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Does diatomaceous earth improve agronomic characteristics and induce resistance to arthropod pest in physalis?

Terra diatomácea melhora as características agronômicas e induz resistência a artrópodes-praga em physalis?

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ABSTRACT

Physalis peruviana (Solanaceae) is an exotic fruit that is still little cultivated in Brazil when compared to other species. As a result, information related to management that can contribute to the development of the crop and pest control is scarce. Thus, the objective of this work was to evaluate the effects of spraying diatomaceous earth (DE) on the phytotechnical parameters of the crop and fruit quality, as well as on the induced resistance to arthropods pest in *P. peruviana*. The experimental design was in randomized blocks, with five treatments, which refer to the concentrations of DE (T1 - 0 g L^{-1}; T2 - 1 g L^{-1}; T3 - 3 g L^{-1}; T4 - 6 g L^{-1} and T5 - 9 g L^{-1}) and eight blocks. Phytotechnical characteristics of the crop and quality (soluble solids) of the fruits were evaluated, as well as the induction of resistance by evaluating the incidence of arthropods pest. There was no significant difference between the DE concentrations for the phytotechnical and quality variables and those related to the feeding preference of herbivorous insects (number and percentage of leaves with holes). However, plants treated with DE were less preferred for oviposition by *Bemisia tabaci* and *Lema bilineata*, and fewer whitefly adults and *L. bilineata* larvae and adults were also recorded. Thus, it is concluded that DE has no effect on phytotechnical and quality parameters of physalis, but induces resistance against arthropods pest such as *B. tabaci* and *L. bilineata*.

KEYWORDS: exotic fruit; non-preference for oviposition; silicon dioxide; *Physalis peruviana*; *Lema bilineata*.

RESUMO

Physalis peruviana (Solanaceae) é uma frutífera exótica ainda pouco cultivada no Brasil quando comparada a outras espécies. Em função disso, informações relacionadas ao manejo que possam contribuir para o desenvolvimento da cultura e controle de pragas são escassas. Assim, objetivou-se neste trabalho avaliar os efeitos da pulverização da terra diatomácea (TD) nos parâmetros fitotécnicos da cultura e de qualidade dos frutos, bem como na resistência induzida a artrópodes-praga em *P. peruviana*. O delineamento experimental foi em blocos casualizados, com cinco tratamentos, que se referem as concentrações de TD (T1 - 0 g L^{-1}; T2 - 1 g L^{-1}; T3 - 3 g L^{-1}; T4 - 6 g L^{-1} e T5 - 9 g L^{-1}) e oito blocos. Foram avaliadas características fitotécnicas da cultura e de qualidade (sólidos solúveis) dos frutos, bem como a indução de resistência mediante avaliação da incidência dos artrópodes-praga. Não houve diferença significativa entre as concentrações de TD para as variáveis fitotécnicas, de qualidade e aquelas relacionadas à preferência alimentar dos insetos herbívoros (número e porcentagem de folhas com orifícios). Contudo, as plantas tratadas com TD foram menos preferidas para oviposição por *Bemisia tabaci* e *Lema bilineata*, sendo registrado também menor número de adultos da mosca-branca e de larvas e adultos de *L. bilineata*. Dessa forma, conclui-se que a TD não apresenta efeito nos parâmetros fitotécnicos e de qualidade da physalis, mas induz resistência contra artrópodes-praga como *B. tabaci* e *L. bilineata*.

PALAVRAS-CHAVE: frutífera exótica; não-preferência para oviposição; dióxido de silício; *Physalis peruviana*; *Lema bilineata*.

INTRODUCTION

Physalis peruviana L. (Solanaceae) is an exotic fruit from Andean countries in South America (ANTUNES & HOFFMANN 2012) with numerous nutritional and medicinal properties (PUENTE et al. 2011, KASALI et al. 2021). In addition, it is an important alternative in obtaining income by small and medium-sized rural producers, due to the low cost of crop implantation and high productivity (HOFFMANN & RUFATO 2012).

In the national agricultural scenario, although there is no large-scale production, physalis has good adaptation, with greater popularity in the Central-South regions (MUNIZ et al. 2014, MUNIZ et al. 2015), and its fruits have high added value (BUFFON et al. 2020), a fact that motivates the intensification of *Physalis* spp. plantations in other Brazilian localities (SANTANA et al. 2020).

Because it is a fruit tree whose cultivation, in a certain way, is still recent in Brazil, there is a lack of research that can provide more information regarding fertilization and phytosanitary control, given that the crop is attacked by a great diversity of pests. Among these are the insects *Lema bilineata* and *Diabrotica speciosa* (Coleoptera: Chrysomelidae), the caterpillar *Agrotis ipsilon* (Lepidoptera: Noctuidae), the tomato moth *Tuta absoluta* (Lepidoptera: Gelechiidae) and the apple caterpillar *Chloridea virescens* (Lepidoptera: Noctuidae), the minadora fly *Liriomyza huidobrensis* (Diptera: Agromyzidae), aphids *Aphis gossypii*, *Macrosiphum euphorbiae* and *Myzus persicae* (Hemiptera: Aphididae), the whitefly *Bemisia tabaci* (Hemiptera: Aleyrodidae), the *Thrips* spp. and *Frankliniella* spp. (Thysanoptera: Thripidae), the *Epitrix* spp. (Coleoptera: Chrysomelidae), the mandarová-do-fumo *Manduca sexta paphus* (Lepidoptera: Sphingidae), the bedbugs *Edessa rufomarginata* (Hemiptera: Pentatomidae) and *Phthia picta* (Hemiptera: Coreidae), cochineal *Planococcus citri* (Hemiptera: Pseudococcidae) and green leafhopper *Empoasca* sp. (Hemiptera: Cicadellidae) (ASSIS et al. 2021, ASSIS & ANDALÓ 2022).

In addition to insects, phytophagous mites such as the rajate mite *Tetranychus urticae* are occurring, *Tetranychus ludeni* (Acari: Tetranychidae), white *Polyphagotarsonemus latus* (Acari: Tarsonemidae) and tanning (*Aculops lycopersici*) (Acari: Eriophyidae) (ASSIS & ANDALÓ 2022). Thus, in order to achieve high productivity, ensure protection against biotic and abiotic adversities and favor plant development, it is possible to use the induced resistance that is characterized by the increase of the level of resistance of plants, through the use of external agents, without promoting any alteration in the genome (BONALDO et al. 2005). Among the substances that function as elicitors in the induction process, there are silicon sources, such as silicon dioxide (SANTOS et al. 2020), potassium silicate (FERREIRA et al. 2022), sylicic acid (LAZZARINI et al. 2020), diatomaceous earth (SOUSA et al. 2020), etc.

The diatomaceous earth stands out for being a powder composed of fossilized bodies of single-celled algae called diatoms that contains varied percentages of silicon dioxide (LORINI et al. 2010), and which is authorized for use in organic cultivation with authorization from the Organic Conformity Assessment Body or the Organization of Social Control (BRASIL 2021).

The applicability of diatomaceous earth has already been reported regarding the increase of height and diameter of the stem in potato plant, cultivar Emeraude, at a concentration of 1.15% (ASSIS et al. 2012). In radish, cultivar Saxa, plant supplementation at a concentration of 1.57% favored an increase in plant height (SOUSA et al. 2020). Regarding the phytosanitary aspect, effects of diatomaceous earth were documented in reducing the number of injuries in tubers and folioles caused by chewing insects (ASSIS et al. 2012).

This inert powder is also widely used to promote the mortality of pests in stored grains, such as *Sitophilus* spp. (Coleoptera: Curculionidae) in husked rice (GASPAROTTO et al. 2020). Currently, research with this compound has also been directed to promote changes in the morphology of eggs of *Diatraea saccharalis* (Lepidoptera: Crambidae) in sugarcane (OLIVEIRA et al. 2020), in addition to reducing their viability.

Based on the above, it is verified the potential that the diatomaceous earth presents in promoting plant development and protection to crops, because it is the basis of silicon. Thus, it is important to define the ideal concentration of this substance to be used in physalis, aiming to improve the agronomic characteristics of the crop and fruit quality, and to explore the effect as an elicitora in the process of induction of pest resistance. This information is relevant, given that there are no phytosanitary products registered in the Plant Health Pesticides System (AGROFIT) for pest control in this fruit tree (AGROFIT 2021), a fact that denotes the relevance of this research.

Thus, the objective of this work was to evaluate the effects of diatomaceous earth spraying on phytotechnical parameters of crop and fruit quality, as well as on the induced resistance to arthropod pest in *P. peruviana*.

MATERIAL AND METHODS

The experiment was conducted in an experimental area of the University Center of Goiatuba (UniCerrado), in Goiatuba (latitude 17º 59' 34'' S, longitude 49º 21' 54'' W and altitude of 815 m), South of Goiás, Brazil. The minimum air temperatures (c), average (C) and maximum (c), as well as precipitation (mm) and relative humidity (%) recorded during the conduction of the experiment are shown in Figure 1.

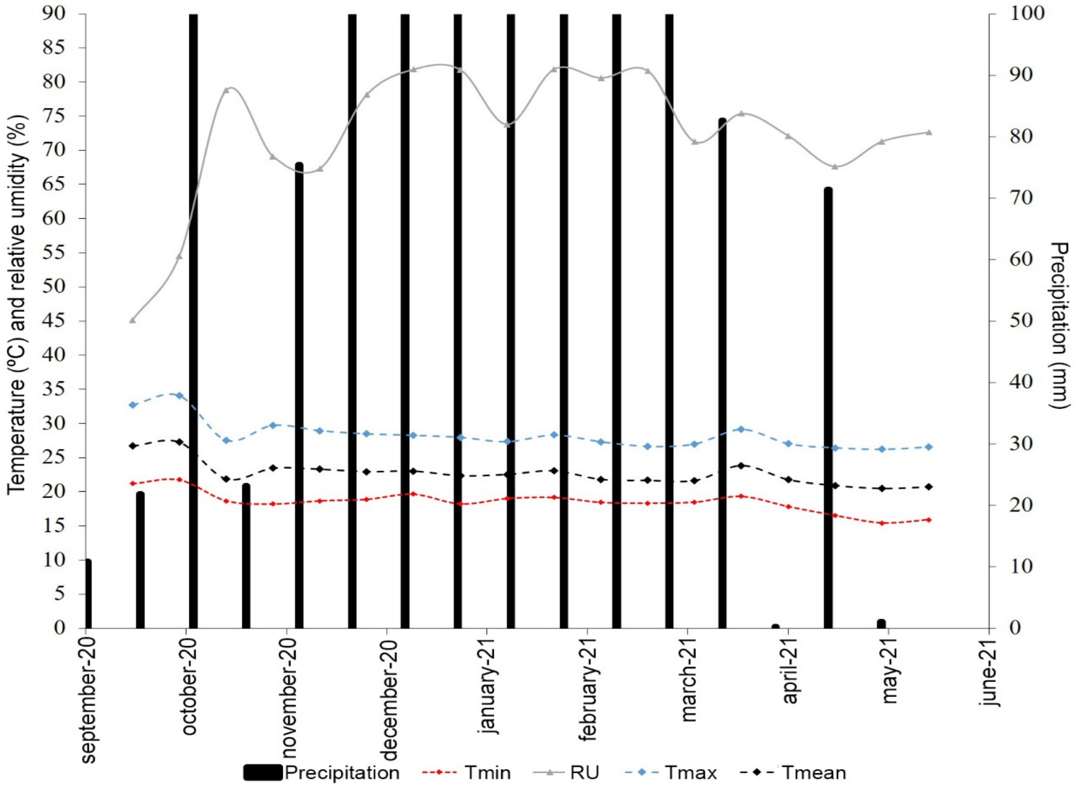

Figure 1. Minimum, average and maximum temperatures (ºC), precipitation (mm) and relative humidity (%) during the experiment. Goiatuba, GO, 2021. Source: Meteorological Station (Agrosystem®) of the Instituto Federal Goiano/Campus Morrinhos, Goiás, Brazil (INMET/SINDA 2021).

The chemical and physical analyses of the soil, classified as Dystrophic Red Latosol (SANTOS et al. 2018), were performed 60 days before transplanting the seedlings. For this, soil samples were collected in the 0-20 cm depth layer by zigzag walking. Subsequently, the composite sample was sent to the Curitiba Laboratory of Agricultural Analyses in Bom Jesus de Goiás, Goiás, Brazil, according to the results presented in Table 1.

Table 1. Chemical and physical characteristics of the soil in the experimental area in the 0-20 cm layer. Goiatuba, GO, 2021.

O. M.	pH	P	S	K	Ca	Mg	Al	H+Al	SB	CTC
g kg^{-1}	$CaCl_2$	---------- mg dm^{-3} ----------			--------------- cmolc dm^{-3} ---------------					
12.1	5.4	4.3	5.2	78.2	2.5	1.1	0.0	4.0	3.8	7.8
Al	Ca	Mg	K	Bases	Nutrient relation					
------------------ % of saturation ------------------					Ca/Mg		Ca/K		Mg/K	
0.0	32.0	14.1	2.6	48.6	2		12		5	
B	Cu	Fe	Mn	Zn			Sand		Silt	Clay
------------- mg dm^{-3} -------------							----------------- % -----------------			
0.4	0.5	86	3.7	1.4			40		13	47

For liming and fertilization, 5.2 g of limestone, 0.5 g of urea, 8.3 g of simple superphosphate and 0.6 g of potassium chloride were used per pot. For the production of *P. peruviana* seedlings, a styrofoam tray with 128 cells was used, filled with commercial substrate (Colina Verde®) (Catiguá, São Paulo, Brazil). In each cell was soed a seed (HGP seeds®) (Petrópolis, Rio de Janeiro, Brazil). The tray was kept on a bench inside a structure 2 m high, 2 m wide and 3 m long, covered with 50% shading sombrite. The seedlings were irrigated daily with the aid of a capacity 8 L watering can in order to meet their water needs.

Forty-seven days after sowing (modified by SANTOS et al. 2020) the 40 most vigorous seedlings that presented two expanded leaves were selected for transplanting (RODRIGUES et al. 2013, BETEMPS et al. 2014). The transplant was performed in polyethylene pots of 5 kg, filled in its entirety with soil sifted from the layer of 0-20 cm depth, and four seedlings were transplanted per vessel. The vessels were kept inside a structure covered with screen and open on the sides, allowing free infestation by the arthropod pest. The seedlings were irrigated daily according to the requirements of the crop. This was made with the aid of a watering of 8L capacity.

Thirty days after transplantation, thinning was performed and only one vigorous seedling per vessel was maintained. The plants were tutored with bamboo cuttings of 1.20 m and tied with string. During the conduction of the culture, no pruning, top pruning, sprouting, thinning and phytosanitary treatment were performed (SANTOS et al. 2020).

To investigate the effect of diatomaceous earth on physalis, a randomized block design was used with five treatments (T1 - 0 g L^{-1} diatomaceous earth; T2 - 1 g L^{-1} diatomaceous earth; T3 - 3 g L^{-1} diatomaceous earth; T4 - 6 g L^{-1} of diatomaceous earth and T5 - 9 g L^{-1} of diatomaceous earth) and eight blocks, making a total of 40 experimental plots, each plot consisting of a vase.

The concentrations of diatomaceous earth were applied via foliar, using manual spray with capacity for 1.5 L, whose name of the commercial product is Kieselguhr® of the BioMarkan Company (Fortaleza, Ceará, Brazil), which presents 90% of SiO_2 in its composition. The sprays were performed weekly, thirty days after transplanting the seedlings to the vessels. A total of 15 sprays were performed throughout the crop cycle, which was conducted up to 192 days (modified by SANTOS et al. 2020).

Regarding phytotechnical analyses, plant height (m) was determined, evaluated from soil level with measuring tape; the diameter of the stem (mm) with digital caliper; fresh dough of the aerial part (g) and the number of leaves. These response variables were evaluated 60 days after the last spraying with diatomaceous earth.

Fruit analyses were performed one week after the last spraying with diatomaceous earth, and six fruits per plant were selected (modified by SANTOS et al. 2020). The harvest began when the chalice presented yellow color (LIMA et al. 2009), that is, 110 days after transplanting the seedlings. The culture was conducted up to 192 days.

To characterize the fruits, the fresh mass (g) with and without chalice, without stalk, was evaluated using a precision scale; longitudinal and transverse diameters with and without goblet, with the aid of the digital caliper. For quality analysis, the soluble solids content (°Brix) was determined by opening the fruits with the aid of a pocket knife and extracting a drop of juice that was placed directly in the manual refractometer (0-32% Brix, Lorben® GT 427 model), with automatic temperature compensation (ATC). At the end, the number of fruits per plant was also determined.

To evaluate the resistance induced in plants regarding the attack of arthropod pests, the food preference of insects was determined in a test with a choice of the number of leaves with holes and the percentage of leaves with orifices. This evaluation occurred 60 days after the last spraying with diatomaceous earth.

The incidence of chewing arthropods pest, sucking and sucking scrapers, as well as that of possible natural enemies, was performed weekly at 17h, three days after each spraying with diatomaceous earth, by visual inspection and beating of plants in a plastic tray of white color with 20 cm wide, 30 cm long and 6 cm high, totaling 15 evaluations. In addition, the preference of insects for oviposition was also evaluated by counting the number of eggs.

To assist in the evaluation of insect density, yellow adhesive traps (10.5 cm x 7.5 cm), Cultivar Mais®, magnum corporation manufacturer, containing adhesive glue on one side, installed in the pots at a height of 1.20 m in relation to the soil surface, using the bamboo cutting to tutor the plants. A trap per pot was installed, in which case the insect counts and the substitutions of traps performed fortnightly (GOMES & CASTRO 2017), totaling five evaluations. Arthropods were sent to the UniCerrado Microscopy Laboratory and identified in the taxonomic categories of order, family and species.

The phytotechnical and quality data were submitted to variance analysis (F test) and the means compared by Tukey test (FERREIRA 2011), after the measurement of residue normality assumptions, by the Shapiro-Wilk test, homogeneity of variances, by Levene test, and block additivity, by Tukey's additivity test, all at 5% probability. Regarding the count data of the arthropods pest, the Generalized Linear Model (LGM) was adjusted with negative binomial distribution and log binding 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 by the Tukey test at 5% probability, as well as regression models were fitted when the means were significant statistical analyses were performed using the statistical software R, version 4.0.4 (R CORE TEAM 2018).

RESULTS AND DISCUSSION

There was no significant difference between the concentrations of diatomaceous earth applied in foliar spraying for the phytotechnical variables, quality (soluble solids) and those related to the food preference of herbivore insects (number of leaves with orifices and percentage of leaves with orifices) (Table 2).

Table 2. Summary of analysis of variance of phytotechnical characteristics, injuries caused by insect pests and quality parameter of physalis (*Physalis peruviana*) submitted to concentrations of diatomaceous earth (DE) applied in foliar spray. Goiatuba, GO, 2021.

		Mean Squares						
SV	DF	ALT^{ns}	DC^{ns}	$MFPA^{ns}$	NF^{ns}	NFO^{ns}	PFO^{ns}	NFP^{ns}
DE	4	0.022	1.515	456.12	1293.55	62.37	109.808	117.90
Block	7	0.099	1.022	2350.29	2760.69	492.12	155.433	637.20
Residual	26	0.014	0.826	214.62	498.28	65.37	39.441	120.96
Total	37	-	-	-	-	-	-	-
CV (%)	-	10.7	10.31	14.83	16.39	28.88	30.09	27.39
SV	DF	$DLFCC^{ns}$	$DTFCC^{ns}$	$DLFSC^{ns}$	$DTFSC^{ns}$	$MFFCC^{ns}$	$MFFSC^{ns}$	SS^{ns}
DE	4	1.801	3.779	0.187	0.220	0.179	0.028	0.279
Block	7	4.015	2.669	0.634	0.489	0.3468	0.070	0.389
Residual	25	2.848	2.843	1.049	0.951	0.111	0.119	0.346
Total	36	-	-	-	-	-	-	-
CV (%)	-	6.76	7.12	6.77	6.81	16.4	18.46	4.31

SV - sources of variation; DF - degrees of freedom; ALT - height; DC - stem diameter; MFPA - fresh dough from the aerial part; NF - number of leaves; NFO - number of sheets with holes; PFO - percentage of sheets with holes; NFP - number of fruits per plant; DLFCC - longitudinal diameter of fruits with chalice; DTFCC - cross diameter of fruits with chalice; DLFSC - longitudinal diameter of fruits without calyx; DTFSC - cross diameter of fruits without chalice; MFFCC - fresh fruit mass with chalice; MFFSC - fresh mass of fruits without chalice; SS - soluble solids. ns - not significant by F test (p>0.05), CV - coefficient of variation.

In this context, it was possible to verify that the means obtained regarding plant characteristics, such as height, stem diameter, fresh mass of shoots and number of leaves were 1.11 m, respectively; 8.83 mm; 98.95 g and 136.32 (Table 3).

Table 3. Plant height, stem diameter, shoot fresh mass and number of leaves of physalis (*Physalis peruviana*) submitted to concentrations of diatomaceous earth (DE) applied in spraying foliar pathway. Goiatuba, GO, 2021.

DE Concentrations (g L^{-1})	ALT (m) ^{ns}	DC (mm) ^{ns}	MFPA (g) ^{ns}	NF ^{ns}
0	1.07	8.64	94.71	144.12
1	1.12	9.58	110.25	155.00
3	1.14	8.63	94.53	121.86
6	1.17	8.91	103.88	133.87
9	1.04	8.40	91.40	126.75
Mean	1.11	8.83	98.95	136.32
F Test	1.5686	1.8344	2.1253	2.5960
p Value	0.2123	0.1525	0.1063	0.0597

ns – not significant by F test (p>0.05). ALT - plant height; DC - stem diameter; MFPA - fresh dough from the aerial part; NF - number of sheets.

The results found in the present study corroborate those reported by SOUZA (2015), in which the supplementation of *P. peruviana* plants with silicon concentrations of 0, 1, 2 and 3 g L^{-1}, using Agrisil® (98% of SiO_2) as a source, in both irrigation regimes (100 and 35% of field capacity) also did not influence the increase in plant stem diameter.

Although it is another crop, in radish, cultivar Saxa, spraying with diatomaceous earth (86.7% SiO_2) at concentrations of 0, 1, 2, 3 and 4% also did not contribute to the increase in the number of leaves and fresh mass of the shoots, although there was an increase in plant height, at the maximum point, concentration of 1.57% by adjusting to the quadratic polynomial model (SOUSA et al. 2020).

With regard to fruits, the average values obtained for number of fruits per plant, longitudinal diameter of fruits with calyx, cross-sectional diameter of fruits with calyx, longitudinal diameter of fruits without calyx, cross-sectional diameter of fruits without calyx, fresh mass of fruits with calyx, and soluble solids were, respectively, 40.23; 24.95 mm; 23.65 mm; 15.13 mm; 14.31 mm; 2.03 g; 1.87 g and 13.66 °Brix (Table 4).

Table 4. Number of fruits per plant; longitudinal diameter of fruits with calyx; transversal diameter of the fruits with calyx; longitudinal diameter of fruits without calyx; transverse diameter of fruits without calyx; fresh fruit mass with calyx; fresh mass of fruits without calyx and soluble solids of physalis (*Physalis peruviana*), subjected to concentrations of diatomaceous earth (DE) applied in foliar spray. Goiatuba, GO, 2021.

DE Concentrations ($g\ L^{-1}$)	NFP ^{ns}	DLFCC (mm) ^{ns}	DTFCC (mm) ^{ns}	DLFSC (mm) ^{ns}	DTFSC (mm) ^{ns}	MFFCC (g) ^{ns}	MFFSC (g) ^{ns}	SS (°Brix) ^{ns}
0	41.50	24.27	23.18	15.08	14.28	1.93	1.84	13.71
1	46.00	24.57	22.80	14.88	14.09	1.89	1.78	13.67
3	37.43	25.36	23.50	15.30	14.31	1.99	1.87	13.95
6	40.62	25.17	24.34	15.15	14.57	2.05	1.95	13.43
9	35.62	25.37	24.41	15.24	14.28	2.28	1.90	13.56
Mean	40.23	24.95	23.65	15.13	14.31	2.03	1.87	13.66
F Test	0.975	0.633	1.329	0.178	0.232	1.607	0.238	0.806
p Value	0.438	0.644	0.286	0.948	0.918	0.204	0.914	0.533

ns - not significant by F test ($p>0.05$). NFP - number of fruits per plant; DLFCC - longitudinal diameter of fruits with chalice; DTFCC - cross diameter of fruits with chalice; DLFSC - longitudinal diameter of fruits without calyx; DTFSC - cross diameter of fruits without chalice; MFFCC - fresh fruit mass with chalice; MFFSC - fresh mass of fruits without chalice; SS - soluble solids (SS).

The results found in this work are similar to those obtained by SANTOS et al. (2020), in which spraying with silicon sources in *P. peruviana* at concentrations of 0 $g\ L^{-1}$ (control), 8 $g\ L^{-1}$ of Agrisil® (98% of SiO_2) and 40 $g\ L^{-1}$ of Insecto® (86.7% of SiO_2), derived from diatomaceous earth, also did not increase the longitudinal diameter of fruits without calyx, as well as soluble solids content, with mean values of 16.37 mm and 15.13 °Brix, respectively. In radish, there was also no increase in longitudinal and transverse diameters, fresh mass and productivity of tuberous roots by spraying plants with diatomaceous earth at concentrations of 0, 1, 2, 3 and 4% (SOUSA et al. 2020).

In onion *Allium cepa* L., cultivar Epagri 362 Crioula Alto Vale, the application of diatomaceous earth (94.58% of SiO_2 - Bugran®) both alone in foliar spraying (0%, 1%, 2% and 3%), in the test carried out in 2004, as well as spraying with 0.5% and 1%, and in application in the planting groove at doses of 40 $kg\ ha^{-1}$ at 30 days after transplantation (DAT) and 45 DAT; 60 $kg\ ha^{-1}$ at 30 and 45 DAT; 20 k $g\ ha^{-1}$ at 30 and 45 DAT; 30 $kg\ ha^{-1}$ at 30 and 45 DAT and the control, without diatomaceous earth application, did not contribute to the increase of the average weight of the bulbs of this vegetable (GONÇALVES 2007).

Regarding injuries, it was found that plants were equally preferred for feeding by chewing phytophagous insects present in the crop, regardless of the concentration of diatomaceous earth used, since the average values obtained for the number of leaves with orifices and percentage of leaves with orifices were, respectively, 28.14 and 20.99% (Table 5).

Recently in radish, cultivar Crimson Gigante, spraying with Silicon AgriSil® (98% of SiO_2) at concentrations 0 and 3 $g\ L^{-1}$ of SiO_2, in isolation or associated with *mulching*, also did not contribute to reduce the number of leaves with defoliation, similar to what was verified in the present study. However, the highest percentage of defoliation was reported in control plants compared to those that were treated at the concentration of 3 $g\ L^{-1}$, a fact that demonstrates that, depending on the crop, the percentage of SiO_2 associated with the product and the concentration used, silicon can promote protection of plants against the attack of herbivore insects, making them less injuried, although it was not detected in the present study (RODRIGUES et al. 2021).

Table 5. Number of leaves with holes and percentage of leaves with holes in physalis (*Physalis peruviana*) submitted to concentrations of diatomaceous earth (DE) applied in foliar spray. Goiatuba, GO, 2021.

DE Concentrations (g L^{-1})	NFO^{ns}	PFO (%) ^{ns}
0	25.00	17.17
1	29.28	19.16
3	32.57	27.48
6	27.25	20.23
9	26.62	20.93
Mean	28.14	20.99
F Test	0.9541	2.7841
p Value	0.4490	0.0476

ns – not significant by F test a (p>0.05) and (p>0.01). NFO - number of sheets with holes; PFO - percentage of sheets with holes.

With regard to preference for oviposition, in the visual evaluation there was a significant difference between the treatments by deviance analysis for the number of eggs laid by the whitefly females *Bemisia tabaci* (Hemiptera: Aleyrodidae) (p<0.01) *and Lema bilineata* (Coleoptera: Chrysomelidae) (*p*=0.0120), although the same was not detected for the chrysopide predator *Chrysoperla* spp. (Neuroptera: Chrysopidae) (*p*=0.3134) (Table 6). Regarding the incidence of arthropods, verified with the beating of plants in tray, there was a significant difference between the concentrations of diatomaceous earth for adults of whitefly (*p*=0.0334) and also for larvae and adults *of L. bilineata* (*p*= 0.0038). In the case of *Planococcus citri* cochineal (Hemiptera: Pseudococcidae) (*p*=0.0373) and thrips (Thysanoptera) (*p*=0.0381), although at the 5% probability level a significant difference was found between treatments (Table 6), the Tukey Test did not detect such difference, possibly due to the high variability of the data, as can be seen in Table 7.

For green leafhopper *Empoasca* spp. (Hemiptera: Cicadellidae) (*p*=0.9375), *Diabrotica speciosa* (Coleoptera: Chrysomelidae) (*p*=0.9656) and *Tetranychus* spp. (Acari: Tetranychidae) (*p*=0.2502) no significant differences were found between diatomaceous earth concentrations regarding the incidence of these arthropod pest (Table 6).

Table 6. Deviance analysis for the incidence of arthropods (eggs, larvae or adults) counted through visual evaluation and beating of the plants in a white plastic tray in the culture of physalis (*Physalis peruviana*), subjected to concentrations of diatomaceous earth (DE) applied in spraying foliar pathway. Goiatuba, GO, 2021.

		Cochineal (*Planococcus citri*)		Green leafhopper (*Empoasca* spp.)	
SV	DF	*Deviance*	*p*-Value	*Deviance*	*p*-Value
Treatments	4	47.708	0.0373*	41.198	0.9375 ^{ns}
Blocks	7	37.965	0.2036 ^{ns}	35.264	0.5475 ^{ns}
		(*Diabrotica speciosa*)		Eggs (*Lema bilineata*)	
SV	DF	*Deviance*	*p*-Value	*Deviance*	*p*-Value
Treatments	4	40.576	0.9656 ^{ns}	80.560	0.0120*
Blocks	7	31.244	0.2297 ^{ns}	48.337	<0.01*
		Larvae and adults (*Lema bilineata*)		Tripes	
SV	DF	*Deviance*	*p-Value*	*Deviance*	*p*-Value
Treatments	4	76.323	0.0038*	83.529	0.0381*
Blocks	7	49.145	0.0003*	43.669	<0.01*
		Mites (*Tetranychus* spp.)		eggs (*Chrysoperla* spp.)	
SV	DF	*Deviance*	*p*-Value	*Deviance*	*p*-Value
Treatments	4	64.583	0.2502 ^{ns}	48.238	0.3134 ^{ns}
Blocks	7	42.807	0.0028*	34.036	0.0477*

*Significant at the 5% probability level. SV: source of variation; DF: degree of freedom. ns - not significant by the Chi-Square test (p>0.05).

It is observed that the oviposition of the females of *B. tabaci* and that the number of larvae and adults *of L. bilineata* in the regression analysis presented quadratic behavior. Thus, at concentrations of 6.7 g L^{-1} and 5.30 g L^{-1} of diatomacea earth, it is possible to obtain, respectively, a lower number of whitefly eggs (17.83) and larvae and adults of *L. bilineata* (1.00) (Figure 2).

Table 7. Arthropod pests counted through visual evaluation and beating of plants in white plastic trays in physalis (*Physalis peruviana*) culture, subjected to concentrations of diatomaceous earth (DE) applied in foliar spray. Goiatuba, GO, 2021.

DE Concentrations ($g L^{-1}$)	Whitefly adult *Bemisia tabaci*	Cochineal *Planococcus citri*	Green leafhopper *Empoasca* spp.
0	62.1±7.31 a	3.94±1.19 a	0.91±0.33 a
1	47.1±5.67 ab	1.03±0.43 a	0.57±0.26 a
3	52.0±6.21 ab	3.67±1.12 a	0.68±0.28 a
6	37.4±4.61 b	2.32±0.78 a	0.68±0.28 a
9	44.4±5.37 ab	3.62±1.11 a	0.79±0.31 a
DE Concentrations ($g L^{-1}$)	*Diabrotica speciosa*	Tripes	Mites *Tetranychus* spp.
0	0.61±0.26 a	8.38±1.40 a	70.8±11.9 a
1	0.51±0.24 a	7.99±1.35 a	81.7±13.7 a
3	0.41±0.21 a	7.75±1.32 a	90.0±15.0 a
6	0.51±0.24 a	4.05±0.84 a	114.5±19.0 a
9	0.41±0.21 a	7.39±1.28 a	67.4±11.3 a

Means followed by the same letter do not differ from each other by Tukey Test to 5% probability.

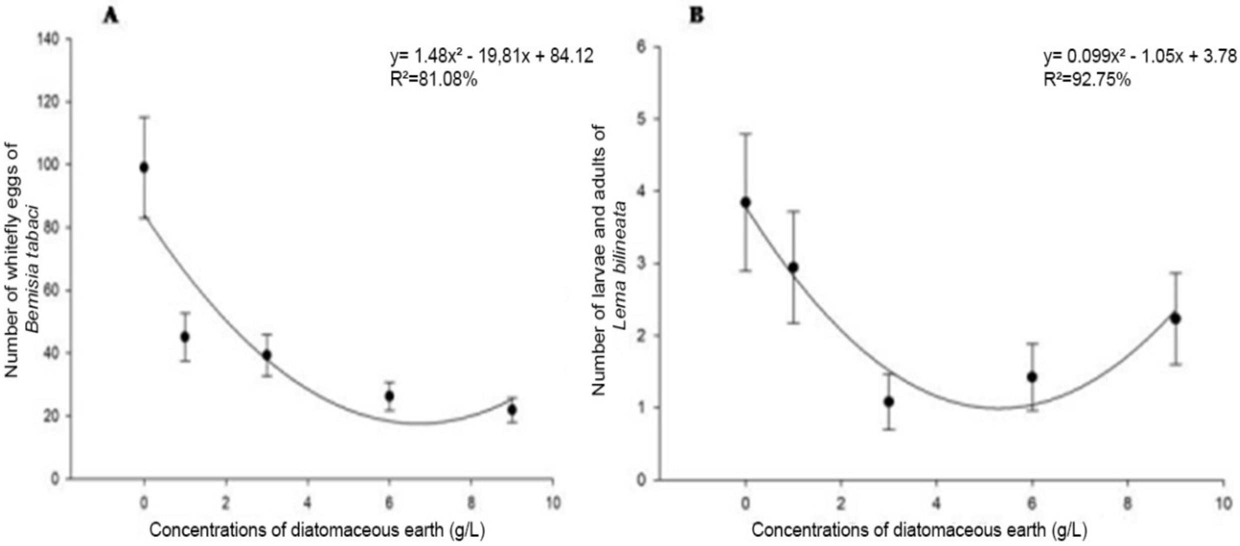

Figure 2. Number of whitefly eggs *Bemisia tabaci* (A) and larvae and adults of *Lema bilineata* (B) counted through visual evaluation and beating of plants in white plastic tray in the culture of physalis (*Physalis peruviana*), submitted to concentrations of diatomaceous earth (DE) applied in foliar spray. Goiatuba, GO, 2021.

In physalis plants treated with diatomaceous earth at a concentration of 6 g L^{-1} there was a 39.8% lower incidence of whitefly adults when compared to the control. On the other hand, no significant differences were found between treatments regarding the occurrence of cochineal *P. citri*, green leafhopper *Empoasca* spp., *D. speciosa*, thrips and *Tetranychus* spp. (Table 7).

Most arthropods found associated with physalis cultivation in this research are phytophagous and polyphagous, with the exception of *Chrysoperla* spp. that is predatory. Whitefly, cochineal and green leafhopper are sap-sucking insects and virus transmitters. Thrips and mites are scraper-sucking arthropods. In the case of chewing insects, the species *D. speciosa* and *L. bilineata* were found associated with leaves and leaves/fruits, respectively.

For *L. bilineata*, special attention should be given due to this insect, both in the larva and adult phase, promoting holes in the leaves, compromising photosynthetic activity, and attacking the chalice, both green and mature, and the fruit, a fact that compromises productivity. All phases of the biological cycle of this insect were recorded in the present study (Figure 3).

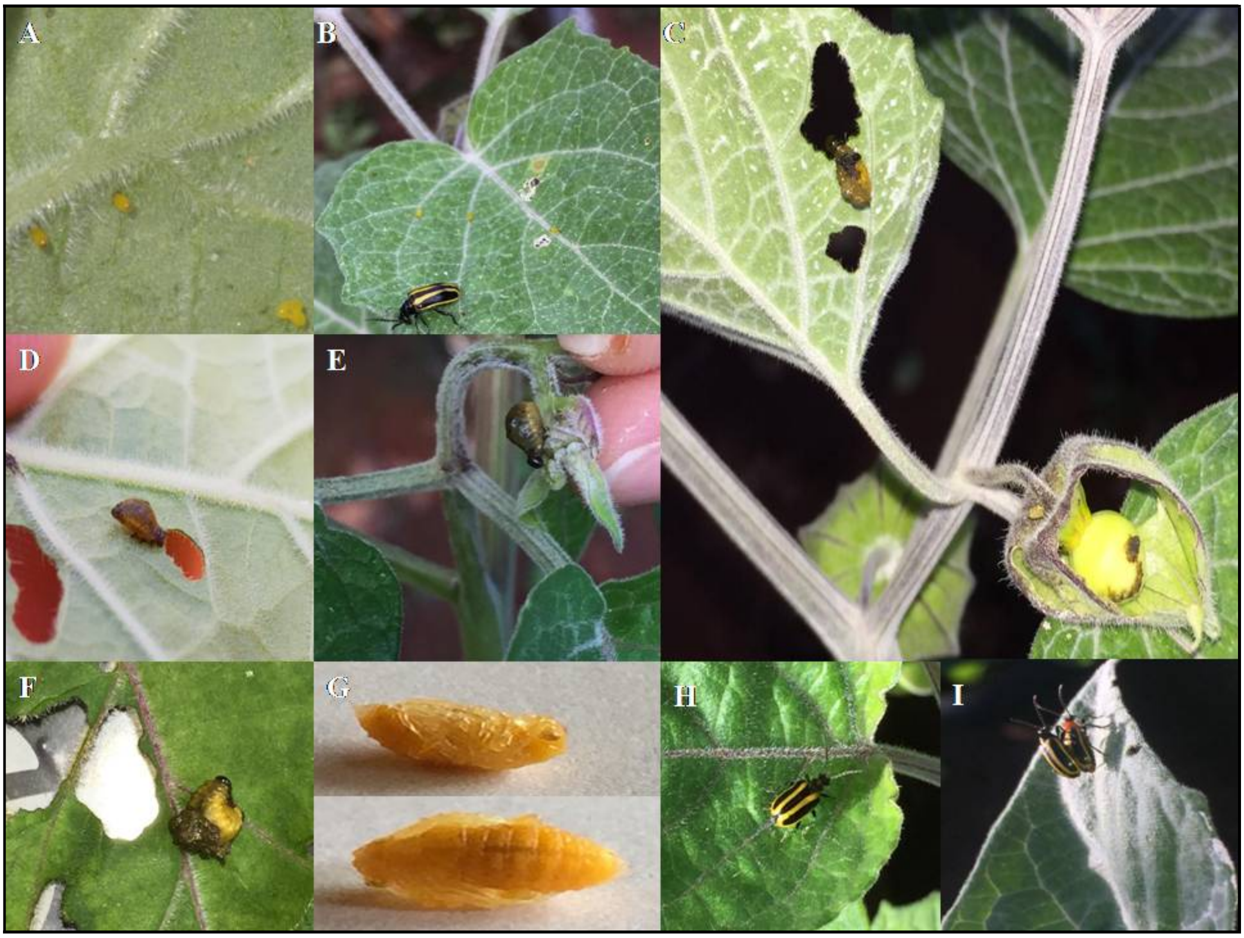

Photo: Elias Silva Melo, 2021.

Figure 3. Life cycle and injuries of *Lema bilineata* (Coleoptera: Chrysomelidae) on *Physalis peruviana*. A) Eggs on the abaxial surface of the leaf; B) Eggs and adult on the adaxial surface of the leaf; C) Larvae injuries on the leaf and fruit calyx; D) and F) Holes caused by the larva in the leaf; E) Larva; G) Pupa of the exarada type; H) Adult; I) Mating. Goiatuba, GO, 2021.

According to BISCHOFF et al. (2021), *L. bilineata* larvae present the dark yellow body with the cephalic capsule ranging from dark brown to black. Adults, have yellow-colored elytra with dark brown longitudinal stripes. The females have light brown pronotum, while the males have dark.

The injuries performed by this insect on both leaves and fruits had already been observed by SANTOS et al. (2020) in a study conducted in the municipality of Goiatuba, Southern Goiás State. Although these authors were not able to identify the species due to the absence of adulthood. Recently BISCHOFF et al. (2021) reported leaf consumption caused by the young and adult phases *of L. bilineata* also in *P. peruviana*.

The species *L. bilineata* is a polyphagous pest that presents as hostesses the solanaceous as well as plants of other botanical families. In the present research, as also reported by SANTOS et al. (2020), this pest attacked the leaves and fruits, a fact that compromises the profitability of the producer, given the high added value that they present in the commercialization. Thus, since there are no phytosanitary products registered in AGROFIT/MAPA, the use of diatomaceous earth becomes a potential strategy for the management of this coleopteran by reducing the incidence of larvae and adults in the areas of cultivation, besides interfering in oviposition.

Regarding the number of eggs of *L. bilineata*, plants treated with concentrations of 3 or 9 g L^{-1} of diatomaceous earth were also less preferred for oviposition in relation to plants that did not receive the application of this product based on silicon dioxide. The eggs are yellow in color and in this research were found both on the adaxial and abaxial face of the leaf, with greater predominance in the abaxial face, being placed in isolation (Figure 3). On the other hand, no significant differences were found between treatments regarding *Chrysoperla* sp. oviposition, which is somewhat a good indication, demonstrating that diatomaceous earth applications do not negatively interfere in the oviposition of this important predator, since the number of eggs was statistically similar to that of the control's plants (Table 8).

In the present study, the use of diatomaceous earth provided protection to plants, since there was a reduction in the incidence of pests, such as adults of whiteflies and larvae and adults *of L. bilineata*, and lower preference for oviposition by females of *B. tabaci* and *L. bilineata*. These results corroborate those found by SANTOS et al. (2020), in which the application of 8 g L^{-1} of Agrisil® (98% of SiO_2) or 40 g L^{-1} of Insecto® (86.7% of SiO_2) favored the reduction of the incidence of whitefly adults in relation to the control plants.

Table 8. *Lema bilineata* (phytophagous insect) and green lacewings (predator insect) eggs counted by visual evaluation in the culture of physalis (*Physalis peruviana*), submitted to concentrations of diatomaceous earth (DE) applied in foliar spray. Goiatuba, GO, 2021.

DE Concentrations (g L^{-1})	*Lema bilineata* *Eggs*	*Chrysoperla* spp. Eggs
0	10.13±3.30 a	2.06±1.17 a
1	8.69±2.86 ab	3.01±1.64 a
3	1.82±0.74 b	1.30±0.78 a
6	7.61±2.53 ab	0.61±0.41 a
9	4.71±1.65 b	0.45±0.32 a

Means followed by the same letter do not differ from each other by Tukey Test to 5% probability.

The arthropods reported in this research are somewhat similar to those mentioned by AFSAH (2015), in which the occurrence of cochineal *P. citri*, whitefly *B. tabaci*, green aphid *M. persicae*, leafhopper *Empoasca lybica* (Hemiptera), thrips, *Tetranychus* spp. and predator *Chrysoperla carnea* was also reported (Neuroptera: Chrysopidae), among other arthropods.

In Diamantina, Minas Gerais, Brazil, the presence of the mite *T. ludeni was* recorded in *P. peruviana* planting. The presence of this arthropod pest culminated in chlorosis of the older leaves and significant fall of the same, which consequently affects the photosynthetic activity, vegetative growth and fruit production (SOARES et al. 2014).

By using the adhesive trap, it was observed by deviance analysis that there was no significant difference between the concentrations of diatomaceous earth in the capture of the green aphid *M. persicae* (p=0.3182), whitefly *B. tabaci* (p=0.3706), green leafhopper *Empoasca* spp. (p=0.1144), and *Colaspis* spp. (Coleoptera) (p=0.6131) (Table 9).

Table 9. Deviance analysis for the incidence of arthropods pest counted in yellow sticky trap in physalis (*Physalis peruviana*) culture, subjected to concentrations of diatomaceous earth (DE) applied in foliar spray. Goiatuba, GO, 2021.

		Green aphid (*Myzus persicae*)	
SV	DF	*Deviance*	*p-Value*
Treatments	4	87.025	0.3182 ns
Block	7	46.933	<0.01*
		Whitefly adult (*Bemisia tabaci*)	
SV	DF	*Deviance*	*p*-Value
Treatments	4	45.270	0.3706 ns
Block	7	42.219	0.8803 ns
		Green leafhopper (*Empoasca* spp.)	
SV	DF	*Deviance*	*p*-Value
Treatments	4	53.114	0.1144 ns
Block	7	46.157	0.4333 ns
		(*Colaspis* sp.)	
SV	DF	*Deviance*	*p*-Value
Treatments	4	48.019	0.6131 ns
Block	7	41.186	0.4465 ns

*Significant at the 5% probability level. SV: source of variation; DF: degree of freedom. ns - not significant by the Chi-Square test (p>0.05).

Thus, the average number of insect pests caught in the adhesive trap was 31.6 *M. persicae*, 30.9 *B. tabaci*, 7.03 *Empoasca* spp. and 1.32 *Colaspis* sp. (Table 10).

Table 10. Arthropod pests counted in a yellow sticky trap in the culture of physalis (*Physalis peruviana*), submitted to concentrations of diatomaceous earth (DE) applied in foliar spray. Goiatuba, GO, 2021.

DE Concentrations ($g\ L^{-1}$)	Winged aphid *Myzus persicae*	Whitefly adult *Bemisia tabaci*	Green leafhopper *Empoasca* spp.	*Colaspis* sp.
0	38.6±6.27 a	37.7±5.79 a	7.90±1.25 a	1.96±0.76 a
1	34.9±5.71 a	27.8±4.38 a	9.14±1.39 a	1.13±0.50 a
3	26.3±4.39 a	30.8±4.81 a	7.08±1.16 a	1.26±0.55 a
6	37.6±6.11 a	33.9±5.26 a	5.43±0.98 a	1.72±0.69 a
9	20.8±3.56 a	24.2±3.87 a	5.61±1.00 a	0.55±0.30 a

Means followed by the same letter do not differ from each other by Tukey Test to 5% probability.

Based on the results presented in this research combined with other literary reports, it can be verified that foliar spraying with diatomaceous earth does not always contribute to the vegetative development and productive characteristics of plant species. However, the existence of favorable results for the use of this product, with regard to the induction of resistance to insect pests contributes to the management of these organisms in the crop, both in conventional and organic production systems (BRASIL 2021), contributing to the obtaining of healthy foods, free of residues of phytosanitary products, in addition to avoiding soil contamination, favor the permanence of the predator population in the cultivation areas, allowing the balance of the agroecosystem.

CONCLUSION

The diatomaceous earth has no effect on phytotechnical and quality parameters of physalis, but itinduces resistance against arthropods pest such *as B. tabaci* and *L. bilineata*.

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