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Effect of the application of paraffinic oil on the control and population fluctuation of the sugarcane aphid (*Melanaphis sacchari* Zehntner) in sorghum

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ABSTRACT

Objective: To determine the effectiveness of different doses of paraffinic oil (SAT-T-SIDE®) and to assess the population fluctuation of the sugarcane aphid (*Melanaphis sacchari*) during sorghum crop development.
Design/methodology/approach: Two experiments were conducted, one under field conditions and the other in a greenhouse. In both experiments, a randomized complete block design with eight treatments and four replications was used. Winged adults were counted. In addition, a pre-evaluation was carried out five days prior to treatment application. After application, the number of insects per plant was recorded, and the biological effectiveness of the treatments was also evaluated. Data were analyzed using the SAS statistical package, and a Tukey mean comparison test ($\alpha \leq 0.05$) was performed as a complementary analysis.
Results: Treatment application resulted in effective pest control, exceeding 80% under field conditions and 90% under greenhouse conditions, with higher effectiveness observed under controlled environments. The highest dose of Saf-T-Side® applied in both field and greenhouse experiments was the most effective for controlling the sugarcane aphid.
Study limitations/implications: The use of paraffinic oil represents a viable alternative for the management of the sugarcane aphid; however, its efficiency is lower than that of conventional chemical control.
Findings/conclusions: Adult populations of *Melanaphis sacchari* showed higher incidence after the first 60 days of crop development. The high dose of Saf-T-Side® was the most effective treatment for controlling the sorghum aphid.

Keywords: population dynamics, biological effectiveness, adult abundance.

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INTRODUCTION

Sorghum (*Sorghum bicolor* L.) Moench is a crop considered highly productive and resistant to water stress conditions. It is an important source of feed for livestock in semi-arid regions (Kimber *et al.*, 2013). Sorghum is regarded as well adapted to arid zones due to its tolerance to prolonged periods of drought. In addition, it shows resistance to viral and fungal diseases, as well as tolerance to high temperatures. However, several factors contribute to yield losses in sorghum production, among which biotic factors are particularly important. One of the most severe sources of damage is caused by the sugarcane aphid, *Melanaphis sacchari* (Zehntner) (Hemiptera: Aphididae) (Singh *et al.*, 2004). Under favorable climatic conditions, it reproduces exponentially, and up to 30,000 aphids may be found on a single sorghum plant (Singh *et al.*, 2004). Both juveniles and adults feed by sucking photosynthates from the plant phloem tissue, causing desiccation, discoloration, and necrosis of the affected leaf area, stunting of young plants, panicle malformation, and the production of sterile grains, which results in losses in yield, grain quality, and forage production (Haar, 2018). Additionally, during feeding, the insect produces honeydew that covers the surface of leaves and stems, promoting the development of sooty mold, which negatively affects the photosynthetic process. Furthermore, scientific evidence indicates that *Melanaphis sacchari* can transmit viral diseases caused by Sugarcane yellow leaf virus and Sugarcane mosaic virus (Schenck, 2000). To effectively control this pest, insecticide applications must be carried out at the most appropriate time to achieve the greatest impact on population reduction (Bowling *et al.*, 2016). Control is normally carried out in a conventional manner, based on the application of chemical insecticides, which provide short-term results and are effective in reducing insect populations (Knutson *et al.*, 2016). One insecticide commonly used for control is flupyradifurone 17.09% (Sivanto® Prime), which shows efficacy greater than 98% mortality and a residual effect lasting 7 to 10 days (Bowling *et al.*, 2016; Buntin *et al.*, 2018). Flupyradifurone is a systemic butenolide insecticide that acts on the insect nervous system, causing rapid mortality and cessation of feeding (Jeschke *et al.*, 2015; Jeschke, 2016; Michaud *et al.*, 2016). Regarding the effect of flupyradifurone application, some researchers such as Zarrabi *et al.* (2017) reported that when the threshold was 100 aphids per leaf, the product applied at three different doses reduced pest populations at 7, 14, and 21 days after application, and that grain yield of sorghum KS585 was significantly higher in treated plots compared with the control. On the other hand, Clark *et al.* (2018) reported that this insecticide achieved effective control of *Melanaphis sacchari* for up to 54 days after application. Although chemical control significantly reduces the impact of this pest, it has also been demonstrated that excessive use of agrochemicals can cause environmental contamination, pest resistance, and the elimination of beneficial insects. Therefore, the current trend is to seek alternative control strategies that are less invasive, among which oils have shown potential to generate positive results (Bográn *et al.*, 2011). In addition, it has been demonstrated that the use of these products is compatible with organic agriculture, as they are approved in these production systems due to their petroleum-derived but highly refined nature and low toxicity. Therefore, they are considered capable of providing effective, safe, and sustainable pest control by reducing dependence on chemical insecticides, assisting in resistance management, and functioning as adjuvants with minimal environmental impact. Based on the above, a commercial product that may represent an alternative is Saf-T-Side®, which is a highly refined, pre-emulsified oil, high in paraffinic components and low in aromatic oils, and is considered ideal for safe and effective pest control. It is registered with the EPA (Environmental Protection Agency) and meets global standards for agricultural spray oils. The mechanism of action is versatile; it acts as a contact insecticide and interferes with respiration, disrupts cell membrane function, and hinders aphid feeding on surfaces covered by the oil until it evaporates (Weidhaas, 1988). In this regard, several studies have reported the beneficial effects of oil sprays, as they kill insects by contact. For example, Najar-Rodríguez *et al.* (2007) found that oil application was highly effective in controlling *Aphis gossypii* Glover in cotton at concentrations ranging from 1 to 10% v/v, causing the highest mortality within 10 minutes after treatment.

Based on the above, the use of paraffinic oil may represent an alternative strategy for pest control; therefore, the objective of the present study was to determine the effectiveness of different doses of paraffinic oil (Saf-T-Side®) and to evaluate the population fluctuation of the sugarcane aphid (*M. sacchari*) during sorghum crop development. The hypothesis proposes that the use of paraffinic oil is effective in controlling *Melanaphis sacchari* by reducing pest insect populations.

MATERIALS AND METHODS

Study area

The research was conducted at the Centro de Estudios Profesionales of the Colegio Superior Agropecuario del Estado de Guerrero (CSAEGro), located at km 14.5 of the Iguala-Cocula federal highway, at coordinates 18° 14″26”′N latitude and 99° 39”46” W longitude, at an altitude of 640 m. The site has an accumulated precipitation of 767 mm and an average temperature of 25 °C (García, 2004).

Genetic material

The sorghum hybrid DKS-32 from the company DEKALB was used. This genetic material has an intermediate-early growth cycle of 110-120 days and reaches an average height of 120 cm.

Separate experiments were conducted, one under field conditions (Experiment I) and the other under greenhouse conditions (Experiment II), as indicated in Table 1.

The methodology for each experiment is described separately below:

Field experiment (Experiment I)

Experimental design and experimental unit

Eight treatments with four replications were arranged using a randomized complete block design, resulting in 32 experimental units. Each unit consisted of four rows 6 m in length, spaced 0.80 m apart. The useful plot comprised the two central rows with full plant competition, eliminating border effects to reduce experimental error. For the establishment and management of the field experiment, the following agronomic practices were carried out: soil preparation was performed by forming rows spaced 0.8 m apart. Sowing was

Table 1. Study treatments under field (Experiment I) and greenhouse (Experiment II) conditions.

No	Treatment	Applied doses (mL)	Symbol
1	Control	0	T1
2	Saf- T-Side®	500	T2
3	Saf- T-Side®	750	T3
4	Saf- T-Side®	1,000	T4
5	Saf- T-Side®	1,250	T5
6	Saf- T-Side®	1,500	T6
7	Saf- T-Side®	2,000	T7
8	SIVANTO® (flupiradyfurone)	1,000	T8

conducted on January 12, 2024, using the drill method, at a population density of 140,000 plants ha^{-1}. The first irrigation was applied one day after sowing, followed by irrigations at 15-day intervals. Nutrient management was carried out according to the recommended rates for the crop. In addition, foliar fertilization with Delfan® Plus was applied at a dose of 1.5 mL L^{-1} of water at 25 days after sowing. Weed control was performed manually.

Treatment application

Treatments were applied twice at eight-day intervals using a backpack sprayer with a 1 L capacity. The commercial products used were Saf-T-Side® (paraffinic oil) and SIVANTO® (flupyradifurone), which were sprayed over the entire plant foliage.

Study variables

A pre-evaluation was conducted five days before treatment application. After application, the number of *M. sacchari* per plant was recorded every 24 h for the following five days. The biological effectiveness (%) of the treatments was also evaluated, which was calculated using the Abbott (1925) formula as follows:

$$\%\, Biological\ effectiveness = \left[(A-B)/A\right]*100$$

Where: A=Value of the untreated control; B=Value of the treatment under evaluation.

To quantify the number of *M. sacchari*, the first evaluation was carried out at 82 days after sowing (DAS), prior to treatment application, during which the number of adults was visually counted on five randomly selected leaves from five plants in the useful plot per treatment. Subsequently, four additional aphid counts were conducted on the dates presented in Table 2.

Statistical analysis

Data from the study variables were subjected to analysis of variance using the Statistical Analysis System (SAS Institute, 2017), according to the experimental design employed. In addition, a Tukey mean comparison test ($p \leq 0.05$) was applied.

Table 2. Schedule of treatment application and aphid counts in Experiments I and II.

Activity	days after sowing (das)
First aphid count	82
1st application of the treatments	85
Second aphid count	88
2nd application of the treatments	93
Third aphid count	96
Fourth aphid count	99
Fifth aphid count	102

Greenhouse experiment (Experiment II)

This experiment was established in a greenhouse at the CEP-CSAEGro, constructed with metal structures, covered with white impermeable plastic and anti-aphid mesh.

Study treatments

The same eight treatments previously evaluated under field conditions were used (Table 1).

Experimental design and experimental unit

Eight treatments with four replications were arranged in a completely randomized design. A total of 24 experimental units were used, each consisting of a black polyethylene pot (12×15 cm) with a capacity of 2.5 kg of substrate. The substrate was prepared with silt soil previously disinfected with Anibac® (quaternary ammonium+copper sulfate) at a dose of 5 mL L^{-1} of water. Sowing was carried out using sorghum seed of the hybrid DKS-32 on February 21, 2024.

Inoculation of *M. sacchari* on sorghum plants

Leaves with high infestations of sugarcane aphid were collected from sorghum plants of the untreated control in the field experiment. These aphid-infested leaves were placed among the plants in each pot to induce pest infestation under greenhouse conditions. This procedure was performed at 44 das. Irrigation was carried out manually by applying 250 mL of water per pot at 3-day intervals starting from sowing. Fertilization consisted of a single application of 2 g of urea per pot at 48 das.

Application of study treatments

The commercial products Saf-T-Side® and SIVANTO® (flupyradifurone), at the doses presented in Table 1, were sprayed twice onto the plant foliage using a manual sprayer, following the schedule indicated in Table 2.

Study variables

A pre-evaluation was conducted five days before treatment application to quantify the number of winged adults of *M. sacchari*. After application, the number of insects per plant was recorded every 24 h for the following five days. The biological effectiveness (%) of the treatments was obtained using the procedure described for the field experiment.

Statistical analysis

Data from the study variables were subjected to analysis of variance using the Statistical Analysis System (SAS Institute, 2017), according to the experimental design employed. In addition, a Tukey mean comparison test ($p \leq 0.05$) was applied.

RESULTS AND DISCUSSION

Number of *M. sacchari* under field conditions (Experiments I and II) Table 3 presents the analysis of variance for Experiments I and II, showing that treatment effects significantly influenced the reduction in aphid numbers. The mean number of aphids on sorghum leaves of the DKS-32 variety decreased as time progressed, with the lowest values observed during the fourth evaluation.

Table 4 shows the number of aphids in relation to the evaluations conducted for both experiments. In the first evaluation, no significant effects were observed due to treatment application in either experiment. However, in the second evaluation, highly significant differences were detected, in which the untreated control showed the highest values for Experiments I and II, respectively. The greatest level of control was achieved with the chemical insecticide. Nevertheless, the high dose of oil also substantially reduced the number of adult aphids. For Experiment I, control resulted in 299 fewer aphids compared to the untreated control, and 764 fewer aphids for Experiment II. The third, fourth, and fifth evaluations showed the same trend, indicating that the higher oil doses provided the greatest level of pest control by significantly reducing the number of adult aphids in the sorghum crop under both field and greenhouse conditions. Several studies reported by other authors demonstrate the positive effect of oil use for pest control. In this regard, some studies have shown favorable responses to oil application. For example, Díaz-Nájera *et al.* (2019) evaluated the biological effectiveness of Saf-T-Side® against *Aphis gossypii* in squash and reported an effectiveness of 82.06%. Likewise, Varela (2013) reported that *Diaphorina citri* nymphs treated with Saf-T-Side® showed a mortality rate of 99% at 16 days after application. In the present study, the high dose (2000 mL) of Saf-T-Side® in the second evaluation of Experiments I and II showed the lowest population

Table 3. Mean values, calculated frequencies (Fc), and coefficients of variation according to the response variables in Experiments I and II.

	Fc Experiment		**C.V (%) Experiment**	
	I	**II**	**I**	**II**
Pre-evaluation	1.17 NS	5.06 NS	48.49	26.41
Evaluación 2	0.19**	3.04**	71.15	48.17
Evaluation 3	0.54**	2.41**	64.68	41.13
Evaluation 4	2.71**	0.48**	93.38	86.09
Evaluation 5	0.96**	12.69**	89.14	72.84

** Highly significant differences, NS=Not significant

Table 4. Number of aphids across five evaluations in Experiment I (field) and Experiment II (greenhouse).

Number	**Treatment**	**Evaluation**				
		1a	**2a**	**3a**	**4a**	**5a**
			Experimen I			
1	T1	367.11 a*	457.56 a	730.67 a	1062.8 a	864.1 a
2	T2	322.56 a	185.56 bc	570.78 ab	358.7 b	357.7 b
3	T3	480.56 a	292.89 ab	213.78 cd	218.3 b	152.8 cb
4	T4	346.89 a	255.44 ab	319.44 bcd	263.2 b	211.2 cb
5	T5	460.33 a	221.44 abc	165.33 cd	175.7 b	139.0 cb
6	T6	354.33 a	214.89 bc	369.67 cd	221.3 b	187.0 cb
7	T7	456.00 a	157.78 bc	216.00 cd	89.2 b	100.1 cb
8	T8	548.33 a	18.11 c	10.67 d	0.0 b	1.6 c
	$HSD_{0.05}$	299.03	237.2	310.39	412.37	331.74
			Experimet II			
1	T1	544.56 a	542.11 a	864.33 a	872.7 a	843.33 a
2	T2	531.11 a	253.11 b	556.11 b	767.6 a	261.78 b
3	T3	629.33 a	233.56 bc	197.67 de	231.6 b	165.56 b
4	T4	545.56 a	188.89 bc	335.78 cd	132.6 b	171.67 b
5	T5	427.44 a	224.11 bc	281.11 cd	189.6 b	226.44 b
6	T6	444.00 a	205.00 bc	428.11 bc	220.9 b	256.67 b
7	T7	575.33 a	90.33 cd	175.56 de	275.0 b	106.89 b
8	T8	503.56 a	11.22 d	15.78 e	0.0 b	0.22 b
	$HSD_{0.05}$	205.04	155.66	217.01	428	273.66

*Treatments with the same letter are not statistically different according to Tukey's test. $HSD_{0.05}$: Honestly Significant Difference. T1: untreated control; T2: mineral oil (Saf-T-Side® 500 mL); T3: mineral oil (Saf-T-Side® 750 mL); T4: mineral oil (Saf-T-Side® 1000 mL); T5: mineral oil (Saf-T-Side® 1250 mL); T6: mineral oil (Saf-T-Side® 1500 mL); T7: mineral oil (Saf-T-Side® 2000 mL); T8: SIVANTO® (flupyradifurone).

incidence and, therefore, the highest biological effectiveness against *M. sacchari*, with percentages of 65.52% and 83.34%, respectively. This effect is attributed to the insect's mechanism of action, as described by Porcura (2011), who indicated that the primary cause of mortality in insects produced by mineral oils is anoxia; that is, oils block the insect spiracles, causing suffocation and ultimately death. On the other hand, Najar-Rodríguez *et al.* (2007) evaluated the effect of nC24 oil on *Aphis gossypii* Glover in cotton and found that petroleum spray oils at concentrations between 1 and 10% were highly effective in controlling the pest; they also determined that the oil can kill insects through direct contact.

In the present study, the reduction in population fluctuation was affected from the first application of mineral oil. Najar-Rodríguez *et al.* (2007) reported that mineral oils are effective and remain so up to six days after field application, although most aphid mortality occurs within the first two days after application.

Additionally, Gonzales *et al.* (2006) reported that the mineral oil Saf-T-Side® showed a significant effect on *Bemisia* spp. nymphs in eggplant at a dose of 1000 mL ha^{-1}; this effectiveness is comparable to the doses of 500 mL and 1500 mL evaluated in the present study. Davidson *et al.* (1991) indicated that mineral oil interferes with insect gas exchange, causing asphyxiation and death by forming an impermeable film over the insect's body.

In both Experiments I and II, the product SIVANTO® showed high effectiveness, ranging from 82 to 100% across all evaluations. In this regard, Guevara *et al.* (2016) reported that the application of SIVANTO® (flupyradifurone) achieved 70.62% effectiveness in the chemical control of aphids in sorghum. However, chemical control of aphids is erratic and unpredictable, and loss of susceptibility has been associated with genetic and agronomic factors of host plants as well as environmental conditions (Godfrey, 2001).

Biological effectiveness of Experiment I (field)

Treatment application resulted in significant differences for the biological effectiveness variable, as shown in Figure 1. The untreated control showed the highest insect incidence, whereas the remaining treatments achieved the following biological effectiveness percentages: T2 (Saf-T-Side® 500 mL) 41.74%, T3 (Saf-T-Side® 750 mL) 60.61%, T4 (Saf-T-Side® 1000 mL) 61.24%, T5 (Saf-T-Side® 1250 mL) 64.84%, T6 (Saf-T-Side® 1500 mL) 59.41%, T7 (Saf-T-Side® 2000 mL) 68.64%, and T8 (SIVANTO®) 84.48%, respectively. Although mineral oils act primarily by causing insect asphyxiation, they may also exert a repellent effect and reduce oviposition (Stansly, 2000). The results indicate that the mineral oil Saf-T-Side® from the third treatment onward showed a biological effectiveness greater than 60% against *M. sacchari*. Similarly, Sieburth *et al.* (1998) reported that the mineral oil SunSpray® Ultra-Fine provided control of *Bemisia tabaci* puparia and nymphs, causing 94-99% and 50-75% mortality, respectively, as well as abnormal development in surviving nymphs, demonstrating that mineral oil is effective for the control of sucking insects.

On the other hand, in another study, Gonzales (2006) reported that mineral oils were effective for controlling *Lepidosaphes gloverii* in Valencia orange and that they are products with lower aggressiveness toward parasitoids, hymenopterans, and entomopathogenic fungi.

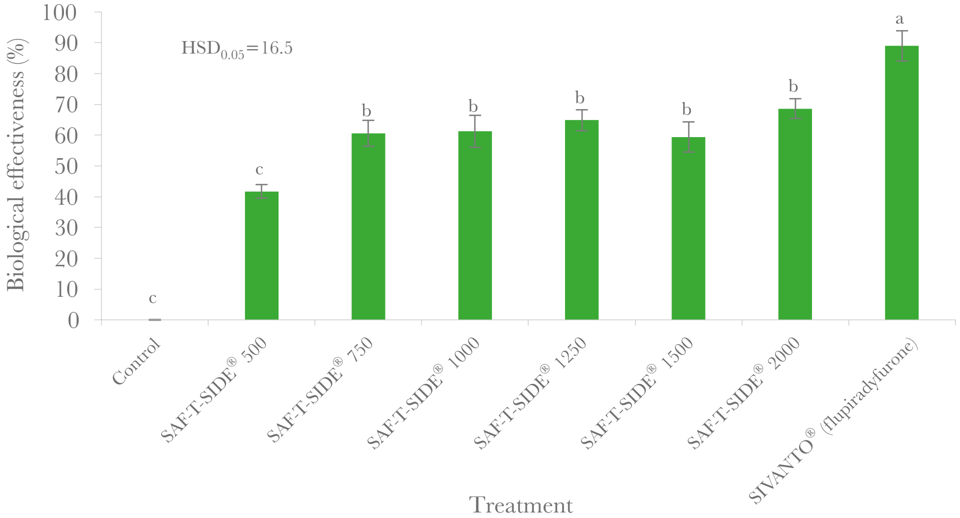

Figure 1. Biological effectiveness of the products used in Experiment I (field). $HSD_{0.05}$: Honestly Significant Difference.

Biological effectiveness of Experiment II (greenhouse)

Figure 2 shows the biological effectiveness generated by treatment application under greenhouse conditions (Experiment II), where the results indicate the presence of significant differences. The untreated control exhibited the highest aphid abundance and, therefore, 0% biological effectiveness, as no control measure was applied. In contrast, the remaining treatments, starting from treatment 2, produced the following biological effectiveness percentages: T2 (Saf-T-Side® 500 mL) 84%, T3 (Saf-T-Side® 750 mL) 61%, T4 (Saf-T-Side® 1000 mL) 84%, T5 (Saf-T-Side® 1250 mL) 74%, T6 (Saf-T-Side® 1500 mL) 87%, T7 (Saf-T-Side® 2000 mL) 88%, and T8 (SIVANTO®) 93%, respectively. Thus, biological effectiveness against *M. sacchari* under controlled conditions was up to 50% higher for all treatments evaluated compared with the results obtained under field conditions. This indicates that, in the greenhouse, where controlled conditions prevailed, treatments were more effective due to the absence of losses caused by volatilization. Stansly *et al.* (2000) indicated that the toxic response of oils is not the only way in which they may protect treated plants from pest damage, as oils can also form a film on the plant surface. Likewise, Butler *et al.* (1993) reported a study conducted in cucumber under heavy infestation of *Bemisia* spp., in which applications of 0.5% soybean oil and Saf-T-Side® resulted in captures of 157 and 268 flies per trap, respectively, compared with 522 in the untreated control, indicating that petroleum-derived mineral oils are effective against insect pests. Additionally, Macías *et al.* (2013), in controlling *Diaphorina citri* psyllids, evaluated mineral oil at concentrations of 1 and 2%, showing reductions in nymph populations of 91.6% and 92.8%, respectively. The results of these studies indicate that oils sprayed onto foliage are effective against nymphs and also demonstrate significant mortality of psyllid eggs. Similarly, Cabrera (2006) reported that the mineral oils Rocio Spray® and Sun Spray® achieved mortality effectiveness of 96% and 95%, respectively, against mobile stages of the citrus rust mite *P. oleivora*, results that are consistent with those found in the present study.

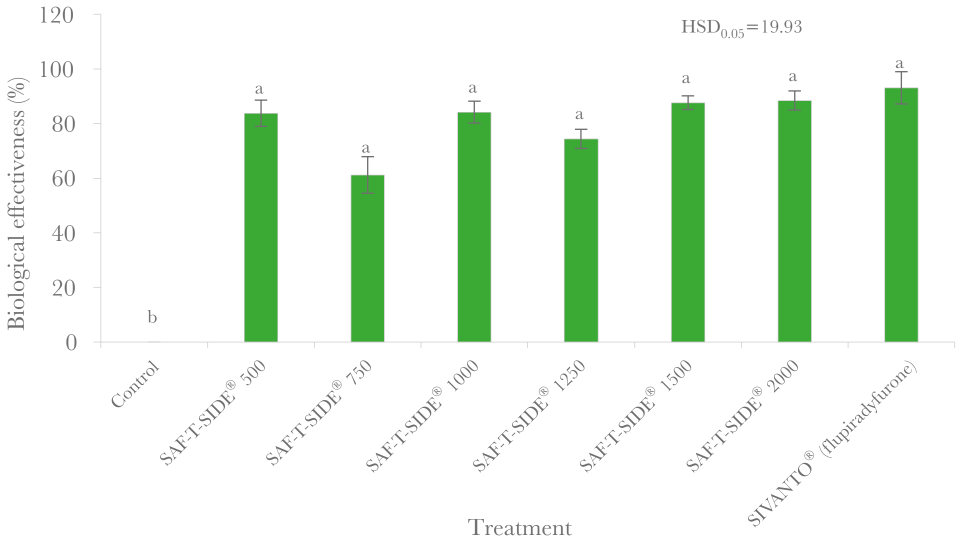

Figure 2. Biological effectiveness of the products used in Experiment II (greenhouse). $HSD_{0.05}$: Honestly Significant Difference.

CONCLUSIONS

The highest concentration of Saf-T-Side® achieved significant control of *Melanaphis sacchari* populations under both field and greenhouse conditions, demonstrating its potential as an ecological alternative to synthetic insecticides.

The treatments evaluated for the control of the sugarcane aphid showed greater control efficiency under greenhouse conditions than under field conditions.

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