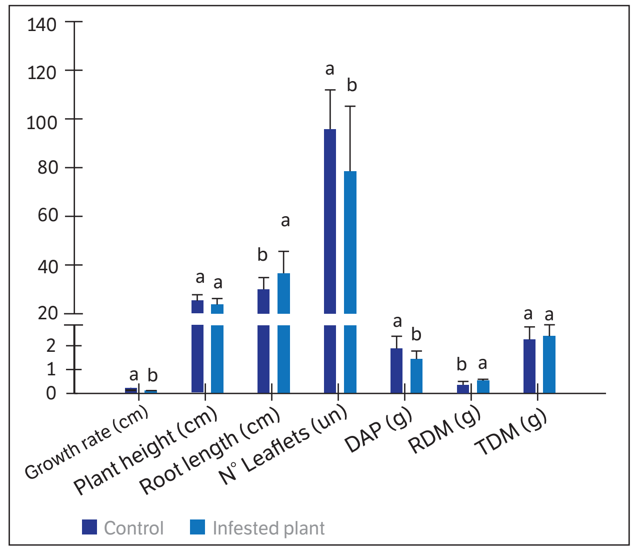

Figure 3. Second experiment - Mean (± ES) growth rate (cm·day-1), plant height (cm), root length (cm), number of leaflets, dry mass of aerial parts - DAP (g), root dry mass - RDM (g) and total dry mass - TDM (g) of peanut plants non-infested (control) and infested with *Tetranychus ogmophallos* at R1 (30 DAE). Means followed by different letters differ significantly by Student's t-test (α= 0.05).

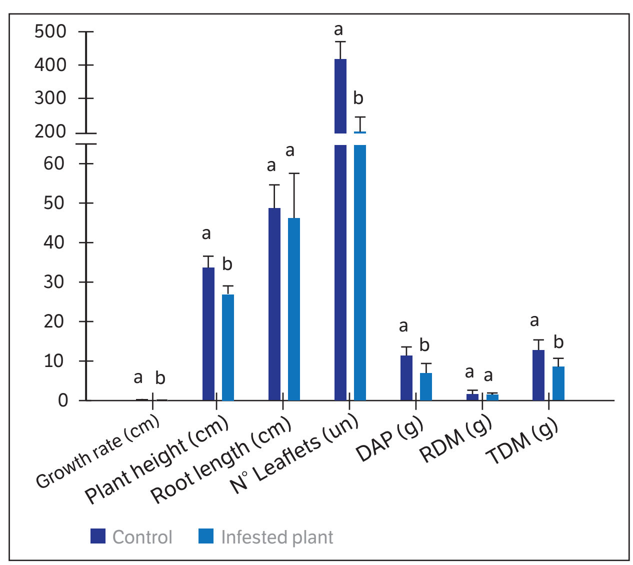

Figure 4. Third experiment - Mean (± ES) growth rate (cm·day-1), plant height (cm), root length (cm), number of leaflets, dry mass of aerial parts - DAP (g), root dry mass - RDM (g) and total dry mass - TDM (g) of peanut plants non-infested (control) and infested with *Tetranychus ogmophallos* at R5 (60 DAE). Means followed by different letters differ significantly by Student's t-test (α = 0.05).

control plants exhibited average values 38.8% higher than did infested plants ($F1,38 = 35.58$; $p < 0.0001$) (Figure 4). Results of total dry mass showed differences among treatments; control plants had an average mass of 4.3 grams more than the infested plants ($F1,38 = 22.64$; $p < 0.0001$). Root length and dry mass had no difference among treatments ($F1,38 = 0.75$; $p = 0.3904$) ($F1,38 = 0.09$; $p = 0.7712$).

Fourth experiment

The growth rate was higher for control plants ($F_{1,38}$ = 208 26.61; $p < 0.0001$) (Figure 5). Regarding plant height, control plants were 8.2 cm taller than were infested plants ($F_{1,38} = 26.35$; $p < 0.0001$). For the number of leaflets, control plants had 436.5 more leaflets than did infested plants ($F_{1,38} = 35.19$; $p < 0.0001$) (Figure 5).

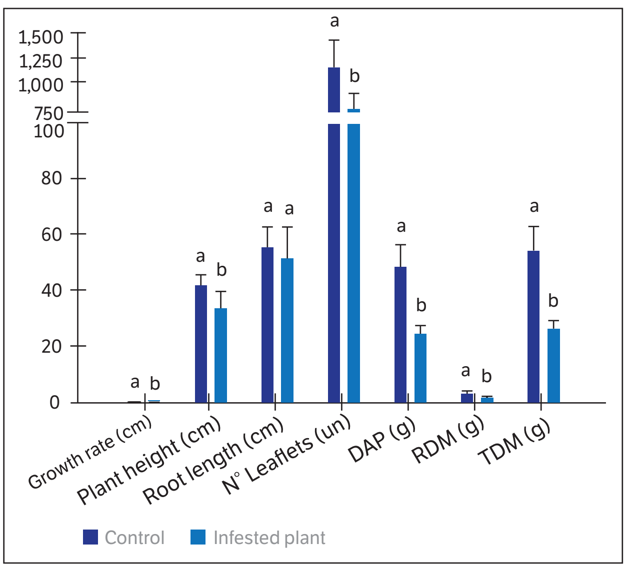

Figure 5. Fourth experiment - Mean (± ES) growth rate (cm·day[-1]), plant height (cm), root length (cm), number of leaflets, dry mass of aerial parts - DAP (g), root dry mass - RDM (g)and total dry mass - TDM (g) of peanut plants non-infested (control) and infested with *Tetranychus ogmophallos* at R7 (90 DAE). Means followed by different letters differ significantly by Student's t-test (α = 0.05).

Shoot dry mass of aerial parts differed among treatments, and control plants weighed 23.9 grams more than the infested plants ($F_{1,38} = 157.85$; $p < 0.0001$) (Figure 5). Root dry mass of control plants was 44% higher than were infested plants ($F_{1,38} = 31.23$; $p < 0.0001$). Control plants exhibited a total dry weight twice as high as infested plants at the end of the experiment. However, there was no difference in root length between treatments ($F_{1,38} = 1.80$; $p = 0.188$).

For yield components of plants infested at R7, a difference was observed for the number of filled pods per plant, in which control plants showed about 63.4% more filled pods than did infested plants ($F_{1,38} = 169.63$; $p < 0.0001$) (Table 1). Moreover, there was a difference in total grain per plant when comparing control and infested plants; control plants presented approximately 68% more grains than did infested ones ($F_{1,38} = 222.04$; $p < 0.0001$). Grain yield in control was 6.4% higher than was in infested plants ($F_{1,38} = 4.55$; $p <$ 229 0.03395) (Table 1). Regarding the weight of ten grains, there were also differences among treatments ($F_{1,38} = 172.89$; $p < 0.0001$).

Table 1. Means (± SE) of peanut plants non-infested (control) and infested with Tetranychus ogmophallos at R7 (90 DAE) (Fourth experiment).

Variables	Control	Infested plant
Number of pods per plant (un)	37.60 ± 1.53a	32.05 ± 0.67a
Number of filled pods per plant (un)	28.80 ± 1.25a	10.50 ± 0.62b
Total grains per plant (un)	50.95 ± 2.14a	16.25 ± 0.90b
Number of grains per pod (un)	1.37 ± 0.05 a	1.36 ± 0.05a
Grain yield (%)	75.45 ± 0.78a	70.67 ± 2.09b
Weight of 10 grains (g)	6.76 ± 0.18a	3.15 ± 0.20b

Means followed by different letters in the column differ significantly by Student's *t*-test (α = 0.05).

There were no differences concerning the number of grains per pod among treatments ($F_{1,38} = 0.01$; $p = 0.9408$). In addition, no difference was observed in number of pods per plant between control and the infested treatments ($F_{1,38} = 3.69$; $p = 0.0622$). Yield was different among treatments, wherein control plants exhibited nearly 85% higher yields than did infested plants ($F_{1,38} = 521.157$; $p < 0.0001$) (Figure 6).

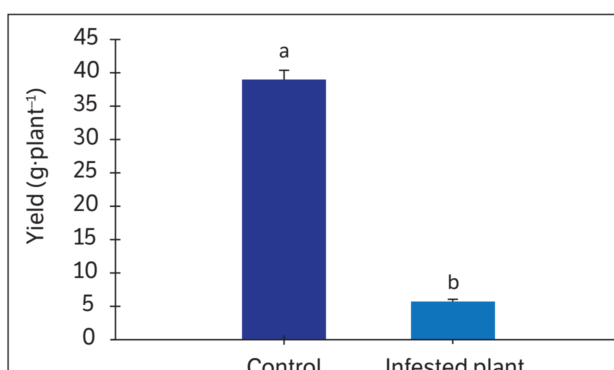

Figure 6. Fourth experiment - Mean (± SE) Yield (g·plant[-1]) of peanut plants non-infested (control) and infested with *Tetranychus ogmophallos* at R7 (90 DAE). Means followed by different letters differ significantly by Student's t-test (α = 0.05).

DISCUSSION

Experiments using artificial infestations are important to investigate potential yield losses for further decision on control methods to be adopted (Oatman et al. 1982; Weihrauch 2003). Moreover, such information is required for a better understanding of plant response to herbivore infestation (Nyoike and Liburd, 2013; Oliveira et al. 2016). For instance, Smith and Mozingo (1983) found that even relatively small (0.1 to 11.5 per leaf) late-occurring populations of the *T. urticae* had measurable detrimental effects on yields and value of large-seeded Virginia-type peanuts.

In all experiments, plants infested with *T. ogmophallos* did not complete the reproductive cycle. In the first experiment, when plants were infested at V3 (15 DAE), plants survived just one day after infestation. In the second and third experiments, when infestations were done at R1 and R5 (30; 60 DAE), plants survived 18 and 19 days, on the average, respectively. For both experiments, infestation occurred in the reproductive stage and pods were not fully expanded. Even plants at advanced phenological stages (R7) had no resistance to *T. ogmophallos* injuries and died with an average of 28 days after infestation. Ferreira and Flechtmann (1997) had firstly reported that potted peanut plants, infested with *T. ogmophallos* and kept in the laboratory, underwent severe damage and died. Similar results were obtained by Brito et al. (1986), who pointed out that even small infestations of *Tetranychus turkestani* (Ugarov and Nikolski) resulted in leaf and fruit drop, which led to the death of cotton plants, mainly those at an early developmental stage.

Regarding the impact of *T. ogmophallos* on the aerial part of infested plants, there was a reduction in growth rate, length, and number of leaflet. These results are because of the feeding habits of peanut red mites, which inhibit photosynthesis by destroying chloroplasts with a consequent reduction in plant growth and development of nodes on the peanut main stem. Phytophagous mites belong to an important herbivorous group that is known to feed on cell contents, leading to plant stress (Lindquist et al. 1996; Oliveira et al. 2016). Some studies have shown that, at high levels, *T. urticae* infestation can suppress flowering and leaf development, affecting the quality and quantity of inflorescences produced by strawberry plants (Sances et al. 1981; Fraulo et al. 2008).

The longer roots and the greater root mass of infested plants, in the second experiment, elicit a change in biomass partitioning pattern in plants, by allocating a greater amount of mass to roots as a mechanism to delay plant desiccation, compensating leaf injuries. Songsri et al. (2008) reported that peanut plants with larger root systems are more able to adapt themselves physiologically when facing abiotic stress. Our results are similar to those of Park and Lee (2005), who reported that cucumber plants injured by *T. urticae* changed the pattern of dry matter partitioning. In that case, injured plants directed most of their dry matter content to leaves to compensate for injuries. Such changes in dry matter partitioning and reductions in leaf productivity resulted in a reduction of dry matter partitioning to fruit growth, thus, reducing the productivity of cucumber plants (Park and Lee 2005). However, in our study, the change in the partitioning of biomass to roots was noticed only when plants were infested at R1, which according to Boote (1982) is a stage characterized by an intense rate of node development and the beginning of bloom phase.

Our study also showed a close correlation between root/aerial parts of the peanut plants with mite injury. When plants were subjected to mite injury, the aerial parts of plants were more affected than were the roots. These results suggest that shoot growth appears to be more sensitive to mite injury, thereby leading to a quick and negative response during all peanut growth stages.

The R7 stage is considered as the beginning of maturation, which is when pods are in the middle of active seed-filling (Boote 1982), as well as the crop. In the fourth experiment, plants were infested at R7 and, at this point, infested plants showed significant decreases regarding mite infestation effect on yield components. Therefore, in this stage, yield losses due to the attack of the pest are because of a decrease in grain filling, besides a reduction in the number of pods per plant. Nonetheless, we may assume that the effect of *T. ogmophallos* on peanut yield might occur at any of the reproductive stages within peanut development. Conversely, such yield reductions were not observed for late-season infestations of *T. urticae* in cotton (Furr and Pfrimmer, 1968).

Another important factor refers to the duration of mite infestation on plants. The longer the infestation period, the greater the injuries and mite population growth will be (Oatman et al. 1982; Meck et al. 2013). Scott et al. (2013) verified that the duration of *T. urticae* infestation affects its population density, as well as injury rates and yield of cotton plants. The same authors reported that cotton →

plants infested for 28 days, after three-leaf growth stage, showed a significant reduction in yield compared with those infested for only 7 and 14 days.

Our results were different from those of Weihrauch (2005), who evaluated *T. urticae* infestation impact on yield and quality (measured in percentage α-acids content) of cones (infructescence) of hop cultivars (*Humulus lupulus* L.). This author found that late season infestations of *T. urticae*, at levels up to 90 mites per leaf, are tolerable at harvest time with little or no risk of causing economic losses to hop growers. Surprisingly, Weihrauch (2005) reported that moderate infestations of *T. urticae* had a positive effect on the quality of cones, especially on the α-acids content.

As seen in our study, *T. ogmophallos* infestation at R7 may cause considerable reduction in peanut yield, reaching up to 85% loss. Likewise, Lourenção et al. (2001) reported a high infestation of *T. ogmophallos* at a peanut crop located in Adamantina - SP (Brazil) during two growing seasons. These authors found an average reduction of 76.5% in pod production of infested plants. This way, we should conclude that peanut plants are quite susceptible to *T. ogmophallos* injuries during both vegetative and reproductive phenological stages. Thus, maintaining populations of *T. ogmophallos* below of the economic threshold level, at any of the peanut phenological stages, is essential to ensure plant health and economic viability of this crop. Finally, our results suggest that the currently adopted level of infestation for control is above the ideal economic threshold since such infestations are striking for peanut growth and yield. Because of this, establishing an economic threshold level at each plant developmental stage becomes essential to determine when control measures should be taken.

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