Foliar Applications of Potassium to Control Green Bean Pests and Improve Yield and Quality Under Greenhouse Conditions

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Abstract

Saaid, A., K.F. Abdelgawad, M.M. Ahmed, R.F. Ali and S.S. Ahmed. 2024. Foliar Applications of Potassium to Control Green Bean Pests and Improve Yield and Quality Under Greenhouse Conditions. Arab Journal of Plant Protection, 42(4): 497-510. https://doi.org/10.22268/AJPP-001279

Green bean is attacked by a variety of insect pests such as whiteflies, aphids, leaf miners, and two spotted red mite, which can reduce plant growth and yield up to 100%. Potassium plays an important role in plant growth and resistance to biotic stress. The aim of this study was to compare the effect of different sources of potassium foliar application on infestation of green bean pests and their effect on productivity and quality of green beans. Two field experiments were conducted during 2018/2019 and 2019/2020 growing seasons to assess the response of aphids, whiteflies, leaf miner, and two spotted red mite as well as plant growth, and yield of green bean to three potassium sources (silicate 30%, citrate 35% and sulfate 50%) application under greenhouse conditions. The plants were sprayed 15 days after sowing with 6 ml/L, 8 ml/L and 1.5 g/L of potassium silicate, citrate and sulfate, respectively. The foliar application was repeated three times. The number of the examined pests (insects and mites) was calculated in the tested and control treatments. The results obtained showed that, in both seasons, the lowest population of whiteflies was recorded in response to potassium silicate treatment (15.4 and 16.7 insects/plant), followed by potassium citrate (19.3 and 19.4 insects/plant) compared to the potassium sulfate treatment (control) (21.8 and 20.5 insects/plant), respectively. The lowest aphid population in the first season was reached following silicate treatment (1.46 insects/plant) compared to citrate and control treatments (2.38 and 2.85 insects/plant), respectively, with no significant difference between them. During the second season, the lowest aphid population (1.08 insect/ plant) was reached after silicate treatment, followed by citrate treatment (2.38 insects/plant), and control treatment (5.38 insects/plant). Silicate treatment significantly reduced the population of two spotted mites compared to the other treatments, in both seasons. Silicate treatment produced the lowest leaf miner population in both seasons, compared to other treatments. All the growth parameters (plant height, number of leaves, relative chlorophyll content, plant fresh and dry weight, and dry matter) were improved by potassium silicate treatment compared to potassium citrate and sulfate treatments. The increase in total yield under foliar application ranged from 15.2 to 40.8 % compared to control treatment. The highest plant phenol, tannins, total carbohydrate, and peroxidase concentration were produced following potassium silicate treatment. It was concluded that potassium silicate can enhance plant growth and resistance to insect pests.

Keywords: Foliar spray, green bean, potassium fertilizers, pests.

Introduction

The green bean, *Phaseolus vulgaris* L. (Fabaceae) is considered as one of the most important leguminous plants in the world (Raja *et al.*, 2020), which is an available source of protein, vitamins, and dietary minerals such as calcium, iron, magnesium, and antioxidants, in addition to its affordable price to consumers (Heiser, 1990; Pedrosa-Harand *et al.*, 2008). The most important external market for Egyptian green bean includes Italy, the United Kingdom, and the Netherlands with 17.71, 16.93, and 11.40%, respectively (Mohamed *et al.*, 2018). Agricultural pests and diseases are the major constraints to the common bean productivity, particularly in the tropical regions (Graham & Vance, 2003). In Egypt, green bean plantations are usually attacked by different species of economically harmful insects belonging to Lepidoptera, Diptera, Hemiptera and Thysanura as well as mites of Tetranychidae (Saleh, 2011). The most economically serious of these pests are aphids, whiteflies, leaf miners, and red mite. These pests cause high damage and yield loss which ranged 35 to 100% (Singh & Schwartz, 2011; Ulrichs & Mewis, 2004). Aphids infestation produced yellowing, wrinkling, and deformation of leaves, followed by delayed flowering and distortion in the pods (Vuković *et al.*, 2021). In addition, aphids can also transmit a number of viruses such as bean common mosaic virus (BCMV) and cucumber mosaic virus (Damayanti *et al.*, 2009) which, cause qualitative and quantitative losses in green bean crop (Valenzuela & Hoffmann, 2015).

Furthermore, leaf miners are one of the most threatening insects on green bean and they can infest more than 70 plant species in greenhouses or in the open field causing severe damage (Hering, 2013). The infestation by leaf miners leads to leaf fall and encourages infection by fungi and bacteria (Abd El-Salam *et al.*, 2014; Dang *et al.*, 2007). In Egypt, *Litiomyza trifolii* has been causing an economically significant loss and damage to many bean crops. Additionally, the two spotted spider mite *Tetranychus urticae* Koch. attacks a broad range of crops including soybean and cowpea (Razmjou *et al.*, 2009). Mites feed on plant sap, causing yellowish and brown spots on the infested leaves that lead to weakening of the plant photosynthesis

https://doi.org/10.22268/AJPP-001279

(Hazarika *et al.,* 2001; Khajehali *et al.,* 2011). Many previous attempts have been applied in the field of integrated control to reduce the infestation of leaf miners and the two spotted red mite (Wahyuni *et al.,* 2017). On the other hand, the most commonly used pesticides for controlling green bean pests are abamectin, spinosad, fenpropathrin, and Chlorfenapyr (Grewal *et al.,* 2003; Mota-Sanchez *et al.,* 2006). Both bean leaf miners and the two spotted red mite were considered among the most resistant pests to pesticides. The resistance rate in bean leaf miners reached 17.5, 10.2, 2.8 and 3.0 times for abamectin, cyromazine, spinosad, and chlorantraniliprole, respectively (Conroy *et al.,* 2008), and there was a significant increase in the resistance rate of the two spotted red mite against abamectin (Abbas *et al.,* 2014). Fertilization plays an important role in pest control as part of an integrated pest management program. Such fertilization program includes adding certain minerals that may help to improve some plant properties, which permit plants to resist pest infestation (Ratnadass *et al.,* 2012). Potassium is the most abundant inorganic cation essential for ensuring optimal plant growth. In addition, potassium fertilizer as an essential element increases the hardness of plant tissues which makes them difficult to infest by pests (Ramesh *et al.,* 2005). Potassium is crucial for the functioning of various plant enzymes and has a direct impact on the metabolic balance in higher plants (Marschner, 2012; Mengel, 2001). In plants with sufficient K levels, there's an increase in the production of large molecules like proteins, starches, and cellulose, which leads to a reduction in the concentration of smaller molecules such as sugars, organic acids, amino acids, and amides in the plant tissues. These smaller molecules enhance susceptibility to insects attack, thus reducing their concentrations make plants less vulnerable to attack by diseases and insect pests (Marschner, 2012). Adequate K also boosts phenol concentrations, which are vital for plant resistance (Ahanger *et al.,* 2017). Additionally, the high levels of potassium lead to reduced pest damage due to less pest attraction under optimal nutrient conditions and the synthesis of defensive compounds that increase pest mortality (Wang *el al.,* 2013). Furthermore, the fertilization program with appropriate potassium level can improve crop yield and quality (White *et al.,* 2021).

Therefore, the aim of this study was to compare the effect of the different supplemental potassium sources on infestation by aphids, whiteflies, leaf miners, and the two spotted red mite and their effect on the chemical composition of plants, plant growth, yield and quality of green beans.

Materials and Methods

Experimental location and design

The current study was conducted in plastic greenhouse (40 m long × 9 m wide) at the experimental station of the Faculty of Agriculture, Cairo University, Giza during the two successive winter seasons of 2018/2019 and 2019/2020. The study area was divided into 5 ridges (1.5 m x 40 m). The plot area was 27 m^2 (1.5 m wide and 18 m long). The seeds of green beans cv. Hama (Suez Canal Trade and Agricultural Development Company) were sown on the two sides of each row with a space of 0.30 m between plants. The experiment had a complete randomized design with four replicates. 15 days after sowing, the plants in each of the three plots were sprayed with one type of potassium sources. The first plot was sprayed with 30% potassium silicate (K_2O_3Si) at the rate 6 ml/l, the second plot was sprayed with 35% potassium citrate ($C_6H_5K_3O_7$) at the rate of 8 ml/l and the third plot was sprayed sulphate 50% potassium sulfate (K_2SO_4) at the rate of 1.5 g/l (control treatment). The plants were sprayed once every 14 days for three times. These concentrations were used according to the recommended dose of commercial company (Neron agency). All normal agricultural practices were performed without insecticide treatment.

Pest populations

Plant samples were collected weekly starting 14 days after sowing until harvest for both seasons. Ten plants from each plot (each replicate/treatment) were chosen randomly and examined to investigate infestation level by aphids, whitefly, leaf miners and the two spotted red mite. Visual count of the insect pests continued until virtually vanished from the field. The population of both aphids and whiteflies were calculated by counting the individual nymphs and adults on the lower and upper surfaces of leaves of each plant in each sample in the field with a magnifier lens. The population of leaf miners was estimated by calculating the new mines in the new leaves/plant in the field with a magnifier lens. The two spotted red mite population was calculated by counting the number of adults/leaf under a stereo-microscope at the Department of Zoology and Agricultural Nematology, Faculty of Agriculture, Cairo University.

Plant growth parameters

Ten plants were randomly sampled from each experimental plot, 45 days after sowing to measure plant length, number of leaves, relative chlorophyll content (SPAD reading) by using Soil Plant Analysis Development (SPAD-502, Minolta Camera Co. Ltd., Japan) device, and fresh and dry weight/plant. The plants were dried at 70ºC in the oven until constant weight to calculate the dry weight. (Chang & Robison, 2003).

Yield parameters

The green pods of beans were harvested when they reached 14 cm in length and 8 mm in diameter during the harvest season (November to January). The total yield was counted from each plot and weighted to calculate the total yield/treatment. The marketable pods yield (free from mechanical injury, insect and diseases damage, uniform in color, slightly curved and straight pod length) was weighted to calculate the marketable yield according to the following equation (Caks *et al.,* 1985):

$$\text{Marketable yield \%} = \frac{\text{Pod free from defects}}{\text{Total yield}} \times 100$$

Pod chlorophyll content

Ten green pods from each plot were chosen to estimate the total pod chlorophyll content. One gram of fresh pod was extracted with 10 ml of N, N-Dimethylformamide for 48 h. The total chlorophyll and carotenoids were measured in the extract by a spectrophotometer (Helios UVG1702E, England) at wavelength of 663 and 470 nm, respectively.

The chlorophyll and carotenoids were expressed as mg/g fresh weight (Moran, 1982).

Total soluble solids (TSS)

TSS was measured by using a digital refractometer (model PR101, Co. Ltd., Japan). A drop of plant sap was placed on the lens and the reading was taken in degrees Brix (Bx) and pressed as % soluble solids content in the fruit. Calibration was made with distilled water and the lens was carefully rinsed every time after testing the samples as reported by Shehata *et al.* (2017).

Leaf chemical composition

To determine the effect of the different types of potassium sources (potassium silicate, potassium citrate, and potassium sulfate) on the quality of green beans, some chemical composition of bean plant such as protein, Glutathione S-transferases (GST), total phenols, mixed function oxidases (MFO), tannins and alkaloids contents were assessed. Ten plant leaves from each plot/treatment were randomly chosen to determine the chemical composition. Total proteins were determined by the method of absorbance shift observed in an acidic solution of the dye Coomassie® Brilliant Blue G-250 according to Bradford (I976). Glutathione S-transferase (GST) was detected as described by the method of Habig *et al.* (I974). Leaves were washed with ΔH_2O and placed in an oven to dry at 45°C for 4 days to determine phenols content. Leaves were ground in an electric grinder into fine powder. Extraction was performed as described by Kâhkônen *et al.* (1999). The number of total phenols in extracts was determined by the Folin–Ciocateu method (Singleton & Rossi, 1965). Total carbohydrates were extracted and prepared for assay according to Crompton & Birt (1967). Phenoloxidase activity was determined according to Ishaaya (I971), peroxidase activity was determined according to the procedure reported by Hammerschmidt *et al.* (1982).

Estimation of plant essential oils by gas Chromatography-mass spectrometry (GC/MS)

The essential oils of the bean leaves were extracted from all tested treatments, potassium silicate and Potassium citrate compared to potassium sulfate (control) of the Elhama variety. A total of 1,000 g of fresh leaves per treatment were collected from the upper half of the bean plants at the 9th week after sowing during the 2019/2020 season. The leaves were kept in a polyethylene bag with a rubber band and stored in an icebox to transport to the Chromatography Laboratory, Central Laboratories Network, National Research Centre, Giza, Egypt. According to the Council of Europe (1997) procedure. The collected leaves were hydro-distilled in a Clevenger-type apparatus. The extracted essential oil was kept at 4°C away from light and analyzed using GC-MS, according to Adam *et al.* (1998). A Thermoquest-Finnigan Trace GC-MS equipped with a DB-5 (5% phenyl) methylpolysiloxane column (60 m–0.25 mm i.d., film thickness 0.25 μm) was used for the GC/MS analysis. The injection temperature was 220°C, and the oven temperature increased at a rate of 5°C per min G1, at a flow rate of 1.0 ml/min G1. A total of 1 μl of the sample was injected using helium as the carrier gas. The mass spectrometer was scanned with a 70-eV ionizing voltage across the 40–500 m/z range. The identification was based on a standard mass library developed by the National Institute of Standards and Technology (NIST Version 2.0) to detect the essential oil components possibly present.

Statistical analysis

Data were statistically analyzed by one-way ANOVA as described by Snedecor & Cochran (1967). The mean values were separated by Duncan test. The least significant difference of means was calculated at P=0.05 for each season. The obtained data were statistically analyzed with one way ANOVA using MSTAT-C program (version 2.1). The correlations between the measured parameters were analyzed Using SPSS program.

Results and Discussion

Effect of potassium sources on some green bean pests

Three types of different potassium sources (silicate, citrate and sulphate) were applied during the two successive winter seasons (2018/2019 and 2019/2020) of green beans to evaluate the effect of foliar potassium fertilizers on the population density of aphis, whiteflies, leaf miners and two spotted red mite.

The whitefly, *Bemisia tabaci*

Results obtained (Table 1) showed the effectiveness of potassium silicate and potassium citrate treatments in reducing white fly population on green beans. Generally, the populations of *B. tabaci* were similar in both seasons when different potassium sources were used. Furthermore, the highest whitefly population appeared in mid-September and gradually decreased until it reached the lowest level at the beginning of November, in both seasons. Both potassium silicate and potassium citrate treatments significantly reduced the population of white fly compared to the potassium sulfate (control) treatment, in both seasons. Statistically, the mean numbers of *B. tabaci* were highly significant between the three sources of potassium fertilizations during both seasons. These findings suggest that both potassium silicate and potassium citrate treatments effectively suppressed white fly infestation on green beans. Furthermore, the data revealed that the potassium silicate treatment was more effective in reducing white fly population on green beans than potassium citrate. These results are consistent with previous studies that have shown the effectiveness of silica-based treatments in reducing insect infestation on faba bean and soybean (Thabet *et al.*, 2021), and potato (Shah *et al.*, 2019).

Previous studies support the efficacy of potassium silicate as an insecticide for pest management in various crops or as part of an integrated pest management strategy. Further research and experimentation can be conducted to explore the mechanisms behind the effectiveness of potassium silicate compared to other treatments and its potential application in integrated pest management strategies. In addition, Bala *et al.* (2018) studied the effect of silicon in reducing insect infestation and reported that high accumulation of silicon in rice stems caused high mortality of larvae of stem borers (*Scirpophaga incertulas* (Walker) *Scirpophaga innotata* (Walker) and reduced borers survival.

The Black bean aphid, *Aphis fabae*

As summarized in Table 2, both potassium silicate and potassium citrate treatments significantly reduced the population of *Aphis fabae* compared to the control treatment of potassium sulfate, in both seasons. Data showed that the population of *Aphis fabae* were higher in the first season than in the second season when different sources of potassium fertilizers were used. The aphids population started appearing in the first week of October with a low population in response to different treatments in the two growing seasons. In the first season, the highest population of aphids was recorded during the 1st and 2nd weeks of December following potassium sulfate treatment (6.0 individuals/leaf), whereas the highest number of aphids were 4.0 individuals/leaf following potassium silicate and potassium citrate treatments during the 3rd week of November. Later on, the aphid's population began to decrease gradually for all treatments and reached the lowest population level at the 2nd week of Jan. (1.0 and 2.0 individuals/leaf for potassium sulfate and potassium citrate treatments, respectively), whereas aphids disappeared in plants treated with potassium silicate from the last week of December. In the second season, at potassium sulfate, the population started appearing in the 2nd week of October with low population and gradually increased to reach the highest level (13 individuals/leaf) in the 2nd week of December, then gradually decreased and reached the lowest level in the 2nd week of January. Whereas, the aphids' populations were low in plants treated with potassium citrate and potassium silicate compared to potassium sulfate. The highest populations (4.0 individuals/leaf) were recorded in 2nd week in December at potassium citrate treatment and last week of November at potassium silicate treatment.

The application of potassium silicate fertilizer produced the lowest mean number of aphids (1.46 and 1.08 individuals/leaf) followed by potassium citrate fertilizer (2.38 individuals/leaf), then potassium sulfate fertilizer (2.85 and 5.38 individuals/leaf), during the two growing seasons, respectively. The mean numbers of aphids were significantly different between the three potassium sources during the second season, but in the first season, the mean numbers of aphids at the potassium silicate fertilizers were highly significant than both potassium citrate and potassium sulfate fertilizers, and insignificant between them. Moreover, the results revealed that potassium silicate treatment has a stronger negative influence on aphid infestation on green beans for both seasons. Previous studies have demonstrated the potential of potassium silicate in managing aphid populations. For instance, Panahandeh & Pahlavan (2022) reported that the foliar application of potassium silicate effectively reduced aphid infestation in soybean crops, and the same was reported for the potato crop (Shah *et al.*, 2019).

The two spotted red mite, *Tetranychus urticae*

The results obtained on effectiveness of potassium silicate and potassium citrate treatments in reducing the infestation of the two spotted red mite, *Tetranychus urticae* on green beans are summarized in Table 3. During both seasons, the application of potassium silicate resulted in a significant reduction in the mite count, with a mean number of 1.60 mites/leaf and 1.83 mites/leaf, respectively. Similarly, potassium citrate treatments also showed significantly less numbers of mite population, with 3.75 mites/leaf during 2019 season and 4.00 mites/leaf during 2020 season. In comparison, the control treatment (potassium sulfate) produced higher mite counts (5.25 and 5.42 mites/leaf for the two seasons). The infestation with the two spotted red mite was observed from the 3rd week of October until the 2nd week of January, during both seasons. Towards the end of October in both seasons, the mite population was reduced on plants treated with potassium silicate, while it was increased in plants treated with potassium citrate. During the last examination period for both seasons, the two spotted red mite population was lower in plants treated with potassium silicate compared to those treated with potassium sulfate and potassium citrate.

The results obtained indicated that the mean numbers of *T. urticae* were highly significant between the three potassium sources during both seasons. Previous studies have proved the potential of potassium silicate in controlling mite infestations of strawberry (Ismail *et al.*, 2022).

Table 1. Effect of foliar application by different potassium sources on whitefly population.

Sampling date	Mean number of whiteflies/leaf (mean ± SE)						
	2018/2019 season			Sampling dates	2019/2020 season		
	Control	Citrate	Silicate		Control	Citrate	Silicate
12 Sept.	29.0±4.21	25.0±1.34	15.0±2.01	17-Sept.	30.0±1.01	24.0±0.13	23.0±0.92
19 Sept.	26.0±4.10	26.0±2.39	22.0±2.13	24-Sept.	21.0±2.32	24.0±0.38	22.0±0.81
26 Sept.	28.0±0.23	22.0±1.98	23.0±1.71	01-Oct.	29.0±0.31	25.0±0.41	21.0±0.85
03 Oct.	24.0±4.51	23.0±1.45	16.0±1.44	08-Oct.	20.0±0.70	21.0±0.25	14.0±1.21
10 Oct.	23.0±2.13	21.0±2.34	13.0±1.49	15-Oct.	20.0±0.81	24.0±0.29	18.0±0.87
17 Oct.	22.0±1.38	22.0±1.59	15.0±1.33	22-Oct.	20.0±1.85	19.0±0.10	14.0±1.22
24 Oct.	14.0±1.08	14.0±1.23	12.0±2.22	29-Oct.	18.0±1.22	18.0±0.23	16.0±1.09
31 Oct.	18.0±3.77	12.0±1.88	12.0±3.10	05-Nov.	16.0±1.11	10.0±0.32	13.0±0.13
07 Nov.	13.0±5.12	9.0±3.12	11.0±1.65	12-Nov.	11.0±0.23	10.0±0.88	10.0±0.73
Mean	21.89±2.95a	19.33±1.92b	15.44±1.90c	Mean	20.56±1.06a	19.44±0.33b	16.78±0.87c
F value		0.563		*F value*		1.415	
P value		0.314		*P value*		0.008	

Mean values for each season followed by the same letter in the same row are not significantly different at P=0.05.

Table 2. Effect of foliar application with different potassium sources on aphid population.

Sampling date	Mean number of aphids/leaf (means ± SE)						
	2018/2019 season			Sampling dates	2019/2020 season		
	Control	Citrate	Silicate		Control	Citrate	Silicate
12 Sept.	0.0±0.00	0.0±0.00	0.0±0.00	17-Sept.	0.0±0.00	0.0±0.00	0.0±0.00
03 Oct.	1.0±0.04	1.0±0.63	1.0±0.20	08-Oct.	2.0±0.52	2.0±0.77	1.0±1.52
31 Oct.	1.0±0.37	2.0±1.12	1.0±0.13	05-Nov.	1.0±0.33	2.0±1.18	1.0±0.09
07 Nov.	2.0±1.72	2.0±1.64	2.0±0.33	12-Nov.	3.0±0.87	2.0±0.33	1.0±0.53
14 Nov.	4.0±0.63	3.0±1.81	3.0±0.03	19-Nov.	6.0±1.23	2.0±1.83	1.0±0.26
21 Nov.	3.0±1.08	4.0±1.03	4.0±0.03	26-Nov.	5.0±0.64	2.0±1.46	4.0±1.81
28 Nov.	6.0±0.19	4.0±0.18	3.0±0.72	03-Dec.	6.0±1.01	2.0±1.29	3.0±1.36
05 Dec.	6.0±1.03	3.0±1.48	2.0±0.23	10-Dec.	11.0±0.19	4.0±1.71	2.0±1.03
12 Dec.	6.0±0.92	4.0±0.77	2.0±0.52	17-Dec.	13.0±1.65	3.0±0.91	1.0±0.45
19 Dec.	3.0±1.61	2.0±0.95	1.0±0.03	24-Dec.	10.0±0.41	4.0±1.67	0.0±0.00
26 Dec.	2.0±0.41	2.0±0.29	0.0±0.00	31-Dec.	8.0±1.32	4.0±1.02	0.0±0.00
02 Jan.	2.0±1.49	2.0±1.36	0.0±0.00	08-Jan.	3.0±1.11	3.0±0.41	0.0±0.00
09 Jan.	1.0±0.03	2.0±0.42	0.0±0.00	14-Jan.	2.0±1.85	1.0±0.12	0.0±0.00
Mean	2.85±0.79a	2.38±0.90a	1.46±0.17b	Mean	5.38±0.86a	2.38±0.98b	1.08±0.54c
F value		3.318		*F value*		3.35	
P value		0.006		*P value*		0.011	

Mean values for each season followed by the same letter in the same row are not significantly different at P= 0.05

Table 3. Effect of foliar application by different potassium sources on two spotted red mite populations.

Sampling date	Mean number of two spotted red mite/leaf (means ± SE)						
	2018/2019 season			Sampling date	2019/2020 season		
	Control	Citrate	Silicate		Control	Citrate	Silicate
24 Oct.	3.0±0.73	4.0±1.23	0.22±0.01	29Oct.	3.0±1.01	4.0±1.47	0.0±0.0
31 Oct.	2.0±0.23	4.0±1.19	1.0±0.23	05Nov.	2.0±0.54	5.0±1.22	1.0±0.43
07 Nov.	6.0±0.18	2.0±0.89	0.0±0.00	12Nov.	6.0±0.21	2.0±0.36	0.0±0.00
14 Nov.	5.0±1.02	4.0±0.17	2.0±0.30	19Nov.	5.0±1.32	5.0±0.78	2.0±1.02
21 Nov.	6.0±1.36	4.0±1.60	1.0±0.13	26Nov.	6.0±0.91	4.0±1.76	2.0±0.03
28 Nov.	6.0±0.98	4.0±0.98	2.0±0.27	03Dec.	6.0±0.42	4.0±0.64	2.0±0.54
05 Dec.	6.0±0.17	4.0±1.73	2.0±0.75	10Dec.	6.0±0.98	5.0±1.05	3.0±0.38
12 Dec.	4.0±2.59	3.0±1.23	3.0±0.01	17Dec.	4.0±0.83	3.0±0.29	3.0±0.03
19 Dec.	5.0±0.10	4.0±1.00	1.0±0.03	24Dec.	6.0±1.07	4.0±1.82	2.0±0.02
26 Dec.	5.0±0.09	3.0±1.05	3.0±1.52	31Dec.	5.0±1.65	3.0±0.91	3.0±0.34
02 Jan.	7.0±0.07	3.0±0.01	3.0±1.01	08Jan.	7.0±0.23	3.0±1.11	3.0±0.13
09 Jan.	8.0±0.80	6.0±1.09	1.0±0.08	14Jan.	9.0±1.01	6.0±1.61	1.0±0.01
Mean	5.25±0.69a	3.75±1.01b	1.6±0.37c	Mean	5.42±0.85a	4.0±1.09b	1.83±0.24c
F value		249.75		*F value*		322.76	
P value		0.006		*P value*		0.002	

Mean values for each season followed by the same letter in the same row are not significantly different at P= 0.05

The leaf miner, *Litiomyza trifolii*

The effect of different sources of potassium (sulfate, citrate, and silicate) on the population of leaf miner that attack the green beans in greenhouses is summarized in Table 4. Results obtained indicated that, in both seasons, the highest number of tunnels were produced in response to the potassium citrate treatment (2.36 tunnels/ leaf). On the other hand, the lowest number of tunnels were observed on plants treated with potassium silicate (1.27 tunnels/leaf in the first season and 1.18 tunnels/leaf in second seasons). However, the mean numbers of *L. trifolii* tunnels were not significantly different between potassium citrate and the potassium sulfate (control) treatments in the first season, whereas these differences were highly significant among the three potassium sources in the second season.

The infestation of leaf miners was observed to start in the 3rd week of October for both seasons with a low number of tunnels. In the first season, leaf miner tunnels gradually increased until the end of November, then started decreasing gradually until they reached the lowest number in the 2nd week of January following both potassium sulfate and potassium citrate treatments, whereas, these tunnels disappeared in plants treated with potassium silicate starting the 4th week of December. In the second season, the leaf miner tunnels disappeared in plants treated with potassium sulfate and potassium silicate at the end of December, whereas tunnels continued to be present until the 2nd week of January following the potassium citrate treatment. These findings are in agreement with previous studies (Alyousuf *et al.*, 2022; Islam *et al.*, 2020).

Table 4. Effect of foliar application by different potassium sources on leaf miner population.

Sampling date	Mean number of leaf miners/leaf (mean ± SE)						
	2018/2019 season			Sampling date	2019/2020 season		
	Control	Citrate	Silicate		control	citrate	silicate
24-Oct.	2.0±0.04	2.0±0.89	1.0±0.90	29-Oct.	3.0±0.07	2.0±0.34	1.0±0.23
31-Oct.	3.0±0.21	2.0±0.33	1.0±0.06	05-Nov.	2.0±0.23	2.0±0.45	2.0±0.07
14-Nov.	4.0±1.03	3.0±1.16	2.0±0.11	19-Nov.	3.0±2.10	3.0±1.09	1.0±0.13
21-Nov.	3.0±0.12	3.0±0.19	3.0±0.06	26-Nov.	3.0±1.02	3.0±1.01	2.0±0.10
28-Nov.	3.0±1.01	3.0±0.41	3.0±0.91	03-Dec.	1.0±0.30	3.0±1.01	2.0±0.62
05-Dec.	2.0±0.08	4.0±0.83	2.0±0.71	10-Dec.	2.0±0.11	4.0±0.93	3.0±0.49
12-Dec.	2.0±0.01	3.0±0.67	1.0±0.06	17-Dec.	2.0±0.91	2.0±0.02	1.0±0.13
19-Dec.	2.0±0.76	2.0±0.81	1.0±0.03	24-Dec.	1.0±0.07	2.0±0.43	1.0±0.39
26-Dec.	2.0±0.11	2.0±0.52	0.0±0.00	31-Dec.	0.0±0.00	2.0±0.03	0.0±0.00
02-Jan.	1.0±0.28	1.0±0.74	0.0±0.00	08-Jan.	0.0±0.00	2.0±1.23	0.0±0.00
09-Jan.	1.0±0.09	1.0±0.28	0.0±0.00	14-Jan.	0.0±0.00	1.0±0.13	0.0±0.00
Mean	2.27±0.34a	2.36±0.62a	1.27±0.26b	Mean	1.55±0.44b	2.36±0.61a	1.18±0.2c
F value		8.91		*F value*		18.67	
P value		0.016		*P value*		0.003	

Mean values for each season followed by the same letter in the same row are not significantly different at P= 0.05

Vegetative growth parameters

All foliar application treatments significantly increased plant growth parameters (Figure 1). Potassium silicate significantly increased plant height by 5.5 and 7.5% compared to the control treatment in both seasons (Figure 1-A). There were no significant difference in plant height between potassium citrate and control treatments. The enhancement effect of potassium silicate on plant height aligns with previous studies (Verma *et al.,* 2017). Potassium is an essential element for cell expansion and cell division, which likely contributed to the observed increase in plant height.

The highest number of leaves/plant was observed in potassium silicate treatment without significant difference from the citrate treatment, and the lowest number of leaves was obtained in potassium sulfate (control) treatment without significant difference from citrate treatment in both seasons (Figure 1-b). This finding suggested that potassium silicate stimulates leaf growth and development, possibly through its positive impact on photosynthesis and nutrient uptake (Hafez *et al.,* 2021).

Bean plants treated with potassium silicate and potassium citrate showed a significant increase in plant fresh weight compared to the control treatment, in both seasons. Potassium silicate achieved the highest plant fresh weight (1762 and 1863 g) followed by potassium citrate (1126 and 1193 g), in both seasons (Figure 1-C). These results are consistent with previous research highlighting the role of potassium in enhancing water and nutrient uptake, ultimately leading to improved plant growth and fresh weight findings (Huang *et al.,* 2018).

In both seasons, potassium silicate treatment gave the highest plant dry weight compared to all other treatments (Figure 1-D). Potassium citrate treatment gave a plant dry weight similar to the control treatment in both seasons. Likewise, plants treated with potassium silicate and potassium citrate demonstrated a significant increase in dry matter content compared to potassium sulfate treatment (control) (Figure 1-E), which is in agreement with previous reports (Felisberto *et al.,* 2021).

Data presented in Figure 1-F showed that potassium silicate treatment achieved the highest relative chlorophyll content (SPAD reading), with values of 55.9 and 51.2, in both seasons. The control treatment recorded the lowest value of SPAD reading without a significant difference from the citrate treatment in the first season, but in the second season, the control treatment gave the lowest SPAD value (43.7). These results are in agreement with previous findings (Kramer & Evans, 2010).

Improving vegetative growth (plant height, number of leaves, fresh and dry weight, dry matter and chlorophyll content) by the application of potassium silicate is likely due to the vital role of silicon in leaf stability and exposing more leaves to light, which increases the canopy of the plant and photosynthesis (Farag *et al.*, 2014), in addition to its negative effect on insect pests population.

Yield and its components

The results obtained revealed that marketable yield rate ranged from 96 to 98.3% in the first season and from 95.6 to 98% in the second season (Figure 1-G). All potassium sources produced the same marketable yield rate with no significant difference among them. The highest total yield/plant was obtained from potassium silicate treatment with values of 1912 and 1883 g/plant in both seasons, followed by the citrate treatment with values 1583 and 1531 g (Figure 1-H). The lowest total yield/plant (1324 and 1327) was obtained from the control treatment in both seasons. The improved marketable yield and total yield can be attributed to the positive effects of potassium silicate on plant growth, leaf development, and overall physiological processes (Ahmad *et al.,* 2007; Hafez *et al.,* 2021). In addition, data presented in Figure 2 indicated that the total soluble solids (TSS) were significantly increased in response to all foliar application treatments. TSS due to silicate and citrate treatments was similar and greater than the control treatment in both seasons (Figure 1-I).

Total Soluble Solids represent the concentration of sugars, organic acids, and other dissolved substances in plant tissues, directly affecting the taste, flavor, and nutritional quality of fruits. The higher TSS % in plants treated with potassium silicate indicates better fruit quality and enhanced sweetness, which is particularly important for fruits intended for fresh consumption or processing industries (Nurbaiti *et al.,* 2023). Pod total chlorophyll and carotenoids content were achieved by all foliar application treatments. The highest value of total chlorophyll content (12.9) was recorded due to the treatment with silicate, without significant difference with citrate treatment (10.79). The lowest value of chlorophyll content was recorded in the control treatment (9.0) without significant difference with citrate treatment (Figure 2-A). The content of pod carotenoids were significantly increased by silicate treatment followed by citrate treatment (Figure 2-B). Control treatment showed the lowest carotenoids content.

Leaves chemical composition

The leaves chemical compositions of the treated plants by different potassium sources were illustrated in Figure 2. Results obtained confirmed that all leaves composition was affected by K sources. Data in Figure 2-C showed that protein content was higher in the silicate treatment than in the control treatment and similar to the silicate treatment. The lowest protein content was recorded in citrate treatment. The Glutathione S-Transferase (GSTs) was at the lowest level due to potassium citrate treatment and potassium silicate compared to those treated with potassium sulfate (Figure 2-D). Functional studies of individual GSTs proved to positively contribute to antimicrobial resistance in host plants by mostly unknown mechanisms (Dixon *et al.*, 2009; 2010; Gullner *et al.*, 2017; Liao *et al.*, 2014; Sappl *et al.*, 2009; Wahibah *et al.*, 2018). A significant increase in the phenolic compounds was recorded in plants treated with potassium citrate followed by those treated with potassium silicate compared to the control treatment (Figure 2-E). These phenolic compounds are involved in incorporating attractive substances to accelerate pollination, colouring for camouflage and defense against herbivores, as well as antibacterial and antifungal activities (Edreva *et al.*, 2008).

The highest level of mixed-function oxidase (MFO) was observed in plants treated with potassium silicate followed by potassium citrate compared to potassium sulfate (control) treatment (Figure 2-F). Potassium citrate treatment produced the highest content of tannins (1987) with no significant difference with silicate treatment (1891). The lowest tannins content was due to the control treatment (Figure 2-G). Additionally, as shown in Figure 2-H, the highest level of alkaloids was obtained in the plants treated with potassium silicate followed by those treated with potassium citrate compared to those treated with potassium sulfate (control). Alkaloids are produced by a large variety of organisms, including bacteria, fungi, and plants. They are mainly involved in plant defense against herbivores and pathogens. It was found that 20% of plant species contain alkaloids. Potassium citrate and silicate treatments increased the total carbohydrate content by 41.6% and 37.4%, compared to the control treatment (Figure 2-I). The highest value of phenoloxidase (5.2) was recorded due to potassium silicate compared to all other treatments (Figure 2-J). Potassium citrate and control treatments produced the same significant value of phenoloxidase. Data presented in Figure 2-K showed that potassium citrate achieved an intermediate value of peroxidase (59.2) which was higher than that produced by potassium silicate (55.8). The decrease of alkaline phosphatases was estimated to be -52.9 due to potassium silicate treatment (Figure 2-L). Citrate treatment and control treatment recorded the highest value of alkaline phosphatase with no significant difference.

Table 5 presented the correlation between the chemical composition of treated plants and tested insect pests and the two spotted red mite. Red mite infestation was positively correlated with leaf miners infestation (0.811), aphids infestation (0.907), peroxidase activity (0.840), and alkaline phosphatase (0.860), whereas, there was negative correlation with phenol oxidase (-0.879), MFO (-0.944), total carbohydrate (-0.723), and alkaloids (-0.890).

Leaf miners infestation was positively correlated with aphids (0.723), peroxidase activity (0.770), and alkaline phosphatase (0.724), and it was negatively correlated with phenol oxidase (-0.745). Whitefly infestation was correlated positively with total protein (0.715), and GST (0.677), however, there was a negative correlation between white fly infestation and total phenol content. Aphids infestation had a statistically significant negative correlation with phenol oxidase (-0.896), MFO (-0.850), and alkaloids (-0.829) content.

Table 5. Correlation coefficient amongst insect population and plant chemical compositions.

	RM	LM	WF	Ap	TP	PO	PX	GST	AP	MFO	TC	TPh	Tn
Leaf miners	0.811*												
Whitefly	0.068	-0.170											
Aphids	0.907**	0.723*	0.067										
T. protein	0.284	0.002	0.715*	0.212									
Phenol oxidase	-0.879**	-0.745*	0.309	-0.896**	0.068								
Peroxidase	0.840**	0.770*	0.199	0.578	0.338	-0.551							
GST	0.665	0.350	0.677*	0.594	0.851**	-0.307	0.629						
Alkaline phosphatase	0.860**	0.724*	-0.304	0.891**	-0.133	-0.968**	0.574	0.269					
MFO	-0.944**	-0.660	-0.089	-0.850**	-0.351	0.807**	0.817**	-0.686	-0.832**				
Total carbohydrate	-0.723*	-0.307	-0.514	-0.588	0.750*	0.388	-0.674*	-0.945**	-0.341	0.723**			
Total phenols	-0.494	-0.720	-0.691*	-0.344	-664**	0.140	-0.466	-0.935**	-0.085	0.546	0.936		
Tannins	-0.101	0.097	-0.620	-0.129	-0.797*	-0.098	-0.043	-0.664	0.212	0.188	0.484	0.689*	
Alkaloids	-0.890**	-0.641	-0.432	-0.829**	-0.55	0.627	-0.770*	-0.898**	-0.601	0.843**	0.899**	0.760*	0.384

RM= Red mite; LM= Leaf miners; WF= Whitefly; Ap= Aphids; TP= Total protein; PO= Phenol oxidase; PX= Peroxidase; AP= Alkaline phosphatase; TC= Total carbohydrates; TPh= Total phenols; Tn= Tannins.
*correlation is significant at P=0.05; **correlation is significant at P=0.01

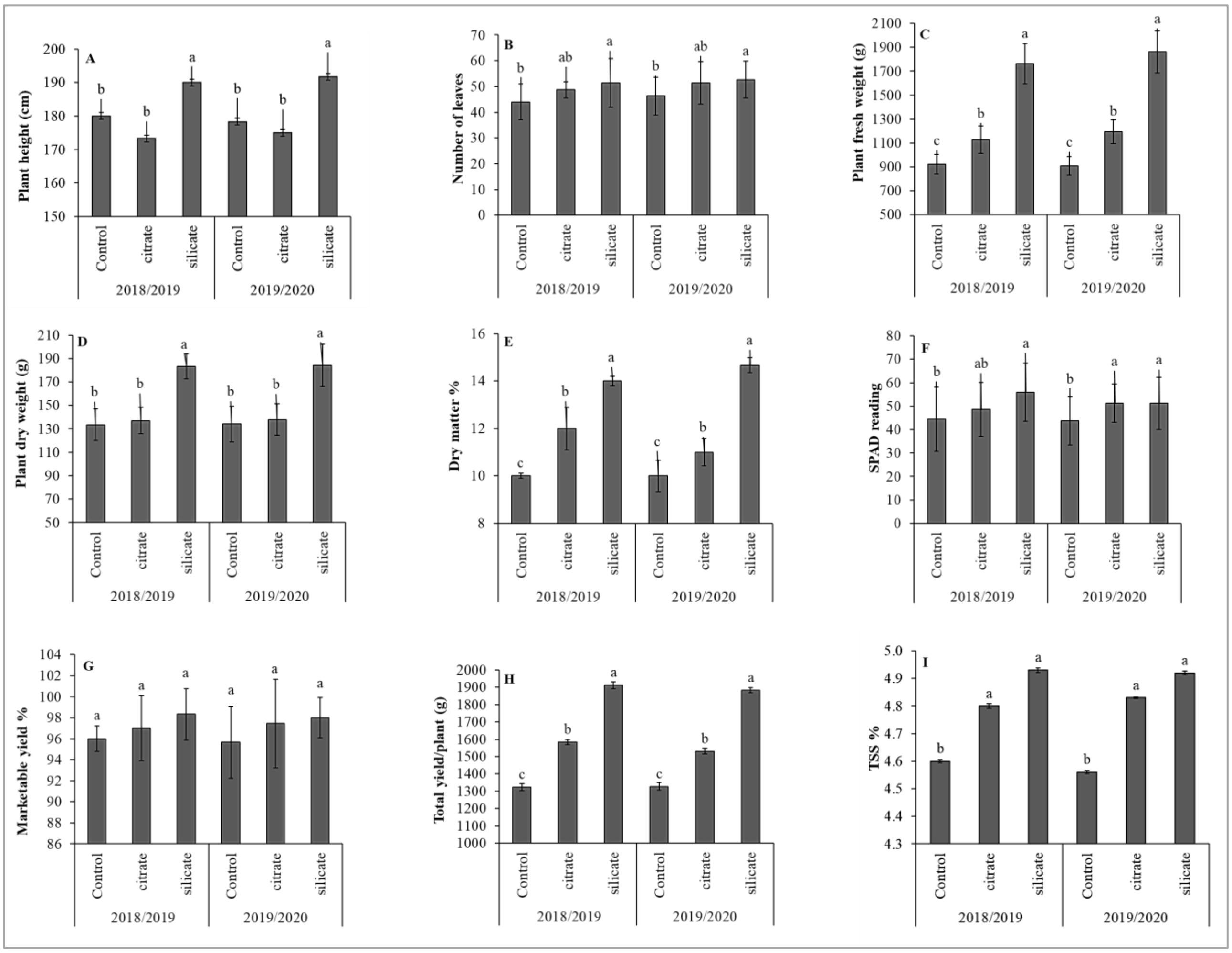

Figure 1. Effect of foliar application by different potassium sources on plant height (A), number of leaves/plant (B), plant fresh weight (C), plant dry weight (D), dry matter (%) (E), SPAD reading (F), marketable yield % (G), total yield /plant (H) and TSS% (I).

Foliar essential oil composition

The fertilization effect of bean plants by potassium sulfate (control treatment), potassium silicate and potassium citrate compared to untreated plants on the foliar essential oil composition of bean cultivars are shown in Table 6. A total of 38 compounds were identified, among these, 34 compounds were considered significant because their relative content was higher than 1%.

Potassium silicate treatment produced 15 compounds in cv. Elhama bean plants, including five new compounds compared to the control, and 20 compounds with potassium citrate treatment from which seven were new compounds compared to the control. In comparison, Potassium sulfate treatment produced 22 compounds including nine new ones compared to the untreated control (Table 6).

Potassium silicate treatment of the cv. Elhama stimulated the synthesis of p-Cymene, Tetradecanal, β-Myrcene, β-Pinene and Isomenthone (relative content 7.13, 2.39, 1.97, 1.22 and 0.87%, respectively). Likewise, the relative content of D-Limonene, Linalool, ç-Terpinene, 2,4-Ditert-Butylphenol, α-Pinene, 1,8-Cineole and 2-Pentadecanone, 6,10,14-trimethyl- increased to 21.48,14.92, 10.92, 4.32, 4.26, 1.35 and 1.00%, respectively, whereas the 9,17-Octadecadienal, (Z), Methyl 2-hydroxy-octadeca-9,12,15-trienoate and 9-Octadecenamide decreased to 0.90, 2.58 and 6.48%, respectively (Table 6).

Likewise, the use of potassium citrate in bean fertilization stimulated the synthesis of p-Cymene, Tetradecanal, β-Myrcene, Isomenthone, β-Pinene, α-Cedrene and 4-Terpineol (relative content 5.37,1.72,1.45,1.22, 1.13,1.12 and 1.01 %, respectively), and the relative content of Linalool, D-Limonene, ç-Terpinene, α-Pinene, 1-Heptacosanol, 1,8-Cineole and 2-Pentadecanone, 6,10,14-trimethyl- increased to 19.10, 15.79, 9.90, 3.90, 1.37, 1.35 and 1.03 %, respectively. Whereas the relative content of Hexadecanamide, Octadecanamide, 2,4-Ditert-Butylphenol, 9-Octadecenamide, (Z)-Methyl 2-hydroxy-octadeca-9,12,15-trienoate and 9-Octadecenamide decreased to 0.99, 1.41, 2.16, 2.50, 3.37 and 8.70%, respectively, compared to Elhama untreated plants.

In comparison, fertilization with potassium sulfate stimulated the synthesis of β-myrcene, z-citral, geraniol, cis-citral, geranyl acetate, caryophyllene oxide, 2-ethyl-1-dodecanol, neryl (S)-2-methylbutanoate and ethyl geranate (relative content 1.18, 3.14, 1.06, 3.44, 1.02, 1.43, 1.34, 1.12 and 1.29%, respectively) (Table 6). In addition, the relative content of ç-terpinene, linalool, 2-pentadecanone,6,10,14-trimethyl, 9,17-Octadecadienal(Z), methyl 2-hydroxy-octadeca-9,12,15-trienoate, 13-docosenamide (Z) and Squalene increased to 1.93, 9.08, 1.41, 3.15, 9.52, 5.40 and 0.86%, respectively, but D-Limonene, 2,4-Ditert-Butylphenol, Hexadecanamide, 9-Octadecenamide, 9-Octadecenamide(Z) and Octadecanamide decreased to 3.48, 3.36, 3.91, 17.24, 12.06 and 2.43%, respectively.

The fertilization of bean plants withy potassium silicate or potassium citrate stimulated the synthesis of new compounds such as β-pinene, β-myrcene, p-cymene, isomenthone and tetradecanal, in addition to the increase of the relative content of some compounds such as α-pinene, D-limonene, 1,8-cineole, ç-terpinene and linalool (Table 6), which enhanced the resistance of bean plants to insect and mite pests. and thus, explain why the population of these pests decreased by fertilization with these treatments.

The highest efficacy rate in both seasons occurred in the usage of the fertilization of bean plants by Potassium silicate decreased the mean number of movable stages of *T. urticae* to 1.0 and 1.0 individual / leaf compared to the control 8.0 and 9.0 individual/leaf at the end of the two seasons, respectively. This is followed by potassium citrate which decreased the population of movable stages of *T. urticae* to 6.0 individuals/leaf in both seasons, which is in agreement with previous findings (Abdellatif *et al.,* 2023; Afifi *et al.*, 2015; Ahmed, 2018).

It can be concluded from this study that potassium silicate treatments had a significant negative influence on the infestation with whiteflies, aphids, two spotted red mite and leaf miners. The effectiveness of potassium silicate was found to be higher than potassium citrate and potassium sulfate treatments. These findings contribute to the understanding of the potential use of potassium silicate as an insecticide in agricultural practices, providing an environmentally friendly and effective solution for pest control on green beans. Moreover, potassium silicate improved the plant growth parameters, yield and quality of green beans under greenhouse conditions.

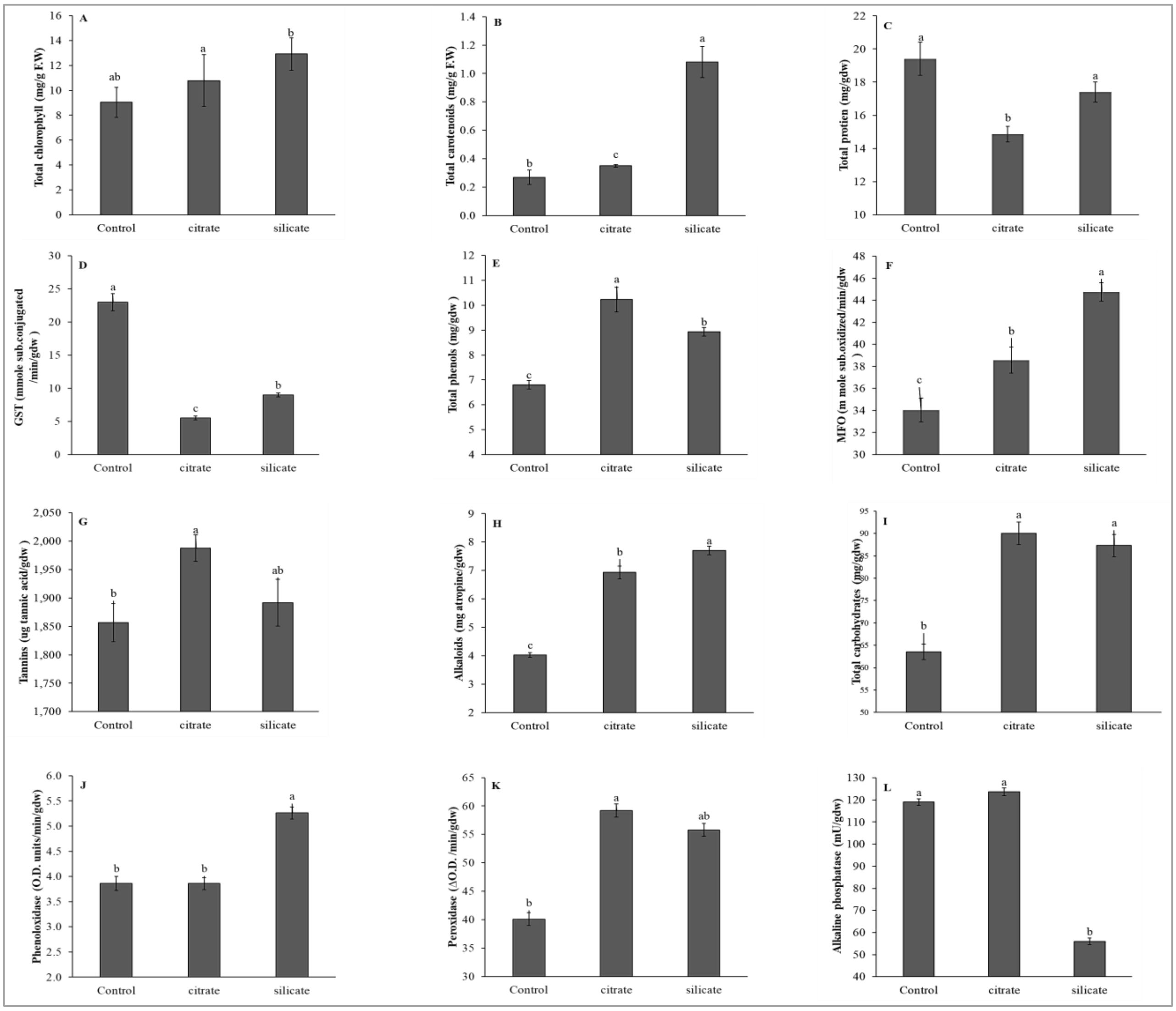

Figure 2. Effect of foliar application by different potassium sources on pod chlorophyll content (A), pod total carotenoids (B), protein (C), GST (D), total phenols (E) MFO (F), tannins (G), alkaloids (H), total carbohydrates/plant (I), phenol oxidase (G), preoxidase (K), and alkaline phosphatase activity (L).

Table 6. The essential oil components of bean plant leaves after foliar potassium application (Potassium silicate and Potassium citrate) compared to bean plants with potassium sulfate (control).

No. of peak	Rt (min)	Components	Relative content (%) of Potassium fertilization		
			P. sulfate	**P. silicate**	**P. citrate**
1	4.26	α-Pinene	--	4.26	3.90
2	5.37	β-Pinene	--	1.22	1.13
3	5.65	β-Myrcene	--	1.97	1.45
4	6.79	p-Cymene	1.18	7.13	5.37
5	6.86	D-Limonene	3.48	21.48	15.79
6	6.99	1,8-Cineole	--	1.35	1.35
7	7.83	ç-Terpinene	1.93	10.92	9.90
8	9.40	Linalool	9.08	14.92	19.10
9	12.07	Isomenthone	--	0.87	1.22
10	12.67	4-Terpineol	--	--	1.01
11	15.13	Z-Citral	3.14	--	--
12	15.60	Geraniol	1.06	--	--
13	16.44	Cis-Citral	3.44	--	--
14	20.93	Geranyl acetate	1.02	--	--
18	25.45	α-Cedrene	--	--	1.12
19	25.60	Cedr-8-ene	--	--	--
20	26.15	2,4-Ditert-Butylphenol	3.36	4.32	2.16
21	28.82	Caryophyllene oxide	1.43	--	--
23	34.20	Tetradecanal	--	2.39	1.72
24	38.31	2-Pentadecanone, 6,10,14-trimethyl-	1.41	1.00	1.03
25	39.84	2-Ethyl-1-dodecanol	1.34	--	--
26	39.98	9,17-Octadecadienal (Z)	3.15	0.90	--
27	40.19	Methyl 2-hydroxy-octadeca-9,12,15-trienoate	9.52	2.58	3.37
28	41.79	Neryl (S)-2-methylbutanoate	1.12	--	--
29	46.37	1-Heptacosanol	--	--	1.37
32	47.82	Ethyl geranate	1.29	--	--
33	49.44	Hexadecanamide	3.91	--	0.99
34	54.60	9-Octadecenamide	17.24	6.48	8.70
35	54.77	9-Octadecenamide, (Z)-	12.06	--	2.50
36	55.27	Octadecanamide	2.43	--	1.41
37	56.10	13-Docosenamide, (Z)	5.40	--	--
38	56.80	Squalene	0.86	--	--

Rt= Retention time, -- = Not detected

الملخص

سعيد، أحمد، كريمة فاروق عبد الجواد، محمود منير أحمد، رهام فتحي علي وسيدة سيد أحمد. 2024. استخدام الرش الورقي للبوتاسيوم لمكافحة آفات الفاصولياء الخضراء وتحسين كمية ونوعية الإنتاج تحت ظروف البيوت المحمية. مجلة وقاية النبات العربية، 42(4): 497-510.
https://doi.org/10.22268/AJPP-001279

تصاب نباتات الفاصولياء الخضراء بالعديد من الآفات الحشرية مثل الذبابة البيضاء، المنّ، حافرة الأوراق والعنكبوت الأحمر ذو البقعتين، مما يؤدي إلى تقليل النمو الخضري وخفض المحصول بنسبة قد تصل إلى 100%. يلعب عنصر البوتاسيوم دوراً مهمّاً في نمو النباتات ومقاومتها للإجهادات الأحيائية. هدفت هذه الدراسة إلى مقارنة تأثير الرشّ الورقي بمصادر مختلفة من البوتاسيوم على الاصابة بآفات الفاصولياء الخضراء وتأثيرها على الإنتاجية وجودة المحصول. تمّ إجراء تجربتين حقليتين خلال موسمي الزراعة 2019/2018 و 2020/2019 لتقييم استجابة المنّ، الذبابة البيضاء، حافرات الأوراق والعنكبوت الأحمر ذو البقعتين ونمو النبات وإنتاجية الفاصولياء الخضراء للرش الورقي بثلاثة مصادر للبوتاسيوم (سيليكات 30%، سترات 35% و كبريتات 50%) تحت ظروف البيوت المحمية. تم رش النباتات بعد 15 يوماً من الزراعة بتركيز 6 مل/ليتر، 8 مل/ليتر و 1.5 غ/ليتر من سيليكات البوتاسيوم، سترات وكبريتات البوتاسيوم، على التوالي. تم تكرار الرشّ الورقي ثلاث مرات. تمّ حساب عدد الآفات (الحشرات والاكاروسات) قيد الدراسة في كل من المعاملات والشاهد. أظهرت النتائج المتحصل عليها أنه في كلا الموسمين، تمّ تسجيل أقل عدد من الذبابة البيضاء (15.4 و 16.7 حشرة/نبات) استجابةً لمعاملة سيليكات البوتاسيوم تلتها معاملة سترات البوتاسيوم (19.3 و 19.4 حشرة/نبات) مقارنةً بمعاملة كبريتات البوتاسيوم (الشاهد) 21.8 و 20.5 حشرة/نبات، على التوالي. في الموسم الأول، تم تسجيل أقل عدد من حشرات المنّ (1.46 حشرة/نبات) عقب المعاملة بالسيليكات مقارنةً بمعاملات السترات والشاهد (2.38 و 2.85 حشرة/نبات)، على التوالي، مع عدم وجود فروق معنوية بينهما. خلال الموسم الثاني، تم الوصول

إلى أقل عدد من حشرات المنّ (1.08 حشرة/نبات) بعد المعاملة بالسيليكات، تلتها معاملة السترات (2.38 حشرة/نبات)، ومعاملة الشاهد (5.38 حشرة/نبات). كما أدّت معاملة السيليكات إلى تقليل معدل الإصابة بالعنكبوت الأحمر ذي البقعتين وكذلك ناخرة الأوراق بشكل ملحوظ مقارنةً بالمعاملات الأخرى في موسمي النمو كليهما. تمّ الحصول على أفضل صفات للنمو (ارتفاع النبات، عدد الأوراق، محتوى الكلوروفيل، الوزن الطازج، الجاف للنبات والمادة الجافة) عند المعاملة بسليكات البوتاسيوم مقارنة بسترات وكبريتات البوتاسيوم. زاد المحصول الكلي بنسبة تراوحت ما بين 15.2–40.8% نتيجة الرش الورقي بالسليكات والسترات مقارنة بمعاملة الشاهد. تمّ تسجيل أعلى تركيز للفينول، التانينات، الكربوهيدرات الكلية والبيروكسيديز بعد المعاملة بسيليكات البوتاسيوم. مما سبق يمكن لسيليكات البوتاسيوم أن تعزز نمو النبات ومقاومته للآفات الحشرية.

كلمات مفتاحية: رش ورقي، فاصولياء خضراء، أسمدة البوتاسيوم، آفات.

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Received: September 20, 2023; Accepted: November 29, 2023

تاريخ الاستلام: 2023/9/20؛ تاريخ الموافقة على النشر: 2023/11/29