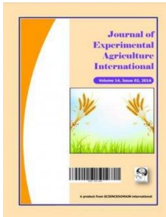

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Evaluation of the Insect Pest Population Dynamics in Common Bean Cultivars in Relation to the Foliar Fertilisation with Potassium Silicate

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Authors' contributions

This work was carried out in collaboration between all authors. Author ALA projected the study, performed the statistical analysis, wrote the protocol, managed the literature searches and wrote the first draft of the manuscript. Author ACTC was the research guiding teacher. Authors MCM and MN helped to carry out the analysis of the study. Authors VP, JBDJ were co-advisors in the development of this work. All authors read and approved the final manuscript.

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ABSTRACT

Effect of foliar fertilisation with potassium silicate on the abundance of pest insects belonging to hemiptera, diptera, coleoptera and lepidoptera in two different genotypes of common bean, cultivated in two sowing seasons. The experiment was conducted under field conditions during the Rainy Season from August to December 2014 and the Dry Season from February to June 2015 in a

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rural area of Assis Chateaubriand, State of Paraná, Brazil. The experimental design was a completely randomised 2 x 5 factorial design with four replications. The first factor refers to the bean genotypes (IPR Campos Gerais and IPR Tuiuiú), and the second factor refers to the doses of potassium silicate (0.0, 250, 500, 750 and 1000 ml ha^{-1}). Potassium silicate at specified doses were sprayed bi-weekly during phenological stages V_3 to R_8. Insect pest samplings were carried out weekly during the phenological stages V_3 through R_8 for both the experiments. Foliar fertilisation with potassium silicate decreased pest insects on the common bean genotypes was studied. IPR Tuiuiú genotype presented a smaller quantity of hemiptera insects in compared to IPR Campos Gerais during the reproductive stage of the Rainy Season Crop (2014). During the vegetative stage of the Dry Season Crop (2015), IPR Campos Gerais presented a smaller quantity of diptera insects in compared to IPR Tuiuiú. Interactions between treatments and the genotypes evaluated occurred, decreasing que population of hemiptera and lepidoptera insects during the vegetative and reproductive stages of the Dry Season Crops (2015). IPR Campos Gerais Genotype represented a smaller quantity of lepidoptera and hemiptera insects than IPR Tuiuiú.

Keywords: Potassium silicate; bean; Lepidoptera; Hemiptera.

1. INTRODUCTION

The common bean (*Phaseolus vulgaris* L.) is susceptible to insect pest attacks which affect its productivity. All the common bean plant structures have been shown to be susceptible due to the diversity of pest species. Many of these species have been reported as bean pests [1], but few of them are known to be of economic importance.

However, several arthropods and molluscs species can cause significant reductions in crop productivity. Such damages may vary according to the pest species, crop growth stage, bean cultivar and sowing season with potential losses up to 100% [2]. Among the insect pests found in bean crops in Brazil, silverleaf whitefly (*Bemisia tabaci*), bean leafhopper (*Empoasca sp.*), cucurbit beetle (*Diabrotica speciosa*), southern armyworm (*Spodoptera eridania*) and tobacco budworm (*Heliothis virescens*), broad mite (*Polyphagotarsonemus latus*), southern green stink Bug (*Nezara Viridula*) and neotropical brown Stink bug (*Euschistus heros*) are responsible for the largest yield losses. In the producing regions, leaf miner (*Lyriomyza sp.*), slugs (*Vaginula langsdorfii*), *Chrysomelidae* and *Caliothrips phaseoli* larvae have been highlighted as an important pests of beans [2].

The importance of common bean in Brazil makes the necessary development of new crop management methods to provide farmers with increased productivity and lower costs. Thus, an alternative is the use of foliar fertilisation with some micronutrients, such as silicon (Si). The use of foliar fertilisation with macro- and micronutrients aiming at an increase of productivity or induction of resistance has become a common practice by farmers in Brazil's bean crops [3].

Silicon does not meet the criteria of an essential nutrient for plants [4]. However, this element is characterised as beneficial for plants since it makes them more resistant to pest attacks and diseases, improves photosynthetic capacity, increases the number of leaves, stem diameter, plant size and, consequently, the productivity [5, 6]. Thus, fertilisation with potassium silicate may result in a lesser occurrence of insect pests in the bean crop.

Studies related to management that employs silicon in the agriculture are still incipient and inconclusive [7], especially those seeking to make clear the relation between plant nutrition and micronutrient and injures caused by insect pests in agronomic aspects of the vegetables.

This study aimed to evaluation the occurrence of insect pests from the entomological orders diptera, hemiptera, lepidoptera and coleoptera in two different genotypes of common bean, cultivated in two sowing seasons, according to the foliar fertilisation with potassium silicate.

2. MATERIALS AND METHODS

The experiment was conducted under field conditions during the rainy season (August to December 2014) and the dry season (February to June 2015)in a typical Eutroferric RED LATOSOL of the rural area of Assis Chateaubriand, located in the Western State of Paraná, Brazil. The area (24°17´27.40´´ S latitude and 53°35´03.99´´ W longitude) is located at an altitude of 321 m.

According to Köppen (1984), the regional climate is type Cfa (subtropical), with an average temperature under 18°C (mesothermic) in the coldest month and an average temperature over 22°C in the hottest month. This climate is characterised by hot summers, infrequent frosts, and by the propensity to concentrate rainfall in summer months, but without a defined dry season. Meteorological data observed during the experiments are shown in Fig. 1 and 2.

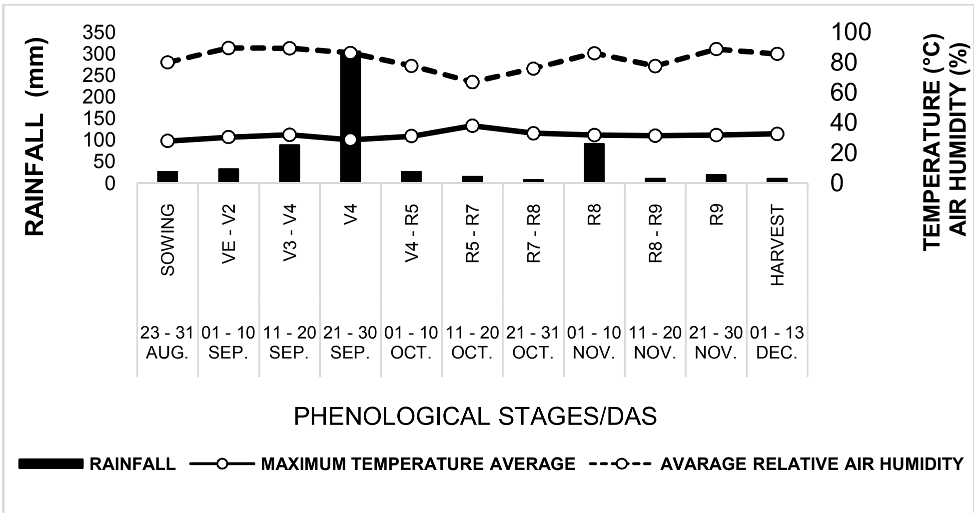

Fig. 1. Maximum temperature, rainfall, and relative air humidity during the experiment conduction

Bean crop phenological stages evaluated: *VE (germination/emergence); V2 (primary leaves totally opened); V3 (first trifoliate leaf); V4 (third trifoliate leaf); R5 (floral buds); R7 (first pods appear); R8 (first full pods); R9 (change of color of pods – physiological maturation). Rainy Season Crop (2014). Assis Chateaubriand, Paraná, Brazil*

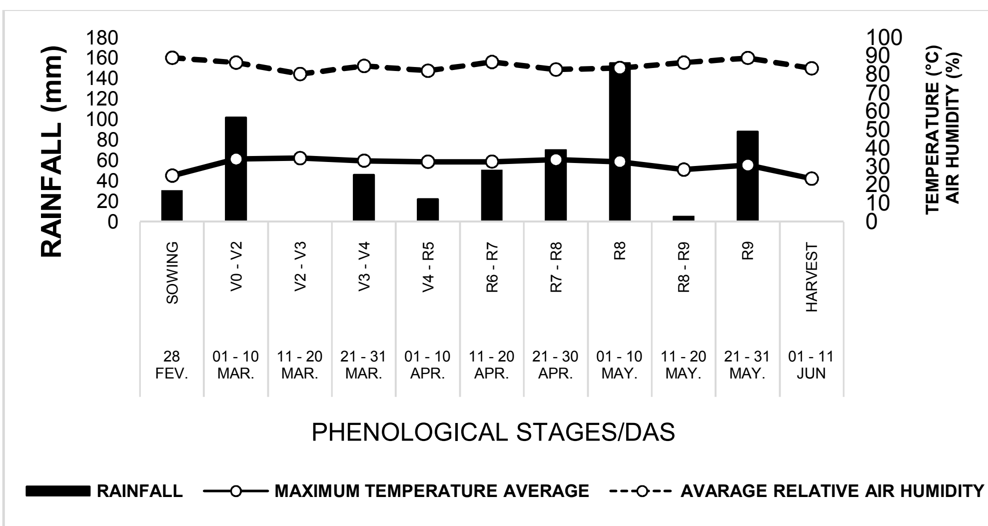

Fig. 2. Maximum temperature, rainfall, and relative air humidity during the experiment conduction

Bean crop phenological stages evaluated: *VE (germination/emergence); V2 (primary leaves totally opened); V3 (first trifoliate leaf); V4 (third trifoliate leaf); R5 (floral buds); R7 (first pods appear); R8 (first full pods); R9 (change of color of pods – physiological maturation). Dry Season Crop (2015). Assis Chateaubriand, Paraná, Brazil*

The experiment used a completely randomised 2 x 5 factorial design with four replications. The first factor refers to the common bean (*Phaseolus vulgares* L.) cultivars (IPR Campos Gerais and IPR Tuiuiú), and the second factor refers to the doses of potassium silicate (0.0, 250, 500, 750 and 1000 ml ha^{-1}) of a commercial product (Supa Sílica – Agrichem ®) containing 0.9 p.v. SiO_2 (90 grams per litre of water) and 18% K_2O in its formulation. The product was diluted in humic acid. Plots were 10 meters long by 7.74 m wide, totalling 18 planting rows and 77.4 m^2 area. A spacing of 0.43 m was used between planting rows, at a density of 12 seeds per linear meter.

A commercial adjuvant (LI 700 – Sangose ®) was added to the spray mixture preparation with potassium silicate to improve retention of the treatments on bean leaves. This adjuvant is composed of a blend of Phosphatidylcholine (Soya lecithin) and Propionic Acid, which boosts foliar absorption of nutrients.

Seeds were treated with fungicide (Carbendazim – dose of 300 ml/100 kg of seeds) and insecticide (Imidacloprid + tiodicarb, dose of 0.6 L/100 kg of seeds), as recommended by the manufacturer, so that the seedlings would be protected until the effective period of the products is finished (approximately 15 days) and the applications of the treatments evaluation begin.

Sowings were made on August 23, 2014 (Rainy Season Crop), and February 28, 2015 (Dry Season Crop). Harvests were made on December 13, 2014, and June 11, 2015 for rainy and dry season crop, respectively.

The weed control (when necessary during the crop growth) was carried out through manual weeding (V2 phenological stage of the Rainy Season Crop – 2014) or application of the herbicide Fomesafen + fluazifop-P-butyl at a dose of 1,6 L ha^{-1}, as recommended by the manufacturer (V7 phenological stage of the Rainy Season Crop and V4 phenological stage of the Dry Season Crop – 2015).

For this study, a composite soil sample (500 grams) was collected, based on 20 sub-samples, to a depth of 0 – 20 cm. The sample was sent to the laboratory for chemical (COODETEC) and physical (UNITHAL) determination of macro/micronutrients, and for soil soluble Silicon determination (Federal University of Uberlândia - UFU), depicted in Table 1.

Base fertilisation was performed according to the soil analysis, by using 16-16-16 (N-P-K) fertiliser at a dose of 300 Kg ha^{-1} in the sowing time (August 23, 2014, for Rainy Season Crop and February 28, 2015, for Dry Season Crop). Subsequently, at the V_4 phenological stage, nitrogen top dressing was applied with urea (45% N) at a dose of 64 kg ha^{-1} (Fig. 1 and 2).

Potassium silicate applications were divided into bi-weekly applications from phenological stage V_3 to R_8 (Fig. 1 and 2). The same quantity of potassium silicate established for each treatment was used at different application times. For this purpose, an electric knapsack sprayer was used with fixed working pressure at 45 psi, aided by a spray bar with 4 flat fan nozzles spaced 50 cm apart, with a spray volume of 186 L ha^{-1}. A digital pH meter was calibrated with pH 4 and 7 buffers and then used to measure the spray mixture pH of each treatment. The pH values of the products used (potassium silicate and spray adjuvant) were provided by the manufacturers.

Table 1. Chemical analysis of soil performed (0 -20 cm) in depth, indicating the characteristics of soil fertility of the experimental area

P	**pH**	**pH**	**H + Al**	**Al^{3+}**	**Mg^{2+}**	**Ca^{2+}**	**K^+**
mg dm^{-3}	**$CaCl_2$)**	**(H_2O)**	**$cmol_c$ dm^{-3}**				
6.30	4.80	5.6	3.18	0.00	1.25	4.05	0.16
Mn	**Fe**	**Cu**		**Zn**		**Si**	
mg dm^{-3}							
146.49	55.72	7.62		3.28		19.6	
V	**Clay**	**Coarse sand**		**Fine sand**		**Gravel**	**Silt**
%							
63.19	73.5	2.3		3.2		0.0	21.0
Textural class							
Clayey soil							

Insect pest samplings, in turn, were carried out weekly between the phenological growth stages V_3 and R_8 for both experiments, as seen in the Fig. 1 and 2. Each Insect pest sample was divided into three sub-samples per plot. Then, insects found in each of these sub-samples were counted to determine the total in one sample from each plot. The same criteria of insect pest sampling were performed in both the crops conducted (Rainy Season Crop, 2014, and Dry Season Crop, 2015). After the sampling time, insects collected in both crops were quantified and grouped according to the entomological orders to determine the pest occurrence. The average number of insects counted in each treatment with potassium silicate was set according to their entomological orders, comparing these results with the phenological stages of both the crops (rainy season crop, 2014, and dry season crop, 2015). Zig-zag samplings were performed in the plots to provide a better representation [8].

For insects belonging to the order diptera, only the leaf sapper (*Lyriomyza sp.*) was sampled between the growth stages of V_3 and V_4. Only larvae present in the galleries formed in the foliar limb of the plants were counted.

As for the insects from other orders evaluated (lepidoptera, hemiptera and coleoptera), samplings were carried out between the phenological stages V_3 - R_8. The sampled insects corresponding to the order Hemiptera were the Southern Green Stink Bug– *Nezara viridula* (Linnaeus, 1758); the Neotropical Brown Stink Bug– *Euschistus heros* (Fabricius, 1798), and the Bean Leafhopper– *Empoasca sp.* (Göethe, 1875). As for coleoptera, the insects sampled were the Cucurbit Beetle – *Diabrotica speciosa* (Gemar, 1824); the *Cerotoma arcuate* (Olivier, 1791); and the *Lagriites Solier* (Sphindidae, 1839). Regarding the order Lepidoptera, caterpillars sampled were the Soybean Looper – *Crysodeixis includes* (Walker, 1858); the Velvetbean Caterpillar – *Anticarsia gemmatalis* (Hübner, 1818); the Southern Armyworm – *Spodoptera eridania* (Cramer, 1782); and the Tobacco Budworm – *Heliothis virescens* (Fabricius, 1781).

To aid the sampling of insect pests belonging to the orders coleoptera (Cucurbit Beetle, *Cerotoma arcuate* and *Lagriites Solier*), Hemiptera (Bedbugs) and Lepidoptera (Caterpillars), a white beat cloth measuring 1 m x 1 m was used. At each sampling, the cloth was inserted between the planting rows, covering the plants of the next row. Afterwards, the plants were shaken on the beat cloth so that the insects contained on them were counted. Samplings were performed at random points of each plot to provide better representation.

Sampling times were divided according to the crop growth stages for the two seasons. In the experiment conducted during the Rainy Season Crop (2014), three sampling times were carried out during the vegetative stages and nine during the reproductive stages. For Dry Season Crop (2015), four sampling times were carried out during the vegetative stages and five during the reproductive stages of bean growth. The quantity of sampling times differed between cultivations due to the growth period of each crop. Sampling times were related to the crops cycle, and the time they were in the field. Use of data transformation was not required.

Data collected from each bean insect pest **found** were grouped according to the entomological orders for both crops evaluated. Afterwards, statistical analysis was conducted by using Sisvar 5.1 software at the 0.05 significance level ($p \leq 0.05$) by the F test. The significant results from the analysis of variance were submitted to regression analysis at the 0.05 significance level ($p \leq 0.05$) as well.

3. RESULTS AND DISCUSSION

Insects found in samplings carried out in the Rainy Season Crop – 2014 (Fig. 1) and in the Dry Season Crop – 2015 (Fig. 2) were counted according to the vegetative and reproductive phenological stages of the crop and according to their entomological classification. From these results, analysis of variance (ANOVA) was performed. The results of analysis of variance have been depicted in Tables 2 and 3.

Regarding the experiment conducted in the Rainy Season Crop (2014), a significant difference ($p \leq 0.05$) was recorded by ANOVA and Tukey's tests between the population means of insect pests for the order hemiptera, in the cultivars evaluated during the reproductive stage of the crop (Table 2 and 4). IPR Tuiuiú cultivar presented a mean population of 2.55 hemiptera insects per sampling, while IPR Campos Gerais cultivar presented that of 3.57 (Table 4). Significant differences ($p \leq 0.05$) were also observed between the common bean cultivars in the vegetative stage during the dry season of

2015 (Table 3). IPR Campos Gerais cultivar presented a mean population of 13.85 dipteran, while IPR Tuiuiú cultivar presented 16.01 insects per sampling (Table 4).

Table 2. Summary of the analysis of variance (ANOVA). Total of insects counted in samplings carried out during the Rainy Season Crop – 2014 (Fig. 1), grouped according to the entomological orders Diptera (DIP), Hemiptera (HEM), Coleoptera (COL), and Lepidoptera (LEP), in the vegetative and reproductive stages of the common bean phenological growth.

Period: vegetative stage of the common bean - rainy season crop (2014)				
		Q.M.		
Source of variation	**GL**	**DIP**	**HEM**	**COL**
Cultivar	1	0.0090 ^{Ns}	0.1323 ^{Ns}	0.9923 ^{Ns}
Block	3	0.8280	0.5883	2.3657
Doses	4	0.4219 ^{Ns}	0.3085 ^{Ns}	1.2594 ^{Ns}
Cultivar x Doses	4	0.2009 ^{Ns}	0.3548 ^{Ns}	0.9591 ^{Ns}
Error	27	0.1769	0.3425	1.0882
C.V. (%)		70.10	89.01	60.91
Overall average		0.6000	0.6575	1.7125
Period: reproductive stage of the common bean - rainy season crop (2014)				
		Q.M.		
Source of variation	**GL**	**LEP**	**HEM**	**COL**
Cultivar	1	0.0303 ^{Ns}	10.4040*	0.7840 ^{Ns}
Block	3	0.1616	8.8767	1.36267
Doses	4	0.3828 ^{Ns}	0.5984 ^{Ns}	3.3216 ^{Ns}
Cultivar x Doses	4	0.4278 ^{Ns}	0.3846 ^{Ns}	5.9871 ^{Ns}
Error	27	0.3401	1.3633	5.1621
C.V. (%)		77.50	38.16	30.01
Overall average		0.7525	3.0600	7.5700

*Q.M (Mean square); GL (Degree of Freedom); C.V. (Coefficient of variation); Ns - not significant; *Significant at (P≤0.05) of probability according to ANOVA test*

Table 3. Summary of the analysis of variance (ANOVA). Total of insects counted in samplings carried out during the Dry Season Crop – 2015 (figure 2), grouped according to the entomological orders Diptera (DIP), Hemiptera (HEM), Coleoptera (COL), and Lepidoptera (LEP), in the vegetative and reproductive stages of the common bean phenological growth.

Period: vegetative stage of the common bean - dry season crop (2015)					
		Q.M.			
Sourceof variation	**GL**	**DÍP**	**HEM**	**COL**	**LEP**
Cultivar	1	46.6560*	0.1288 ^{Ns}	0.0723 ^{Ns}	57.3603 ^{Ns}
Block	3	135.6653	1.1595	0.6423	20.5743
Doses	4	3.3873 ^{Ns}	1.7834*	2.5584 ^{Ns}	18.2294 ^{Ns}
Cultivar x Doses	4	11.5460 ^{Ns}	0.3299 ^{Ns}	0.7891 ^{Ns}	53.4434*
Error	27	10.5251	0.2076	0.9985	17.0904
C.V. (%)		21.73	53.81	49.41	73.33
Overall average		14.9300	0.8468	2.0225	5.6375
Period: reproductive stage of the common bean - dry season crop (2015)					
		Q.M.			
Source of variation	**GL**	**LEP**		**HEM**	**COL**
Cultivar	1	445.5296*		4.9000*	6768.5567*
Block	3	4.8116		7.7723	873.0629
Doses	4	31.0205 ^{Ns}		0.8397 ^{Ns}	123.5023 ^{Ns}
Cultivar x Doses	4	26.1835 ^{Ns}		2.4380*	970.9799*
Error	27	15.5485		0.6752	152.1777
C.V. (%)		34.93		33.31	26.37
Overall average		11.2875		2.4667	46.7832

*Q.M (Mean square); GL (Degree of Freedom); C.V. (Coefficient of variation); Ns - not significant; *Significant a (P≤0.05) of probability according to ANOVA test*

Tabela 4. Average of the samples per plot. Population of insect pests in the vegetative and reproductive stages of the common bean phenological growth for the Rainy Season Crop – 2014 (Fig. 1) and the Dry Season Crop – 2015 (Fig. 2). Assis Chateaubriand, Paraná, Brazil

Period: reproductive stage of the common bean - rainy season crop (2014)			
Entomological Order	Hemiptera		
Cultivars	IPR Campos Gerais	IPR Tuiuiú	
N° of insects	3.57 b	2.55 a	
C.V. (%)	38.16		
Period: vegetative stage of the common bean - dry season crop (2015)			
Entomological Order	Diptera		
Cultivars	IPR Campos Gerais	IPR Tuiuiú	
N° of insects	13.85 a	16.01 b	
C.V. (%)	21.73		
Period: reproductive stage of the common bean - dry season crop (2015)			
Entomological Order	N° of insects		
	Lepidoptera	Hemiptera	Coleoptera
Cultivars			
IPR Campos Gerais	7.95 a	2.12 a	59.79 b
IPR Tuiuiú	14.62 b	2.82 b	33.78 a
C.V. (%)	34.93	33.31	26.37

C.V. (Coefficient of variation). Means followed by the same letter are not significantly different by Tukey's test at(p≤ 0.0) probability

For the dry season crop, the Tukey's test pointed out a significant difference (p≤ 0.05) between the means of the cultivars evaluated in their reproductive stage for the orders lepidoptera, hemiptera and coleoptera. The average numbers of insects per sampling point in the IPR Campos Gerais cultivar were 7.95 (lepidoptera), 2.12 (hemiptera), and 59.79 (coleoptera). In the IPR Tuiuiú cultivar, the average numbers of insects per sampling point for the cited orders were 14.62, 2.82, and 33.78, respectively. It is important to emphasise that the evaluated cultivars belong to different genotypes of common bean. The IPR Campos Gerais cultivar belongs to the Pinto bean group, whereas the IPR Tuiuiú belongs to the Black turtle bean group. Thus, different in characters can be observed between them since they present an unique genetical characteristics of each material.

The bean cultivars studied have an indeterminate growth habit type II, and its inflorescences arise from axillary buds. Apical bud continues to grow even in the reproductive stage, forming a branch that does not exceed a few centimetres; total plant height reaches approximately 70 cm. The side branches are a bit short, and the cultivars present a flowering season ranging from 15 to 20 days. Pods mature evenly and, in general, plants have a life cycle from 80 to 90 days, with about 3,897 Kg ha^{-1} of yield potential for IPR Campos Gerais cultivar, and 3,950 Kg ha^{-1} for IPR Tuiuiú cultivar [9].

For both experiments, the results can probably be assigned to the genetic basis of the cultivars, since different common bean genotypes are concerned. Results obtained in the experiments conducted during the rainy season (2014) and dry season (2015) crops made possible to observe contestations among the genotypes, suggesting a difference in the preference of the insect pests for the evaluated materials. Plants resistance to insects is determined by the chemical, physical and morphological factors that probably act separately or in combination. Such factors provide a plant with different degrees of resistance, especially through toxins, digestibility reducers, trichomes, hardness of the leaf epidermis, and nutritional improprieties as present in common bean genotypes [10].

Another study evaluated the behaviour of 19 bean genotypes [11], focusing the infestation of *Bemisia tabaci* biotype B in rainy, dry and winter season crops. It concluded that genotypes IAC Una, Pérola, Gen 96A45-3-51-52-1, Gen 96A98-15-32-1, FT Nobre, IAC Tybatã, IAC Alvorada, LP 02-130, LP 01-38, LP 98-122, IAC Diplomata and Gen 96A3P1-1-1 are less ovoposited by *B. tabaci* biotype B in the experiment conducted during rainy season crop. The study also concluded that the highest incidence of nymphs occurred in the experiment conducted during dry season crop. The present study recorded the same dynamics regarding the attraction of the insect pests analysed to the bean cultivars evaluated, as seen in the tables presented above.

The highest insect pest population indices in the common bean crop, apart from a typical climatic changes or environmental balance alterations, have been observed in the warmer months [12]. Such pattern of occurrence negatively affects the sowing of the dry season crop since the problems with pests at that season intensify from the beginning of the crop development. This can be seen in this study, where statistically significant differences were observed ($p \leq 0.05$) by Tukey's test regarding the insect pest orders hemiptera and lepidoptera evaluated for the cultivars concerned (Table 4).

During the study period, meteorological conditions unfavourable to the development of the bean occurred, with temperatures above 30°C and high relative humidity of the air above 75% during the entire crop growth stage (Fig. 1 and 2). It is also worth mentioning that rainfall in this period was irregular, presenting an uneven water distribution during the physiological growth stages of the common bean cultivars. Environments under conditions similar to those observed in this study are considered favourable to the reproduction of insect pests, thus justifying the high population of the insects from the entomological orders evaluated.

There was a significant effect ($p \leq 0.05$) of probability, by the Tukey's test, regarding potassium silicate doses evaluated for the order hemiptera during the vegetative stage of the Dry Season Crop (2015). It is important to note that insect pests from the order hemiptera usually do not cause damage to bean culture when it is in the vegetative stage. Damages are commonly observed during the reproductive growth stage when plants produce flowers and pods. In this case, insects from this order begin to cause damage to the crop, providing abortion of flowers and pods. Besides hemipterans damage causes an uneven formation of grains. The main bean insect pest from the order hemiptera is Bedbug [13].

The results presented in Fig. 3 are believed to have been obtained because potassium silicate was not absorbed by the bean plant tissue (waxy cuticle present in leaves and pods). When in contact with the plant tissue, potassium silicate was transformed in polysilicic acid, forming a solid external layer of protection that prevented possible damages caused by the insects from the order Hemiptera.

By working with silicon in solution, as its concentration increases, long-chain polymers are created from monosilicic acid (H_4SiO_4), forming polysilicic acid which readily polymerises in the acid environment [14]. Thus, most likely is that the compound provides plants with an external protective barrier on the leaves to the pest attacks, causing differentiation regarding the population of insects according to the treatments used. In this situation, the formation of potassium silicate-polymer external to the plant tissue hinders insect pests from feeding on plants.

The interaction between cultivars x doses was also analysed for the occurrence of the orders

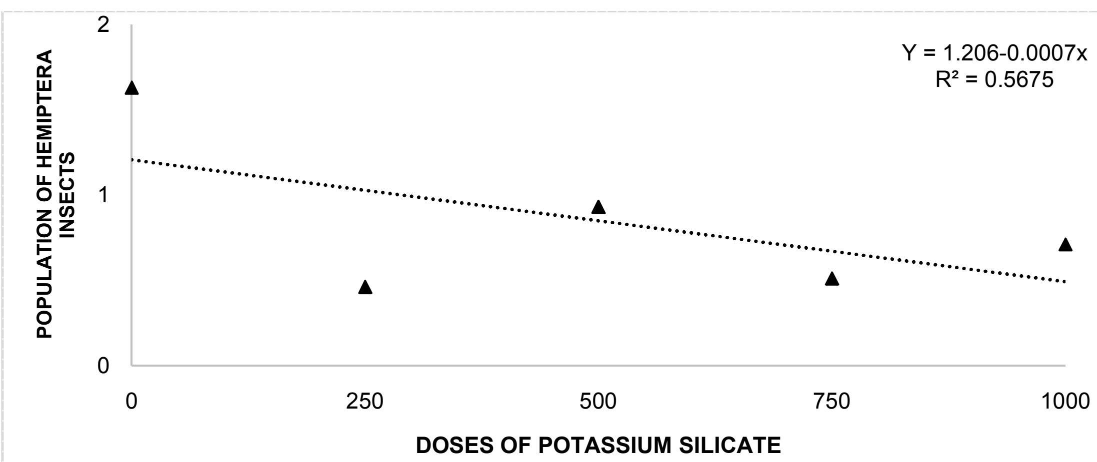

Fig. 3. Number of Hemiptera in relation to treatments with doses of potassium silicate. Vegetative stage of the common bean (*Phaseolus vulgaris* L.) – dry season crop (2015)

lepidoptera (vegetative stage of the crop phenological growth), hemiptera and coleoptera (reproductive stage of the crop phenological growth) during the dry season crop of 2015 (Fig. 4, 5 and 6).

Such interaction may have resulted in an external layer of silica on leaves, working as a protective layer that reduced the insect attacks. This justifies the genetic characteristics (colour of leaves, plant height, dry matter, cellulose content, among others) found in the common bean evaluated.

When analysing the climate (meteorological behaviour) during the course of the study (2014 and 2015) and the phenological development of materials in the cultivation environment of both

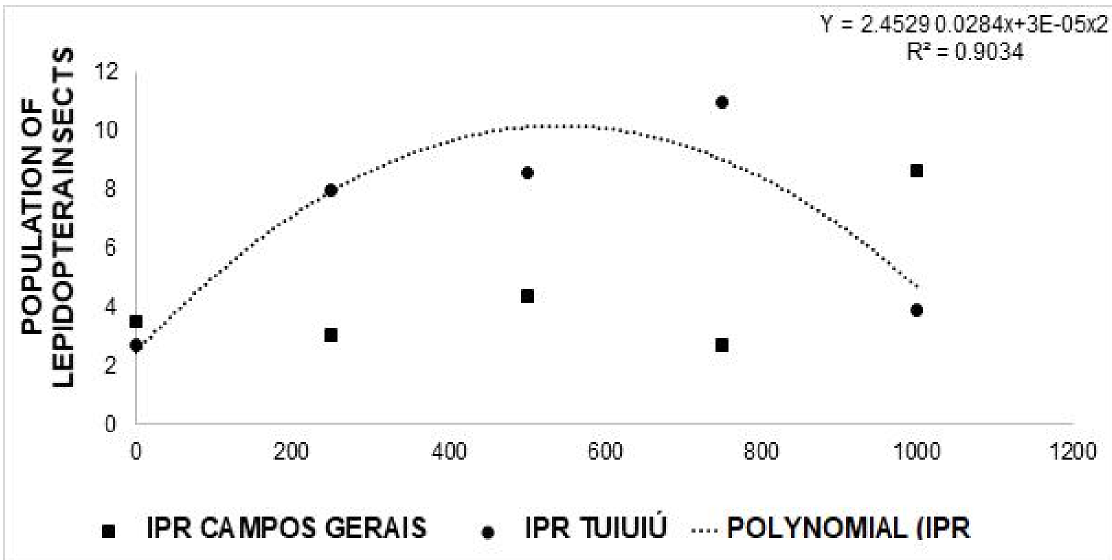

Fig. 4. Lepidoptera population in the vegetative stage of common bean (*Phaseolus vulgaris* L.) by applying doses of potassium silicate – dry season crop (2015)

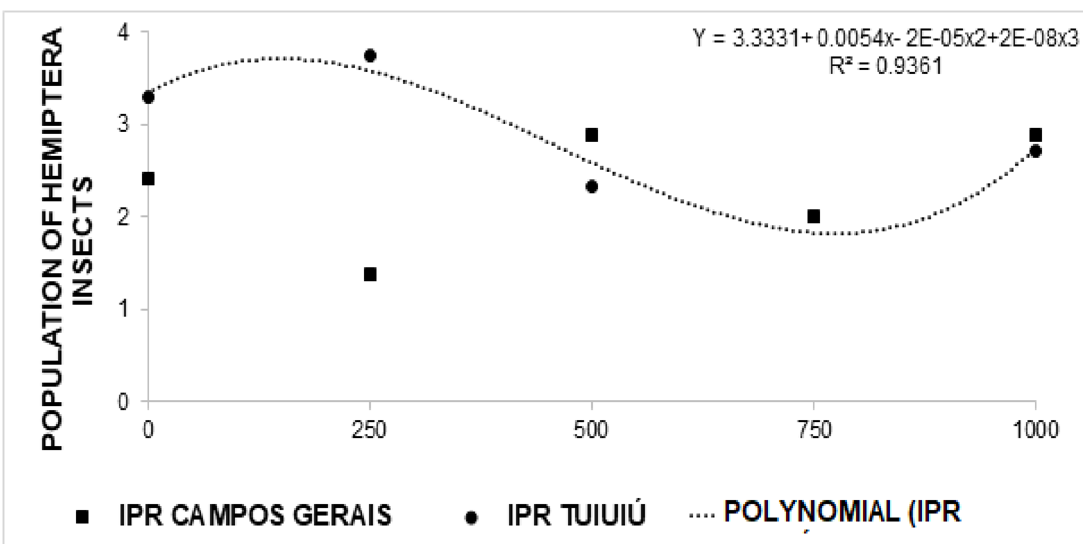

Fig. 5. Hemiptera population in the reproductive stage of common bean (*Phaseolus vulgaris* L.) by applying doses of potassium silicate – dry season crop (2015)

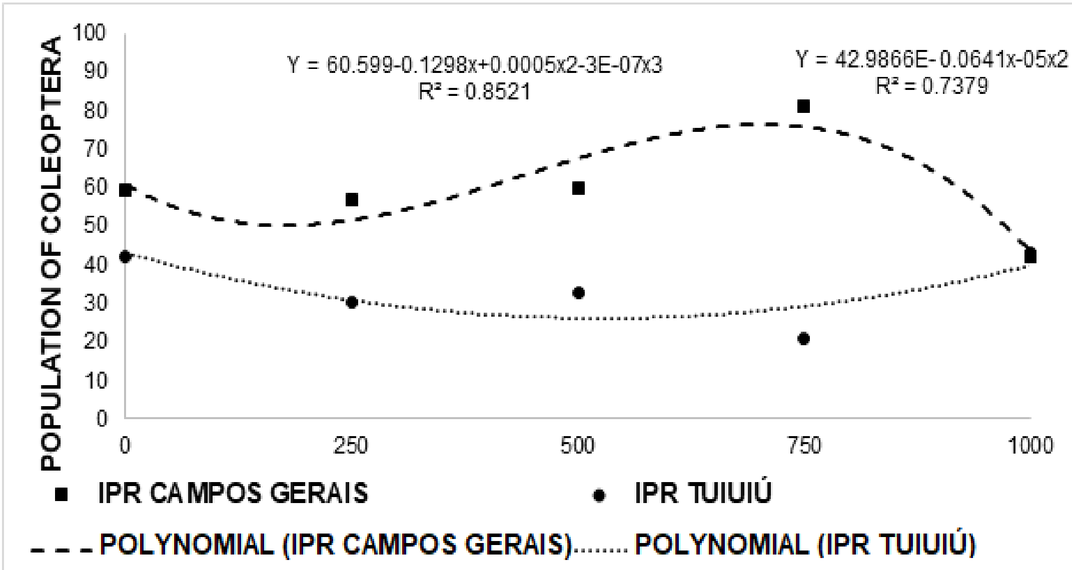

Fig. 6. Coleoptera population in the reproductive stage of common bean (*Phaseolus vulgaris* L.) by applying doses of potassium silicate – dry season crop (2015)

crops (Fig. 1 and 2), differences observed in each crop demonstrated that adverse environmental conditions (especially rainfall and temperature) may cause changes in the insect pests behaviour and population dynamics at different stages of the phenological growth.

No significant effect was recorded regarding the potassium silicate application for some insect pest orders evaluated (Table 2 and 4). It probably happened because the experiment was conducted in a soil containing 73.5 % clay.

The soluble Si content is higher in that type of soil. Red Latosol soils are very weathered, with higher quantity of clay [15]. The location where the experiment was conducted represents 19.6 mg dm^3 of soil soluble silicon, a value considered to be very high. This is the reason why Si would hardly demonstrate its effects on the crop, mainly by the fact that common bean is a silicon-non-accumulating plant.

When Si is found in the liquid phase of the soil as a monocyclic acid, it is absorbed by the plant roots through passive transport, which occurs when soil nutrient moves to the root surface in favour of the concentration gradient, requiring no expenditure of metabolic energy by the plant. Thus, nutrient moves from the highest concentration area (rhizosphere) to the lowest concentration area (root) [16].

Plants can absorb mineral more easily through the root system since it has a greater quantity of membrane transport proteins by which molecules and ions can diffuse [16]. Consequently, plants absorb silicon by the roots with less energy expenditure, not justifying its foliar absorption- which would require the plant to spend more metabolic energy.

It is important to emphasise that Latosol soils contain a large quantity of kaolinite, which still undergoes weathering action and consequently releases soluble Si to soil [17].

For future studies, it is important to explore the results for potassium silicate application in plants grown in soils with different clay percentages and soluble Si, and in Si-accumulating plants.

4. CONCLUSION

Foliar fertilisation with potassium silicate caused a population decrease of the entomological orders evaluated for the common bean genotypes studied. During the reproductive stage of the Rainy Season Crop (2014), there was a significant difference ($p \leq 0.05$) between the bean genotypes for the order hemiptera. In the vegetative stage of the Dry Season Crop (2015), there was a significant difference ($p \leq 0.05$) between the bean genotypes for the order diptera. Potassium silicate also caused a population decrease of the entomological orders hemiptera and lepidoptera in the vegetative stage of the Dry Season Crop (2015), for cultivar x doses interaction. In addition, there was a significant difference ($p \leq 0.05$) in the reproductive stage of the Dry Season Crop (2015) for the entomological orders lepidoptera, hemiptera, and coleoptera between the genotypes evaluated.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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