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Lime sulfur and cow urine in agronomic development and population density of arthropods in jiló plants

Calda sulfocálcica e urina de vaca no desenvolvimento agronômico e densidade populacional de artrópodes em jiloeiro

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ABSTRACT

This study aimed to evaluate the potential of lime sulfur (CS) and cow urine (UV) on agronomic development, the reduction of phytophagous insect populations, and the incidence of natural enemies in jiló plants. A randomized block design (RBD) was used in a 2 (UV doses - 0 and 120 mL per pot) x 5 (CS concentrations via foliar application – 0.0; 1.5; 3.0; 4.5 and 6.0 g L^{-1}) factorial scheme. Agronomic traits, as well as the population density of phytophagous insects and predators, were determined. A significant isolated effect of UV was observed for the number of leaves, shoot height, stem diameter, and fresh shoot weight (PFPA). For CS, the isolated effect was significant for PFPA, leaf length, and leaf area of the middle third. A significant interaction effect was observed for the width of the middle third leaf. No significant differences were found for traits related to the upper and lower thirds of leaves, the number of flowers, and fruit characteristics. Among arthropods associated with the crop, whiteflies (MB) (nymphs and adults) and lacewings were recorded. For MB nymphs, there was a significant isolated effect of UV and CS. For MB adults and lacewings, a significant interaction was observed. It is concluded that CS (1.5, 3.0, or 6.0 g L^{-1}) and UV (120 mL per pot) promote agronomic development of jiló plants. A reduction in the population of MB nymphs (120 mL per pot of UV or 6.0 g L^{-1} of CS) and MB adults (120 mL per pot of UV with 0.0 or 3.0 g L^{-1} of CS; 0 mL per pot of UV with 6.0 g L^{-1} of CS) was achieved through UV and/or CS application. The spraying of CS (3.0 g L^{-1}) associated with UV (120 mL per pot) does not negatively affect the presence of lacewings.

KEYWORDS: Bio-input. Fertilizer-protector. Fruit vegetable. Insecta. Solanaceae. *Solanumaethiopicum* L.

RESUMO

Objetivou-se neste trabalho avaliar o potencial da calda sulfocálcica (CS) e da urina de vaca (UV) no desenvolvimento agronômico, na redução populacional de insetos fitófagos e incidência de inimigos naturais em jiloeiro. Foi utilizado o delineamento em blocos casualizados em esquema fatorial 2 (doses de UV - 0 e 120 mL $vaso^{-1}$) x 5 (concentrações de CS via foliar – 0,0; 1,5; 3,0; 4,5 e 6,0 g L^{-1}). Foram determinados os aspectos agronômicos, além da densidade populacional de insetos fitófagos e predadores. Houve efeito significativo isolado para UV para número de folhas, altura da parte aérea, diâmetro do caule e peso fresco da parte aérea (PFPA). Já para CS, o efeito isolado foi significativo para PFPA, comprimento da folha e área foliar do terço médio. Houve interação significativa para largura da folha do terço médio. Não houve diferenças significativas para atributos relacionados aos terços superior e inferior das folhas, número de flores e características dos frutos. Quanto aos artrópodes associados ao cultivo foram constatados a mosca-branca (MB) (ninfas e adultos) e crisopídeo. Para ninfas de MB, houve efeito significativo isolado da UV e da CS. Já para adultos de MB e crisopídeos, a interação foi significativa.

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Conclui-se que a CS (1,5; 3,0 ou 6,0 g L^{-1}) e a UV (120 mL $vaso^{-1}$) favorecem o desenvolvimento agronômico do jiloeiro. Ocorre redução populacional de ninfas (120 mL $vaso^{-1}$ de UV ou com 6,0 g L^{-1} de CS) e adultos (120 mL $vaso^{-1}$ de UV com 0,0 ou 3,0 g L^{-1} de CS; 0 mL $vaso^{-1}$ de UV com 6,0 g L^{-1} de CS) de MB mediante aplicação de UV e/ou CS. A pulverização de CS (3,0 g L^{-1}) associada à UV (120 mL $vaso^{-1}$) não interferem negativamente na presença de crisopídeos.

PALAVRAS-CHAVE: Bioinsumo.Fertiprotetor.Hortaliça-fruto.Insecta.Solanaceae.*Solanum.aethiopicum* L.

INTRODUCTION

The jiló plant (*Solanum aethiopicum* L.) is a vegetable belonging to the Solanaceae family and is widely cultivated in Brazil (PINHEIRO et al. 2015). The largest producers of jiló are the states of Rio de Janeiro, Minas Gerais, São Paulo, Goiás, Espírito Santo, Mato Grosso, and Mato Grosso do Sul (IBGE 2017). In Goiás, the municipalities that stood out in the supply of this vegetable in 2023 were Abadia de Goiás, Bela Vista de Goiás, Bonfinópolis, Damolândia, Goiânia, Goianápolis, Guapó, Inhumas, Leopoldo de Bulhões, Nerópolis, and Nova Veneza (SIQUEIRA 2023).

To achieve high yields, farmers need to make the correct choice of cultivar to be planted (NATIONAL REGISTER OF CULTIVARS - RNC 2024), based on adaptability and growing conditions, as well as adopting appropriate management practices related to plant nutrition and phytosanitary control, especially of arthropod pests associated with the crop (PEREIRA et al. 2012).

With regard to fertilizing jiló plants, nitrogen and potassium ensure greater flower setting and commercial-sized fruits. Phosphorus, on the other hand, promotes good root system formation. Boron, zinc, and sulfur are also required to ensure the proper development of plants. However, it is important to note that excessive doses of fertilizers can cause a decrease in fruit production (PINHEIRO et al. 2015).

On the other hand, phytosanitary control in jiló plant cultivation focuses on sap-sucking insects, such as the whitefly *Bemisia tabaci* (Hemiptera: Aleyrodidae), aphids *Myzus persicae* and *Macrosiphum euphorbiae* (Hemiptera: Aphididae), the lace bug *Corythaica cyathicollis* (Hemiptera: Tingidae), and the fruit bug *Phthia picta* (Hemiptera: Coreidae); in addition to the scraping-sucking insects represented by the thrips *Frankliniella schultzei* and *Thrips palmi* (Thysanoptera: Thripidae) (PEREIRA et al. 2012). Among the chewing insects are the beetles *Diabrotica speciosa*, *Epitrix fasciata* and *Maecolaspis assimilis* (Coleoptera: Chrysomelidae), *Epicauta atomaria* (Coleoptera: Meloidae), cutworms *Agrotis ipsilon* and *A. subterranea* (Lepidoptera: Noctuidae), fruit borers *Neoleucinodes elegantalis* (Lepidoptera: Crambidae) and *Helicoverpa zea* (Lepidoptera: Noctuidae) (BRANDÃO FILHO et al. 2018) and wood-boring beetles *Agathomerus spp.* (Coleoptera: Megalopodidae), *Adetus pulchellus* and *Alcidion bicristalum* (Coleoptera: Cerambycidae) and *Faustinus sp* (Coleoptera: Curculionidae) (PEREIRA et al. 2012). In addition to phytophagous insects, the crop is also attacked by mites, which are scraping-sucking arthropods, such as the two-spotted spider mite *Tetranychus urticae* (Acari: Tetranychidae), the red spider mite *T. evansi* (Acari: Tetranychidae), and the tomato russet mite *Aculops lycopersici* (Acari: Eriophyidae) (PEREIRA et al. 2012).

In conventional jiló plant cultivation, farmers use mineral fertilizers to improve plant nutrition, and synthetic chemical plant protection products, mainly from the neonicotinoid, pyrethroid, oxadiazine, thiadiazinone, naphthyl methylcarbamate, anthranilamide, spinosyn, ketoenol, pyrazole, butenolide, and benzoylurea groups, for the management of arthropod pests (BRASIL 2024). However, the excessive use of pesticides can lead to control failures due to the resistance of pest arthropods, mortality of natural enemies and pollinating agents, as well as environmental and food contamination (GARRIDO & BOTTON 2021).

Therefore, it is fundamental to analyze the potential of substances that can stimulate the agronomic development of the crop and, at the same time, have a phytoprotective effect. Among these substances are lime sulfur (MAZARO et al. 2013, ANDRADE et al. 2020) and cow urine (OLIVEIRA et al. 2023, BIJEWAR et al. 2018). Lime sulfur is a foliar fertilizer that provides calcium and sulfur, which, in addition to nourishing plants, also acts as an acaricide, insecticide, and fungicide. It has ovicidal and repellent action against some phytophagous arthropods, such as mites, scale insects, thrips, leaf miners, borers, etc. (FREITAS et al. 2011).

Some researchers have been testing the effect of lime sulfur, both in aspects related to the development of strawberry plants (MAZARO et al. 2013) and dwarf green coconut trees (SILVA et al. 2017), and as a ferti-protective agent in reducing the severity of citrus leprosis caused by the mite *Brevipalpus yothersi* (Acari: Tenuipalpidae) in orange trees (ANDRADE et al. 2020), in decreasing the infestation of the brown scale insect *Parthenolecanium persicae* (Hemiptera: Coccidae) in grapevines (AFONSO et al. 2007), and in increasing the mortality of the San Jose scale insect *Comstockaspis perniciosa* (Hemiptera: Diaspididae) in peach trees (PERAZZOLI et al. 2022) and the mite *Tenuipalpus pacificus* (Acari: Tenuipalpidae) in orchids (SILVA 2019).

Cow urine is an easily obtainable organic input (FREIRE & LIMA 2022) that is typically composed of nitrogen, potassium, chlorine, sulfur, sodium, phenols, indoleacetic acid (CELESTINO et al. 2015), among others. It is used in agriculture as a biofertilizer, biopesticide and biorepellent, due to its strong odor (JESUS et al. 2020). The application can be carried out both on the leaves, via spraying (SILVA et al. 2015), and in the soil, assisting in the development of the root system (DANTAS & GOMES JÚNIOR 2024). Its use can promote an increase in the number of shoots, leaves, flowers, and fruits; and reduce the use of plant protection products, helping to lower the cost of crop production (CELESTINO et al. 2015).

Research has been conducted to verify the effect of cow urine applied to the soil on plant growth and productive aspects in lettuce (OLIVEIRA et al. 2023, FREIRE & LIMA 2022), radish (PATROCINIO et al. 2023) and arugula (CRUZ et al. 2021). However, there are gaps in verifying the reduction in the population density of arthropod pests, as well as in evaluating the effects of the interaction between lime sulfur, applied foliarly, and cow urine, applied to the soil, specifically on jiló plants.

Based on the above, this study aimed to evaluate the potential of lime sulfur and cow urine in the agronomic development, reduction of phytophagous insect populations, and incidence of natural enemies in jiló plants.

MATERIALS AND METHODS

The research was conducted in an experimental area of the University Center of Goiatuba – UniCerrado (latitude 17° 59' 34'' S, longitude 49° 21' 54'' W and altitude of 815 m), in Goiatuba, Southern Goiás. According to the Köppen classification, the climate of the region is classified as Aw (tropical humid), with a wet summer and a dry winter (CLIMATE-DATA 2024).

Chemical and physical analysis of the soil was performed before transplanting the seedlings into the pots. For this purpose, simple soil samples, Dystrophic Red Latosol (SANTOS et al. 2018), were collected from the 0-20 cm layer of depth, using a zigzag pattern and a hoe. Subsequently, the composite sample was sent to the Curitiba Agricultural Laboratory in Bom Jesus, Goiás, for analysis.

The chemical characterization of the soil showed the following results:: pH $CaCl_2$ = 5.3; P and K = 6,9 and 58.7 mg dm^{-3}, respectively; Ca^{2+}, Mg^{2+} e Al^{3+} = 2.5; 1.1 and 0.0 $cmol_c$ dm^{-3}, respectively; H+Al = 4.4 $cmol_c$ dm^{-3}, S = 5.8 mg dm^{-3}, potential cation exchange capacity = 8.1 $cmol_c$ dm^{-3}, sum of bases = 3.7 $cmol_c$ dm^{-3}, base saturation = 46.1% and organic matter = 21.5% g kg^{-1}.

Based on the results of the soil chemical analysis, dolomitic limestone (5.5 g per pot) and fertilizers such as urea (0.22 g per pot), simple superphosphate (2.77 g per pot), and potassium chloride (0.27 g per pot) were applied to 5 L polyethylene pots containing sieved soil, as recommended by BLANK & SOUZA (1999).

Jiló plant seedlings, of the Comprido Verde Claro (Topseed®) cultivar, were acquired from Viveiro Floresta nursery in Goiatuba, Goiás, when they had 3 to 4 true leaves and were 5 to 5.5 cm tall. Transplanting into pots was carried out 14 days after liming and planting fertilization.

Three seedlings were transplanted per pot, and after 19 days, thinning was performed, leaving only the most vigorous seedling. The pots with the seedlings were kept inside a structure covered with 50% shade cloth and open on the sides, allowing for free infestation by phytophagous insects and the presence of natural enemies. The seedlings were irrigated daily.

Thirty-four days after transplanting the seedlings, the first top dressing was applied with 0.33 g per pot of urea and 0.40 g per pot of potassium chloride. In total, two top dressings were applied (modified from BLANK & SOUZA 1999) at intervals of 27 days. A randomized complete block design in a 2 x 5 factorial scheme was adopted, with the first factor (A) referring to fertilization with doses of cow urine diluted in water and applied via the soil, at two levels (0 and 120 mL per pot), and the second factor (B) relating to the concentrations of lime sulfur sprayed on the leaves, at five levels (0.0; 1.5; 3.0; 4.5 and 6.0 g L-1), totaling 10 treatments (Table 1) and three blocks, making a total of 30 experimental plots. Each plot consisted of two pots, each containing one plant, totaling 60 plants.

Table 1. Experimental treatments: fertilization with cow urine (factor A) and lime sulfur (factor B) for

agronomic development and arthropod population density in jiló crops. Goiatuba, Goiás, 2024.

Treatments	Description of treatments
A1B1	Absence of cow urine (0 mL per pot) and 0.0 g L^{-1} of lime sulfur
A1B2	Absence of cow urine (0 mL per pot) and 1.5 g L^{-1} of lime sulfur
A1B3	Absence of cow urine (0 mL per pot) and 3.0 g L^{-1} of lime sulfur
A1B4	Absence of cow urine (0 mL per pot) and 4.5 g L^{-1} of lime sulfur
A1B5	Absence of cow urine (0 mL per pot) and 6.0 g L^{-1} of lime sulfur
A2B1	Presence of cow urine (120 mL per pot) and 0.0 g L^{-1} of lime sulfur
A2B2	Presence of cow urine (120 mL per pot) and 1.5 g L^{-1} of lime sulfur
A2B3	Presence of cow urine (120 mL per pot) and 3.0 g L^{-1} of lime sulfur
A2B4	Presence of cow urine (120 mL per pot) and 4.5 g L^{-1} of lime sulfur
A2B5	Presence of cow urine (120 mL per pot) and 6.0 g L^{-1} of lime sulfur

The cow urine was collected from lactating cows of a dairy herd (Girolando and Gir breeds) at Fazenda Lagoado, in the municipality of Panamá, Goiás, Brazil. These animals were fed guinea grass (*Panicum maximum*), 24% cereal feed – 24% Agrocentro® total diet, and salt (mineral supplement) Fosquima®. All urine used in the experiment was collected on the same day. Subsequently, the collected liquid was stored in a plastic container for three days to allow fermentation to occur, and kept in a shaded location. After this time, a 0.5L sample of urine was sent to the Terra Análises laboratory for Agriculture and Livestock, Goiânia, Goiás, for the determination of nutrients, organic matter, C/N ratio, and pH.

The results of the urine analysis showed that it was composed of: P_2O_5 - 3 g L^{-1}; N - 6 g L^{-1}; Ca - 2.6 g L^{-1}; Mg - 0.4 g L^{-1} ; S – 0.2 g L^{-1} ; Cu – 0.005 g L^{-1}; Fe - 19.16 g L^{-1}; Mn - 0.03 g L^{-1}; Zn - 0.063 g L^{-1}; Na – 0.003 g L^{-1}; Organic carbon – 3g L^{-1}, K_2O total - 14.4 g L^{-1}, organic matter – 5g L^{-1}; C/N ratio - 0.5 and pH - 8.2.

Applications of lime sulfur solution and cow urine were started 23 days after transplanting the seedlings. The lime sulfur solution was weighed on a precision balance and diluted in water according to the treatments. The cow urine was diluted to 1%, that is, 125 mL of cow urine in 12.5 L of water. Subsequently, a dose of 120 mL of the solution was applied per pot to the soil (modified from ARAÚJO et al. 2014). In total, five applications of the lime sulfur and/or cow urine were carried out, with applications performed every 15 days.

For the evaluation of agronomic development, the following parameters were determined in the plants: height of the aerial part (cm), measured with a millimeter tape measure; stem diameter (mm), with a digital caliper; number of fully expanded leaves; number of flowers per plant; and fresh weight of the aerial part (g). The leaf length (cm) was also determined, evaluated by the distance between the point of petiole insertion on the leaf blade and the opposite end of the leaf; as well as leaf width (cm), measured by the largest dimension perpendicular to the length axis (COELHO 2021), measured with a graduated ruler; and leaf area (m²) as indicated in the formula: $LA = L \times W \times f$, where, LA – leaf area (m²); L – leaf length (m); W – leaf width (m); and f – form factor (0.59) (COELHO 2021), evaluated in the upper, middle, and lower thirds of the plants. Regarding the fruit-related attributes, the average number of fruits per plant was analyzed; in addition to the longitudinal (mm) and transverse (mm) diameters, using a digital caliper.

To determine the population density of arthropods (phytophagous and predatory), insect counts were performed at 5:30 PM, three days after each application of lime sulfur and/or cow urine. For the treatments that did not receive any of these applications, the arthropod evaluation schedule was the same as for the plants that did receive the application. The assessment was carried out through visual inspection, shaking the plants over a white plastic tray, and using a pocket magnifying glass. The arthropods were identified to the taxonomic categories of order, family, and species, when possible. A total of five assessments were performed.

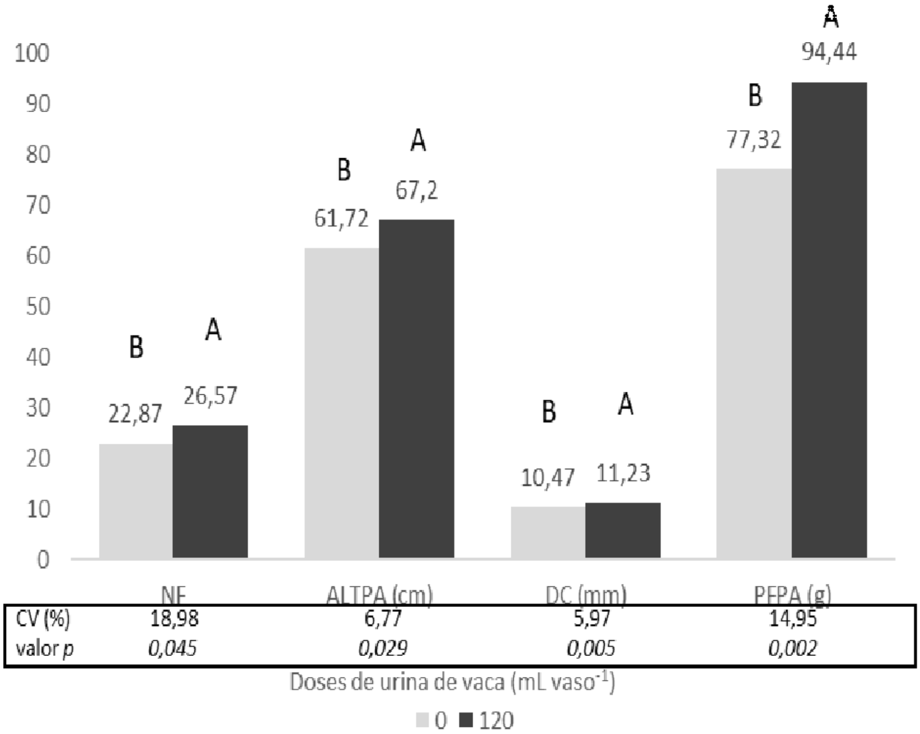
In the statistical analysis, the data related to the phytotechnical parameters were subjected to analysis of variance using the F-test at a 5% significance level, after meeting the assumptions of the model, using the Sisvar® statistical software (FERREIRA 2011). For the arthropod count data (phytophagous and predatory insects), number of flowers, and average number of fruits per plant, a Generalized Linear Model (GLM) with a Poisson distribution and log link function was fitted. The significance of the factors was verified using the Chi-squared test ($X^2<0.05$), employing Deviance analysis (ANODEV), in the statistical software R version 4.0.0 (R CORE TEAM 2020). If significant, the means were compared using Tukey's test at a 5% significance level. An attempt was made to fit regression models to the means of the significant variables of the calcium polysulfide factor, but these models were either not significant or showed an unsatisfactory coefficient of determination in the regression.

Pearson's correlation was also calculated between the variables in order to identify trends between them, with significance tested using the t-test at a 5% significance level in the statistical software R version 4.0.0 (R CORE TEAM 2020).

RESULTS AND DISCUSSION

The factors under study (cow urine and lime sulfur) showed significance for some parameters. An isolated effect of cow urine was observed for the number of leaves, plant height, stem diameter, and fresh weight of the aerial part. The isolated effect of the lime sulfur was observed for the fresh weight of the aerial part and the length and area of the leaves in the middle third. On the other hand, there was a significant interaction between cow urine and lime sulfur only for leaf width in the middle third. However, there was no significant difference between the factors for leaf length, width, and area in the upper and lower thirds of the plants, as well as for the number of flowers, average number of fruits per plant, and the longitudinal and transverse diameters of the fruits.

The analysis of the isolated effect of cow urine showed that the addition of 120 mL per pot favored an increase in the number of leaves, plant height, stem diameter, and fresh weight of the aerial part compared to the control group (Figure 1).



CV: Coefficient of variation. Means followed by the same letter in the column do not differ significantly from each other according to the F test at the 5% significance level..

Figure 1. Number of leaves (NF), shoot height (ALTPA), stem diameter (DC), and fresh shoot weight (PFPA) in jiló (*Solanum aethiopicum* L.), Comprido Verde Claro cultivar, submitted to cow urine doses. Goiatuba, Goiás, 2024.

The results found in the present research are similar to those observed by DANTAS & GOMES JUNIOR (2024) in lettuce, in which in the Maravilha, Romana, Romana Branca, Regina and Regina Verão varieties, the application of cow urine to the soil (45 mL of solution per plant) compared to the absence of application contributed to an increase in the number of leaves, the average diameter of the plants, height and green matter of the aerial part. Regarding the number of leaves and average plant diameter, the Regina and Regina Verão varieties showed the highest values obtained through the application of cow urine, being 36.20 and 34.40 units and 42.10 and 40.80 cm, respectively. Regarding plant height and above-ground green matter, the Romana and Romana Branca varieties stood out when subjected to cow urine application, presenting 32.15 and 33.70 cm, respectively; and 328.42 and 340.49 g.

Regarding the isolated effect of the lime sulfur, the greatest fresh weight of the aerial part of the eggplant plant was obtained by spraying the plants with 1.5; 3.0 or 6.0 g L^{-1}. The increase in leaf length in the middle third was obtained both in the absence of lime sulfur and with concentrations of 1.5; 3.0 or 6.0 g L^{-1}. On the other hand, the leaf area of the middle third showed the greatest increase with 0.0; 1.5 or 6.0 g L^{-1},compared to the 4.5 g L^{-1} concentration (Table 2).

Table 2. Fresh shoot weight (PFPA), middle third leaf length (CFTM), and middle third leaf area (AFTM) in jiló (*Solanum aethiopicum* L.), Comprido Verde Claro cultivar, submitted to lime sulfur concentrations. Goiatuba, Goiás, 2024.

Concentrations of lime sulfur (g L^{-1})	PFPA (g)	CFTM (cm)	AFTM (cm^2)
0.0	72.53 b	13.23 a	49.71 a
1.5	91.05 a	12.07 a	37.91 a
3.0	93.40 a	11.89 a	36.70 ab
4.5	80.24 b	9.12 b	20.29 b
6.0	92.18 a	12.54 a	41.64 a
CV (%)	14.95	10.48	26.72
Teste F	13.331	9.72	7.01
p Value	0.002	0.0002	0.0014

CV: Coefficient of variation. Averages followed by the same letter in the column do not differ significantly from each other according to Tukey's test at the 5% significance level.

In bean plants, the application of lime sulfur (20 L of water, 2.5 kg of sulfur and 2.0 kg of quicklime, at a concentration of 1:6 L) resulted in a higher content of green biomass in the aerial part of the plants (kg ha^{-1}) when compared to the control (water) (BAÚ 2023).

Regarding the interaction between the factors cow urine and sulfur-lime solution, it was found that it was significant only for the leaf width of the middle third. Thus, it is observed that the greatest width was obtained at a concentration of 3 g L^{-1} of the lime sulfur solution associated with a dose of 120 mL per pot of cow urine. For the other concentrations of lime sulfur solution, regardless of the absence or presence of cow urine, there was no significant difference in increasing the width of the leaves in the middle third (Table 3).

Table 3. Middle third leaf width (LFM) in jiló (*Solanum aethiopicum* L.), Comprido Verde Claro cultivar, submitted to cow urine doses and lime sulfur concentrations. Goiatuba, Goiás, 2024.

	LFTM (cm) Cow urine (mL per pot)	
Lime sulfur (g L^{-1})	0	120
0.0	8.25 aA	8.23 aA
1.5	7.70 aA	6.55 aAB
3.0	6.08 bA	8.03 aA
4.5	6.15 aA	5.17 aB
6.0	6.85 aA	8.43 aA

Means followed by the same letter, lowercase in the row and uppercase in the column, do not differ significantly from each other according to Tukey's test at the 5% significance level.

In the absence of cow urine, there was no significant difference in the increase in leaf width in the middle third, regardless of the concentration of lime sulfur used. However, the soil application of 120 mL per pot of cow urine associated with spraying with 0.0; 3.0 or 6.0 g L^1 of lime sulfur resulted in an increase in leaf width in the middle third (Table 3).

There was no significant difference between the factors for leaf length, width, and area in the upper and lower thirds of the plants. The average values obtained for these parameters were 10.40 cm, 6.17 cm, and 26.83 cm^2, respectively, in the upper third, and 11.43 cm, 7.47 cm, and 38.92 cm^2 in the lower third of the plants. In zucchini, the application of cow urine solution to the soil at concentrations of 0, 1, 2, 3, 4, and 5% was also ineffective in increasing the leaf area of this vegetable. The authors attributed this to the fact that the leaf area of zucchini is very large and the concentrations used were insufficient to promote such an increase (OLIVEIRA et al. 2013).

There was also no significant difference between the factors under study for the number of flowers and the average number of fruits per plant. The average number of flowers was substantially low. This fact may have compromised fruit production, given that, in addition to the small number of flowers obtained, not all of them formed fruits due to flower abortion (Table 4).

Table 4 . Number of flowers (NFL) and average number of fruits per plant (NMFP) in jiló (*Solanum aethiopicum* L.), Comprido Verde Claro cultivar, submitted to cow urine doses and lime sulfur concentrations. Goiatuba, Goiás, 2024.

Cow urine (mL per pot)	**NFL**	**NMFP**
0	3.58±0.51 a	0.40±0.16 a
120	2.86±0.45 a	0.81±0.25 a
Lime sulfur (g L^{-1})	**NFL**	**NMFP**
0.0	2.90±0.72 a	0.72±0.36 a
1.5	2.53±0.65 a	0.55±0.32 a
3.0	4.83±0.89 a	0.55±0.29 a
4.5	2.72±0.67 a	0.68±0.36 a
6.0	3.46±0.79 a	0.39±0.25 a

Averages followed by the same letter in the column do not differ significantly from each other according to Tukey's test at the 5% significance level.

The authors believe that lime sulfur and cow urine were not responsible for the reduced flowering in the jiló plants, given that the same behavior was also observed in the control plants. Therefore, it is concluded that this reduction in flowering, which consequently affected fruit production, is associated with environmental causes. The problems observed in relation to the fruits were also found in the response variables equatorial diameter and longitudinal diameter. Thus, the estimated average values for these parameters were, respectively, 23.48±11.62 mm and 34.71±18.34 mm.

Based on the characteristics of the jiló plants and fruits, excluding equatorial and longitudinal diameters, it was possible to develop a Pearson correlation matrix between the response variables in order to verify trends among them (Figure 2).

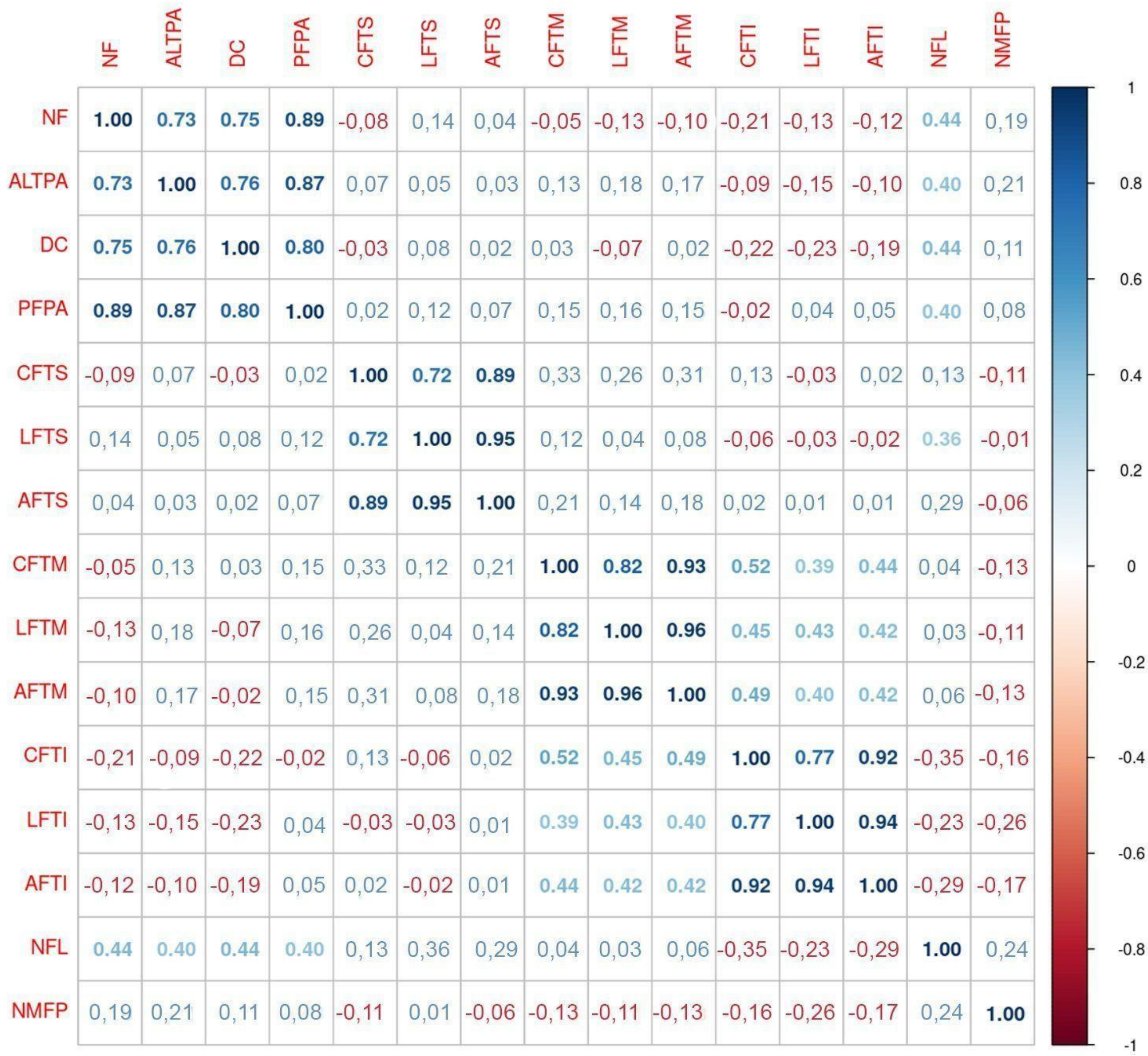


Figure 2. Pearson correlation matrix between the variables - NF: number of leaves; ALTPA: shoot height; DC: stem diameter; PFPA: fresh shoot weight; CFTS: upper third leaf length; LFTS: upper third leaf width; AFTS: upper third leaf area; CFTM: middle third leaf length; LFTM: middle third leaf width; AFTM: middle third leaf area; CFTM: lower third leaf length; LFTI: lower third leaf width; AFTI: lower third leaf area; NFL: number of flowers; NMFP: average number of fruits per plant. Goiatuba, Goiás, 2024.

In the present study, positive and significant correlations were observed between the number of leaves and the parameters of shoot height (p<0.01), stem diameter (p<0.01), fresh weight of the shoot (p<0.01), and number of flowers (p=0.01). Shoot height also correlated with the number of leaves (p<0.01), stem diameter (p<0.01), fresh weight of the shoot (p<0.01), and number of flowers (p=0.03). Stem diameter correlated with the number of leaves (p<0.01), shoot height (p<0.01), fresh weight of the shoot (p<0.01), and number of flowers (p=0.01). The fresh weight of the shoot correlated with the number of leaves (p<0.01), shoot height (p<0.01), stem diameter (p<0.01), and number of flowers (p=0.03) (Figure 2).

The length of the leaf in the upper third showed a positive and significant correlation with the width of the leaf in the upper third (p<0.01) and the leaf area of the upper third (p<0.01). The width of the leaf in the upper third, in turn, correlated with the length of the leaf in the upper third (p<0.01), the leaf area of the upper third (p<0.01), and the number of flowers (p<0.01). The leaf area of the upper third correlated with the length of the leaf in the upper third (p<0.01) and the width of the leaf in the upper third (p<0.01) (Figure 2).

For the middle third of the plants, leaf length was positively and significantly correlated with leaf width of the middle third (p<0.01), leaf area of the middle third (p<0.01), leaf length of the lower third (p<0.01), leaf width of the lower third (p=0.03), and leaf area of the lower third (p=0.01). Leaf width, in turn, was correlated with leaf length of the middle third (p<0.01), leaf area of the middle third (p<0.01), leaf length of the lower third (p=0.01), leaf width of the lower third (p=0.02), and leaf area of the lower third (p=0.02). For leaf area of the middle third, it was correlated with leaf length of the middle third (p<0.01), leaf width of the middle third (p<0.01), leaf length of the lower third (p<0.01), leaf width of the lower third (p=0.03), and leaf area of the lower third (p=0.02) (Figure 2).

In the lower third of the plants, leaf length correlated with length (p<0.01), width (p=0.01), and leaf area of the middle third (p=0.01), as well as with the width (p<0.01) and leaf area of the lower third (p<0.01). The leaf width of the lower third correlated with length (p=0.03), width (p=0.02), and leaf area of the middle third (p=0.03), as well as with the width (p<0.01) and leaf area of the lower third (p<0.01). The leaf area of the lower third correlated with length (p=0.02), width (p=0.02), and leaf area of the middle third (p=0.02), as well as with the width (p<0.01) and leaf area of the lower third (p<0.01) (Figure 2).

The number of flowers was positively correlated with the number of leaves (p=0.01), plant height (p=0.03), stem diameter (p=0.01), and fresh weight of the aerial part (p=0.03). However, the average number of fruits per plant did not show significance with any other parameter evaluated (Figure 2).

Regarding the intensity of the correlations, they can be classified as very strong (r ± 0.91 to ± 1.00), strong (r ± 0.71 to ± 0.90), medium (r ± 0.51 to ± 0.70), and weak (r ± 0.31 to ± 0.50), according to Guerra & Livera (1999) cited by Chaves Neto et al. (2018).

Regarding the population density of arthropods, it was found that the whitefly *Bemisia tabaci* (Hemiptera: Aleyrodidae), in both nymph and adult stages, was the most prevalent insect pest in the jiló crop during the experiment. On the other hand, regarding natural enemies, the presence of the lacewing *Chrysoperla spp.* (Neuroptera: Chrysopidae) was observed in the egg, larval, and adult stages.

It was observed that for the whitefly nymph, there was a significant isolated effect of both cow urine and lime sulfur solution. However, for the adult stage of this sucking insect and for the chrysopid predator (egg, larva, and pupa stages), the interaction between the two factors under study proved to be significant.

For whitefly nymphs, it was found that the isolated application of cow urine to the soil (120 mL per pot) contributed to reducing the population density of this sucking insect when compared to the absence of application. Regarding lime sulfur, the concentration of 6.0 g L^{-1} resulted in lower infestation compared to 4.5 g L^{-1} (Table 5).

Table 5. Whitefly nymphs *Bemisiatabaci* in jiló (*Solanum aethiopicum* L.), Comprido Verde Claro cultivar, submitted to cow urine doses and/or lime sulfur concentrations. Goiatuba, Goiás, 2024.

Cow urine (mL per pot)	Whitefly nymphs
0	26.8±1.37 a
120	21.0±1.18 b
Lime sulfur (g L^{-1})	**Whitefly nymphs**
0.0	20.6±1.77 bc
1.5	26.6± 2.05 b
3.0	23.2± 1.89 bc
4.5	34.9± 2.35 a
6.0	17.0± 1.61 c

Averages followed by the same letter in the column do not differ significantly from each other according to Tukey's test at the 5% significance level.

In iceberg lettuce, applications of cow urine at 25 and 50%, as well as the use of chemical control with Avatar® (16 mL 100 L^{-1}), were effective in repelling insect pests such as the cutworm (*Agrotis ipsilon*) (Lepidoptera: Noctuidae) and the hairy beetle (*Lagria villosa*) (Coleoptera: Tenebrionidae) when compared to the control group (ATHAHYDES et al. 2023). Similarly, in eggplant, a repellent effect on whitefly nymphs of *B. tabaci* was observed after the first spraying of the plants with cow urine (20 mL per pot) when compared to the use of rosemary leaf extract (80, 160 and 320 g L^{-1}) or the control group (CULAU & SILVA 2015).

However, unlike the present research, the results for both iceberg lettuce and eggplant were obtained through foliar spraying and not soil application. This demonstrates the practical contribution of the obtained result, since, in addition to the strong odor released by the urine, its rich composition in macro and micronutrients, phenols, and indoleacetic acid can contribute to greater resistance of plants to insect pests, as well as favoring agronomic aspects of the crop.

Regarding lime sulfur solution, its application (20 mL L^{-1}) to cassava leaves, variety Fécula Branca, contributed to an increase in the mortality of nymphs of the lace bug *Vatiga manihotae* (Hemiptera: Tingidae) when compared to the use of Mattan Plus®, Pironat®, or the control group (BELLON et al. 2014).

Regarding adult whiteflies, spraying with lime sulfur solution at concentrations of 0.0 and 3.0 g L^{-1}, both combined with a dose of 120 mL per pot of cow urine, reduced the population of this phytophagous insect. Using a concentration of 6.0 g L^{-1}, the reduction of this pest occurred in the absence of cow urine. For 1.5 g L^{-1} and 4.5 g L^{-1} of lime sulfur solution, there was no significant difference in the pest population when used in combination with or without cow urine. In the absence of cow urine, a concentration of 6.0 g L^{-1} of sulfur-lime solution showed better results compared to 0.0; 1.5 and 3.0 g L^{-1} for reducing the insect pest. With the application of a 120 mL dose per pot of cow urine, the concentrations of 0.0, 3.0 and 4.5 g L^{-1} of the lime sulfur solution were more efficient (Table 6).

Table 6. Adult whiteflies (*Bemisia tabaci*) and lacewings (eggs, larvae, and pupae) in jiló (*Solanum aethiopicum* L.), Comprido Verde Claro cultivar, submitted to cow urine doses and/or lime sulfur concentrations. Goiatuba, Goiás, 2024.

	Adult whiteflies Cow urine (mL per pot)		Chrysopids Cow urine (mL per pot)	
Lime sulfur (g L^{-1})	**0**	**120**	**0**	**120**
0.0	48.6±3.88 aA	28.1±2.93 bC	1.69±0.77 aA	0.19±0.20 bA
1.5	54.7±4.11 aA	57.4±4.22 aB	0.75±0.44 aA	0.38±0.21 aA
3.0	50.5±3.95 aA	37.2±3.38 bC	0.19±0.20 bA	1.69±0.77 aA
4.5	41.1±3.56 aAB	35.7±3.31 aC	0.00±0.00 aA	0.19±0.19 aA
6.0	31.4±3.10 bB	80.7±5.03 aA	0.19±0.19 aA	0.38±0.29 aA

Averages followed by the same lowercase letter in the row and uppercase letter in the column do not differ significantly from each other according to Tukey's test at the 5% significance level.

For another insect of the order Hemiptera, *Diaphorina citri* (Liviidae), it was observed that among the concentrations of lime sulfur solution tested (0.15; 0.25; 0.35; 0.45 and 0.50%), the lowest and highest concentrations showed significant results against the psyllid. It was found that at a concentration of 0.15%, the instantaneous population growth rate was zero. Furthermore, a 0.57% solution of lime sulfur proved effective in ensuring 95% mortality of this phytophagous insect population (RESTREPO-GARCÍA & SOTO-GIRALDO 2017).

The use of lime sulfur has also proven effective in controlling the coffee berry borer *Hypothenemus hampe*i (Coleoptera: Curculionidae), as it showed an insecticidal effect, with a concentration of 7.12% resulting in 95% mortality of the population (MARULANDA et al. 2018).

Regarding lacewings, it can be observed that the population density found was extremely low. The absence of lime sulfur combined with the absence of cow urine, and 3.0 g L^{-1} of lime sulfur with 120 mL per pot of cow urine showed differences in the population density of this predator. However, spraying with 1.5 g L^{-1}, 4.5 g L^{-1} and 6.0 g L^{-1}, whether or not combined with the application of cow urine, did not show a significant difference. Furthermore, the use of 0 mL per pot and 120 mL per pot of cow urine, regardless of the concentration of lime sulfur used, did not differ from each other in the population of this natural enemy (Table 6).

Selectivity studies are being conducted to identify the effects of lime sulfur solution on beneficial organisms. In this context, it was verified in the laboratory that the concentrations of lime sulfur (1250, 2500, 5000, 10000 mL 100 L^{-1} of water), by topical application or residual exposure, did not interfere with the survival of adult *Cryptolaemus montrouzieri* ladybugs (Coleoptera: Coccinellidae) (EFROM et al. 2011).

Although selectivity tests were not conducted in this research, different phases of the biological development of lacewings were detected. However, the population density was low in all treatments evaluated, including the control group, so this fact cannot be attributed solely to the applications of cow urine and/or lime sulfur solution It was observed that plants not treated with these factors, or that received a concentration of 3.0 g L^{-1} of lime sulfur via foliar application, and the highest dose of cow urine via soil application, showed better results, possibly due to the fact that the urine, as applied, did not come into direct contact with this predator, unlike the lime sulfur, which was sprayed.

The results presented in this research show that there were contributions both to the improvement of certain agronomic aspects of the jiló plant and to the reduction of pest insect infestation through the application of cow urine, via the soil, and lime sulfur mixture, via foliar application. However, there is a clear need to expand the investigation of these substances and their doses/concentrations regarding the characteristics of the fruits and their action on natural enemies.

Thus, it is understood that the adoption of these two strategies by vegetable producers assists in integrated pest management, reducing the use of synthetic chemical products, and also providing an increase in crop development, which can enable the production of food in a safer and more sustainable way.

CONCLUSION

Lime sulfur (1.5; 3.0 or 6.0 g L^{-1}) and cow urine (120 mL per pot) promote the agronomic development of the jiló plant. A reduction in the population of nymphs (120 mL per pot of cow urine or with 6.0 g L^{-1} of lime sulfur) and adults (120 mL per pot of cow urine with 0.0 or 3.0 g L^{-1} of lime sulfur; 0 mL per pot of cow urine with 6.0 g L^{-1} of lime sulfur) of whiteflies occurs through the application of cow urine and/or lime sulfur. Spraying with lime sulfur solution (3.0 g L^{-1}) combined with cow urine (120 mL per pot) does not negatively affect the presence of chrysopids.

AUTHOR'S CONTRIBUTIONS

Conceptualization, methodology, and formal analysis, Franscinely Aparecida de Assis, Maria Júlia Oliveira Garcia Marques, Augusto Henrique Naves dos Santos, Carla Cristina Alves Mendes, Fábio Janoni Carvalho, and Gleice Aparecida de Assis; software and validation, Franscinely Aparecida de Assis, Fábio Janoni Carvalho, and Gleice Aparecida de Assis; investigation, Maria Júlia Oliveira Garcia Marques and Augusto Henrique Naves dos Santos; resources and data curation, Franscinely Aparecida de Assis, Maria Júlia Oliveira Garcia Marques, Augusto Henrique Naves dos Santos; writing - original draft preparation, Franscinely Aparecida de Assis, Maria Júlia Oliveira Garcia Marques, Augusto Henrique Naves dos Santos, Carla Cristina Alves Mendes, Fábio Janoni Carvalho, and Gleice Aparecida de Assis; writing - review and editing, Franscinely Aparecida de Assis, Maria Júlia Oliveira Garcia Marques, Augusto Henrique Naves dos Santos, Carla Cristina Alves Mendes, Fábio Janoni Carvalho, and Gleice Aparecida de Assis; visualization, Franscinely Aparecida de Assis, Maria Júlia Oliveira Garcia Marques, Augusto Henrique Naves dos Santos, Carla Cristina Alves Mendes, Fábio Janoni Carvalho, and Gleice Aparecida de Assis; supervision, Franscinely Aparecida de Assis; project administration, Franscinely Aparecida de Assis; funding acquisition, Franscinely Aparecida de Assis and Carla Cristina Alves Mendes. All authors have read and agreed to the published version of the manuscript.

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STATEMENT OF THE INSTITUTIONAL REVIEW BOARD

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

The data can be made available upon request.

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CONFLICTS OF INTEREST

Não há conflitos de interesse

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