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Original Research Article

Evaluation of the insect pest population dynamics in common bean cultivars in relation to the foliar fertilization with potassium silicate.

ABSTRACT

This study evaluated the dynamics of the insect pests belonging to the orders diptera, hemiptera, lepidoptera, and coleoptera in two different genotypes of common bean, cultivated in two sowing seasons, according to the foliar fertilization with potassium silicate. The experiment was conducted under field conditions during the Rainy Season Crop and the Dry Season Crop (from August to December 2014 and from February to June 2015, respectively), in a typical eutroferric Red Latosol, in the rural area of Assis Chateaubriand, State of Paraná, Brazil. The experiment used a completely randomized 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 applications were divided into biweekly sprays from phenological stage V_3 to R_8, using the same amount of potassium silicate established for each treatment at different times of application. Insect pest samplings were carried out weekly during the phenological stages V_3 through R_8 for both experiments. The number of sampling times differed between crops due to the physiological development cycle of the genotypes in each of them. Samplings were performed at random points of each plot to provide a better representation. Collected data were submitted to statistical analysis using Sisvar 5.1 software at the 0.05 significance level ($P \leq 0.05$) by the F test. When significant, they were submitted to regression analysis at the 0.05 significance level ($P \leq 0.05$) as well. Foliar fertilization with potassium silicate caused a population decrease of the insect orders hemiptera, lepidoptera and coleopteran.

Keywords: Crysodeiscis includens; Diabrotica speciosa; Liryomusa sp.; Hemiptera.

1. INTRODUCTION

The common bean (*Phaseolus vulgaris* L.) is very susceptible to insect pest attacks, which affects its productivity. All the 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, and such damages may vary according to the pest species, crop growth stage, bean cultivar and sowing season, with potential losses up to 100%. 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 those responsible for the largest productivity losses.

In the producing regions, Leaf Miner (*Lyriomyza sp.*), slugs (*Vaginula langsdorfii*), *Chrysomelidae* and *Caliothrips phaseoli* larvae have been highlighted as important pests of beans [2].

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The importance of common bean in Brazil makes development of new crop management methods necessary, in order to provide farmers with increased productivity and lower costs. Thus, an alternative is the use of foliar fertilization with some micronutrients, such as silicon (Si).

Silicon [3] does not meet the criteria of essentiality for plants. However, [4, 5] this element is characterized 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. Thus, fertilization with potassium silicate may result in a lesser occurrence of insect pests in the bean crop.

In view of that, this study aimed to evaluate the dynamics of the insect pests belonging to the orders diptera, hemiptera, lepidóptera, and coleopteran, in two different genotypes of common bean cultivated in two sowing seasons, according to the foliar fertilization with potassium silicate.

2. MATERIAL AND METHODS

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

According to Köppen, the region 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 characterized by hot summers, infrequent frosts, and by the propensity to concentrate rainfall in summer months, but without a defined dry season. The meteorological data observed during the experiments conduction are in figures 1 and 2.

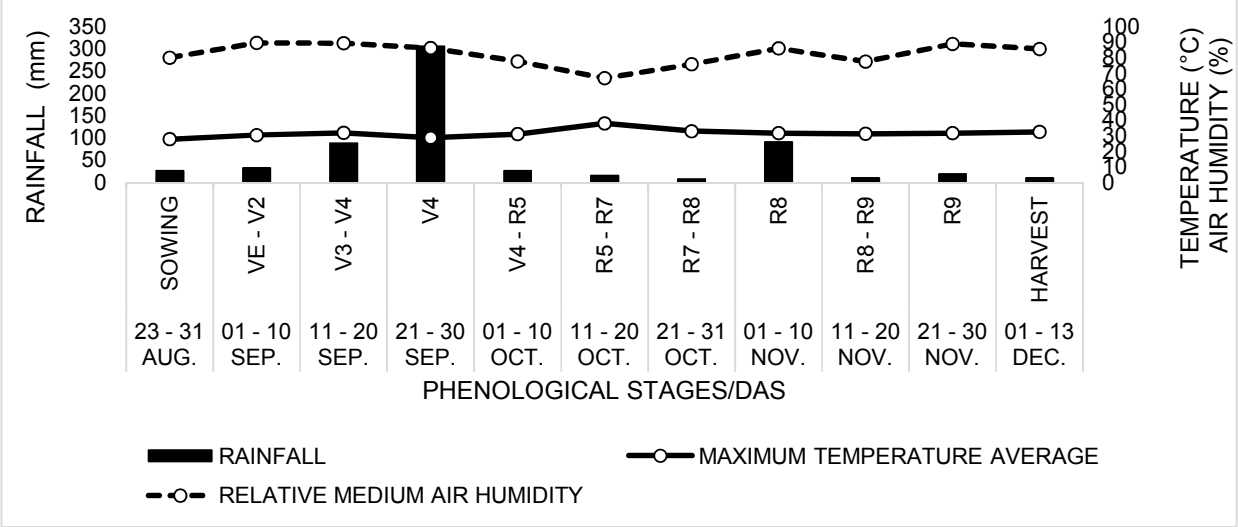

Figure 1: **Maximum temperature, rainfall, and relative air humidity during the experiment conduction – rainy season crop (2014). Assis Chateaubriand, Paraná, Brazil.**

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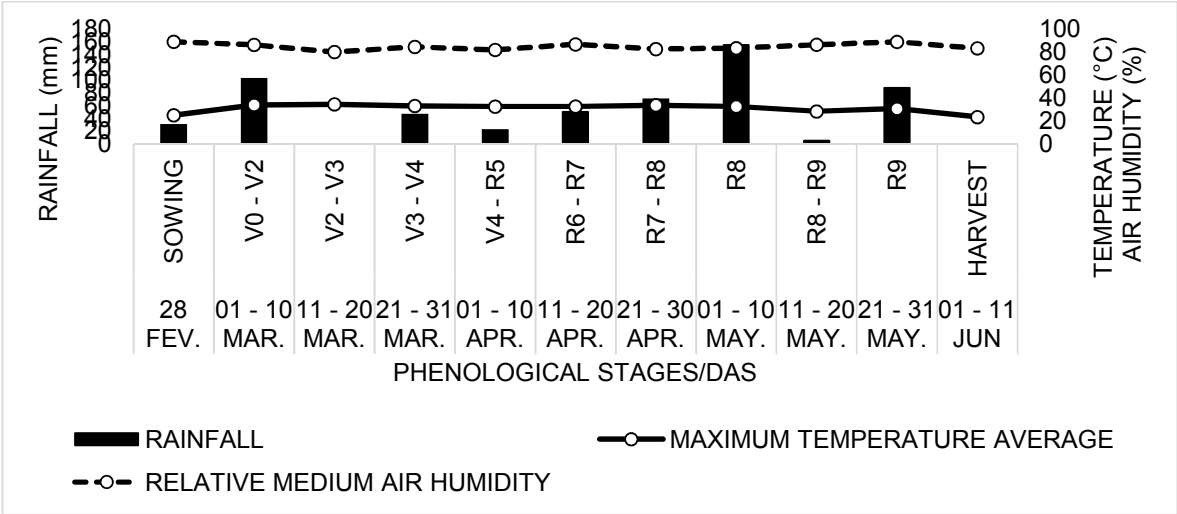

Figure 2: Maximum temperature, rainfall, and relative air humidity during the experiment conduction - dry season crop (2015). Assis Chateaubriand, Paraná, Brazil.

The experiment used a completely randomized 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 containing 0.9 p.v. SiO_2 (90 grams per liter 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, totaling 18 planting rows and 77.4 m^2 area. Spacing used was 0.43 m between planting rows, at a density of 12 seeds per linear meter.

A commercial adjuvant 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) and insecticide (Imidacloprid + tiodicarb), according to the dose recommended by the manufacturer.

Sowings were made on August 23, 2014 (rainy season crop), and february 28, 2015 (dry season crop), respectively. Harvests were made on December 13, 2014, and June 11, 2015, respectively.

During the crop growth, weed control through manual weeding and/or through herbicide Fomesafen + fluazifop-P-butyl use (according to the dose recommended by the manufacturer to control most weeds) was adopted in both experiments when necessary.

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 laboratory for chemical (COODETEC) and physical (UNITHAL) determination of macro and micronutrients, and for soil soluble Silicon determination (Federal University of Uberlândia - UFU), presenting the following results: P = 6.30 mg dm^{-3} (Mehlish-1); pH ($CaCl_2$) = 4.80; H + Al = 3.18 $cmol_c$ dm^{-3}; Al^{3+} = 0.00 $cmol_c$ dm^{-3}; Mg^{2+} = 1.25 $cmol_c$ dm^{-3}; Ca^{2+} = 4.05 $cmol_c$ dm^{-3}; K^+ = 0.16 $cmol_c$ dm^{-3}; Mn = 146.49 mg dm^{-3}; Fe = 55.72 mg dm^{-3}; Cu = 7.62 mg dm^{-3}; Zn = 3.28 mg dm^{-3}; Si = 19.6 mg dm^{-3}; V% = 63.19; Clay = 73.5 %; Coarse sand = 2.3 %; Fine sand = 3.2%; Gravel = 0.0%; Silt = 21.0 %; Textural class = Clayey soil.

Base fertilization was performed with 300 kg^{-1} of 16-16-16 (N-P-K) fertilizer, according to the soil analysis. Subsequently, at the V_4 phenological stage, nitrogen top dressing was applied with urea (45% N) at a dose of 64 kg ha^{-1}.

Potassium silicate applications were divided into biweekly applications, from phenological stage V_3 to R_8. 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 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.

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Insect pest samplings, in turn, were carried out weekly during the phenological growth stages V_3 and R_8, for both experiments. Insect pests from each of the three sampling points in each plot were counted, in both crops conducted. The number of insects to determine the incidence of pests was established from the mean between the total of insects counted in the treatments for both crops. Zig-zag samplings were performed in the plots to provide a better representation.

For insects belonging to the order Díptera, only the leaf sapper (*Lyriomyza sp.*) was sampled, between the growth stages 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 the other orders evaluated (Lepidoptera, Hemiptera and Coleopteran), 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 coleopteran, 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 coleopteran (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 shaked on the beat cloth so that the insects contained on them were counted. Samplings were performed at random points of each plot to provide a 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. No use of data transformation was required.

After data collection, statistical analysis was conducted using Sisvar 5.1 software at the 0.05 significance level ($P \leq 0.05$) by the F test. When significant by analysis of variance, they were submitted to regression analysis at the ($P \leq 0.05$) significance level ($P \leq 0.05$) as well. When data referring to the cultivars were significant, thus indicating difference between them ($P \leq 0.05$), they were compared by the F test.

3. RESULTS AND DISCUSSION

The insects counted in the samplings carried out in the rainy season crop (2014) and in the dry season crop (2015) were measured according to the vegetative and reproductive phenological stages of the crop and according to their entomological classification. From these results, analysis of variance (ANAVA) was carried out. The results of the analysis of variance can be observed in tables 1 and 2.

Table 1. Summary of the analysis of variance (ANAVA). Number of insects counted in the samplings carried out during the rainy season crop (2014), in the vegetative and reproductive stages of the common bean phenological growth, for the entomological orders díptera (DIP), hemóptera (HEM), coleopteran (COL), and lepidóptera (LEP).

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}

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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
Average overall		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
Average overall		0,7525	3,0600	7,5700

Q.M (Middle square); GL (Freedom measure); C.V. (Coefficient of variation); Ns - not significant; *Significant at 5% (P≤0.05) of probability according to F test.

Table 2. Summary of the analysis of variance (ANAVA). Number of insects counted in the samplings carried out during the dry season crop (2015), in the vegetative and reproductive stages of the common bean phenological growth, for the entomological orders Díptera (DIP), hemiptera (HEM), coleopteran (COL), and lepidóptera (LEP).

Period: vegetative stage of the common bean - dry season crop (2015)

		Q.M.			
Source of 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

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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
Average overall		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
Average overall		11,2875	2,4667	46,7832

Q.M (Middle square); GL (Freedom measure); C.V. (Coefficient of variation); Ns - not significant; *Significant at 5% (P≤0.05) of probability according to F test.

Table 3. Average of the samples per plot. Population of insect pests in the vegetative and reproductive growth stages of the common bean for the rainy season crop (2014) and the dry season crop (2015). Assis Chateaubriand, Paraná, Brazil.

Period: reproductive stage of the common bean - rainy season crop (2014)		
Entomological Order	Hemipera	
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)

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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		
	Lepdoptera	Hemiptera	Coleopteran
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 5% (P≤0.05) probability.

As seen in tables 1 and 3, regarding the experiment conducted in the rainy season crop (2014), a significant difference (P≤0.05) was observed by the Tukey test between the population means of insect pests from the order hemiptera, in the cultivars evaluated during the reproductive stage of the crop (table 1). IPR Tuiuiú cultivar presented a population of 28.6% of Hemiptera per sampling point, while IPR Campos Gerais cultivar presented a population of 71.4% (table 3).

Significant differences (P≤0.05) were also observed between the bean cultivars, in the vegetative stage, during the dry season of 2015, as seen in table 2. IPR Campos Gerais cultivar presented a population of insects from the order diptera of 13.4%, while IPR Tuiuiú cultivar presented 86.5% of insects per sampling point (table 3).

For the dry season crop, the Tukey test pointed out a significant difference (P≤0.05) between the population means of insect pests from the orders lepidoptera, hemiptera and coleopteran in the cultivars evaluated in the reproductive stage. The mean values of insects per sampling point in the IPR Campos Gerais cultivar were 45.7% (lepidoptera), 24.8% (hemiptera), and 56.5% (coleopteran). In the IPR Tuiuiú cultivar, the mean values of insects per sampling point for the cited orders were 54.3%, 75.2%, and 43.5%, respectively.

It is important to emphasize 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 behaviors are observed between them since they present unique genetic 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 centimeters; total plant height reaches approximately 70 cm. The side branches are a bit short and the cultivars present a flowering season range 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 3950 Kg ha^{-1} for IPR Tuiuiú cultivar [6].

For both experiments, the results can probably be assigned to the genetic basis of the cultivars studied, since different common bean genotypes are concerned. Results obtained in the experiments conducted during 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

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pests for the evaluated materials. Plants resistance to insects is determined by chemical, physical and morphological factors that probably act separately or jointly. Such factors provide 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 [7].

Another study evaluated the behavior of 19 bean genotypes [8], 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. That study also concluded that the highest incidence of nymphs occurred in the experiment conducted during dry season crop. The present study observed the same dynamics regarding the attraction of the insect pests analyzed 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 atypical climatic changes or environmental balance alterations, have been observed in the warmer months [9]. 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 test regarding the evaluated insect pest orders hemiptera and lepidoptera for the cultivars concerned (table 3).

During the conduction of this study, as observed in the (figures 1 and 2), meteorological conditions unfavorable 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. 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 favorable 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 test, regarding the potassium silicate doses evaluated for the order hemiptera during the vegetative stage of the bean crop, conducted in the dry season (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 vegetative stages of phenological growth. Damages are commonly observed during the reproductive growth stages, when plants present formation of flowers and pods and grains arise. In this case, insects from this order begin to cause damage to the crop, providing abortion of flowers and pods, besides causing uneven formation of grains. The main bean insect pest from the order hemiptera is Bedbug [10].

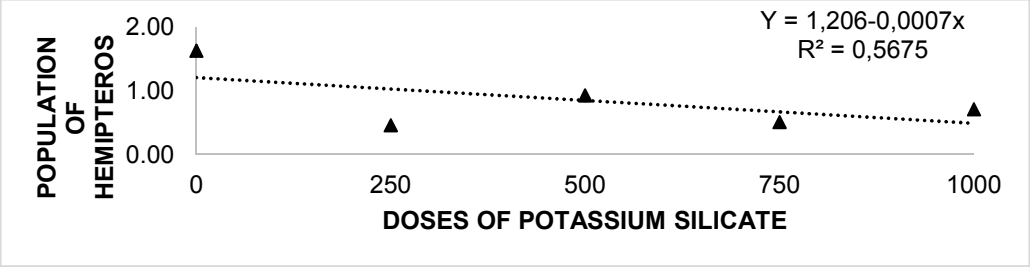

Figure 3. Number of Hemiptera in relation to treatments with doses of potassium silicate. Vegetative stage of the common bean (Phaseolus vulgaris L.) – dry season crop (2015).

As seen in (figure 3), significant results ($p \leq 0.05$) by the Tukey test were found due to the foliar application of potassium silicate, which in contact with the surface of the plant tissue, formed a silica compound that is not absorbed by plants, called polysilicic acid.

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 easily polymerizes in acid environment [11]. Thus, the most likely is that this 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 occurs, which hinders insect pests from feeding on plants.

Significance was also analyzed ($P \leq 0.05$) in relation to the cultivars x doses interaction for the orders lepidoptera (vegetative stage of the crop phenological growth), hemiptera and coleopteran,

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(reproductive stage of the crop phenological growth), during the dry season crop of 2015 (figures 4, 5 and 6).

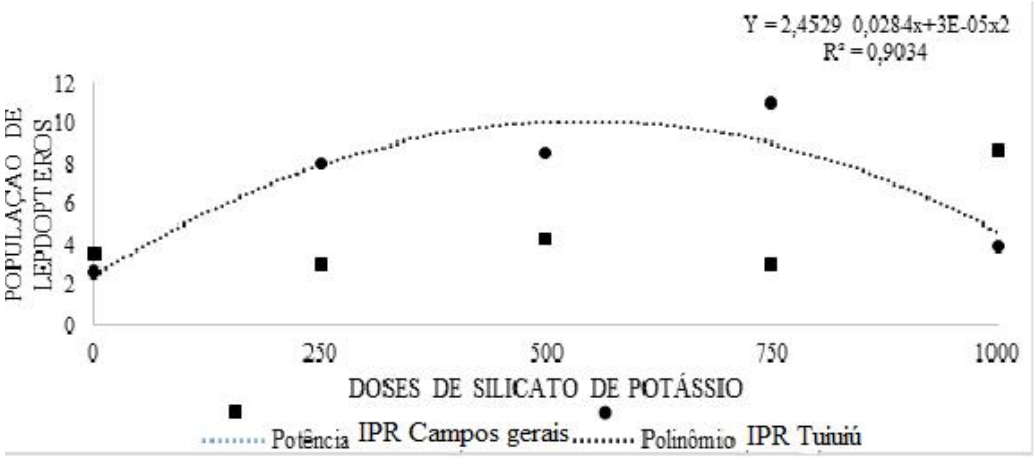

Figure 4. Lepidoptera population in the vegetative stage of common bean (*Phaseolus vulgaris* L.) by applying doses of potassium silicate – dry season crop (2015).

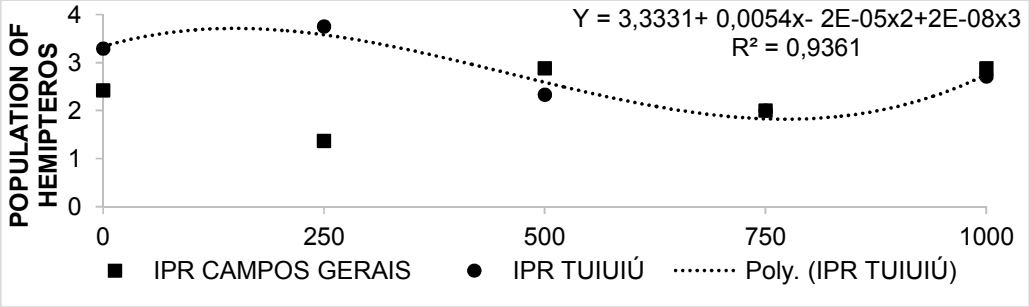

Figure 5. Hemiptera population in the reproductive stage of common bean (*Phaseolus vulgaris* L.) by applying doses of potassium silicate – dry season crop (2015).

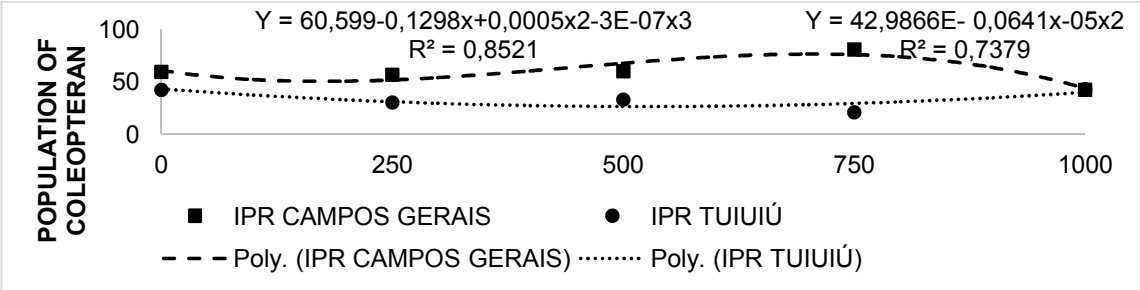

Figure 6. Coleopteran population in the reproductive stage of common bean (*Phaseolus vulgaris* L.) by applying doses of potassium silicate – dry season crop (2015).

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 (color of leaves, plant height, dry matter, cellulose content, among others) found in the common bean evaluated.

When analyzing the climate (meteorological behavior) during the course of the study (2014 and 2015) and the phenological development of materials in the cultivation environment of both crops (figure 1 and 2), differences were observed in each crop, demonstrating that adverse environmental

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conditions (especially rainfall and temperature) may cause changes in the insect pests behavior and population dynamics at different stages of the phenological growth.

No significant effect was observed regarding potassium silicate application for some insect pest orders evaluated (tables 1 and 3). It probably happened because the experiment was conducted in a clayey soil (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 [12]. The location where the experiment was conducted presents 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 plant roots through passive transport, which occurs when soil nutrient moves to the root surface in favor 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) [13].

Plants can absorb mineral more easily through root system, since it has a greater quantity of membrane transport proteins by which molecules and ions can diffuse [14]. 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 emphasize that Latosol soils contain a large quantity of kaolinite, which still undergoes weathering action, and consequently releases soluble Si to soil [15].

4. CONCLUSION

Foliar fertilization with potassium silicate led to a decreased occurrence of insect pest populations, from orders hemiptera, lepidoptera and coleopteran, in the common bean crop.

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