Arquivos do Instituto Biológico
ISSN 1808-1657
https://doi.org/10.1590/1808-1657000752019

SCIENTIFIC ARTICLE
Plant Health

Population growth of *Tetranychus urticae* Koch (Acari: Tetranychidae) and predation rate of the pest mite by *Neoseiulus idaeus* Denmark & Muma (Acari: Phytoseiidae) in two grape cultivars*

Andréia Alex Sandra da Silva Pantaleão[1] https://orcid.org/0000-0002-4921-1445
José Osmã Teles Moreira[1] https://orcid.org/0000-0002-2759-5492
Mário Eidi Sato[2,**] https://orcid.org/0000-0001-5947-7717
José Anchieta de Assunção Pionório[1] https://orcid.org/0000-0002-8797-6852

1. Universidade do Estado da Bahia – Departamento de Tecnologia e Ciências Sociais – Laboratório de Entomologia – Juazeiro (BA), Brazil.
2. Instituto Biológico – Centro Avançado de Pesquisa em Proteção de Plantas e Saúde Animal – Laboratório de Acarologia – Campinas (SP), Brazil.

*This paper is part of the dissertation thesis of the first author.

**Corresponding author: mesato2012@gmail.com

ABSTRACT

The two-spotted spider mite, *Tetranychus urticae* Koch, has caused significant damage to vineyards in the valley of the São Francisco River in Brazil. *Neoseiulus idaeus* Denmark & Muma is one of the most abundant species of predatory mites on vines in this region. This study evaluated the population growth rates of T. urticae on leaves of two grape (*Vitis vinifera* L.) cultivars ('Italia' and 'Superior Seedless') and jack bean [*Canavalia ensiformis* (L.) DC.] and, also, to estimate the predation rates of the pest mite by *N. idaeus* on leaves of both grape cultivars and jack bean. A higher oviposition rate of *T. urticae* was observed on 'Superior Seedless' than on 'Italia' grape leaves; however, there was no significant difference in the instantaneous growth rates of *T. urticae* for these grape cultivars. For 'Superior Seedless', the spider mite egg viability was significantly lower than on 'Italia' grape, indicating a resistance factor in this grape cultivar. The phytoseiid *N. idaeus* preyed higher number of *T. urticae* females on 'Superior Seedless' leaves than on 'Italia' grape and jack bean leaves for the densities of 10 and 20 pest mites per leaf arena (9 cm^2). Evaluations of leaf trichomes in both grape cultivars indicated the occurrence of longer trichomes on the basal portion of the main veins of 'Superior Seedless' leaves. The presence of these longer trichomes may be associated with the better performance of *N. idaeus* on 'Superior Seedless' leaves.

Keywords: two-spotted spider mite; plant resistance; biological control.

INTRODUCTION

The grapevine, *Vitis vinifera* L., is a crop of great importance for Brazilian agriculture, mainly in the Northeast region of the country (ACADEMIA DO VINHO, 2014). The edaphoclimatic conditions of the São Francisco River Valley (SILVA et al., 2009) are favorable for the occurrence of several pests, including some phytophagous mites that cause losses in production and quality of fruits (BERTOLO et al., 2011). The two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae), is responsible for significant damages to several crops, such as cotton, kidney beans, papaya, strawberries and roses, in Brazil (MORAES; FLECHTMANN, 2008).

The two-spotted spider mite is highly polyphagous, colonizing especially the under surface of the leaves, hindering the productivity and vigor of the plants (MORAES; FLECHTMANN, 2008). Symptoms of attack on vineyards start with small chlorotic areas on the leaves, between the main veins, and subsequently the damaged area becomes necrosed (CARMONA et al., 1996). In high infestations, the spider mite can cause plant defoliation and tanning of the berries (BERTOLO et al., 2011).

Received: Oct 23, 2019 Accepted: Oct 30, 2020
Associate Editor: Silvia Galleti
Peer Review History: Double-blind Peer Review.

Chemical control is still the primary method used against the pest mites, causing quite a significant environmental impact (MORAES; FLECHTMANN, 2008). An alternative method is the biological control with the use of predatory mites of the family Phytoseiidae, which are considered the most important agents for the biological control of phytophagous mites in agricultural systems (MORAES; FLECHTMANN, 2008). In Brazil, several studies on the use of phytoseiid mites for the control of *T. urticae* were carried out in the South and Southeast regions of Brazil, with emphasis on strawberries and ornamental plants (FERLA et al. 2007; SATO et al., 2007; BERNARDI et al., 2010; IWASSAKI et al., 2015); however, studies on predaceous mites in vineyards cultivated in the Northeast region of the country are still scarce (DOMINGOS et al., 2014).

The presence of the phytoseiid mites *Euseius citrifolius* Denmark & Muma and *Neoseiulus idaeus* Denmark & Muma associated with *T. urticae* infestations in Brazilian vineyards (MOREIRA et al., 2010; DOMINGOS et al., 2014) have been recorded. The occurrence of *N. idaeus* was reported in commercial vineyards of the cultivars Sugraone and Italia Muscat, with high infestations of *T. urticae* in the São Francisco Valley (DOMINGOS et al., 2014).

The species *N. idaeus* is widely distributed in South America and is frequently found in manioc plantations in the northeast and southeast regions of Brazil (MORAES et al. 1994; MORAES, 2002). Although there is little information on its importance to vineyards, *N. idaeus* has potential use for spider mite biological control programs in this crop. *Neoseiulus idaeus* is a type II selective predator (HOLLING, 1959) with preference for feeding on tetranychid mites (WATANABE et al., 1994; CROFT et al., 2004; MCMURTRY et al., 2013). This phytoseiid mite presented a good performance in controlling *T. urticae* in commercial papaya fields in the states of Rio de Janeiro and Espírito Santo in Brazil (COLLIER et al., 2004; 2007; MORAES; FLECHTMANN, 2008).

Phytophagous and predaceous mites might be directly affected by the host plants via some structures or chemical compounds present on leaves and other plant parts, which may influence their movement, feeding and reproduction behaviors. In this aspect, structures like trichome and domatium may affect the searching and prey-capture efficiency for predaceous mites, influencing on the survival and oviposition rates of the mites (WALTER, 1996; KRIPS et al., 1998; AFZAL; BASHIR, 2007; ROMERO et al., 2011; RAMALHO et al., 2014).

Considering the limited knowledge on the phytophagous and predaceous mites on vineyards of the São Francisco Valley, this study aimed at evaluating the population growth rates of the two-spotted spider mite and the predation rates of *N. idaeus* on *T. urticae* mites on leaves of two grape cultivars ('Italia' and 'Superior Seedless') for establishing a management program for this pest mite in Brazilian vineyards.

MATERIALS AND METHODS

Mite populations

Samples of *T. urticae* and predatory mites were collected from commercial vineyards located in São Francisco Valley [Casa Nova municipality (9°10'S; 40°58'W), state of Bahia (BA), and Petrolina city (9°20'S; 40°30'W), state of Pernambuco (PE)] in the period from November 2011 to November 2012. Collected mites were reared in jack bean [*Canavalia ensiformis* (L.) DC.] leaf arenas, constituted of a bean leaf placed on a layer of polyurethane foam saturated with water in a Petri dish. Arenas were replaced when they showed initial deterioration, generally every 5 days. The rearing room was kept at 25 ± 2 °C, relative humidity of 70 ± 10% and a photoperiod of 12:12 h (L:D).

Preliminary surveys for phytoseiid mites in vineyards of São Francisco Valley (Casa Nova, BA; Petrolina, PE) indicated that *N. idaeus* was the most abundant species in this region. The predaceous mites were collected from the vineyards at the same cultivation areas where *T. urticae* were collected. After collection, *N. idaeus* mites were maintained in jack bean leaf arenas, as described for the spider mite.

All life stages (eggs, larvae, protonymphs, deutonymphs, and adults) of *T. urticae* mites were provided as food source for the predatory mites.

Samples of adults of the predatory and phytophagous mites were mounted in Hoyer's medium on microscope slides for identification.

Instantaneous growth and oviposition rates of *Tetranychus urticae*

The experiment was conducted under laboratory conditions from January to February 2013. Mature leaves were collected from vineyards of the grape cultivars Italia and Superior Seedless. Jack bean leaves were obtained from the plants cultivated

under laboratory conditions. The leaves of both plant species were washed with running water prior to the arena preparation. Each leaf disc (9 cm^2) was placed on water-soaked cotton in a Petri dish. The edge of the leaf disc was surrounded by a wet cotton wool to prevent the mites from escaping.

The treatment with jack bean leaves was used as a comparison standard. The experiment of *T. urticae* population growth was based on the method described by MATIOLI; OLIVEIRA (2007).

A four-day old previously mated female of *T. urticae* was placed into each leaf arena. The evaluations were carried out daily until the tenth day, assessing the mite survival and oviposition rates. Arenas were kept at the temperature of 25 ± 2 °C, relative humidity of 70 ± 5% and a 12-hour photophase. The total number of eggs and active forms of *T. urticae* were recorded on the tenth day after the mite introduction into each arena. Eq. 1 was used to calculate the instantaneous growth rate (r_i) of *T. urticae*:

$$r_i = \text{Ln}\,(N_f / N_0) / \Delta t \quad (1)$$

where N_f is the total number of *T. urticae* mites on the tenth day after the arena infestation, N_0 is the initial number of mites placed into each arena and Δt is the period in which the mites were in contact with the substrates (grape or jack-bean leaves) (STARK; BANKS, 2003).

For statistical analysis, groups of four arenas were considered as one replicate per treatment. The experiment was completely randomized with 20 replicates.

Data were submitted to the analysis of variance (one-way ANOVA) and the comparisons of means were done using LSD Post-Hoc test ($p < 0.05$).

Another aspect observed was the number of *T. urticae* trapped in the cotton barrier, which would be considered an indicative of a repellent effect of each substrate. Chi-square (X^2) test was used to compare the results for jack bean and grape cultivars.

Pest predation by *Neoseiulus idaeus*

The predation rate of *T. urticae* by the predatory mite *N. idaeus* was evaluated in leaf disc arenas of the grape cultivars Italia and Superior Seedless and of jack bean, using different prey densities. Leaf arenas were prepared as described before, infesting each arena with adult females of *T. urticae* at the densities of 5, 10, 20, and 30 mites per arena. One adult female of *N. idaeus* was placed into each leaf disc arena. Arenas were kept at the temperature of 25 ± 2 °C, relative humidity of 70 ± 5% and a 12-hour photophase. The number of females killed by the predator was evaluated every 24 h during 5 days. All preyed females were replaced by live females at each evaluation time. Only adult females of *T. urticae* were kept on the arenas, removing all other stages of mites.

For statistical analysis, groups of five arenas were considered as one replicate per treatment (leaves of the two grape cultivars and of jack bean). The experiment was completely randomized with 12 treatments and five replicates.

Data on the number of preyed females were analyzed using two-way ANOVA (3 leaf types × 4 prey densities). Comparisons of mean number of preyed mites for each treatment were conducted using LSD test ($p < 0.05$).

In addition, to observe the relationship between the number of *T. urticae* adult females offered to and preyed by *N. idaeus* in the leaf disc arenas, a correlation analysis was performed using the Pearson correlation coefficient.

Grape leaf trichomes

Leaves of both grape cultivars and jack bean were morphologically characterized based on the number and size of leaf trichomes. The leaves of grape cultivars ('Italia' and 'Superior Seedless') practically do not have trichomes on the surface, however, there are a large number of these structures on the lateral sides of the leaf veins, especially on the basal portion of the main veins (Fig. 1).

The number and size of trichomes were evaluated in five replicates of 1 mm, distributed in the first centimeter of the basal region of the leaf veins of both grape cultivars, totaling 21 veins observed per cultivar. The size of trichomes was estimated based on the measurement of at least 10 trichomes per mm of leaf vein. Images of a stereoscopic microscope with image overlapping and analyzing resources (Leica Microsystems) were used for counting and measurement of the leaf trichomes.

Trichomes were not counted or measured for jack bean leaves due to the lack of these structures on the leaves.

Data of the number and length of trichomes were submitted to the analysis of variance, using the t test to compare means.

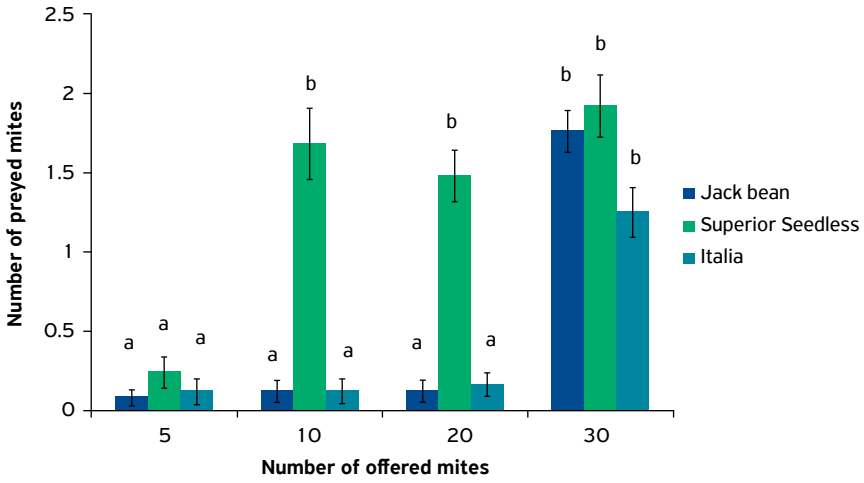

Figure 1. Number of *T. urticae* adult females offered and preyed per day by *N. idaeus* in leaf disc arenas of two grape cultivars ('Italia' and 'Superior Seedless') and jack bean. Columns with the same letter are not significantly different at 5% significance.

RESULTS

Instantaneous growth and oviposition rates of *Tetranychus urticae*

Results indicated a higher oviposition rate (F = 37.41; d.f. = 57; p < 0.0001) of *T. urticae* on the leaves of 'Superior Seedless' than those of 'Italia'; however, the egg viability was significantly lower (F = 17.95; d.f. = 57, p < 0.0001) in 'Superior Seedless' (57.5%) than in 'Italia' grape (96.7%). The population growth rates ($0.211 \leq r_i \leq 0.225$) of the spider mite were similar in both grape cultivars (Table 1).

Table 1. Number of *Tetranychus urticae* eggs per female per day (mean values ± SD) (n = 20); percentage of egg viability (mean values ± SD), and instantaneous growth (r_i) per day (mean values ± SD) in leaf disc arenas of two grape cultivars ('Italia' and 'Superior Seedless') and jack bean.

Substrate	Number of eggs/female/day	Egg viability (%)	r_i (day)
'Italia' grape	1.20 ± 0.19 a	94.87 ± 5.13 b	0.225 ± 0.017 a
'Superior Seedless' grape	1.93 ± 0.42 b	57.50 ± 8.38 a	0.211 ± 0.028 a
Jack bean	4.36 ± 0.53 c	97.52 ± 0.94 b	0.353 ± 0.011 b

Averages followed by the same letter, in the same column, are not significantly different at 5% significance.

The oviposition (4.4 eggs/female/day) and population growth rates (r_i= 0.35) of *T. urticae* were significantly higher (F = 41.61; d.f. = 54; p < 0.0001) on the leaves of jack bean than those of 'Italia' and 'Superior Seedless' grapes.

The viability of *T. urticae* eggs was high (94.9%) in 'Italia' grape and did not differ from jack bean (97.5%). Lower egg viability (57.5%) was observed for 'Superior Seedless' grape, differing significantly (F = 43.93; d.f. = 54; p < 0.0001) from the other two treatments.

A higher and significant (X^2 = 5.556; p = 0.00184) percentage of mites trapped and killed in the wet cotton barrier around the leaves was observed for 'Superior Seedless' grape (17.5%) in comparison with 'Italia' grape (10%) and jack bean leaves (5%). No significant difference was detected between 'Italia' grape and jack bean leaves.

Pest predation by *Neoseiulus idaeus*

Considering the three evaluated substrates (leaves of two grape cultivars and jack bean) and the four prey densities, the number of preyed mites was affected significantly by the substrates [$F_{(2, 44)}$ = 60.84, p < 0.001] and prey densities [$F_{(3, 44)}$ = 72.77, p < 0.001], with interactions of both parameters [$F_{(6, 44)}$ = 11.07, p < 0.001].

Positive and significant correlations (p ≤ 0.0012) were observed between the prey densities and the number of mites consumed by *N. idaeus* for the leaves of both grape cultivars and jack bean (Table 2).

Table 2. Relationship between the number of *T. urticae* adult females offered and preyed by *N. idaeus* in leaf disc arenas of two grape cultivars ('Italia' and 'Superior Seedless') and jack bean.

Plant species/cultivar	r[a]	d.f.	P
'Italia' grape	0.778	18	< 0.0001
'Superior Seedless' grape	0.672	18	0.0012
Jack bean	0.789	18	< 0.0001

[a]Pearson's correlation coefficient

Significant differences among the substrates for the predation rates of *N. idaeus* on *T. urticae* adult females were observed only for the densities of 10 and 20 prey mites per leaf arena (9 cm^2), without significant differences for the lowest (5 mites/arena) and the highest prey (30 mites/arena) densities (Fig. 1).

At the intermediate densities (10 and 20 prey mites/arena), the number of *T. urticae* females consumed by *N. idaeus* on 'Superior Seedless' leaves varied from 1.5 to 1.7 mite a day, which was up to 14 times higher than the mite consumption values observed for 'Italia' grape and jack bean.

No significant differences were observed between 'Italia' grape and jack bean leaves for the preying behavior of *N. idaeus* for the different prey densities.

Grape leaf trichomes

Evaluations of the leaves of both grape cultivars indicated significant differences in the number ($t = 4.99$; d.f. = 20; $p < 0.0001$) and size ($t = 6.21$; d.f. = 20; $p < 0.0001$) of trichomes located on the basal portion of the main leaf veins (Figs. 2 and 3). No trichomes were observed on the surface of leaves (between the veins) of these grape cultivars.

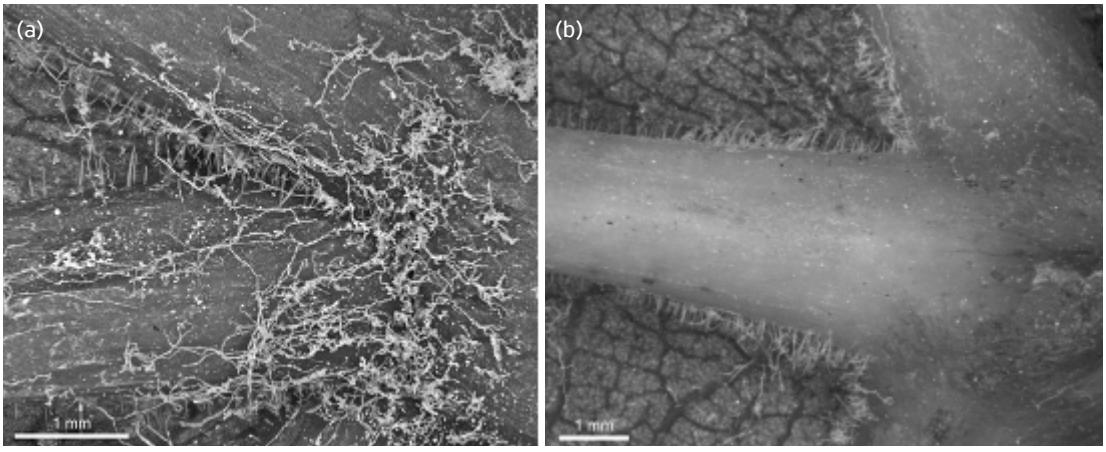

Figure 2. Aspects of leaf trichomes for 'Superior Seedless' (2a) and 'Italia' (2b) grape cultivars.

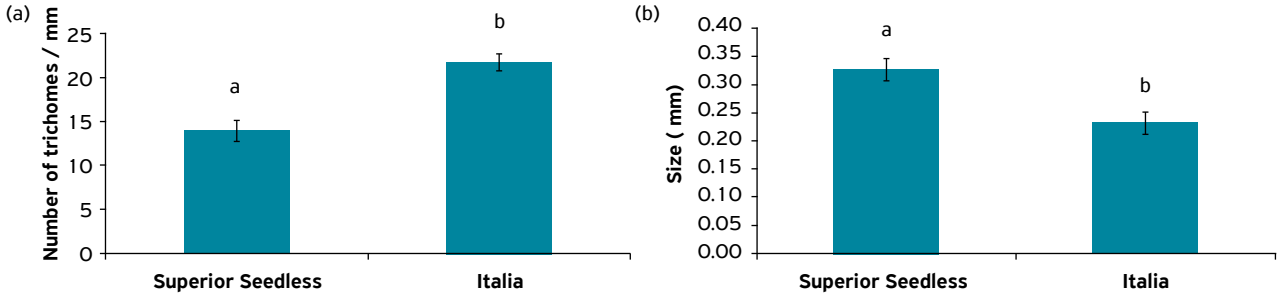

Figure 3. Number (a) and size (b) of leaf trichomes for 'Superior Seedless' and 'Italia' grape cultivars.

DISCUSSION

The spider mite egg viability in grape cultivar Italia was high and similar to that observed for jack bean (~ 98%), which is considered an excellent host plant for *T. urticae* (SATO et al., 2011a). VALADÃO et al. (2012) also reported high egg viabilities (> 85%) for the spider mite in the grape cultivars Italia, Benitaka and Redimeire, evaluating *T. urticae* populations from the Jales municipality, in the state of São Paulo.

High values (0.40 to 0.49/female/day) of instantaneous growth rate (r_i) of *T. urticae* in jack bean leaves were also reported by SATO et al. (2011a), mentioning values similar to or slightly higher than that (0.35/female/day) observed in the present study.

The number of eggs laid by *T. urticae* females on grape leaves (1.2 to 1.9 eggs/females/day) was similar to the values (between 1.5 and 2.0 eggs/female/day) reported by VALADÃO et al. (2012) for leaves of some grape cultivars ('Italia', 'Redimeire', 'Benitaka', 'Niagara').

Oviposition and population growth rates of *T. urticae* on the leaves of 'Italia' and 'Superior Seedless' grapes were lower than on jack bean leaves, possibly due to the lower nutritional quality of the grape leaves (AWMACK; LEATHER, 2002; MORO et al. 2012). Another possibility is the presence of one or more defense mechanism (MITCHELL et al., 2016) in grapes that limit the *T. urticae* population growth on their leaves.

Comparing the number of eggs of *T. urticae* on the leaves of the evaluated grape cultivars, it was observed a higher oviposition rate in 'Superior Seedless'; however, the value of the instantaneous growth rate of the spider mite was similar to that verified for 'Italia', indicating that leaves of 'Superior Seedless' may have an unfavorable factor for the pest population increase (MITCHELL et al. 2016).

The lower egg viability for the spider mite in 'Superior Seedless' is an indicative of the presence of toxic compounds (allelochemicals) in the leaves. Allelochemicals, such as alkaloids, ketones and organic acids, present in plants might be toxic to arthropods (GERHOLD et al., 1984; MITCHELL et al., 2016). Antibiosis resistance in vineyards was also reported by VALADÃO et al. (2012), who observed lower fertility and survival of *T. urticae* in the cultivar Niagara Rosada.

In the grape cultivar Superior Seedless, a higher percentage (≥ 75%) of mites trapped in the wet cotton barrier (around the leaf) was observed. This escaping behavior of *T. urticae* on the leaves of 'Superior Seedless' may be associated with the presence of allelochemicals unfavorable to the settlement of this species, with repellent and/or phagodeterrent effect (VENDRAMIM; GUZZO, 2009; VALADÃO et al., 2012). This repellent effect of the leaves may also have affected the walking behavior of the mites, leading them to spend more time walking on the leaves in attempt to escape the arenas, wasting more energy and resulting in a lower oviposition rate.

However, to elucidate the possible mechanism involved in the resistance of 'Superior Seedless' grape to the spider mite, further biochemical studies for this grape cultivar are required.

In the case of *N. idaeus*, other authors (WATANABE et al., 1994; COLLIER et al., 2004; DOMINGOS et al., 2014) also reported the association of this phytoseiid mite with the biological control of the two-spotted spider mite in crops like strawberry, cucumber and papaya in Brazil.

Very low predation rates of *T. urticae* by *N. idaeus* were observed for the lowest prey density (5 spider mites per arena); however, a trend towards increasing the predation rate was observed as the number of offered prey increased. The influence of prey density on the predation performance of phytoseiid mites was also reported by other authors. REIS et al. (2003) observed an increase in the predation rate of *Brevipalpus* sp. (Acari: Tenuipalpidae) by *Iphiseiodes zuluagai* Denmark & Muma (Acari: Phytoseiidae) as the available prey densities increased. These authors attributed to the lower consumption rate at low pest densities to the difficulty of the predators in finding their preys in these conditions.

Relative low predation rates of *Tetranychus* adult females by phytoseiid mites, as observed for *N. idaeus* (1.4 to 2.6 adult spider mites/phytoseiid female/day), were also reported by FURUICHI et al. (2005), evaluating the performance of *Neoseiulus womersleyi* Schicha (Acari: Phytoseiidae) fed on eggs or adults of *Tetranychus kanzawai* Kishida. The authors observed a rate of approximately 1.7 adult spider mites preyed by each phytoseiid female per day, which was similar to that verified for *N. idaeus* in the present study. The number of *T. kanzawai* eggs (14.6) preyed by *N. womersleyi* was 8.6 times higher than that for adults, indicating a clear preference of the predatory mites in preying eggs rather than adults.

A greater predation of *T. urticae* adult females by *N. idaeus* was observed for 'Superior Seedless' leaves rather than 'Italia' grape and jack bean leaves, only at the prey densities of 10 and 20 adult tetranychid mites per leaf arena.

This higher consumption of *T. urticae* by *N. idaeus* on 'Superior Seedless' leaves compared with other substrates is probably associated with the chemical and morphological characteristics of the leaves of this grape cultivar (KRIPS et al., 1999; LOUGHNER et al., 2008; MITCHELL et al., 2016).

In this aspect, it is possible that some compounds (allelochemicals) present in the leaves of 'Superior Seedless' may have affected the vigor and behavior of *T. urticae* mites, making them more susceptible to the attack by the predatory mite (BAIER et al., 2015). The higher movement of the spider mites on the leaves of this grape cultivar (escaping behavior) may have favored their encounter with the predatory mites, resulting in increased predation rates.

The allelochemicals present on 'Superior Seedless' grape leaves may also have affected the nutritional quality and taste of the preys (*T. urticae* females), leading the predator to abandon the prey mites before their complete consume. This possible behavior change may induce higher rates of spider mite killing by *N. idaeus* to compensate the lower nutritional gain resulting from each attack (ELBROCH; WITTMER, 2013; ELBROCH et al., 2014). In this aspect, according to SUNDERLAND (1999), for some spider species, if the pest is distasteful spiders may kill more than they consume, which increases the rate of pest kill per unit of the predator food demand.

Other factors that may be associated with the differential predation rates on spider mites in different grape cultivars are the abundance and characteristic of the leaf trichomes. The presence of longer trichomes on the basal portion of main leaf veins of 'Superior Seedless' grape, forming a structure similar to the domatia described in vineyards by LOUGHNER et al. (2008), may serve as shelter for predaceous mites, increasing the oviposition rate and improving their predation performance (WALTER; DENMARK, 1991; MATOS et al., 2006; LOUGHNER et al., 2008).

In vines, domatia are comprised of groups of trichomes on main leaf axils (LOUGHNER et al., 2008). The presence of leaf trichomes forming domatia was also associated with a higher performance in the biological control of the red mite *Panonychus ulmi* (Koch) (Acari: Tetranychidae) by the predaceous mite *Typhlodromus pyri* Scheuten (Acari: Phytoseiidae) in different grape cultivars in Europe. GROSTAL; O'DOWD (1994) also showed that leaf domatia in the ornamental plant *Viburnum tinus* L. (Adoxaceae) favored the predation of *T. urticae* by *Galendromus occidentalis* (Nesbitt) (Acari: Phytoseiidae).

Although the longer leaf trichomes, present in the leaf veins of 'Superior Seedless', have been associated with a better performance of *N. idaeus*, negative effects of different types of trichomes on predatory mites were also reported by some authors, for instance, by limiting the movement of these predators on the leaves and affecting their predatory capacity (DRUKKER et al., 1997; SATO et al., 2011b). However, due to the absence of trichomes on the leaf surface of both grape cultivars (trichomes only on the main veins), the possible negative effect of trichomes on the movement and predation performance of *N. idaeus* on *T. urticae* is probably very low or absent.

In the case of the highest evaluated prey density (30 mites/arena), it was not observed any difference among the substrates for the predation rates of *T. urticae* by *N. idaeus*. This result is probably associated with the greater availability of preys on the leaf arenas, increasing the consumption of *T. urticae* by the predaceous mites on 'Italia' grape and jack bean leaves, due to the lower necessity of searching for preys (REIS et al., 2003; HIGGINSON; RUXTON, 2015).

Further field studies are still necessary to evaluate the actual influence of the different grape cultivars on the establishment and reproduction of two-spotted spider mites, as well as the importance of *N. idaeus* as a biological control agent against the pest mite in the vineyards of the São Francisco Valley in Brazil.

CONCLUSION

The oviposition rate of *T. urticae* was higher on 'Superior Seedless' than on 'Italia' grape leaves; however, the instantaneous growth rates of *T. urticae* were similar for these grape cultivars. For 'Superior Seedless', the spider mite egg viability was significantly lower than on 'Italia' grape. The phytoseiid *N. idaeus* preyed higher number of *T. urticae* mites on the leaves of 'Superior Seedless' than of 'Italia' grape, for the densities of 10 and 20 pest mites per leaf arena. Longer leaf trichomes were found on the basal portion of the main veins of 'Superior Seedless' leaves. The present study indicates that the use of *N. idaeus* in combination with grape cultivars, like 'Superior Seedless', with possible resistance to *T. urticae* and favorable characteristic for the establishment of the predaceous mite, can be an interesting strategy for the management of the spider mite in the northeast region of Brazil.

AUTHORS' CONTRIBUTIONS

Conceptualization: Pantaleão, A.A.S.S.; Moreira, J.O.T.; Sato, M.E. **Data Curation**: Pantaleão, A.A.S.S.; Moreira, J.O.T.; Sato, M.E. **Formal Analysis:** Pantaleão, A.A.S.S.; Moreira, J.O.T.; Sato, M.E. **Investigation:** Pantaleão, A.A.S.S.; Moreira, J.O.T.; Sato, M.E.; Pionório, J.A. **Methodology:** Pantaleão, A.A.S.S.; Moreira, J.O.T.; Sato, M.E.; Pionório, J.A. **Writing – Review & Editing:** Pantaleão, A.A.S.S.; Moreira, J.O.T.; Sato, M.E.

AVAILABILITY OF DATA AND MATERIAL

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

FUNDING

Conselho Nacional de Desenvolvimento Científico e Tecnológico
http://dx.doi.org/10.13039/501100003593
Grant No: 306852/2019-5

Coordenação de Aperfeiçoamento de Pessoal de Nível Superior
http://dx.doi.org/10.13039/501100002322
Finance Code 001

CONFLICTS OF INTEREST

All authors declare that they have no conflict of interest.

ETHICAL APPROVAL

Not applicable.

ACKNOWLEDGEMENTS

We would like to thank Dr. Jeferson Luiz de Carvalho Mineiro (Instituto Biológico, São Paulo) for the identification of the predaceous mites and Dr. Valmir Antonio Costa (Instituto Biológico, São Paulo) for the assistance to get the images of the leaf trichomes.

REFERENCES

ACADEMIA DO VINHO. Brasil - Vale do São Francisco. 2014. Available from: http://www.academiadovinho.com.br/_regiao_mostra.php?reg_num=BR04. Access on: 25 Oct. 2017.

AFZAL, M.; BASHIR, M.H. Influence of certain leaf characters of some summer vegetables with incidence of predatory mites of the family Cunaxidae. *Pakistan Journal of Botany*, Karachi, v.39, n.1, p.205-209, 2007. Available from: http://www.pakbs.org/pjbot/PDFs/39(1)/PJB39(1)205.pdf. Access on: 10 Jun. 2019.

AWMACK, C.S.; LEATHER, S.R. Host plant quality and fecundity in herbivorous insects. *Annual Review of Entomology*, Palo Alto, v.47, p.817-844, 2002. https://doi.org/10.1146/annurev.ento.47.091201.145300

BAIER, J.E.; RESENDE, J.T.V.; FARIA, M.V.; SCHWARZ, K.; MEERT, L. Indirect selection of industrial tomato genotypes that are resistant to spider mites (*Tetranychus urticae*). *Genetics and Molecular Research*, Ribeirão Preto, v.14, n.1, p.244-252, 2015. https://doi.org/10.4238/2015.January.16.8

BERNARDI, D.; BOTTON, M.; CUNHA, U.S.; NAVA, D.E.; GARCIA, M.S. *Bioecologia, monitoramento e controle do ácaro-rajado com o emprego da azadiractina e ácaros predadores na cultura do morangueiro* (Circular Técnica 83). Bento Gonçalves: Embrapa Uva e Vinho, 2010. 8p. Available from: https://www.infoteca.cnptia.embrapa.br/infoteca/bitstream/doc/879820/1/cir083.pdf. Access on: 10 Jun. 2019.

BERTOLO, F.O.A.; OTT, A.P.; FERLA, N.J. *Ácaros em videira no Rio Grande do Sul* (Boletim Técnico 21). Porto Alegre: Fepagro, 2011. 24p. Available from: http://www.fepagro.rs.gov.br/upload/20111227185231boletim_a%C2%81caros___versao_online.pdf. Access on: 20 Jun. 2019.

CARMONA, M.M.; DIAS, J.C.S.; GANHÃO, J.F.P. *Fundamentos de Acarologia Agrícola*. Lisboa: Fundação Calouste Gulbenkian, 1996. 423p.

COLLIER, K.F.S.; ALBUQUERQUE, G.S.; LIMA, J.O.G.; PALLINI, A.; MOLINA-RUGAMA, A.J. *Neoseiulus idaeus* (Acari: Phytoseiidae) as a potential biocontrol agent of the two-spotted spider mite, *Tetranychus urticae* (Acari: Tetranychidae) in papaya: performance on different prey stage-host plant combinations. *Experimental and Applied Acarology*, Amsterdam, v.41, n.1-2, p.27-36, 2007. https://doi.org/10.1007/s10493-006-9041-2

COLLIER, K.F.S.; LIMA, J.O.G.; ALBUQUERQUE, G.S. Predacious mites in papaya (*Carica papaya* L.) orchards: in search of a biological control agent of phytophagous mite pests. *Neotropical Entomology*, Londrina, v.33, n.6, p.799-803, 2004. https://doi.org/10.1590/S1519-566X2004000600020

CROFT, B.A.; BLACKWOOD, J.S.; MCMURTRY, J.A. Classifying Life-Style Types of Phytoseiid Mites: Diagnostic Traits. *Experimental and Applied Acarology*, Amsterdam, v.33, n.4, p.247-260, 2004. https://doi.org/10.1023/B:APPA.0000038622.26584.82

DOMINGOS, C.A.; MELO, J.W.S.; OLIVEIRA, J.E.M.; GONDIM JÚNIOR, M.G.C. Mites on grapevines in northeast Brazil: occurrence, population dynamics and within-plant distribution. *International Journal of Acarology,* Arkansas, v.40, n.2, p.145-151, 2014. https://doi.org/10.1080/01647954.2014.891651

DRUKKER, B.; JANSSEN, A.; RAVENSBERG, W.; SABELIS, M.W. Improved control capacity of the mite predator *Phytoseiulus persimilis* (Acari: Phytoseiidae) on tomato. *Experimental and Applied Acaralogy*, Amsterdam, v.21, n.6-7, p.507-518, 1997. https://doi.org/10.1023/B:APPA.0000018885.35044.c6

ELBROCH, L.M.; ALLEN, M.L.; LOWREY, B.H.; WITTMER, H.U. The difference between killing and eating: ecological shortcomings of puma energetic models. *Ecosphere*, v.5, n.5, p.1-16, 2014. https://doi.org/10.1890/ES13-00373.1

ELBROCH, L.M.; WITTMER, H.U. Nuisance Ecology: Do Scavenging Condors Exact Foraging Costs on Pumas in Patagonia? *PLoS ONE*, San Francisco, v.8, n.1, p.e53595, 2013. https://doi.org/10.1371/journal.pone.0053595

FERLA, N.J.; MARCHETTI, M.M.; GONÇALVES, D. Ácaros predadores (Acari) associados à cultura do morango (*Fragaria* sp., Rosaceae) e plantas próximas no Estado do Rio Grande do Sul. *Biota Neotropica*, Campinas, v.7, n.2, p.bn01807022007, 2007. https://doi.org/10.1590/S1676-06032007000200012

FURUICHI, H.; OKU, K.; YANO, S.; TAKAFUJI, A.; OSAKABE, M. Why does the predatory mite *Neoseiulus womersleyi* Schicha (Acari: Phytoseiidae) prefer spider mite eggs to adults? *Applied Entomology and Zoology*, Tokyo, v.40, n.4, p.675-678, 2005. https://doi.org/10.1303/aez.2005.675

GERHOLD, D.L.; CRAIG, R.; MUMMA, R.O. Analysis of trichome exudates from mite-resistant geraniums. *Journal of Chemical Ecology,* Penn, v.10, n.5, p.713-722, 1984. https://doi.org/10.1007/BF00988538

GROSTAL, R.; O'DOWD, D.J. Plants, mites and mutualism: leaf domatia and the abundance and reproduction of mites on *Viburnum tinus* (Caprifoliacea). *Oecologia*, Buenos Aires, v.97, n.3, p.308-315, 1994. https://doi.org/10.1007/BF00317319

HIGGINSON, A.D.; RUXTON, G.D. Foraging mode switching: the importance of prey distribution and foraging currency. *Animal Behaviour*, Saunt Aundraes, v.105, p.121-137, 2015. https://doi.org/10.1016/j.anbehav.2015.04.014

HOLLING, C.S. Some Characteristics of Simple Types of Predation and Parasitism. *The Canadian Entomologist*, Cambridge, v.91, n.7, p.385-398, 1959. https://doi.org/10.4039/Ent91385-7

IWASSAKI, L.A.; SATO, M.E.; CALEGARIO, F.F.; POLETTI, M.; MAIA, A.H.N. Comparison of conventional and integrated programs for control of *Tetranychus urticae* (Acari: Tetranychidae). *Experimental and Applied Acarology*, Amsterdam, v.65, n.2, p.205-217, 2015. https://doi.org/10.1007/s10493-014-9853-4

KRIPS, O.E.; KLEIJN, P.W.; WILLEMS, P.E.L.; GOLS, G.J.Z.; DICKE, M. Leaf hairs influence searching efficiency and predation rate of the predatory mite *Phytoseiulus persimilis* (Acari: Phytoseiidae). *Experimental and Applied Acarology*, Amsterdam, v.23, n.2, p.119-131, 1999. https://doi.org/10.1023/A:1006098410165

KRIPS, O.E.; WITUL, A.; WILLEMS, P.E.L.; DICKE, M. Intrinsic rate of population increase of the spider mite *Tetranychus urticae* on the ornamental crop gerbera: intraspecific variation in host plant and herbivore. *Entomologia Experimentalis et Applicata*, Wageningen, v.89, n.2, p.159-168, 1998.

LOUGHNER, R.; GOLDMAN, K.; LOEB, G.; NYROP, J. Influence of leaf trichomes on predatory mite (*Typhlodromus pyri*) abundance in grape varieties. *Experimental and Applied Acarology*, Amsterdam, v.45, n.3-4, p.111-122, 2008. https://doi.org/10.1007/s10493-008-9183-5

MATIOLI, A.L.; OLIVEIRA, C.A.L. Biologia de *Agistemus brasiliensis* Matioli, Ueckermann & Oliveira (Acari: Stigmaeidae) e sua potencialidade de predação sobre *Brevipalpus phoenicis* (Geijskes) (Acari: Tenuipalpidae). *Neotropical Entomology*, Londrina, v.36, n.4, p.557-582, 2007. https://doi.org/10.1590/S1519-566X2007000400016

MATOS, C.H.C.; PALLINI, A.; BELLINI, L.L.; FREITAS, R.C.P. Domácias e seu papel na defesa das plantas. *Ciência Rural,* Santa Maria, v.36, n.3, p.1021-1026, 2006. https://doi.org/10.1590/S0103-84782006000300050

MCMURTRY, J.A.; MORAES, G.J.; SOURASSOU, N.F. Revision of the lifestyles of phytoseiid mites (Acari: Phytoseiidae) and implications for biological control strategies. *Systematic and Applied Acarology*, Auckland, v.18, n.4, p.297-320, 2013. https://doi.org/10.11158/saa.18.4.1

MITCHELL, C.; BRENNAN, R.M.; GRAHAM, J.; KARLEY, A.J. Plant Defense Against Herbivorous Pests: Exploiting Resistance and Tolerance Traits for Sustainable Crop Protection. *Frontiers in Plant Science*, Lausanne, v.7, p.1132, 2016. https://doi.org/10.3389/fpls.2016.01132

MORAES, G.J. Controle biológico de ácaros fitófagos com ácaros predadores. In: PARRA, J.R.P.; BOTELHO, P.S.M.; CORRÊA-FERREIRA, B.S.; BENTO, J.M.S. (Orgs.). *Controle biológico no Brasil*: parasitoides e predadores. São Paulo: Manole, 2002. p.225-237.

MORAES, G.J.; FLECHTMANN, C.H.W. *Manual de Acarologia*: Acarologia básica e ácaros de plantas cultivadas no Brasil. Ribeirão Preto: Holos, 2008. 288p.

MORAES, G.J.; SILVA, C.A.D.; MOREIRA, A.N. Biology of a strain of *Neoseiulus idaeus* (Acari: Phytoseiidae) from Southwest Brazil. *Experimental and Applied Acarology,* Amsterdam, v.18, n.4, p.213-220, 1994. https://doi.org/10.1007/BF00114168

MOREIRA, A.N.; OLIVEIRA, J.V.; OLIVEIRA, J.E.M.; SANTOS, A.C.; GONDIM JÚNIOR, M.G.C. Acarofauna of vineyards associated with three production systems in the São Francisco River Valley, northeast Brazil. In: XXI INTERNATIONAL CONGRESS OF ACAROLOGY. *Anais...* Recife: Sociedade Entomológica do Brasil, 2010. Available from: https://www.alice.cnptia.embrapa.br/bitstream/doc/862359/1/AcarofaunaofvineyardsassociatedwiththreeproductionsystemsintheRioSaoFranciscoRiverValleyNortheastBrazil.pdf. Access on: 20 Jun. 2019.

MORO, L.B.; POLANCZY, R.A.; CARVALHO, J.R.; PRATISSOLI, D.; FRANCO, C.R. Parâmetros biológicos e tabela de vida de *Tetranychus urticae* (Acari: Tetranychidae) em cultivares de mamão. *Ciência Rural*, Santa Maria, v.42, n.3, p.487-493, 2012. https://doi.org/10.1590/S0103-84782012000300016

RAMALHO, T.K.A.; MATOS, C.H.C.; MELO, A.L.; OLIVEIRA, C.R.F.; MENEZES, T.G.C.; SILVA, J.K.L. Leaf domatia in montane forest and caatinga in the semiarid of Pernambuco State: Morphology and ecological implications. *Acta Scientiarum*. *Biological Sciences*, Maringá, v.36, n.3, p.327-332, 2014. https://doi.org/10.4025/actascibiolsci.v36i3.20275

REIS, P.R.; SOUSA, E.O.; TEODORO, A.V.; PEDRO NETO, M. Effect of prey density on the functional and numerical responses of two species of predaceous mites (Acari: Phytoseiidae). *Neotropical Entomology*, Londrina, v.32, n.3, p.461-467, 2003. https://doi.org/10.1590/S1519-566X2003000300013

ROMERO, G.Q.; DAUD, R.D.; SALOMÃO, A.T.; MARTINS, L.F.; FERES, R.J.F.; BENSON, W.W. Mites and leaf domatia: no evidence of mutualism in *Coffea arabica* plants. *Biota Neotropica*, Campinas, v.11, n.1, p.27-34, 2011. https://doi.org/10.1590/S1676-06032011000100002

SATO, M.E.; SILVA, M.Z.; RAGA, A.; CANGANI, K.G.; VERONEZ, B.; NICASTRO, R.L. Spiromesifen toxicity to the spider mite *Tetranychus urticae* and selectivity to the predator *Neoseiulus californicus*. *Phytoparasitica*, Bet Dagan, v.39, n.5, p.437-445, 2011a. https://doi.org/10.1007/s12600-011-0189-x

SATO, M.E.; SILVA, M.Z.; SOUZA FILHO, M.F.; MATIOLI, A.L.; RAGA, A. Management of *Tetranychus urticae* (Acari: Tetranychidae) in strawberry fields with *Neoseiulus californicus* (Acari: Phytoseiidae) and acaricides. *Experimental and Applied Acarology*, Amsterdam, v.42, n.2, p.107-120, 2007. https://doi.org/10.1007/s10493-007-9081-2

SATO, M.M.; MORAES, G.J.; HADDAD, M.L.; WEKESA, V.W. Effect of trichomes on the predation of *Tetranychus urticae* (Acari: Tetranychidae) by *Phytoseiulus macropilis* (Acari: Phytoseiidae) on tomato, and the interference of webbing. *Experimental and Applied Acarology*, Amsterdam, v.54, n.1, p.21-32, 2011b. https://doi.org/10.1007/s10493-011-9426-8

SILVA, P.C.G.; CORREIA, R.C.; SOARES, J.M. Histórico e importância socioeconômica. In: SOARES, J.M.; LEÃO, P.C.S. (ed.) *A vitivinicultura no semiárido brasileiro*. Petrolina: Embrapa, 2009. p.21-34.

STARK, J.D.; BANKS, J.E. Population-Level Effects of Pesticides and Other Toxicants on Arthropods. *Annual Review of Entomology*, Palo Alto, v.48, p.505-519, 2003. https://doi.org/10.1146/annurev.ento.48.091801.112621

SUNDERLAND, K. Mechanisms underlying the effects of spiders on pest populations. *The Journal of Arachnology*, Portland, v.27, n.1, p.308-316, 1999.

VALADÃO, G.S.; VIEIRA, M.R.; PIGARI, S.A.A.; TABET, V.G.; SILVA, A.C. Resistência de cultivares de videira ao ácaro-rajado *Tetranychus urticae* na região de Jales, estado de São Paulo. *Revista Brasileira de Fruticultura*, Jaboticabal, v.34, n.4, p.1051-1058, 2012. https://doi.org/10.1590/S0100-29452012000400011

VENDRAMIM, J.D.; GUZZO, E.C. Resistência de plantas e a bioecologia e nutrição dos insetos. In: PANIZZI, A.R.; PARRA, J.R.P. (ed). *Bioecologia e nutrição de insetos*: base para o manejo integrado de pragas. Brasília: Embrapa, 2009. p.1055-1058.

WALTER, D.E.; DENMARK, H.A. Use of leaf domatia on wild grape (Vitis munsoniana) by arthropods in Central Florida. *The Florida Entomologist*, Lutz, v.74, n.3, p.440-446, 1991. https://doi.org/10.2307/3494838

WALTER, D.E. Living on Leaves: Mites, Tomenta, and Leaf Domatia. *Annual Review of Entomology*, Palo Alto, v.41, p.101-114, 1996. https://doi.org/10.1146/annurev.en.41.010196.000533

WATANABE, M.A.; MORAES, G.J.; GASTALDO JÚNIOR, I.; NICOLELLA, G. Controle biológico do ácaro rajado com ácaros predadores fitoseídeos (Acari: Tetranychidae, Phytoseiidae) em culturas de pepino e morango. *Scientia Agricola*, Piracicaba, v.51, n.1, p.75-81, 1994. https://doi.org/10.1590/S0103-90161994000100012