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Research Article

Viçosa mixture in tomato cultivation as a potential strategy for crop development and insect pest repellency

Calda Viçosa em tomateiro como potencial estratégia para desenvolvimento da cultura e repelência a insetos-praga

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ABSTRACT

Viçosa misture is a modification of Bordeaux mixture, as it contains macro and micronutrients in its composition, which contribute to improving plant nutrition, favoring increased productivity. In addition, it repels phytophagous insects, helping with pest management. It can be used in organic farming, as long as it complies with the legislation governing this type of farming. Based on the above, the objective of this study was to evaluate the effect of spraying Viçosa mixture on agronomic development, repellency to insect pests, and incidence of natural enemies in tomato plants (*Solanum lycopersicum* L.). For this purpose, a randomized block design with five treatments (concentrations of Viçosa mixture) was used, as follows: T1 - 0 g L^{-1}; T2 - 1 g L^{-1}; T3 - 2 g L^{-1}; T4 - 3 g L^{-1} and T5 - 4 g L^{-1}, and five blocks, totaling 25 plots, each plot consisting of three pots, totaling 75 experimental units. Parameters related to tomato plants were evaluated, as well as the characterization of fruits and quality attributes of tomatoes, in addition to the population density of insect pests and the number of eggs of natural enemies. It was found that there was a significant difference between the concentrations of Viçosa mixture for some characteristics related to tomato plants and fruits. Positive correlations were also obtained between certain variables analyzed. As for phytophagous arthropods, there was repellency for insects with scraping-sucking, sucking, and chewing feeding habits as a result of the application of Viçosa mixture. In addition, a higher density of predatory insect eggs was obtained on plants sprayed with this mixture. Thus, it can be concluded that spraying with Viçosa mixture contributes to improving the agronomic aspects of tomato plants and repels insect pests, without negatively interfering with the oviposition of chrysopids.

KEYWORDS: Fertility protector. Insecta. *Solanum lycopersicum* L. Chrysopids. Insect pest management. Organic farming.

RESUMO

A calda Viçosa é uma modificação da calda bordalesa, por conter macro e micronutrientes em sua composição, que contribui para melhorar a nutrição das plantas, favorecendo o aumento da produtividade. Além disso, apresenta efeito repelente a insetos fitófagos, auxiliando no manejo de pragas. Pode ser utilizada em cultivos orgânicos, desde que esteja em conformidade com a legislação voltada para este tipo de cultivo. Com base no exposto, objetivou-se neste trabalho avaliar o efeito da pulverização da calda Viçosa no desenvolvimento agronômico, na repelência a insetos-praga e incidência de inimigos naturais em tomateiro (*Solanum lycopersicum* L.). Para isso foi utilizado o delineamento em blocos casualizados com cinco tratamentos (concentrações de calda Viçosa), sendo: T1 - 0 g L^{-1}; T2 - 1 g L^{-1}; T3 - 2 g L^{-1}; T4 - 3 g L^{-1} e T5 - 4 g L^{-1}, e cinco blocos, perfazendo 25 parcelas, sendo cada parcela constituída por três vasos, totalizando 75 unidades experimentais. Foram avaliados os parâmetros relativos às plantas de tomateiro, bem como a caracterização dos frutos e atributos de qualidade do tomate, além da densidade populacional de insetos-praga e número de ovos de inimigos naturais. Verificou-se que houve diferença significativa entre as concentrações de calda Viçosa para algumas características relativas às plantas e aos frutos do tomateiro. Também foram obtidas correlações positivas entre determinadas variáveis analisadas. Quanto aos artrópodes fitófagos, houve repelência para insetos de hábitos alimentares raspador-sugador, sugador e mastigador em função das aplicações de calda Viçosa. Além disso, maior densidade de ovos de inseto predador foi obtida em plantas pulverizadas com esta calda. Dessa forma, conclui-se que a pulverização com calda Viçosa contribui para melhorar os aspectos agronômicos do tomateiro e apresenta repelência a insetos-praga, não interferindo negativamente na oviposição dos crisopídeos.

PALAVRAS-CHAVE: Fertiprotetor. Inseto. *Solanum lycopersicum* L. Crisopídeos. Manejo de insetos-praga. Agricultura orgânica.

INTRODUCTION

The tomato (*Solanum lycopersicum* L.), a fruit vegetable belonging to the Solanaceae family, is one of the main vegetables grown in Brazil. The harvested area throughout the national territory in 2022 was 54,300 ha^{-1}, with a production of 3.8 million $tons^{-1}$, with Goiás being the largest producing state with 11,600 ha^{-1} of harvested area and 993,400 $tons^{-1}$ produced. The municipality of Cristalina is a leader in tomato production in the state (IBGE 2022).

To continue achieving high productivity, it is necessary to minimize critical issues related to the tomato production chain, such as dependence on imported fertilizers, seeds, and phytosanitary products; high production costs; and the emergence or resurgence of pests. In the latter case, this situation is exacerbated by the lack of integrated pest management and the intensive use of broad-spectrum insecticides that eliminate natural enemies, among other factors (PEDROSO et al. 2020, SILVA et al. 2020).

In addition, inadequate fertilization of crops can lead to disorders that are observed in the plant, due to reduced growth and shortening of internodes; in the root system, due to malformation; in the leaves, due to deformation, senescence, chlorosis, reduced development, and photosynthetic capacity; in flowers, due to reduced flowering; and in fruits, in which delayed ripening, reduced size, unevenness, apical rot, open locules, and low soluble solids content can be observed (OLIVEIRA et al. 2009, SILVA et al. 2012). Thus, it appears that nutrition-related problems can interfere with both the development and productive capacity of tomato plants.

In addition to nutritional issues, it is important to mention phytosanitary aspects, given that tomato plants are attacked by a wide variety of insect pests that cause damage to crops, which can also contribute negatively to reduced productivity and the quality of the final product. The most common pests in this crop include virus vectors such as the whiteflies *Bemisia tabaci* (Gennadius, 1889) and *Trialeurodes vaporariorum* Westwood, 1856 (Hemiptera: Aleyrodidae), thrips *Frankliniella schultzei* (Trybom, 1910), *F. occidentalis* (Pergande, 1895), *Thrips tabaci* Lindeman, 1889, *T. palmi* Karny, 1925 (Thysanoptera: Thripidae) and aphids *Aphis gossypii* Glover, 1877, *Macrosiphum euphorbiae* (Thomas, 1878) and *Myzus persicae* (Sulzer, 1776) (Hemiptera: Aphididae); and fruit borers, represented by the tomato leaf miner *Tuta absoluta* (Meyrick, 1917) (Lepidoptera: Gelechiidae) and the small fruit borer *Neoleucinodes elegantalis* (Guenée, 1854) (Lepidoptera: Crambidae). There are also secondary pests, represented by the leaf miner *Liriomyza huidobrensis* (Blanchard, 1926), *L. sativa* Blanchard, 1938, and *L. trifolii* (Burgess, 1880) (Diptera:

Agromyzidae); the armyworm (*Spodoptera* complex) *Spodoptera eridania* Stoll, 1782, *S. cosmioides* Walker, 1858, and *S. frugiperda* (JE Smith, 1797) (Lepidoptera: Noctuidae); the false armyworm *Chrysodeixis includens* (Walker, 1858), *Trichoplusia ni* (Hübner, 1803) and *Rachiplusia nu* (Guenée, 1852) (Lepidoptera: Noctuidae); the large borer represented by *Helicoverpa armigera* (Hübner, 1808), *H. zea* (Boddie, 1850), and *Chloridea virescens* (Fabricius, 1777) (Lepidoptera: Noctuidae) (LINS JÚNIOR 2019, MICHEREFF FILHO et al. 2022, MOURA et al. 2014).

To manage insect pests, synthetic chemical insecticides from the chemical groups carbamates, organophosphates, neonicotinoids, avermectins/milbemycins, oxadizines, diamides, among others, are often used (MAPA 2024). However, the inappropriate use of insecticides, due to the lack of rotation in the mode of action, can lead to resistance problems (GARRIDO & BOTTON 2021). In addition, the indiscriminate use of these substances can cause the death of natural enemies, environmental and food contamination (SILVA et al. 2022), and increased production costs (LINS JÚNIOR et al. 2020).

Based on the above, there is a need to test alternative substances to synthetic chemical insecticides that also contribute to plant development. The Viçosa mixture, consisting of copper sulfate, zinc sulfate, magnesium sulfate, boric acid, hydrated lime, and water, is an improvement on Bordeaux mixture (copper sulfate and lime) because it contains additional macro- and micronutrients (SCHWENGBER et al. 2007).

Due to its composition, it acts as a foliar fertilizer, authorized for use in organic farming, fungicide, and repellent (GALLI & TIVELLI 2017, MOTTA 2018). Due to the bottlenecks presented in tomato cultivation, it is believed that this fertilizer-protective mixture could be a promising alternative, aiming to promote both agronomic improvement in cultivation and pest population management, without interfering with the incidence of natural enemies.

The potential of Viçosa mixture has already been investigated by some researchers. In chili peppers, its effect was evaluated both in disease control, such as cercosporiosis (PINTO et al. 2022), and in the management of arthropod pests, such as the white mite *Polyphagotarsonemus latus* (Banks, 1904) (Acari: Tarsonemidae) (VENZON et al. 2006). In addition, there are reports of increased production in bean crops (ARAÚJO et al. 2000). Although the results are promising for these crops, there is a lack of information regarding their use in tomato cultivation, a fact that motivated the development of this research.

In this context, the objective of this study was to evaluate the effect of spraying Viçosa mixture on agronomic development, repellency to insect pests, and incidence of natural enemies in tomato plants (*S. lycopersicum* L).

MATERIALS AND METHODS

The experiment was conducted at Chácara Santo Antônio (latitude 17º57’57’’ S, longitude 50º00’05” W and altitude of 562.25 m) in Marcianópolis, District of the city of Goiatuba, Goiás, Brazil (GOOGLE EARTH 2024), from December 2022 to June 2023. The climate is of the Aw type, humid in summer and dry in winter, classified as humid tropical according to the Köppen-Geiger climate classification (CLIMATE

DATA 2024).

Soil samples were collected using a zigzag pattern at a depth of 0-20 cm with the aid of a spade-type auger. At each point, a soil sample was collected, classified as Dystrophic Red Latosol (SANTOS et al. 2018), and added to a 20-liter plastic bucket lined with a 50-liter plastic bag. Immediately after collection, the simple samples were mixed, and 0.5 kg was sent to the Curitiba Agricultural Analysis Laboratory in Bom Jesus de Goiás, Goiás (GO), Brazil, for analysis, as shown in Table 1.

Table 1. Chemical and physical soil atributes in the experimental area at the depth of 0-20 cm, Marcianópolis, GO, 2023.

Tabela 1. *Características químicas e físicas do solo da área experimental na camada de 0-20 cm, Marcianópolis, GO, 2023.*

M. O.	**pH**	**P**	**S**	**K**			**cmol$_c$ dm^{-3}**			
g kg^{-1}	$CaCl_2$	mg dm^{-3}	mg dm^{-3}	mg dm^{-3}	Ca	Mg	Al	H+Al	SB	CTC
26.8	5.8	19.7	11.6	195.5	5.1	1.9	0.0	3.7	7.5	11.2
		Saturation %					**Nutrient ratio**			
Al	Ca	Mg	K	Bases	Ca/Mg		Ca/K		Mg/k	
0.0	45.4	16.9	4.5	66.8	3		10		4	
	mg dm^{-3}						**Sand**	**Silt**		**Clay**
B	Cu	Fe	Mn	Zn			%	%		%
0.5	0.7	84	7.6	2.3			52	11		37

Based on the results of the analysis, 4.65 g pot^{-1} of dolomitic limestone with 80% Total Neutralizing Power was applied to 5 kg pots containing sieved soil, with the aim of increasing base saturation to 80%. Planting fertilization was performed with the application of 2.5 g pot^{-1} of urea, 17 g pot^{-1} of simple superphosphate, 3.33 g pot^{-1} of potassium chloride, equivalent to, respectively, 400 kg of N ha^{-1}, 800 kg of K_2O ha $^{-1}$, and 1200 kg of P_2O_5 ha^{-1}, using, respectively, urea (45% N), potassium chloride (KCl - 60% K_2O and 48% Cl), and monoammonium phosphate (MAP) ($NH_4H_2PO_4$ - 48% P_2O_5 and 9% N), following the recommendation of FILGUEIRA et al. (1999).

For the experiment, industrial tomatoes, hybrid HMX 7885 F1, from Agristar® were used, whose characteristics are: medium-sized open plant, large oblong fruits, firm, excellent internal quality, excellent wall thickness, good ripening concentration, high firmness, high cube yield, Brix of 4.5 to 5.5, average weight of 103 g, high productivity, and an average cycle of 117 days (AGRISTAR 2024). The tomato seedlings were donated by Viveiro de Mudas Brambilla (Morrinhos, Goiás, Brazil) when they were 31 days old. At the time, they had four to five expanded leaves, intense green coloration, an average height of 10 cm, and a well-developed root system.

Seventy-one days after liming and fertilizing the planting, the most vigorous seedlings were selected for transplanting, with two seedlings transplanted per pot. After 11 days, thinning was carried out, leaving one seedling per pot. The trellis was constructed using 1.20 m high bamboo stakes and string. The pots were kept inside a structure measuring 4 m wide, 8 m long, and 2.10 m high, covered with netting (50% shade) and open on the sides, allowing free infestation by insects, both phytophagous and predatory. The seedlings were watered daily according to crop requirements, using a 3/8-inch diameter hose. Thirty days after transplanting the seedlings, the first top dressing was applied. A total of four applications were made, with 1.16 g pot^{-1} of urea and 1.33 g pot^{-1} of potassium chloride, the first two at monthly intervals and the last two every two weeks.

To investigate the effect of spraying Viçosa mixture on tomato plants, a randomized block design was used with five treatments: T1 – 0 g L^{-1} (control); T2 – 1 g L^{-1}; T3 - 2 g L^{-1}; T4 – 3 g L^{-1} e T5 - 4 g L^{-1} of Viçosa mixture per application, and five blocks, totaling 25 plots, each plot consisting of three pots, totaling 75 experimental units. The product concentrations were applied by foliar spraying, using the commercial mixture Viçosa HF®, from Empresa Verde Mania (São Paulo, São Paulo, Brazil), composed of 9.0% copper, 8.0% potassium, 8.0% magnesium, 8.0% sulfur, 3.5% boron, and 3.0% zinc.

Spraying with Viçosa mixture began 11 days after transplanting (DAT) the seedlings into pots and was repeated every 14 days. A total of six applications were made with a 2L manual plastic sprayer with pre-compression until the start of harvesting, when the crop was 83 DAT, with a total of eight harvests, ending at 115 DAT. The experiment was conducted until 116 DAT, when all tomato plants were removed from the pots and the agronomic parameters began to be evaluated.

In determining the agronomic parameters related to tomato plants, the following were evaluated: the number of leaves, plant height (m), measured using a tape measure from the base of the plant to the top of the main stem, the number of fully open flowers (RODRIGUES et al. 2018), the diameter of the stem (cm) measured two centimeters above the plant collar with a digital caliper (PONTELO 2020), the length of the largest root (cm), measured from the plant collar to the tip of the largest root (SILVA JÚNIOR et al. 2014), the fresh mass of the aerial part without the fruits and root (g), and the dry mass of the root system (g), using a scale. These variables, except for the number of flowers, were evaluated 36 days after the last spraying with Viçosa mixture. The flowers were counted immediately after they had fully opened, with the start of flowering recorded at 35 DAT.

To characterize the fruits and quality attributes, they were harvested when they reached peak ripeness (SANTOS 2019). The harvest started 83 DAT. The number of clusters per plant, the number of fruits per plant, and the fruit mass per plant (g) were evaluated. To determine the length (mm) and equatorial diameter of the fruits (mm), pericarp thickness (mm) (SANTOS 2019), soluble solids (ºBrix), and average fruit weight (g), 12 fruits per plot were evaluated. A digital scale was used to determine the average weight of the fruits, while a Starrett® 799 series digital caliper was used to analyze the length, equatorial diameter, and thickness of the pericarp.

To assess fruit quality, the soluble solids content (°Brix) was determined by cutting the fruit open with a knife and extracting a drop of the internal liquid, which was placed in a manual refractometer (0-32% BRIX, Lorben® model GT427) with automatic temperature compensation (ATC).

In order to evaluate the repellent effect of Viçosa mixture on the population density of phytophagous insects and its action on natural enemies, these arthropods were counted at 5:30 p.m., three days after each spraying with Viçosa mixture, through visual inspection and beating the plants with a white cloth 63 cm wide and 96 cm long, totaling six evaluations.

The insect pests were removed from the plants and taken to the Microscopy Laboratory at the Goiatuba University Center (UniCerrado) for identification in the taxonomic categories of species, order, and family. The eggs of natural enemies were identified, counted, and mechanically destroyed at the location where they were found on the plant.

After confirming the assumptions of normality of the residues using the Jarque-Bera test, homogeneity of variances using the Levene test, and block additivity using the Tukey additivity test, the data were subjected to analysis of variance using the F test at a 5% probability level. For the variables number of fully open flowers and dry mass of the root system, log (x) and cube root (x) transformations were used, respectively. For the characteristics number of leaves, number of fully open flowers, and soluble solids content, which were significant in the ANOVA, regression was used, with the model chosen based on the highest coefficient of determination (R^2). Statistical analyses were performed using the SPEED Stat program (CARVALHO & MENDES 2017).

For the data on the number of insect pests and eggs of natural enemies, the Generalized Linear Model (GLM) was adjusted with Poisson distribution and log link function. The significance of the factors was verified by the Chi-square test ($X^2<0.05$) using Deviance analysis (ANODEV). The means estimated by the model were compared using Tukey's test at a 5% probability level, and regression models were adjusted. A boxplot was plotted for all variables analyzed to check data variability, and the q-q norm graph was adjusted to verify the quality of the model fit. Pearson's linear correlation was also verified between the variables collected in order to verify trends among them, with their significance tested by the *t*-test at 5% significance. Statistical analyses were performed using statistical software R, version 4.0.0 (R CORE TEAM 2020).

RESULTS AND DISCUSSION

It was found that there was a significant difference between the concentrations of Viçosa mixture for agronomic variables related to tomato plants, such as the number of leaves and fully open flowers, and also for fruit quality, with regard to soluble solids content. For the other parameters evaluated, there was no significant difference between the concentrations tested (Table 2).

Table 2. Summary of the analysis of variance of the agronomic characteristics of plants, fruits and quality attributes of *Solanum lycopersicum* L., hybrid HMX 7885 F1, with different Viçosa mixture concentrations Marcianópolis, GO, 2023. Marcianópolis, GO, 2023.

		Medium Squares							
SV	**DF**	**NL***	**PH^{ns}**	**SD^{ns}**	**LLR^{ns}**	**FMAP^{ns}**	**DMRS^{ns}**	**NFOF****	**NCP^{ns}**
VMC	4	108.451	0.003	0.001	32.162	77.038	0.012	0.007	0.149
Block	4	6.729	0.001	0.002	37.807	240.304	0.039	0.007	0.371
Residue	16	12.287	0.002	0.002	26.073	54.088	0.001	0.002	0.513
Total	24	-	-	-	-	-	-	-	-
CV (%)	-	10.32	5.65	5.30	12.49	7.07	6.37	3.03	16.23
SV	DF	NFP^{ns}	FMP^{ns}	FL^{ns}	EDF^{ns}	PT^{ns}	SS**	AFW^{ns}	
VMC	4	10.707	7645.804	7.358	5.449	0.208	0.165	48.273	
Block	4	6.429	4577.515	7.208	3.325	0.539	0.023	54.995	
Residue	16	7.248	2789.31	12.579	3.249	0.190	0.051	37.985	
Total	24	-	-	-	-	-	-	-	
CV (%)	-	18.41	14.90	5.33	4.49	6.45	4.98	10.44	

SV – sources of variation; DF – degrees of freedom; VMC – Viçosa mixture concentrations; CV – coefficient of variation; NL – number of leaves; PH – plant height; SD – stem diameter; LLR – length of the largest root; FMAP – fresh mass of the aerial part; DMRS – dry mass of the root system; NFOF – number of fully open flowers; NCP – number of clusters per plant; NFP – number of fruits per plant; FMP – fruit mass per plant; FL – fruit length; EDF – equatorial diameter of the fruit; PT – pericarp thickness; SS – soluble solids; and AFW – average fruit weight. *significant by F-test (p≤0.01); ** significant by F-test (p≤0.05).

For the number of leaves (Figure 1A) and fully open flowers (Figure 1B), the regression was significant, and the quadratic model provided the best fit, with a coefficient of determination (R^2) of 95.49% and 80.15%, respectively. As for the soluble solids content (Figure 1C), there was a linear behavior, that is, as the concentrations of Viçosa Mixture increased, the values obtained were higher, with R^2 at 87.65%. Thus, concentrations of 3.06 g L^{-1} and 2.19 g L^{-1} yielded the highest values for number of leaves (37.68) and number of fully open flowers (36.58), respectively. As for soluble solids content, applying 4 g L^{-1} of Viçosa mixture will make it possible to reach 4.76ºBrix (Figure 1C).

With regard to fruit, the soluble solids content is a parameter that can be influenced by the genetic characteristics of the cultivar, temperature, irrigation, and fertilization (RAMOS et al. 2013), in addition to being an interesting chemical characteristic for processing industries, because for every degree Brix increase in the raw material, there is a 10% to 20% increase in industrial yield (BOITEUX et al. 2012).

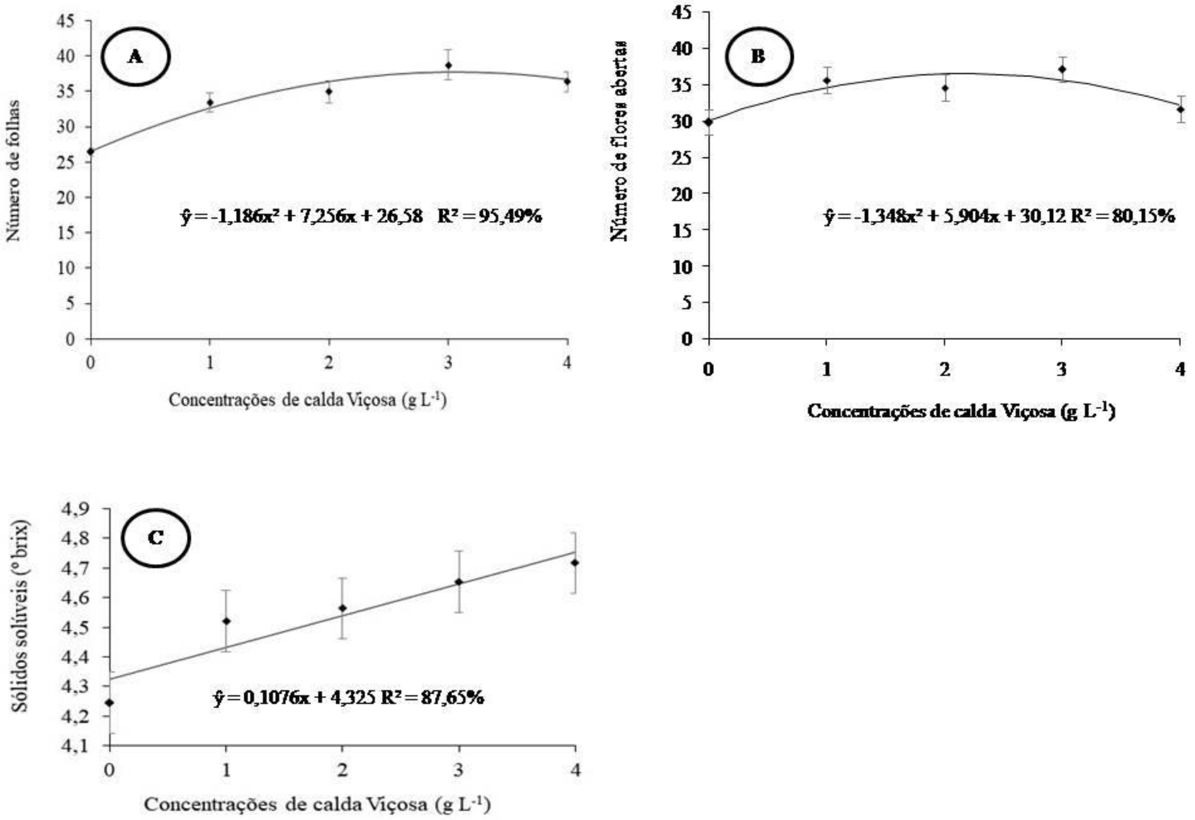

Figure 1. Number of leaves (A) and fully open flowers (B) in plants, and soluble solids (C) in tomato fruits (*Solanum lycopersicum* L.), hybrid HMX 7885 F1, sprayed with different concentrations of Viçosa mixture. Marcianópolis, GO, 2023.

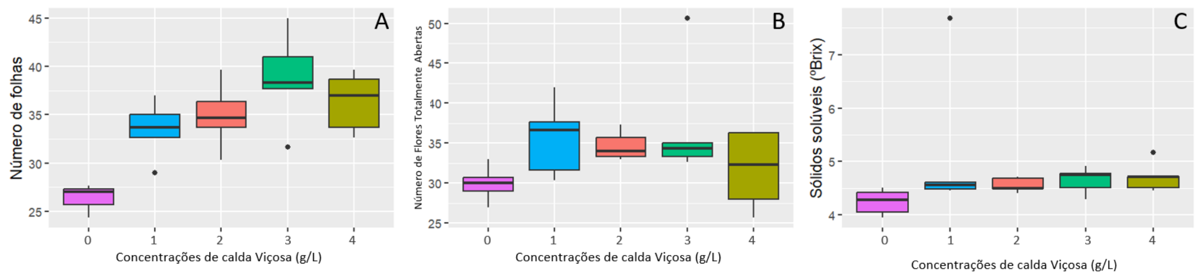

Figure 2. Boxplot for number of leaves (A) and fully opened flowers (B) in plants, and soluble solids (C) in fruits of tomato (*Solanum lycopersicum* L.), hybrid HMX 7885 F1, sprayed with different concentrations of Viçosa mixture. Marcianópolis, GO, 2023.

The range of soluble solids content in leading tomato hybrids for processing in the Brazilian market varies from 3.60 °Brix to 5.5 °Brix (BOITEUX et al. 2012). The value found in this study is within the expected range and consistent with the reference values for the hybrid used (HMX 7885 F1), which are 4.5ºBrix to 5.5ºBrix, as reported by AGRISTAR (2024).

Although some concentrations of Viçosa mixture contributed to an increase in the number of leaves (Figure 2A) and fully open flowers (Figure 2B), as well as the soluble solids content (Figure 2C) in tomato fruits, the same was not observed for parameters related to plant height, stem diameter, longest root length, fresh mass of the aerial part, and dry mass of the root system, with average values obtained of 0.75 m, 0.85 cm, 40.89 cm, 103.98 g, and 3.19 g (Table 3; Figures 3A, B, C, D, and E).

Table 3. Plant height (m), stem diameter (cm), length of the longest root (cm), fresh mass of the aerial part (g), and dry mass of the root system (g) of tomato (*Solanum lycopersicum* L.), hybrid HMX 7885 F1, sprayed with different concentrations of the Viçosa mixture. Marcianópolis, GO, 2023.

Concentrations of Viçosa mixture (g L^{-1})	PH (m)^{ns}	SD (cm)^{ns}	LLR (cm)^{ns}	FMAP (g)^{ns}	DMRS (g)^{ns}
0	0.78±0.03	0.83±0.02	37.40±2.01	99.13±2.72	2.73±0.32
1	0.71±0.02	0.86±0.02	44.20±2.22	106.13±2.32	3.20 ± 0.34
2	0.75±0.02	0.86±0.02	40.33±3.28	102.13±2.54	3.13±0.08
3	0.76±0.01	0.84±0.02	40.27±2.14	109.40±3.99	3.27±0.61
4	0.77±0.02	0.84±0.02	42.27±2.03	103.13±7.49	3.60± 0.27
Average	0.75	0.85	40.89	103.98	3.19
F-test	1.83	0.43	1.23	1.42	1.42
p-value	0.173	0.785	0.336	0.271	0.272

ns – not significant by the F-test (p>0.05). PH - Plant height, SD - Stem diameter, LLR - Length of the largest root, FMAP - Fresh mass of the aerial part, and DMRS - Dry mass of the root system.

The results obtained in this study corroborate those reported by MELO et al. (2019) in Dominador and Serato tomato hybrids, where spraying with fungicides at a concentration of 3 g L^{-1} of mancozeb, 1 mL L^{-1} of tebuconazole, and 3 g L^{-1} of copper oxychloride, mineral fertiprotective mixtures (Bordeaux, Viçosa, and Sulfocalcic), both at 1%, and water (control) were not effective in promoting significant increases in the dry root mass of this vegetable. In addition, in chili peppers, the use of Viçosa mixture (1.5%), Bordeaux mixture (1.5%), sulfur-lime mixture (1%), sodium bicarbonate (0.2 M), neem oil (0.5%), raw cow's milk (20%), methyl thiophanate (0.7 g L^{-1}), and water (control) did not show a significant difference in plant height (PINTO et al. 2022).

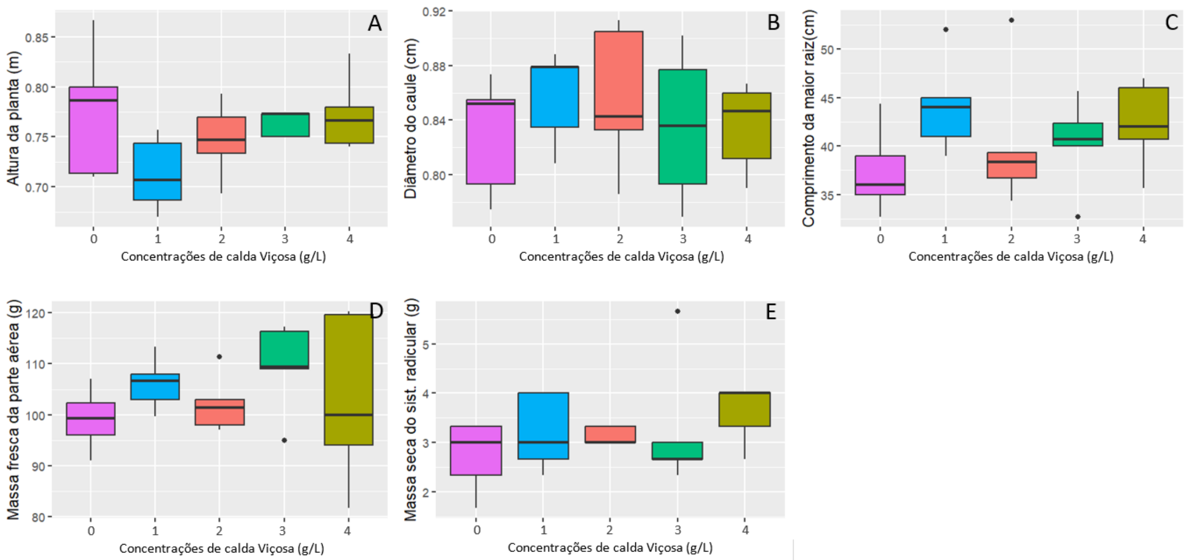

Figure 3. Boxplot for plant height (m) (A), stem diameter (cm) (B), length of the longest root (cm) (C), fresh mass of the aerial part (g) (D), and dry mass of the root system (g) (E) of tomato (*Solanum lycopersicum* L.), hybrid HMX 7885 F1, sprayed with different concentrations of the Viçosa mixture. Marcianópolis, GO, 2023.

As for fruit-related aspects, there was no significant difference between Viçosa mixture concentrations in terms of the number of bunches per plant (4.41), number of fruits per plant (14.63), fruit mass per plant (354.52 g), fruit length (66.59 mm), equatorial diameter of the fruit (40.14 mm), pericarp thickness (6.76 mm), and average fruit weight (59.04 g) (Table 4; Figures 4 A, B, C, D, E, F, and G).

In a study conducted by MELO et al. (2019), no significant effects of Viçosa spray were observed on tomato fruit development, as the authors found that spraying with 1% sprays (Bordalesa, Viçosa, and Sulfocalcica), fungicides (mancozeb - 3 g L^{-1}; tebuconazole - 1 mL L^{-1}, and copper oxychloride - 3 g L^{-1}) and water (control) did not promote increases in the number and average weight of tomato fruits.

In chili peppers, a plant belonging to the same botanical family as tomatoes, the use of Viçosa mixture (1.5%), Bordeaux mixture (1.5%), sulfur-lime mixture (1%), sodium bicarbonate (0.2 M), neem oil (0.5%), raw cow's milk (20%), methyl thiophanate (0.7 g L^{-1}), and water (control) did not contribute to improving fruit attributes such as length, diameter, and average weight (PINTO et al. 2022).

Table 4. Number of clusters per plant, number of fruits per plant, fruit mass per plant (g), fruit length (mm), equatorial diameter of fruits (mm), pericarp thickness (mm), and average fruit weight (g) of tomato (*Solanum lycopersicum* L.), hybrid HMX 7885 F1, sprayed with concentrations of Viçosa mixture. Marcianópolis, GO, 2023.

Concentrations Viçosa mixture (g L^{-1})	NCP^{ns}	NFP^{ns}	FMP $(g)^{ns}$	FL $(mm)^{ns}$	EDF $(mm)^{ns}$	PT $(mm)^{ns}$	AFW $(g)^{ns}$
0	4.27±0.41	12.13±0.65	296.67±19.93	68.30±1.64	41.16±0.71	6.88±0.25	62.65±2.42
1	4.47±0.23	15.73±1.10	369.20±22.09	67.20±1.10	40.99±0.51	6.99±0.17	61.28±2.61
2	4.53±0.23	15.47±1.27	392.93±27.30	65.90±1.10	39.80±0.63	6.61±0.16	56.97±1.63
3	4.60±0.27	14.53±1.15	333.80±15.93	65.15±2.31	38.57±1.33	6.49±0.34	55.02±4.60
4	4.20±0.37	15.27±1.58	380.00±35.54	66.40±1.02	40.17±0.57	6.84±0.17	59.30±2.21
Average	4.41	14.63	354.52	66.59	40.14	6.76	59.04
F-test	0.29	1.48	2.74	0.58	1.68	1.09	1.27
p-value	0.880	0.256	0.065	0.678	0.204	0.393	0.322

ns – not significant by the F-test ($p>0.05$). NCP – number of clusters per plant; NFP – number of fruits per plant; FMP – fruit mass per plant; FL – fruit length; EDF – equatorial diameter of the fruit; PT – pericarp thickness; and AFW – average fruit weight.

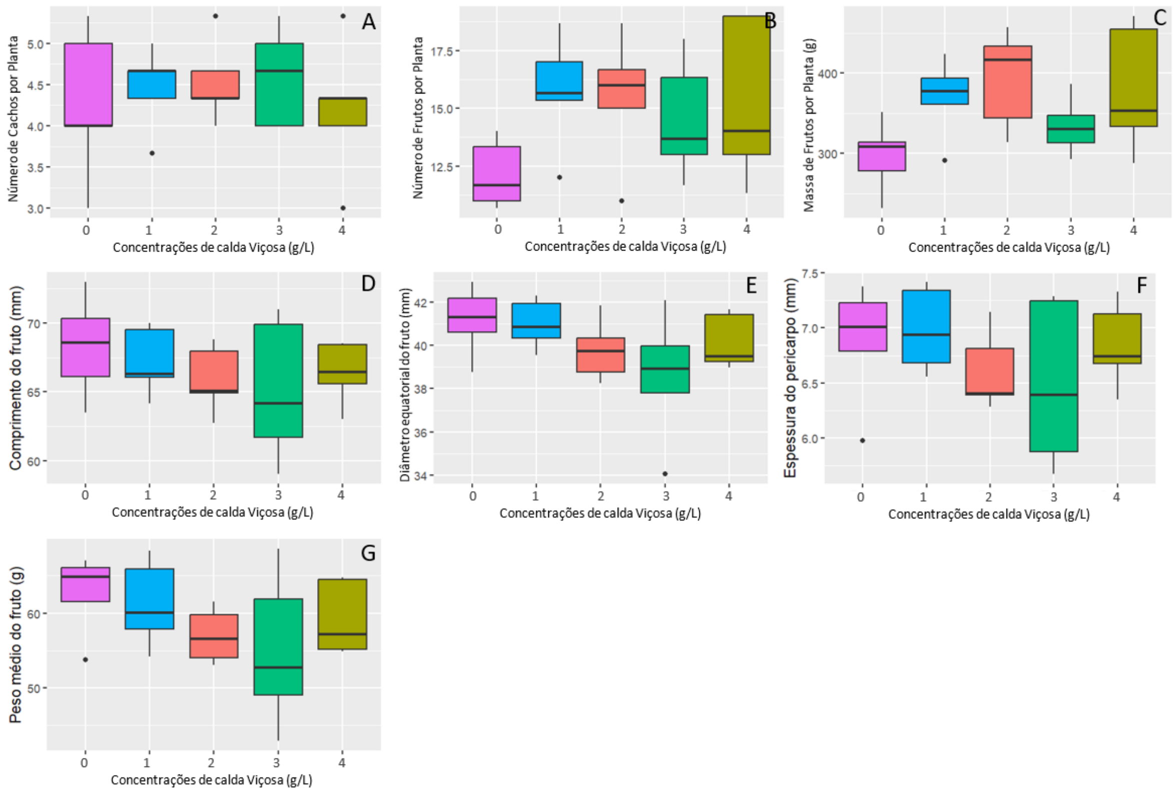

Figure 4. Boxplot for number of clusters per plant (A), number of fruits per plant (B), fruit mass per plant (g) (C), fruit length (mm) (D), equatorial diameter of the fruits (mm) (E), pericarp thickness (mm) (F), and average fruit weight (g) (G) of tomato (*Solanum lycopersicum* L.), hybrid HMX 7885 F1, sprayed with different concentrations of the Viçosa mixture. Marcianópolis, GO, 2023.

Based on agronomic parameters related to the tomato plant and fruit, it was possible to establish significant positive correlations (at 1% and 5% probability levels) between some variables. Thus, the number of clusters per plant correlated with the average number of fruits per plant (0.42). The fruit mass per plant was related to both the number of clusters per plant (0.46) and the average number of fruits per plant (0.68). The length of the largest root, on the other hand, correlates with the average number of fruits per plant (0.54). The fresh mass of the aerial part influences both the average number of fruits per plant (0.54) and the number of leaves (0.47) (Table 5).

Table 5. Pearson correlation between the agronomic traist of tomato plants and fruits (*Solanum lycopersicum* L.), hybrid HMX 7885 F1, sprayed with different concentrations of the Viçosa mixture. Marcianópolis, GO, 2023.

Characteristics	NCP	ANFP	NL	FL	PT	EDF
ANFP	0.42**	1	0.18^{ns}	-0.17^{ns}	- 0.14^{ns}	- 0.25^{ns}
FMP	0.46**	0.68*	0.22^{ns}	-0.06^{ns}	0.08^{ns}	0.04^{ns}
LLR	0.01^{ns}	0.54*	0.19^{ns}	-0.16^{ns}	-0.11^{ns}	-0.15^{ns}
FMAP	0.30^{ns}	0.54*	0.47**	0.07^{ns}	0.17^{ns}	-0.04^{ns}
PT	- 0.24^{ns}	- 0.14^{ns}	0.05^{ns}	0.65*	1	0.82*
EDF	- 0.15^{ns}	- 0.25^{ns}	- 0.06^{ns}	0.77*	0.82*	1
AFW	- 0.18^{ns}	- 0.19^{ns}	- 0.03^{ns}	0.90*	0.82*	0.94*

ns – not significant; * significant at 1% probability; ** significant at 5% probability according to Student's t-test. NCP – number of clusters per plant; ANFP – average number of fruits per plant; NL – number of leaves; DMRS – dry mass of the root system; MFP – mass of fruits per plant; LLR – length of the largest root; FMAP – fresh mass of the aerial part; FL – fruit length; EDF – equatorial diameter of the fruit; PE – pericarp thickness and AFW – average fruit weight.

The thickness of the pericarp was related to the length of the fruit and equatorial diameter of the fruit, with ratios of 0.65 and 0.82, respectively. It was also possible to establish a correlation between the equatorial diameter of the fruit and variables related to fruit length (0.77) and pericarp thickness (0.82). For the average fruit weight, a positive correlation was observed with pericarp thickness (0.82), fruit length (0.90), and equatorial fruit diameter (0.94) (Table 5).

As for phytophagous insects, those with significant population densities were adults of the thrips (Figures 5A and 5B) *Frankliniella schultzei* (Thysanoptera: Thripidae), nymphs and adults of the whitefly (Figure 5C) *Bemisia tabaci* (Hemiptera: Aleyrodidae), winged adults of the aphid (Figure 5D) *Myzus persicae* (Hemiptera: Aphididae), adults of the leafhopper (Figure 5E) *Agallia albidula* (Uhler, 1895) (Hemiptera: Cicadellidae) and leaf beetle (Figures 5F and 5G) *Diabrotica speciosa* (Germar, 1824) (Coleoptera: Chrysomelidae). As for predators, eggs of *Chrysoperl*a spp. (Neuroptera: Chrysopidae) were counted (Figure 5H) (Table 6).

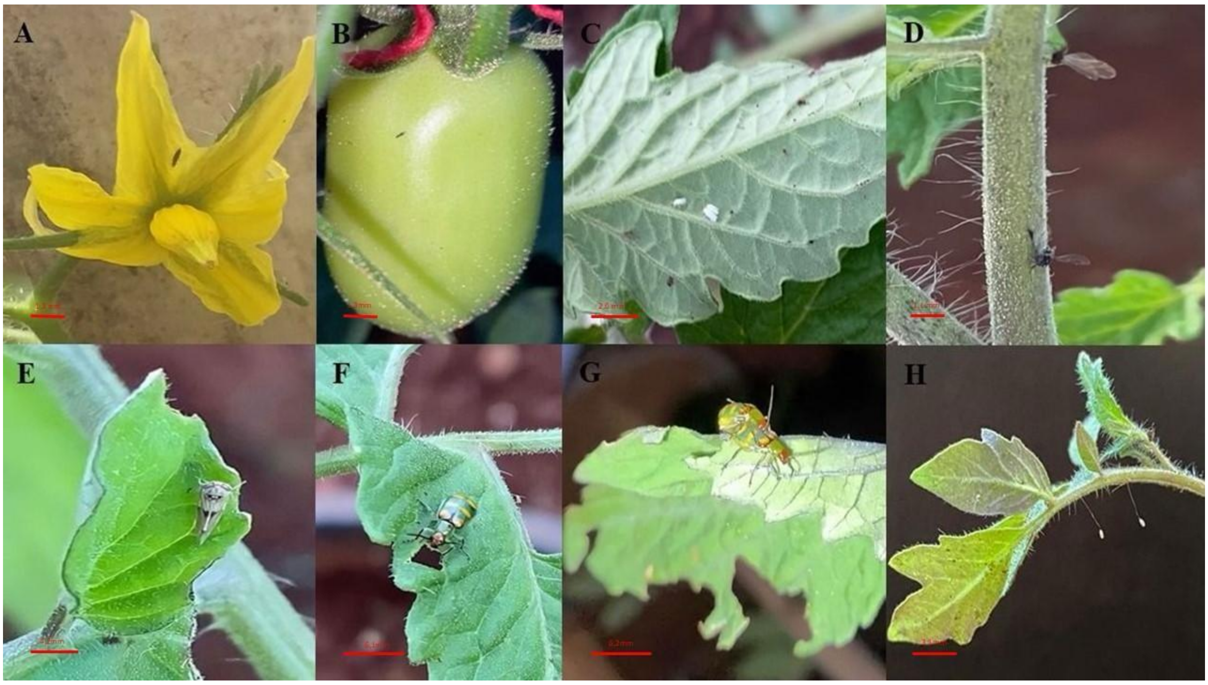

Photo: Grazielly Santos Félis, 2023.

Figure 5. Thrips (*Frankliniella schultzei*) on the flower (A) and fruit of the tomato plant (B); whitefly (*Bemisia tabaci*) on the underside of tomato leaves (C); winged aphid (*Myzus persicae*) on the stem of the tomato plant (D); leafhopper (*Agallia albidula*) on tomato leaf (E); injury (F) and mating (G) of the tomato leaf beetle (*Diabrotica speciosa*) on tomato leaves and (H) oviposition of the predatory lacewing (*Chrysoperla* spp.) on leaves of *Solanum lycopersicum* L., hybrid HMX 7885 F1, sprayed with concentrations of Viçosa mixture. Marcianópolis, GO, 2023.

Table 6. Deviance Analysis for the incidence of phytophagous insects (thrips, whitefly, aphid, leafhopper, and leaf beetle) and predator (chrysopid eggs) recorded through visual evaluation and plant shaking on white cloth in tomato (*Solanum lycopersicum* L.), hybrid HMX 7885 F1, sprayed with different concentrations of the Viçosa mixture. Marcianópolis, GO, 2023.

		Thrips		**Whitefly**		**Aphid**	
SV	DF	*Deviance*	*p*-value	*Deviance*	*p*-value	*Deviance*	*p*-value
Viçosa mixture	4	30.763	0.0014**	45.945	<0.001**	592.87	<0.001**
Blocks	4	21.786	0.0639ns	36.454	0.0499*	151.37	<0.001**
		Leafhopper		Leaf Beetle		Chrysoped eggs	
SV	DF	*Deviance*	*p*-value	*Deviance*	*p*-value	*Deviance*	*p*-value
Viçosa mixture	4	30.732	0.0014**	52.081	<0.001**	47.807	0.0079**
Blocks	4	26.374	0.3597 ns	29.800	0.0001**	34.886	0.0116*

SV: source of variation; DF: degrees of freedom. *Significant at the 5% probability level, **significant at the 1% probability level, ns – not significant, according to the Chi-Square Test.

It was found that for insect pests, the regression was significant and fit the quadratic model. Thus, at concentrations of 3.12 g L^{-1} (Figure 6A); 2.84 g L^{-1} (Figure 6B); 2.90 g L^{-1} (Figure 6C); 2.51 g L^{-1} (Figure 6D), and 3.05 g L^{-1} (Figure 6E) of Viçosa mixture, it is possible to verify the repellent effect, with a lower population density of thrips (Figure 6A) (0.36 insects), whitefly (Figure 6B) (19.21 insects), aphid (Figure 6C) (152.86 insects), leafhopper (Figure 6D) (5.71 insects), and leaf beetle (Figure 6E) (6.42 insects), respectively, in tomato crops using these concentrations (Figures 6 and 7A, B, C, D, and E).

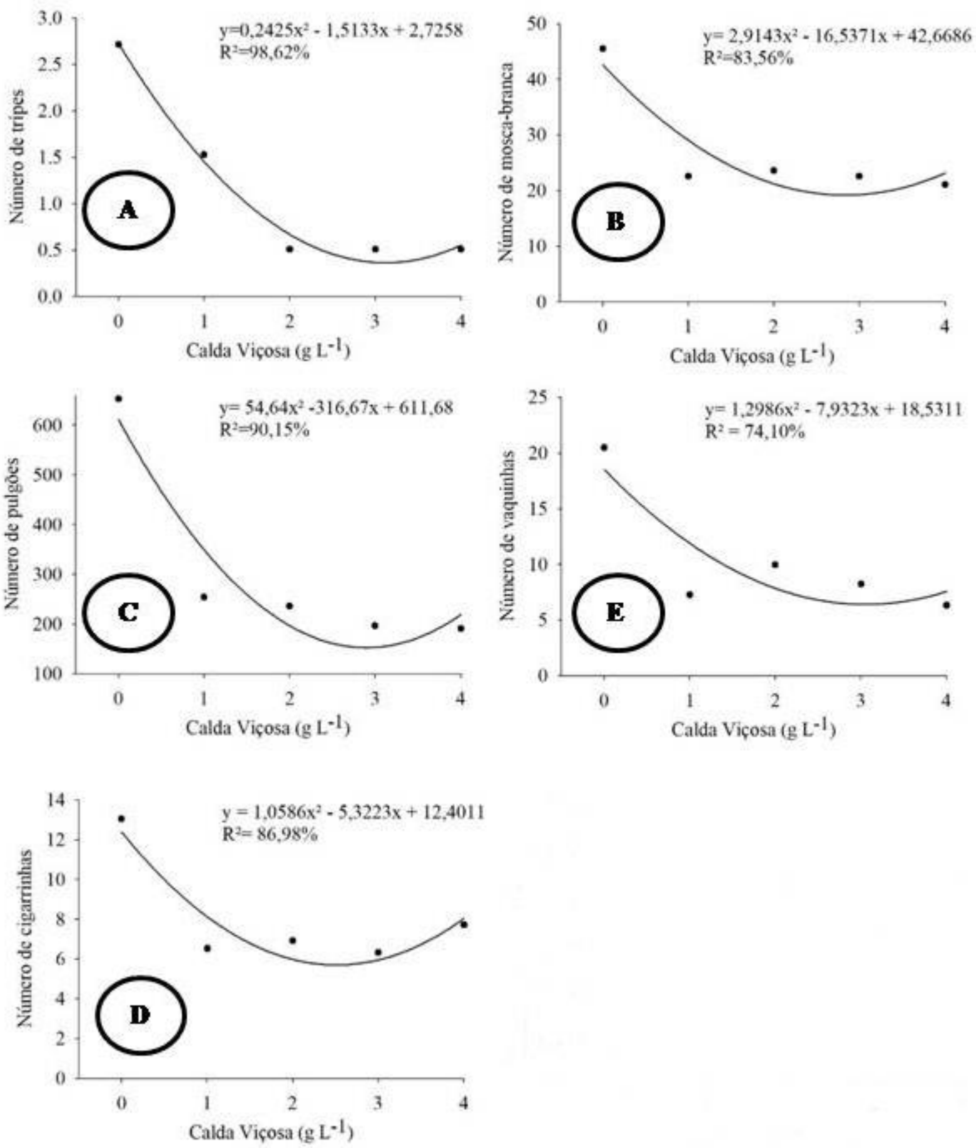

Figure 6. Number of thrips (*Frankliniella schultzei*, adults) (A), whitefly (*Bemisia tabaci*, nymphs and adults) (B), aphid (*Myzus persicae*, winged adults) (C), leafhoppers (*Agallia albidula*, adults) (D), and leaf beetle (*Diabrotica speciosa*, adults) (E) recorded through visual assessment and plant shaking on white cloth in *Solanum lycopersicum* L., hybrid HMX 7885 F1, pulverizated with different concentrations of the Viçosa mixture. Marcianópolis, GO, 2023.

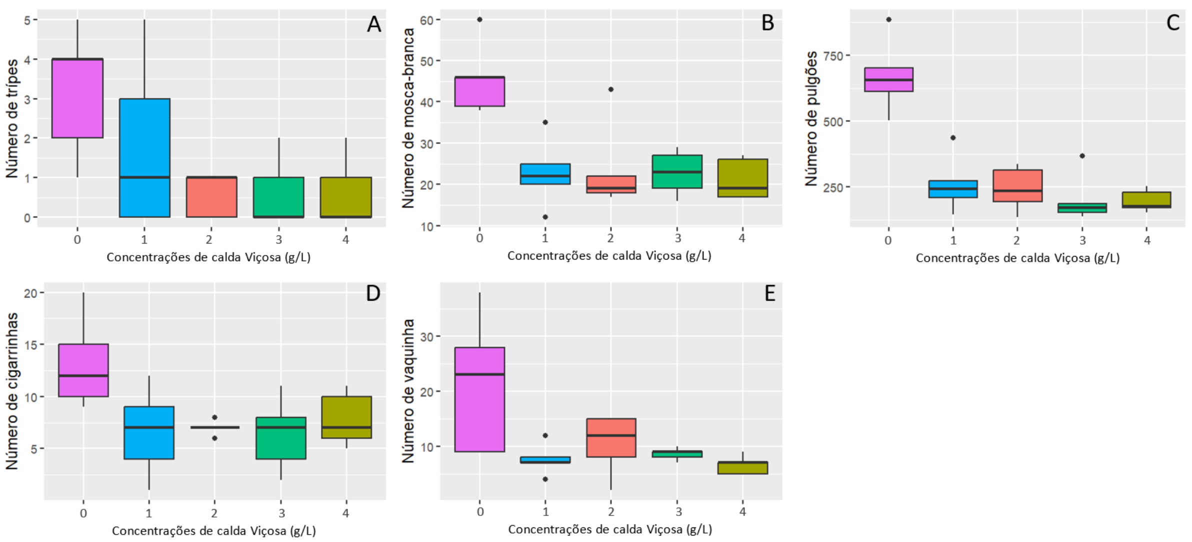

Figure 7. Boxplot for number of thrips *(Frankliniella schultzei*, adults) (A), whitefly (*Bemisia tabaci*, nymphs and adults) (B), aphid (*Myzus persicae*, winged adults) (C), leafhoppers (*Agallia albidula*, adults) (D), and leaf beetle (*Diabrotica speciosa*, adults) (E) recorded through visual assessment and plant shaking on white cloth in *Solanum lycopersicum* L., hybrid HMX 7885 F1, sprayed with different concentrations of the Viçosa mixture. Marcianópolis, GO, 2023.

The importance of controlling these phytophagous insects with substances that act as an alternative to synthetic chemical insecticides, such as Viçosa mixture, is based on the fact that the damage caused by these arthropods to tomato plants, due to their feeding habits, can cause economic losses to producers when their population density reaches the level of economic damage. Thrips are scraping-sucking insects, while whiteflies, aphids, and leafhoppers are sap suckers, and leaf beetles are chewing feeders (SANTOS 2016, WALGENBACH 2017).

In this context, the damage caused by *F. schultzei* thrips to tomato plants is characterized by tissue perforation and suction of cellular content, causing whitish or silvery spots with dark dots that are fecal particles. They are responsible for transmitting viruses such as tomato spotted wilt virus orthotospovirus (TSWV), groundnut ringspot orthotospovirus (GRSV), and tomato chlorotic spot orthotospovirus (TCSV). The whitefly *B. tabaci* sucks the sap from the plant and injects toxins that can leave the fruit tasteless, with uneven ripening and discolored pulp. In addition, it excretes honeydew that promotes the formation of sooty mold caused by the fungus *Capnodium* sp. It transmits viruses that cause tomato severe rugose virus (ToSRV), tomato mottle leaf curl virus (ToMoLCV) and tomato chlorosis virus (ToCV). The aphid *M. persicae* also sucks sap, injects toxins, excretes honeydew, and transmits the potato leafroll virus (PLRV, which causes yellow top/yellow bottom disease in tomato plants), potato virus Y (PVY, which causes Mexican blight), and pepper yellow mosaic virus (PepYMV, which causes yellow mosaic disease) (MICHEREFF FILHO et al. 2022).

The leafhopper *A. albidula* sucks sap and is a vector of the tomato curly top virus (TCTV), which causes dwarfism, swelling of the conducting vessels, growth of axillary buds, curling, and yellowing of tomato leaves (NOGUEIRA et al. 2000, KITAJIMA 2020). Adults of *D. speciosa* feed on pollen and vegetative parts. The attack on the leaves causes several perforations, reducing the photosynthetic capacity of the tomato plant (MICHEREFF FILHO et al. 2019).

The results found in this study, with regard to phytophagous arthropods, are similar to those observed by VENZON et al. (2006), in which spraying with Viçosa mixture (5 g of salts and 0.75 g of lime L^{-1}) or Sulfocalcica mixture (3 mL $L^{-1)}$ or abamectin (0.5 mL L^{-1}) on chili pepper plants resulted in a lower final population of the white mite *Polyphagotarsonemus latus* (Acari: Tarsonemidae) when compared to the use of Supermagro (100 mL L^{-1}) or water (control).

As for the chrysopid eggs (Figure 5H), although the regression was significant, there was no fit to any model, which justified the use of a test of means. Thus, in tomato plants sprayed with concentrations of 1 or 4 g L^{-1} of Viçosa mixture, it was possible to observe a higher density of eggs from this predatory insect (Table 7; Figure 8).

Table 7. Average number of chrysopid eggs (*Chrysoperla* spp.) (Neuroptera: Chrysopidae) on *Solanum lycopersicum L*., hybrid HMX 7885 F1, sprayed with different concentrations of the Viçosa mixture. Marcianópolis, GO, 2023.

Concentrations of Viçosa mixture (g L^{-1})	Number of chrysopid eggs
0	0.35±0.25 b
1	2.80±0.73 a
2	2.10±0.63 ab
3	1.58±0.54 ab
4	2.28±0.65 a

Means (± standard deviation) followed by the same letter do not differ according to Tukey's test at 5% probability.

The results found in this study show that spraying with Viçosa mixture did not negatively interfere with the oviposition of this important predator, given that in the larval stage they can feed on thrips, whiteflies, and aphids, insects that were found associated with tomato crops. It is important to note that chrysopids are predatory insects only in the larval stage, as adults feed on pollen and nectar from plants (SUJII et al. 2020). Therefore, the use of Viçosa mixture contributes to maintaining this natural enemy in cultivation, favoring the reduction of phytophagous insects.

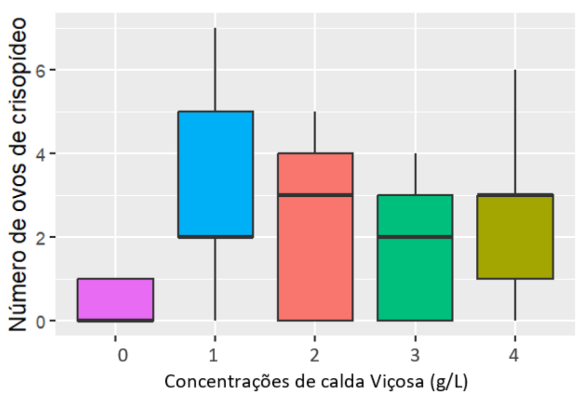

Figure 8. Boxplot for average number of chrysopid eggs (*Chrysoperla* spp.) (Neuroptera: Chrysopidae) on *Solanum lycopersicum* L., hybrid HMX 7885 F1, sprayed with different concentrations of the Viçosa mixture. Marcianópolis, GO, 2023.

In laboratory tests, AMARAL (2003) found that coffee leaf discs from the Catuaí cultivar treated with Supermagro (200 mL L^{-1}), Viçosa mixture (20 g of salts and 3 g of calcium per liter of water), Sulfocalcic mixture (34 mL L^{-1}), and water (control) that the predatory mite *Iphiseiodes zuluagai* Denmark&Muma, 1972 (Acari: Phytoseiidae) was repelled by the Sulfocalcic mixture, a fact that limits its use in ecological pest management. The Viçosa mixture and Supermagro, on the other hand, were selective toward this predatory arthropod.

Therefore, through this research, it was possible to observe the importance of using Viçosa mixture in tomato cultivation, both for agronomic aspects and for altering the host selection of phytophagous insects. The greater number of leaves obtained on the plants may increase the photosynthetic area. In addition, the increase in the number of flowers, which favors self-pollination and pollination by insects, shows that the Viçosa mixture did not cause flower abortion, which can sometimes happen when using high concentrations of fertilizing sprays.

It was also possible to observe an increase in the soluble solids content of tomato fruits, ensuring a sweeter flavor, which is an important characteristic for commercialization, especially for industrial processing. Spraying with Viçosa mixture also resulted in a decrease in the population of phytophagous insects, making it a good alternative to the use of broad-spectrum insecticides and enabling its use in production systems where balance in the agroecosystem is valued, given that the fertiprotector did not compromise the oviposition of the chrysopid predator.

CONCLUSION

Spraying with Viçosa mixture helps improve the agronomic aspects of tomato plants and repels insect pests without negatively affecting the oviposition of chrysopids.

AUTHORS' CONTRIBUTIONS

Conceptualization, methodology, and formal analysis, Grazielly Santos Félis, Franscinely Aparecida de Assis, Fábio Janoni Carvalho, and Gleice Aparecida de Assis; software and validation, Franscinely Aparecida de Assis, Fábio Janoni Carvalho, and Gleice Aparecida de Assis; research, Grazielly Santos Félis; resources and data curation, Grazielly Santos Félis and Franscinely Aparecida de Assis; writing - preparation of the original draft, Grazielly Santos Félis, Franscinely Aparecida de Assis, Fábio Janoni Carvalho, and Gleice Aparecida de Assis; writing - revision and editing, Grazielly Santos Félis, Franscinely Aparecida de Assis, Fábio Janoni Carvalho, and Gleice Aparecida de Assis; visualization, Grazielly Santos Félis, Franscinely Aparecida de Assis, Fábio Janoni Carvalho, and Gleice Aparecida de Assis; supervision, Franscinely Aparecida de Assis; project management, Franscinely Aparecida de Assis; All authors have read and agreed to the published version of the manuscript.

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Not applicable to studies that do not involve humans or animals.

INFORMED CONSENT STATEMENT

Not applicable because this study did not involve humans.

DATA AVAILABILITY STATEMENT

Data can be made available upon request.

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CONFLICTS OF INTEREST

There are no conflicts of interest.

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