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EFEITO DE AGENTES BIOLÓGICOS NO MANEJO DE ÁCAROS FITÓFAGOS EM MORANGUEIRO (*Fragaria × ananassa*)

EFFECT OF BIOLOGICAL AGENTS IN THE MANAGEMENT OF PHYTOPHAGOUS MITES IN STRAWBERRY (*FRAGARIA × ANANASSA*)

EFECTO DE AGENTES BIOLÓGICOS EN EL MANEJO DE ÁCAROS FITÓFAGOS EN FRUTILLA/FRESA (*FRAGARIA × ANANASSA*)

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Resumo

A ocorrência de ácaros fitófagos na cultura do morango representa um dos principais desafios fitossanitários da cultura, devido à elevada capacidade reprodutiva e rápida dispersão dessas pragas. Nesse contexto, o presente estudo avalia o efeito de diferentes estratégias de controle no manejo de *Tetranychus urticae* (ácaro rajado) e *Tetranychus ludeni* (ácaro vermelho) em cultivo comercial de morango. O experimento foi conduzido em delineamento em blocos casualizados, com cinco tratamentos: *Chromobacterium subtsugae*, *Pseudomonas fluorescens* + *Pseudomonas chlororaphis*, *Azadirachta indica*, abamectina e testemunha. As avaliações foram realizadas semanalmente durante

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seis semanas, por meio do monitoramento populacional dos ácaros, número de folíolos infestados, presença de ovos, bronzeamento foliar, formação de teia e produção de frutos comerciais e não comerciais. Ao final do experimento, também foi realizada a amostragem de ácaros predadores. Os tratamentos à base de *A. indica* e *C. subtsugae* apresentaram menores médias de infestação de *T. urticae* e menores níveis de danos visuais nas plantas. Para *T. ludeni* e para as variáveis relacionadas à produção de frutos, não foram observadas diferenças significativas entre os tratamentos. Os resultados indicam que *A. indica* e *C. subtsugae* apresentam potencial para o manejo sustentável do ácaro rajado em cultivo comercial de morango.

Palavras-chave: Ácaros fitófagos; Controle biológico; *Chromobacterium subtsugae*; *Azadirachta indica*; Manejo integrado de pragas.

Abstract

The occurrence of phytophagous mites in strawberry crops represents one of the main phytosanitary challenges of the culture, due to the high reproductive capacity and rapid dispersal of these pests. In this context, the present study evaluates the effect of different control strategies in the management of *Tetranychus urticae* (two-spotted spider mite) and *Tetranychus ludeni* (red spider mite) in a commercial strawberry crop. The experiment was conducted in a randomized block design with five treatments: *Chromobacterium subtsugae*, *Pseudomonas fluorescens* + *Pseudomonas chlororaphis*, *Azadirachta indica*, abamectin, and a control. Evaluations were performed weekly for six weeks by monitoring the mite population, number of infested leaflets, presence of eggs, leaf bronzing, web formation, and production of commercial and non-commercial fruits. At the end of the experiment, sampling of predatory mites was also conducted. The treatments based on *A. indica* and *C. subtsugae* showed lower average infestations of *T. urticae* and lower levels of visual damage to the plants. For *T. ludeni* and the variables related to fruit production, no significant differences were observed among the treatments. The results indicate that *A. indica* and *C. subtsugae* have potential for the sustainable management of the two-spotted spider mite in commercial strawberry cultivation.

Keywords: Phytophagous mites; Biological control; *Chromobacterium subtsugae*; *Azadirachta indica*; Integrated pest management.

Resumen

La ocurrencia de ácaros fitófagos en el cultivo de fresa representa uno de los principales desafíos fitosanitarios del cultivo, debido a la elevada capacidad reproductiva y rápida dispersión de estas plagas. En este contexto, el presente estudio evalúa el efecto de diferentes estrategias de control en el manejo de *Tetranychus urticae* (ácaro de dos puntos o araña roja) y *Tetranychus ludeni* (ácaro rojo) en un cultivo comercial de fresa. El experimento se realizó bajo un diseño de bloques al azar con cinco tratamientos: *Chromobacterium subtsugae*, *Pseudomonas fluorescens* + *Pseudomonas chlororaphis*, *Azadirachta indica*, abamectina y un testigo. Las evaluaciones se realizaron semanalmente durante seis semanas, mediante el monitoreo poblacional de los ácaros, el número de folíolos infestados, la presencia de huevos, el bronceado foliar, la formación de telarañas y la producción de frutos comerciales y no comerciales. Al final del experimento, también se realizó un muestreo de ácaros depredadores. Los tratamientos a base de *A. indica* y *C. subtsugae* presentaron menores promedios de infestación de *T. urticae* y menores niveles de daños visuales en las plantas. Para *T. ludeni* y para las variables relacionadas con la producción de frutos, no se observaron diferencias significativas entre los tratamientos. Los resultados indican que *A. indica* y *C. subtsugae* presentan potencial para el manejo sostenible del ácaro de dos puntos en el cultivo comercial de fresa.

Palabras clave: Ácaros fitófagos; Control biológico; *Chromobacterium subtsugae*; *Azadirachta indica*; Manejo integrado de plagas.

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1.Introduction

Strawberry is a high-value crop with strong consumer acceptance due to its desirable sensory attributes and nutritional value (Calella *et al*., 2026). Furthermore, the continued development of strawberry production has been supported by advances in grower expertise and technologies aimed at improving cultivar adaptation to diverse climatic conditions, enhancing resistance to pests and diseases, and optimizing production and distribution systems (Antunes & Bonow, 2023; Sindarov, 2025).

Global strawberry production has expanded considerably in recent years. In Brazil, the crop has shown increasing importance, with an average yield of approximately 30 t ha^{-1}, although substantial regional variability exists, with production concentrated mainly in the state of Minas Gerais (Da Conceição *et al*., 2025). Despite the adoption of improved production technologies, the national average yield remains lower than that reported in major producing countries such as the United States and Spain, where yields often exceed 50 t ha^{-1} (Antunes *et al*., 2021).

Given the high economic value of the crop, pest management represents one of the major challenges faced by strawberry growers (Lee *et al*., 2026). The occurrence of pests and diseases negatively affects both fruit yield and quality and is considered one of the main constraints to strawberry production (Zawadneak, 2020). According to Michereff Filho *et al*. (2020), arthropods and mollusks are associated with strawberry crops throughout the production cycle, from crop establishment to harvest.

Among the most important phytosanitary problems affecting strawberry production are phytophagous mites, particularly the two-spotted spider mite (*Tetranychus urticae*) and the red spider mite (*Tetranychus ludeni*), which are considered key pests of the crop (Pamuk *et al*., 2025). These species cause direct damage by feeding on plant sap, reducing the photosynthetically active leaf area,

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impairing vegetative growth, and ultimately decreasing crop productivity (Cortez-Madrigal *et al*., 2026).

In this context, Integrated Pest Management (IPM) has become an essential strategy for the sustainable management of these pests by considering the interactions among the crop, the environment, and pest population dynamics, with the objective of maintaining pest populations below the economic injury level (Pobożniak & Olczyk, 2025). IPM relies on regular pest monitoring, timely decision-making, and the integration of multiple control strategies, thereby reducing dependence on chemical pesticides (Waquil *et al*., 2021).

Among the strategies incorporated into IPM, biological control has emerged as an important tool for managing phytophagous mites. The use of predatory organisms, entomopathogenic microorganisms, and botanical products contributes to reducing the use of chemical pesticides while promoting more sustainable strawberry production (Valadares-Inglis *et al*., 2020; Waquil *et al*., 2021).

Despite recent advances in the development of biopesticides, information regarding the performance of new biological control agents under commercial field conditions remains limited. Among these, the bacterium *Chromobacterium subtsugae* has shown promising potential because of its multiple modes of action, which may help mitigate the development of resistance to synthetic acaricides in mite populations (Priya *et al*., 2025).

Therefore, the objective of this study was to evaluate the effects of different pest management strategies, with emphasis on biological control tools, on the management of the phytophagous mites *Tetranychus urticae* and *Tetranychus ludeni* under commercial strawberry production conditions.

2. Materials and Methods

2.1 Experimental Site and Experimental Design

The experiment was conducted in a commercial strawberry field located in the municipality of Ressaquinha, Minas Gerais, Brazil, where a natural infestation of

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phytophagous mites was present. The experimental area consisted of five low tunnels, each measuring 25 m in length and 1.5 m in width and containing 110 plants. Both the border rows and each treatment plot occupied 2.30 m of tunnel length (Figure 1).

Seedlings of the cultivar 'San Andreas', imported from Chile, were transplanted in May 2025. Treatments were initiated on September 7, 2025, during a period characterized by low rainfall and increased mite infestation, when the plants were at the beginning of the reproductive stage.

The experiment was arranged in a randomized complete block design with five treatments and five replications. Each low tunnel represented one experimental block. Each experimental plot consisted of 10 central plants used for evaluations and 10 border plants positioned at the ends of the plots and between adjacent treatments to minimize interference among treatments. In addition, cardboard sheets were installed as physical barriers between treatment plots. During spraying, the sides of adjacent tunnels remained closed to reduce the risk of spray drift. All evaluations were performed on the 10 central plants of each experimental plot, as illustrated in Figure 1.

Figure 1 - Schematic representation of the experimental area.



Source: Survey data. (2026)

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2.2 Treatments and applications

Five treatments were evaluated, as shown in Table 1:

Table 1 - Description of the treatments used

Treatments	Description
T1	Commercial products based on *Chromobacterium subtsugae*
T2	Commercial products based on *Pseudomonas fluorescens* and *Pseudomonas chlororaphis*
T3	Commercial products based on *Azadirachta indica*
T4	Chemical products based on abamectin
T5	Control (water application)

Source: Survey data. (2026)

Treatments were applied according to the manufacturers label recommendations, following the prescribed application rates, spray volumes, and application intervals. Applications were performed using a backpack sprayer. Separate sprayers were used for the synthetic acaricide and the remaining treatments to prevent cross-contamination, and the equipment was thoroughly cleaned between applications.

As the manufacturers' recommendations differed among products, the number of applications was not identical across treatments. Therefore, the comparison focused on the performance of complete application programs rather than on the isolated effects of the active ingredients.

Table 2 presents the chemical and biological characterization and the application parameters of the phytosanitary treatments.

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Table 2 - Chemical and biological characterization and application parameters of phytosanitary treatments.

Product / Active Ingredient	Class / Formulation	Composition / Active Ingredients	Toxicological / Environmental Classification	Spray Volume	Maximum Number / Interval
Abamectin	Acaricide, insecticide, and nematicide / EC[1]	Abamectin: 18 g/L (1.8% w/v) \n• Diethylene glycol monoethyl ether: 599.8 g/L (59.98% w/v)	Cat. 3 (Moderately Toxic) \n• Class III (Highly hazardous to the environment)	800 L/ha (terrestrial application)	3 applications / 8 days
Chromobacterium subtsugae	Biological insecticide and acaricide / -[3]	C. subtsugae and enzymatic complex (phosphatase, pectinase, amylase, and cellulase)	NS[2]	Foliar application	10 days[4]
Azadirachta indica	Insecticide / -[3]	Neem seed oil: 0.12% \n• Propylene glycol USP surfactants and Silicon oxide	NS[2]	Foliar application (boom or backpack sprayers)	NS[2]
Pseudomonas spp.	Biological insecticide / SC[5]	P. chlororaphis (isolate CCTB 19): 12 g/L \n• P. fluorescens (isolate CCTB 03): 6 g/L	Class 5 / Cat. IV (Unlikely to cause acute hazard)	Terrestrial: 200 L/ha \n• Aerial: 30 to 50 L/ha	3 applications / 10 days

[1]EC: Emulsifiable Concentrate; [2]NS: Not specified by the manufacturer/cited literature; [3]Formulation not specified in the original text; [4]Interval experimentally adopted based on the management of *Pseudomonas* spp.; [5]SC: Suspension Concentrate.

All applications were standardized for the late afternoon period (17:00 to 18:00). For **C. subtsugae**, applications were performed under controlled environmental conditions (25 to 35°C and RH ≥ 60%).

Table 3 presents the total number of applications and the dosages used in each treatment, considering a spray volume of 5 L per application—thereby adding 1 L per treatment and 100 mL per plant.

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Table 3 - Number of applications and dosages used during the experiment.

Treatments	Product description	Total applications	Amount per spray mixture (5L)
T1	*Chromobacterium*	4	37.5 mL
T2	*Pseudomonas*	4	10 mL
T3	Azadirachta	6	50 mL
T4	Abamectin	5	2.5 mL
T5	Control	5	5 L

Source: Survey data. (2026)

2.3 Crop Management

During the experimental period, additional pest control was required, mainly for thrips and fall armyworm (*Spodoptera frugiperda*). A thiamethoxam-based insecticide belonging to the neonicotinoid chemical group (IRAC Group 4A), formulated as water-dispersible granules (WG) and containing 250 g kg^{-1} (25% w/w) of active ingredient (Syngenta, 2024), was used exclusively for the control of these pests according to the manufacturer's recommendations. The insecticide was applied at a rate of 2 g per 20 L of water and sprayed uniformly across all treatments and border rows.

This management practice was standardized throughout the experiment and, therefore, did not represent an additional source of variation among treatments. Although insecticides may exert indirect effects on non-target arthropods, their uniform application across all experimental plots minimized any potential interference with treatment comparisons. Furthermore, thiamethoxam is not registered for mite control and was used exclusively for the management of thrips and fall armyworm.

Foliar fertilization was also carried out during the experiment using a nutritional formulation containing boron (B), calcium (Ca), manganese (Mn), magnesium (Mg), potassium (K), copper (Cu), and phosphorus (P). The foliar fertilizer was added to the spray solution and applied uniformly to all experimental plots, regardless of treatment, using the same application dates and rates. Fertigation was performed weekly according to the crop's nutritional requirements, while drip irrigation was applied every two days. Both practices were standardized across all experimental units.

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2.3 Assessments

Population monitoring of the two-spotted spider mite (*Tetranychus urticae*) and the red spider mite (*Tetranychus ludeni*) was conducted weekly from September 7 to October 3, 2025, through direct in situ counts. Assessments were performed using a 10× hand lens. Species identification of both phytophagous and predatory mites was confirmed by morphological examination under a stereomicroscope in the laboratory.

For each experimental plant, the abaxial surface of three fully expanded leaves located in the lower, middle, and upper thirds of the canopy was evaluated, totaling nine leaflets per plant. The number of adults and nymphs present on each leaflet was recorded. A threshold of five mites per leaflet was adopted as the action threshold for corrective acaricide application (abamectin) and served as the technical reference for decision making.

A total of two previously trained evaluators conducted all assessments. Counts were performed during daylight hours, between 08:00 and 16:00, under full sunlight. Adult mites and nymphs present on the entire abaxial leaf surface were recorded. Eggs were assessed only for their presence or absence and were not quantified.

In addition to mite infestation, variables related to plant damage were also evaluated, including:

- leaf bronzing;
- webbing;
- presence of eggs on the leaflets; and
- presence of predatory mites.

Predatory mites were observed only during the final assessment of the experiment, as they were absent during the initial evaluation period.

Fruit production was monitored throughout the experimental period according to the commercial harvest schedule, with harvests performed twice a week, on Thursdays and Sundays. Fruits were collected, weighed in bulk, and classified as either marketable or non marketable.

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Marketable fruits were defined as those meeting the commercial quality standards for sale, whereas non-marketable fruits were those showing deformities, symptoms of pest or disease damage, or a fresh weight of less than 5 g.

2.4 Statistical Analysis

The data were initially subjected to the Shapiro–Wilk normality test. Variables that did not meet the assumption of normality were transformed using the $\sqrt{(Y + 1)}$ transformation. Subsequently, the data were analyzed by analysis of variance (ANOVA), and treatment means were compared using Tukey's test at the 5% significance level. All analyses were performed using SISVAR® software (Ferreira, 2019).

To complement the analyses, the Area Under the Disease Progress Curve (AUDPC) was calculated using RStudio® software. The AUDPC was used as a summary variable for each experimental plot, thereby reducing the temporal dependence among successive observations. The AUDPC was calculated individually for each experimental unit (treatment × block), integrating both the intensity and duration of mite infestation into a single index. The resulting data were subsequently subjected to analysis of variance and Tukey's test at the 5% significance level, following the methodology described by Campbell and Madden (1990).

We acknowledge that repeated-measures or mixed-effects models represent alternative statistical approaches for this type of data structure. However, in the present study, each evaluation week was considered an assessment factor, while the AUDPC was used as a complementary summary variable, as the primary objective was to compare treatment effects throughout the experimental period.

The AUDPC was calculated using the following equation:

$$AUDPC = \sum_{i=1}^{n-1} \left(\frac{(Y_i + Y_{i+1})}{2}\right)(t_{i+1} - t_i)$$

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Where:

- AUDPC = area under the disease progress curve;
- Y_i= infestation intensity at evaluation i;
- Y_{i+1}= infestation intensity at the subsequent evaluation;
- t_i= time of evaluation i;
- t_{i+1}= time of the subsequent evaluation;
- n= total number of evaluations.

3. Results and Discussion

The analysis of variance showed significant effects of treatments and evaluation weeks on the population of the two spotted spider mite. However, no significant interaction between treatments and weeks was observed, indicating similar treatment behavior throughout the experimental period.

For the other evaluated variables, including the number of red spider mites, leaflets infested by red spider mites, leaflets containing eggs, and commercial and non-commercial fruit production, no significant interaction between the evaluated factors was observed (Table 4).

The coefficient of variation (CV%) was high for most variables, except for the number of leaflets with red spider mites (13.04%). The high CV values reflect the considerable variability inherent to biological data related to mite populations (Table 4). Arnemann (2013), in a study on phytophagous mites associated with soybean crops, also reported high coefficients of variation, with most values exceeding 100%. According to the author, this variability is related to mite biology and their behavior in the environment and does not necessarily indicate statistical error, but rather represents a natural characteristic of biological datasets.

Although Gomes (1985) classified coefficients of variation below 10% as low, between 10 and 20% as moderate, between 20 and 30% as high, and above 30% as very high, Garcia (1989) pointed out that this classification is broad because it does

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not consider the specific characteristics of the evaluated species or the nature of the measured variables.

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Table 4 - Transformed mean values of mites, infested leaflets, and fruit weight as a function of treatments.

Treatment	*T. urticae*	Leaflets with *T. urticae*	*T. ludeni*	Leaflets with *T. ludeni*	Leaflets with eggs	Commercial yield	Non-commercial yield	*Phytoseiulus macropilis*
Chromobacterium subtsugae	2.323 a	1.641 ab	1.121 a	1.087 a	1.548 a	4.593 a	1.336 a	1.020 a
Pseudomonas fluorescens + P. chlororaphis	3.097 ab	1.771 ab	1.126 a	1.085 a	1.541 a	4.943 a	1.254 a	0.773 a
Azadirachta indica	1.945 a	1.463 a	1.167 a	1.099 a	1.429 a	4.503 a	1.350 a	1.203 a
Abamectin	3.658 ab	1.953 b	1.095 a	1.108 a	1.680 a	4.254 a	1.310 a	0.967 a
Control	4.504 b	1.868 b	1.382 a	1.158 a	1.684 a	4.284 a	1.349 a	1.130 a
CV (%)	84.31	27.16	34.40	13.04	26.29	27.69	38.68	73.69

Source: Survey data. (2026)
*Means followed by the same letter in a column do not differ significantly from each other according to Tukey's test (P ≤ 0.05). All data were transformed prior to the analysis of variance, as described in the Materials and Methods section.

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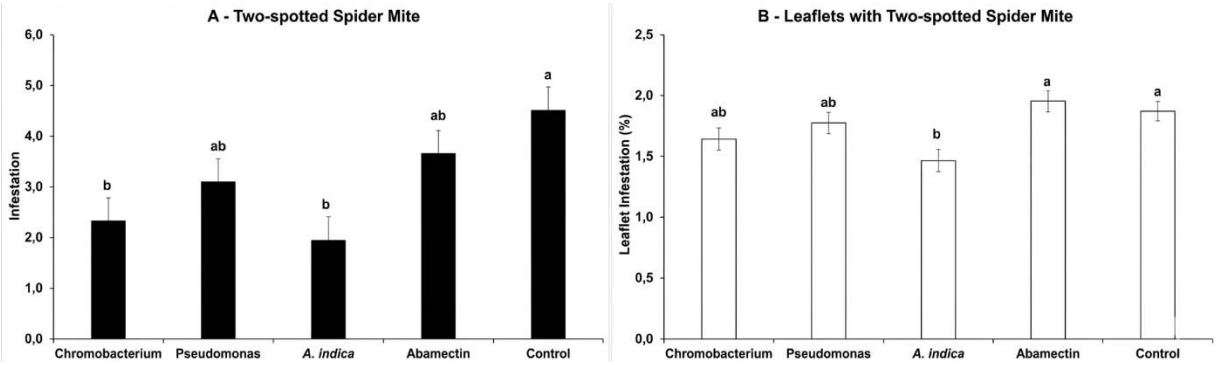
Figure 2 presents the transformed mean values of two-spotted spider mite infestation and the number of infested leaflets as a function of the applied treatments. The treatments based on *A. indica* and *Chromobacterium subtsugae* showed lower mean infestation levels of two-spotted spider mites compared with the control treatment. For the number of infested leaflets, the treatment with *A. indica* showed the lowest mean value, differing statistically from the abamectin treatment and the control.

Figure 2 - Transformed mean values of mites and infested leaflets according to the different treatments. Means followed by different letters in the columns differ from each other according to Tukey's test at 5% probability.



Source: Survey data. (2026)

Treatments based on *A. indica* and *Chromobacterium subtsugae* showed lower mean infestation levels of two-spotted spider mites compared with the control treatment, differing significantly for this variable. In contrast, treatments based on *Pseudomonas* spp. and abamectin did not differ from the other evaluated treatments.

The occurrence of predatory mites (*Phytoseiulus macropilis*) was low throughout the experiment, and no differences were observed among the evaluated treatments (Table 4). These results indicate that there were no differences among treatments regarding the low final occurrence of predatory mites.

Regarding the evaluation weeks, a progressive increase in infestation was observed throughout the experimental period, with the highest values recorded in the sixth week (Table 5). A similar pattern was observed for the number of infested leaflets

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and leaflets containing eggs, which also showed higher mean values in the final evaluations.

Table 5 - Transformed mean values of mites, infested leaflets, and fruit weight as a function of evaluation weeks. Means followed by different letters within columns differ significantly according to Tukey's test at 5% probability.

Weeks	Two-spotted spider mite	Leaflets with two-spotted spider mite	Leaflets with eggs	Commercial fruit weight	Non-commercial fruit weight
1	1.595 b	1.282 d	1.066 b	5.258 ab	1.270 ab
2	2.410 b	1.552 cd	1.160 b	4.251 bc	1.103 b
3	2.529 b	1.507 cd	1.398 b	3.262 c	1.026 b
4	2.875 b	1.721 bc	1.791 a	4.240 bc	1.529 a
5	3.707 ab	2.016 ab	1.958 a	4.000 c	1.357 ab
6	5.518 a	2.355 a	2.086 a	6.081 a	1.633 a
CV%	84.31	27.60	26.29	27.69	38.68

Source: Survey data. (2026)

The population dynamics of phytophagous mites may favor migration processes among areas subjected to different pest management practices. Areas with greater control effects may exert displacement pressure on mite populations, promoting movement toward neighboring crops with lower management pressure and greater host availability (Komagata *et al*., 2024). This behavior may have influenced the population dynamics observed throughout the evaluation period and represents a potential limitation of field-based studies.

The abamectin treatment showed one of the highest mean infestation levels of two-spotted spider mites, which may be associated with reduced susceptibility or resistance of the pest population to this active ingredient. According to Sato *et al*. (2009), populations of *Tetranychus urticae* resistant to abamectin and fenpyroximate have already been identified in strawberry crops. More recent studies indicate that resistance to abamectin remains an important challenge for the management of *T. urticae* in different production regions (Waquil *et al*., 2021). Silva *et al*. (2022), working with mites in banana crops, also observed greater efficacy of reduced abamectin rates compared with higher doses, demonstrating that inadequate product management may compromise its performance.

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Although two-spotted spider mite infestation differed among treatments and evaluation weeks, the same pattern was not observed for red spider mites or for the number of leaflets infested by this pest. The number of leaflets containing eggs also did not differ among treatments; however, it increased over time, especially after the fourth evaluation. This behavior indicates that pest population growth occurred progressively throughout the experimental period.

Dara *et al*. (2018), when evaluating products based on *Chromobacterium subtsugae* in strawberry fields in California, did not observe significant differences in *T. urticae* populations. Similar results were reported by Bilbo *et al.* (2019), who observed performance comparable to the untreated control in tomato crops. However, recent reviews highlight that the effects of bacterial biopesticides may vary according to bacterial strain, applied dose, and environmental microclimatic conditions (Cavalcante *et al*., 2022; Shapiro-Ilan & Wells, 2022).

The treatments based on *A. indica* and *C. subtsugae* showed lower infestation levels and reduced percentages of leaf bronzing and webbing throughout the evaluations. These results indicate the potential of these tools for the management of phytophagous mites, particularly in reducing visual symptoms associated with pest feeding.

Ismail *et al*. (2022) demonstrated high efficacy of abamectin nanoformulations for mite control, showing superior performance compared with conventional formulations and botanical oils. The authors also observed moderate toxicity of neem-based products against adult mites, mainly through reduced egg viability. Under field conditions, the evaluated formulations promoted population reductions greater than 90%. Similarly, Waked *et al*. (2020) reported a 75.21% reduction in pest population using *Pseudomonas fluorescens* in cucumber cultivation, with performance superior to synthetic acaricides.

None of the evaluated treatments significantly affected commercial or non-commercial fruit production. These results suggest that the infestation levels observed during the experimental period were not sufficient to negatively affect strawberry

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productivity. Furthermore, the evaluated treatments did not reduce crop yield during the relatively short experimental period.

Golec *et al*. (2020) found that products based on *C. subtsugae* showed moderate toxicity against different developmental stages of *T. urticae*, with lower effects on eggs. The authors observed reduced female fecundity, indicating potential for population suppression and a possible reduction in reliance on chemical acaricides.

Similar results were reported by Shapiro-Ilan and Wells (2022) for the management of *Curculio caryae*, in which applications of lower rates of *C. subtsugae*-based products effectively reduced pest damage over two consecutive years. According to these authors, the use of lower rates may improve the economic feasibility of the product and facilitate its adoption in agricultural systems.

Figure 3 presents the Area Under the Disease Progress Curve (AUDPC) for the evaluated variables. An increase in two-spotted spider mite infestation was observed from the fourth week onward, mainly in the untreated control, followed by the abamectin and *Pseudomonas* spp. treatments. The treatments based on *A. indica* and *C. subtsugae* showed lower infestation progression curves throughout the experimental period.

The number of red spider mites and the number of leaflets infested by this pest did not differ significantly among treatments (Figure 3). However, variation over time was observed, with fluctuations in infestation levels throughout the experimental period.

For the number of leaflets containing eggs (Figure 3), no significant differences were observed among treatments. Nevertheless, a gradual increase in oviposition was observed throughout the evaluations, particularly from the fourth week onward.

The variables related to commercial and non commercial fruit production showed no significant differences among treatments (Figure 3). However, treatments with *C. subtsugae* and *Pseudomonas* spp. showed higher commercial fruit production curves throughout the experimental period. Non commercial fruits showed low values during the first weeks, followed by an increase from the fourth week onward, a pattern observed in all treatments. These results indicate that the main agronomic relevance

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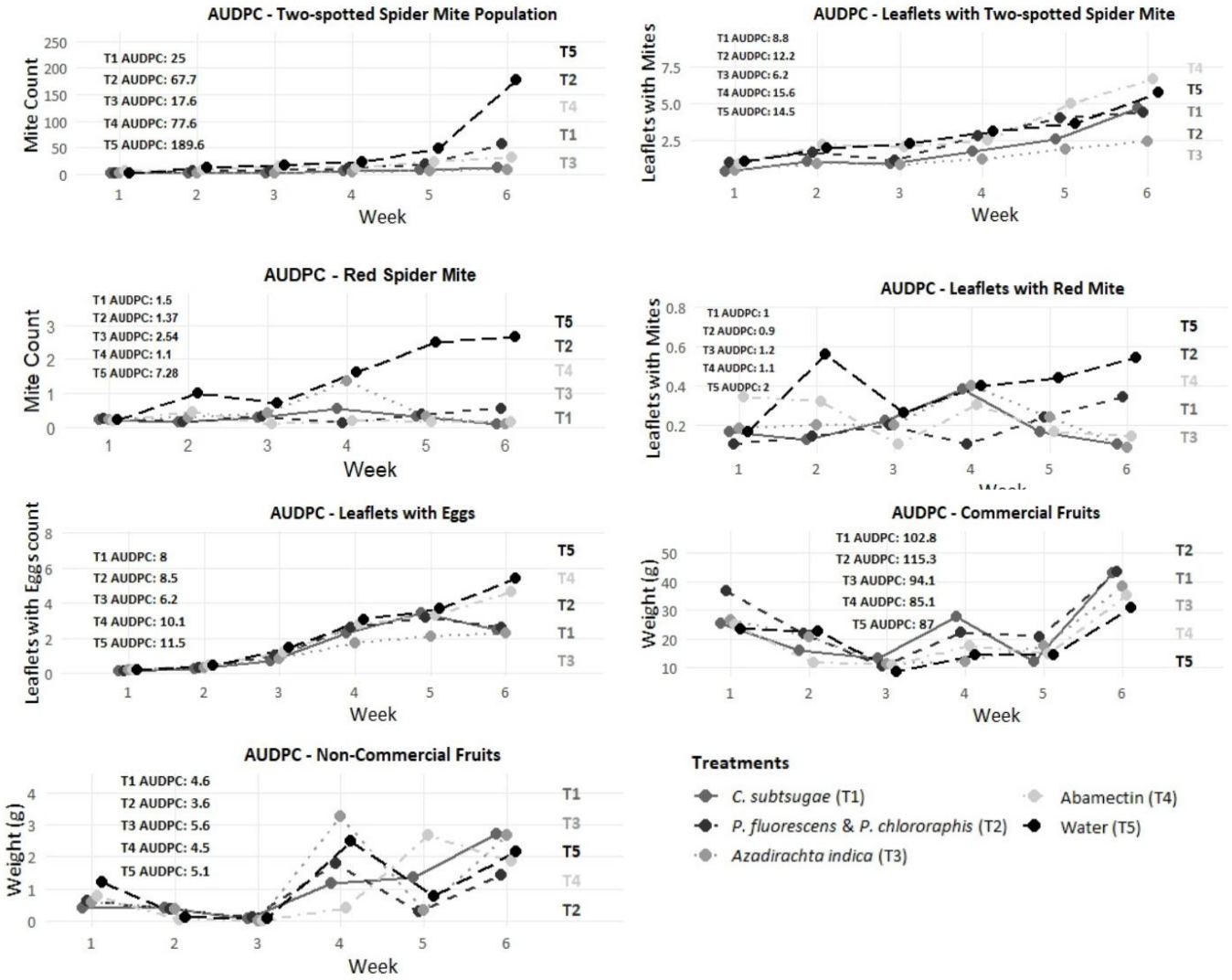
of the treatments was associated with effects on infestation and visual symptoms rather than measurable changes in productivity during the evaluated period.

Figure 3 - Area under the progression curve of the analyzed variables.



Source: Survey data. (2026)

Regarding the Area Under the Disease Progress Curve (AUDPC), no significant differences were observed among treatments throughout the experimental period. The lack of significance may be related to the low population density observed during part of the evaluations, the natural variability of mite infestation, and the short experimental period. Nevertheless, an increasing population trend was observed, particularly in the

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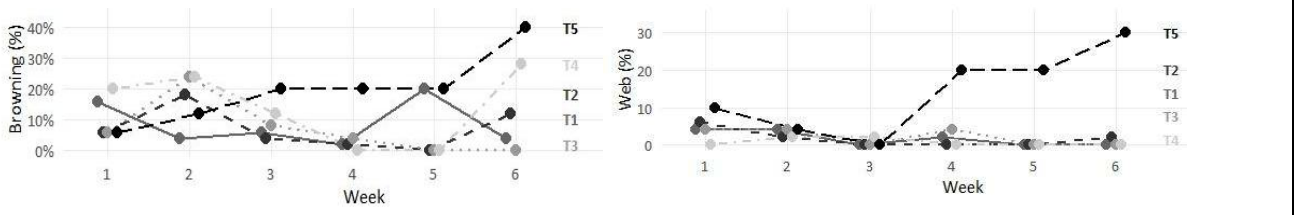
untreated control, indicating the natural progression of infestation in the absence of management practices.

The visual symptoms caused by mite feeding increased throughout the experimental period, mainly in the untreated control (Figure 4). Leaf bronzing showed an increasing trend in the final evaluations, reaching the highest values in the absence of pest management.

The treatments based on *A. indica* and *C. subtsugae* showed lower percentages of leaf bronzing and webbing throughout the evaluation weeks, whereas the untreated control exhibited the highest levels of visual damage (Figure 4). For the webbing variable, a similar pattern to leaf bronzing was observed, following the increase in mite populations throughout the evaluations.

Figure 4 - Percentage of plants affected by leaf bronzing and webbing caused by mite feeding damage.



Source: Survey data. (2026)

Regarding treatment selectivity, Schmidt-Jeffris *et al*. (2021) observed that abamectin and bifenazate caused high mortality in both T. urticae and the predatory mite Neoseiulus fallacis in watermelon crops. Similarly, Akbay and Kazak (2025) reported negative effects of abamectin on Euseius finlandicus across different developmental stages. These findings underscore the need for more selective products to preserve natural enemies and enhance biological control within integrated pest management (IPM) programs.

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4. Conclusion

Treatments based on *Azadirachta indica* and *Chromobacterium subtsugae* reduced the infestation of *Tetranychus urticae* and the visual damage caused by this pest, demonstrating their potential for managing this species in commercial strawberry cultivation. For *Tetranychus ludeni*, no significant differences were observed among the treatments, nor for the area under the disease infestation progress curve (AUDPC) or the occurrence of *Phytoseiulus macropilis*.

The results indicate that *A. indica* and *C. subtsugae* may be incorporated into Integrated Pest Management (IPM) programs. However, further studies under different growing conditions and over longer evaluation periods are needed to confirm the effectiveness of these treatments and their economic feasibility.

REFERENCES

AKBAY, H.; KAZAK, C. Acute toxicity of acaricides on different biological stages and oviposition of citrus-inhabiting population of predatory mite *Euseius finlandicus* (*Oudemans*) (*Mesostigmata: Phytoseiidae*). **Experimental and Applied Acarology**, [S. l.], v. 95, n. 4, p. 51, 2025. https://doi.org/10.1007/s10493-025-01073-z

ANTUNES, L. E. C.; BONOW, S. Morango. In: BRASIL. Ministério da Agricultura e Pecuária. **Brasil em 50 alimentos**. Brasília, DF: Embrapa, 2023. p. 259-263.

ANTUNES, L. E. C.; REISSER JUNIOR, C.; BONOW, S. Morango: produção aumenta ano a ano. **Anuário HF-2021**, Santa Cruz do Sul, p. 87-90, 2021. Disponível em: https://www.alice.cnptia.embrapa.br/alice/handle/doc/1131057. Acesso em: 27 maio 2026.

ARNEMANN, J. A. **Flutuação e densidade populacional de ácaros fitófagos associados a cultivares de soja no Rio Grande do Sul**. 2013. Dissertação (Mestrado em Agronomia) – Universidade Federal de Santa Maria, Santa Maria, 2013.

REMUNOM
ISSN 2178-6925

Received: 13/06/2026 - **Accepted:** 17/07/2026
Vol: 13.16
DOI: 10.66104/k6vf4j52
Pages: 1-24

BILBO, T. R.; SCHOOF, S. C.; WALGENBACH, J. F. Miticide Efficacy Against Twospotted Spider Mite in Staked Tomato, 2019. **Arthropod Management Tests**, [S. l.], v. 45, n. 1, p. 1-2, 2020. https://doi.org/10.1093/amt/tsaa064

CALELLA, P. *et al.* Consumers' Knowledge, Attitudes, and Sensory Perception of Soilless-Grown Strawberries in the Context of Sustainable Diet. **Foods**, [S. l.], v. 15, n. 10, p. 1614, 2026. https://doi.org/10.3390/foods15101614

CAMPBELL, C. L.; MADDEN, L. V. **Introduction to plant disease epidemiology**. New York: J. Wiley, 1990. 532 p. ISBN 9780471832362.

CAVALCANTE, J. K. G. *et al.* Potencial biotecnológico de *Chromobacterium subtsugae*: uma breve revisão voltada ao manejo biológico de artrópodes-praga. **Revista Ibero-Americana de Ciências Ambientais**, [S. l.], v. 13, n. 3, p. 200-211, 2022. https://doi.org/10.6008/CBPC2179-6858.2022.003.0016

CORTEZ-MADRIGAL, Hipolito; ROMERO-QUINTANA, Alejandro. Conservation of natural enemies and productivity in strawberries: toward an economic-ecological convergence of agriculture. **Agroecology and Sustainable Food Systems**, v. 50, n. 5, p. 979-997, 2026. https://doi.org/10.1080/21683565.2025.2568459

DA CONCEIÇÃO, G. S. *et al.* Strawberry production in Brazil: a bibliometric analysis and systematic review. **Revista de Gestão Social e Ambiental**, [S. l.], v. 19, n. 3, p. 1-17, 2025. https://doi.org/10.24857/rgsa.v19n3-099

DARA, S. K.; PECK, D.; MURRAY, D. Chemical and Non-Chemical Options for Managing Twospotted Spider Mite, Western Tarnished Plant Bug and Other Arthropod Pests in Strawberries. **Insects**, [S. l.], v. 9, n. 4, p. 1-15, 2018. https://doi.org/10.3390/insects9040156

FERREIRA, D. F. SISVAR: A computer analysis system to fixed effects split plot type designs. **Brazilian Journal of Biometrics**, [S. l.], v. 37, n. 4, p. 529-535, 2019. https://doi.org/10.28951/rbb.v37i4.450

GARCIA, C. H. Tabelas para classificação do coeficiente de variação. Piracicaba, SP: Instituto de Pesquisas e Estudos Florestais (IPEF), 1989. **Circular Técnica IPEF**, n. 171. ISSN 0100-3453. 10 p. Disponível em: https://www.ipef.br/publicacoes/ctecnica/nr171.pdf. Acesso em: 05 dez. 2025.

REMUNOM
ISSN 2178-6925

Received: 13/06/2026 - **Accepted:** 17/07/2026
Vol: 13.16
DOI: 10.66104/k6vf4j52
Pages: 1-24

GOLEC, J. R.; HOGE, B.; WALGENBACH, J. F. Effect of biopesticides on different *Tetranychus urticae* Koch (Acari: Tetranychidae) life stages. **Crop Protection**, [S. l.], v. 128, p. 105015, 2020. https://doi.org/10.1016/j.cropro.2019.105015

GOMES, F. P. Curso de estatística experimental. São Paulo: **Livraria Nobel**, 1985. 467 p.

ISMAIL, T.; KERATUM, A.; EL-HETAWY, L. Formulation of abamectin and plant oil-based nanoemulsions with efficacy against the two-spotted spider mite *Tetranychus urticae* (Acari: Tetranychidae) under laboratory and field conditions. **Applied Biological Chemistry**, [S. l.], v. 65, n. 1, p. 1-11, 2022. https://doi.org/10.1186/s13765-022-00731-9

KOMAGATA, Y. *et al.* Small-scale dispersal and gene flow of the agricultural pest two-spotted spider mite in apple orchards: Implication from landscape ecological and population genetic analyses. **Ecological Research**, [S. l.], v. 39, n. 3, p. 341–352, 2024. https://doi.org/10.1111/1440-1703.12434

LEE, Y. *et al.* Strawberry Propagation: Progress on Propagation Methods, Environmental Regulation, and Disease Management Strategies over the Past 20 Years. **Horticulturae**, [S. l.], v. 12, n. 3, p. 351, 2026. https://doi.org/10.3390/horticulturae12030351

MICHEREFF FILHO, M. *et al.* **Guia para identificação de pragas do morangueiro**. Brasília, DF: Embrapa Hortaliças, 2020. 120 p. (Documentos, 178). Disponível em: https://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/1124694. Acesso em: 27 maio 2026.

PAMUK, F. *et al.* Diversity of mites (Acari) in open-field strawberries from Western Türkiye. **Systematic and Applied Acarology**, [S. l.], v. 30, n. 12, p. 2127-2142, 2025. https://doi.org/10.11158/saa.30.12.1

POBOŻNIAK, M.; OLCZYK, M. Biocontrol in integrated pest management in fruit and vegetable field production. **Horticulturae**, [S. l.], v. 11, n. 5, p. 522, 2025. https://doi.org/10.3390/horticulturae11050522

PRIYA, S. S. *et al.* Breaking acaricide resistance: Sustainable strategies for phytophagous mite control with natural and advanced solutions. **Persian Journal of Acarology**, [S. l.], v. 14, n. 4, p. 140403, 2025. https://doi.org/10.22073/pja.v14i4.87081

REMUNOM
ISSN 2178-6925

Received: 13/06/2026 - **Accepted:** 17/07/2026
Vol: 13.16
DOI: 10.66104/k6vf4j52
Pages: 1-24

SATO, M. E. *et al.* Monitoramento da resistência de *Tetranychus urticae* Koch (Acari: Tetranychidae) a abamectina e fenpiroximato em diversas culturas no estado de São Paulo. **Arquivos do Instituto Biológico**, São Paulo, v. 76, n. 2, p. 217-223, 2009. https://doi.org/10.1590/1808-1657v76p2172009

SCHMIDT-JEFFRIS, R. A. *et al.* Residual Activity of Acaricides for Controlling Spider Mites in Watermelon and Their Impacts on Resident Predatory Mites. **Journal of Economic Entomology**, [S. l.], v. 114, n. 2, p. 818-827, 2021. https://doi.org/10.1093/jee/toaa320

SHAPIRO-ILAN, D. I.; WELLS, L. Control of *Curculio caryae* (Coleoptera: Curculionidae) with reduced rates of a microbial biopesticide. **Journal of Entomological Science**, [S. l.], v. 57, n. 2, p. 310-313, 2022. https://doi.org/10.18474/JES21-54

SILVA, R. A. *et al.* Eficiência de acaricidas no controle de *Tetranychus* sp. (Acari: Tetranychidae) em bananeira. **Revista Ciência Agrícola**, Maceió, v. 20, n. esp., e14572, 2022. https://doi.org/10.28998/rca.v20i0.14572

SINDAROV, O. Integration of Smart Farming Technologies for Sustainable Strawberry Production in Controlled Environments. **Sustainable Agriculture**, [S. l.], v. 26, n. 2, p. 45-51, 2025.

SYNGENTA. [s.l.: s.n.], 2024. Disponível em: https://www.adapar.pr.gov.br/sites/adapar/arquivos_restritos/files/documento/2025-03/actara_250_wg.pdf. Acesso em: 4 July 2026.

VALADARES-INGLIS, M. C.; FONTES, E. M. G.; FARIA, M. R. **Controle biológico de pragas da agricultura**. Brasília, DF: Embrapa, 2020. 513 p.

WAKED, D. A. *et al.* Bioefficacy of bacterium *Pseudomonas fluorescens* using foliar spray and cultivated soil application against *Tetranychus urticae* on cucumber plants comparing with an acaricide. **Journal of Plant Protection and Pathology**, [S. l.], v. 11, n. 3, p. 165–172, 2020. https://doi.org/10.21608/jppp.2020.86016

WAQUIL, J. M.; VIANA, P. A. V.; CRUZ, I. **Manejo Integrado de Pragas**. Brasília, DF: Embrapa, 2021. Disponível em: https://www.embrapa.br/agencia-de-informacao-tecnologica/cultivos/milho/producao/pragas-e-doencas/pragas/manejo-integrado-de-pragas. Acesso em: 27 maio 2026.

REMUNOM
ISSN 2178-6925

Received: 13/06/2026 - **Accepted:** 17/07/2026
Vol: 13.16
DOI: 10.66104/k6vf4j52
Pages: 1-24

ZAWADNEAK, M. A. C. *et al.* **Manejo integrado de pragas do morangueiro**: caderno de campo. Curitiba: SENAR AR/PR, 2020. 74 p.