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Relationship Between Potassium Fertilization Sources and Improvement of Snap Bean Green Pods Quality for Exportation

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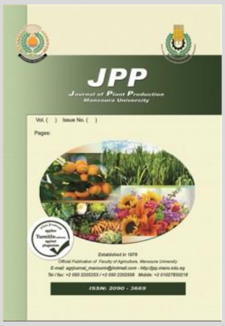
Walaa M. E. Swelam[1]* and E. A. Abd El-Basir[2]

[1]Veget. and Flori. Dept. Fac. Agric., Mans. Univ., Egypt.
[2]Self-Pollination Vegetables Crops Research Dept., Hort. Res. Inst., Agric. Res. Center, Giza, Egypt.



ABSTRACT

Snap bean have been cultivated in winter season for succulent green pods with reduced fiber and highly minerals and carbohydrates content for either exportation or local markets. The immature pods are consumed as green vegetables. It responds much better to foliar fertilizers application specially potassium (K).In this concern, two experiments were conducted to study the effect of K fertilizers sources on yield and pods quality of snap bean under clay loam soil conditions. The experiment consisted of nine sources of K fertilizers arranged in randomized complete block design with three replications. There were significant differences among most K sources in their effects on most studied parameters. The results showed that, potassium phosphite recorded the best vegetative and chemical parameters followed by potassium silicate (without significate differences between them in most cases). Also, maximum early and total green pod yield were obtained from potassium phosphite foliar application. On the other hand, maximum marketable pod yield was recorded from the application of potassium silicate. Since, the experiment was conducted in a single location and two seasons, so repeating the experiment for more locations (different soils) and other new K fertilizers could be help in drawing sound conclusive recommendations to the applied production and achieving excellent pods quality for local marketing, exportation and storage.

Keywords: Snap bean, potassium, phosphite, fertilization, green pods.

INTRODUCTION

Snap bean *(Phaseolus vulgris* L.*)*, has a high profitability due to its short growth cycle and its high productivity. There is a high demand in the international market (Seif *et al.*, 2016). It is one of the most widely cultivated vegetable legumes in Egypt. Also, it is considered a highly perishable vegetable because it is harvested immature and has a high moisture content. Green bean is a good source of important nutrients, proteins, carbohydrates, fiber, and vitamins A and C (Fabbri and Crosby, 2016). The visual quality of pods is one of the most important quality parameters affected due to rapid deterioration after harvest. Many nutritional and compositional changes occur after harvesting. Green bean color is an important visual quality parameter which changes from bright green after harvest to pale green or yellowish color (Trail *et al.*, 1992). Loss of quality in pods begins immediately after harvesting and increases throughout the supply chain. Yellowing of pods is often due to green pigment degradation (chlorophylls a and b).

Unacceptable quality in green bean pods is often related to decay due to microbial growth, fiber development due to over-maturity, shriveling due to moisture loss, injured pods due to mechanical harvest or rough handling, chilling injury due to storage at lower than the recommended temperature and browning due to injuries caused during harvesting (Cantwell, 2004).

Potassium (K) is one of the most important mineral element for plant growth and development, also plays a basic role in allowing plants to achieve high yield, involved in tissue osmotic regulation, stomatal regulation as well as enzymatic activation (Malavolta, 2006). Also, it is important for water balance, plant growth and metabolism (Rosolem *et al*., 2010). Most of K element found in soil is not available to plants and can fall into four pools: exchangeable K, soil solution K, structural K and non-exchangeable K (Moody and Bell, 2006). Also, K is known as quality element because of its role in improving quality of economic parts i.e., fruits, pods, dry seeds and tubers (Lester *et al.*, 2006). Due to the lack of potassium in the market, its high price (manufacturing materials) as well as the low efficiency of its use through ground fertilization, alternatives must be searched to fill these shortages of K fertilizers and improve the efficiency used. Potassium shows a highly mobility and when taken up by leaves they can be rapidly distributed throughout the entire plant compared with soil application. Once fertilizer application constitutes a practical, cost-saving and environmentally sound technique in crop production (Yang *et al.*, 2012 and Geng *et al.*, 2015).

So, K foliar treatments could be a fast method to increase K nutrient in plant tissues. Therefore, foliar plants feeding with nutrients (macro and micro) has become an established procedure in plant production to increase productivity (Roemheld and El-Fouly, 1999), minimize environmental pollution and production costs as well as improving nutrient utilization by reducing the amounts of fertilizers added to soil (Abou El-Nour, 2002). K foliar

*** Corresponding author.**
E-mail address: walaamohameed@mans.edu.eg
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spray is a significant method of fertilization specially during the maturation stage since there is an intense mobilization of it from leaf to fruit, also K uptake by roots may be inadequate to meet the demand of this nutrient (Mengel and Kirkby, 2001). Foliar fertilization has the advantage of low application rates, uniform distribution of fertilizer materials and quick responses to applied nutrients (Abdalla, 2016), improve both yield and quality attributes (Marchand and Bourrie, 1999). In Egypt, K is available in a range of fertilizers (which contain potassium only or two or more nutrients), include potassium sulphate (K_2SO_4), potassium chloride (KCl), potassium nitrate (KNO_3) (Magen, 2004). Also, new K fertilizers such as potassium phosphite (KH_2PO_3) and potassium silicate (K_2O-$4SiO_2$) improved plants performance represented in plant growth, yield and resistance against many a biotic stress and fungi diseases (Salim *et al.,* 2014 and Gomez-Merino and Trejo-Tellez, 2015 and 2016).

Due to the lack of information related to the use of enhanced efficiency potassium fertilizers, the present study aimed to evaluate the productivity, nutritional characteristics and agronomic efficiency in snap bean production (green pods) using K sources as foliar application.

MATERIALS AND METHODS

Experimental site:

Two open-field experiments were carried out at privet vegetable farm in Aga near El-Mansoura, Dakahlia Governorate, Egypt during winter seasons of 2016 and 2017.

Experimental soil:

The soil of the experimental research is classified clay-loam. Some chemical and physical properties of soil samples are given in Table 1.

Table 1. Some physical and chemical properties of the experimental soil profile of cultivated area

Soil properties		2016	2017
Physical analysis	Fine sand %	18.14	18.34
	Coarse sand %	7.71	7.91
	Silt %	33.65	33.45
	Clay %	40.50	40.30
	Texture	Clay-loam	Clay-loam
Chemical analysis	pH	7.91	7.99
	E.C. (dSm^{-1})	1.12	1.13
	Organic matter %	1.45	1.45
	Available P (ppm)	11.72	11.70
	$CaCo_3$	4.55	4.58
	Total N %	0.2	0.2
Soluble anions (meq/L)	Cl^-	3.56	3.46
	HCo^-_3	3.20	3.40
	Co^-_3	0.00	0.00
	So^-_4	5.16	5.26
Soluble cations (meq/L)	Ca^{++}	4.03	4.03
	Mg^{++}	1.35	1.35
	Na^+	1.21	1.21
	K^+	5.33	5.33
Available micronutrients (ppm)	Fe	3.62	3.62
	Mn	1.51	1.51
	Zn	1.35	1.35
	Cu	0.52	0.52

Weather conditions:

Some climatic variables were recorded daily during the two growing seasons (October-January) were given in Table 2.

Table 2. Monthly climatic variables during winter seasons of 2016 and 2017.

Season	Parameters	October	November	December	January
2016	Temperature max. (°C)	29	26	19.3	16
	Temperature min. (°C)	20	17	12	10.2
	Temperature avg. (°C)	25	20	16.5	12.2
	Sunshine (h)	11.5	10.3	10.0	9.3
	Relative humidity (%)	60	64	55	57
2017	Temperature max. (°C)	28	25	18.5	15
	Temperature min. (°C)	19	16	11	10.1
	Temperature avg. (°C)	24	20	11.2	12.4
	Sunshine (h)	11.2	10.7	10.2	9.4
	Relative humidity (%)	58	61	56	57

Plant materials:

Seeds of snap bean "Paulista" were provided by Suez Canal Trade & Agricultural Co. Cairo, Egypt. Paulista is a winter green bean cultivation basically for exportation (as un-maturity green pods) especially for European market and period from sowing to maturity 55-60 days.

Crop administration and treatments:

Seeds of snap bean "Paulista" were sown on 5^{th} of September in 2016 and 2017. Experiment plot area was 15 m^2 (5 rows × 5 m length × 60 cm width), two seeds were sown per hill and after two weeks from sowing seed, leaving only the most vigorous plants from the two seedlings. All of cultural practices (fertilization and pest management) were done as recommended by Egyptian Ministry of Agriculture and Land Reclamation.

The comprising treatments were 10 (potassium sources Table 3) as follow:

1. Control (without potassium)
2. Potassium fulvate
3. Potassium citrate
4. Potassium gluconate
5. Potassium humate
6. Potassium magnesium sulfate
7. Potassium nitrate
8. Potassium phosphite
9. Potassium silicate
10. Potassium sulfate

The treatments were applied as foliar spray as individual treatments with one concentration (1.5 g K/L), three times with 10 days' interval (30, 40 and 50 days after sowing seeds) in the two seasons.

Table 3. Chemical formula and constituents of potassium sources.

Title	Chemical formula	Chemical constituents
Potassium sulfate	K_2SO_4	50 % K_2O / 18 % S
Potassium nitrate	K NO_3	45 % K_2O / 11 % N
Potassium silicate	K_2SiO_3	10 % K_2O / 25 % Si
Potassium citrate	KCHO	38 % K_2O / Citric acid
Potassium gluconate	$C_6H_{11}KO_7$	16 % K_2O / Gluconic acid
Potassium phosphite	KH_2PO_3	42 % K_2O / 52 % P_2O_5
Potassium magnesium sulfate	$K_2SO_42MgSO_4$	22 % K_2O / 11 % Mg / 22 % S
Potassium humate		15 % K_2O / 65 % Humic acid
Potassium fulvate		10 % K_2O / 50 % Fulvic acid

Experiment design and statistical analysis:

Complete randomize bloke design (CRBD) with three replicates were used and Dunken test was applied at 5 % probability to determine differences among means by using Co-Stat software computer program (V.6.311).

Data collection:

The two outer rows were used for vegetative samples and the other rows used for yield and its components.

Plant growth parameters: Five plants were randomly chosen from each treatment plot at 60 days after sowing seeds for determining following traits: Plant height, total leaf area, total fresh weight and total dry weight

Leaf biochemical parameters:

Total nitrogen: it was determined by the modified microkeldahl method as described by Plummer, 1978.

Total phosphorous: it was determined calorimetrically according to Jackson, 1967.

Total potassium: it was determined using flame photometer as described by Piper, 1950.

Total chlorophylls (a + b): using spectrophotometer method according to Mackinny, 1941.

Yield components parameters*:* Green pods of five plants from each plot were harvested at the proper maturity stage, counted and weighed in each harvest and the following parameters were estimated:

Early yield (ton/fed),

Marketable yield (ton/fed),

Non-marketable yield (ton/fed) and

Total fresh green pods yield (ton/fed.).

Green pods quality parameters: Representative samples from green pods from each experimental plot were taken randomly for determining the following characteristics:

Pod chlorophylls: Chlorophyll a, b and total were determined according to Mackinny, 1941 by using spectrophotometer.

Carbohydrates content: It was determined according to Shaffer and Hartman, 1921.

Fibers content: It was determined according to method described in AOAC, 1984.

Protein content: It was determined according to Piper, 1947.

Titratable acidity: It was determined according to method described in AOAC, 1975.

Total Soluble Solids (T.S.S.): It was determined by a hand refract meter.

RESULTS AND DISCUSSION

Results

Plant growth parameters:

All studied parameters of snap bean vegetative growth (Table 4) were higher in 2017 season than 2016 due to the interaction between climatic data (Table 2) and plants response to K fertilizers. All sources of potassium fertilizers increased plant height, leaf area, total fresh eight as well as total dry weight compared to untreated plants in the two seasons of study. Potassium phosphite (KH_2PO_3) came in the first order followed by potassium silicate (K_2SiO_3) in achieving the best values of all growth attributes (without significant in 2017 season).

Table 4. Plant growth parameters of snap bean plants as affected by foliar applications of potassium sources.

Treatments	Plant height (cm)		Leaf area (cm^2/plant)		Total fresh weight (g)		Total dry weight (g)	
	2016	2017	2016	2017	2016	2017	2016	2017
Control	44.8 g	42.1 d	177.8 h	198.0 d	90.9 e	96.8 f	17.4 e	18.9 f
Potassium fulvate	46.5 f	54.4 c	183.2 g	207.9 c	95.1 bc	102.5 cd	18.3 b	20.1 bcd
Potassium citrate	47.3 de	56.5 bc	195.3 c	218.6 b	94.1 bcd	104.8 b	18.2 bc	20.4 b
Potassium gluconate	48.2 c	56.4 bc	194.3 cd	220.4 b	94.2 bcd	101.5 de	18.1 bc	19.9 d
Potassium humate	46.9 ef	54.4 c	186.2 f	209.8 c	93.6 cd	99.7 e	17.9 cd	19.4 e
Potassium magnesium sulfate	48.1 c	55.6 c	194.1 d	219.7 b	95.2 bc	101.7 cd	18.3 b	19.9 d
Potassium nitrate	47.5 d	55.5 c	188.5 e	219.6 b	92.5 de	103.6 bc	17.7 de	20.3 bc
Potassium phosphite	50.2 a	59.7 a	201.82 a	228.3 a	98.6 a	107.1 a	18.9 a	21.0 a
Potassium silicate	49.6 b	58.0 ab	198.0 b	225.3 a	95.6 b	106.9 a	18.3 b	20.8 a
Potassium sulfate	47.5 d	55.5 c	187.5 e	217.2 b	95.3 bc	101.6 d	18.3 b	19.9 cd

Means followed by the same letter in the same column are significantly different at the 5% level according to Duncan's multiple range test.

Leaf biochemical parameters:

In this study, spraying potassium treatments have positive influence on both mineral NPK and photosynthesis pigments content in snap bean leaves (Table 5) in the two seasons. Maximum values of N content in snap bean leaves were recorded in plants supplied with potassium nitrate followed by potassium Phi and potassium silicate (without significant differences) in both seasons. Snap bean plants treated with potassium Phi followed by potassium silicate (with significant differences between them) recorded the best values of P content in leaves in the two season. Moreover, potassium Phi followed by potassium sulfate (without significant differences between them) achieved the highest values of K content in leaves.

Table 5. Leaf biochemical parameters of snap bean plants as affected by foliar applications of potassium sources.

Treatments	N (%)		P (%)		K (%)		Total chlorophylls (mg/gm F. Wt.)	
	2016	2017	2016	2017	2016	2017	2016	2017
Control	1.89 g	2.43 g	0.309 h	0.209 h	1.85 g	2.18 g	8.40 e	8.95 g
Potassium fulvate	2.51 de	3.05 de	0.362 f	0.262 f	2.19 bc	2.52 bc	9.85 bc	10.50 cd
Potassium citrate	2.69 bcd	3.23 bcd	0.443 c	0.343 c	2.25 ab	2.58 ab	9.79 cd	10.66 bc
Potassium gluconate	2.02 fg	2.56 fg	0.331 g	0.231 g	1.96 f	2.29 f	9.54 cd	10.29 de
Potassium humate	2.35 ef	2.89 ef	0.350 fg	0.250 fg	1.96 f	2.29 f	10.28 ab	10.87 b
Potassium magnesium sulfate	2.45 de	2.99 de	0.437 c	0.337 c	2.03 ef	2.36 ef	9.59 cd	9.92 f
Potassium nitrate	3.10 a	3.64 a	0.387 e	0.287 e	2.09 de	2.42 de	9.37 d	10.09 ef
Potassium phosphite	2.97 ab	3.51 ab	0.506 a	0.406 a	2.29 a	2.62 a	10.61 a	11.54 a
Potassium silicate	2.86 abc	3.40 abc	0.485 b	0.385 b	2.17 cd	2.50 cd	9.90 bc	10.72 bc
Potassium sulfate	2.59 cde	3.13 cde	0.414 d	0.314 d	2.31 a	2.64 a	9.69 cd	10.29 de

Means followed by the same letter in the same column are significantly different at the 5% level according to Duncan's multiple range test.

Concerning photosynthetic pigments, external application with potassium phosphite is the superior followed by potassium humate then potassium silicate. In contrast, the control plants recorded the lowest values of either NPK content or total chlorophylls in 2016 and 2017 seasons.

Yield components parameters:

Different applied sources of K fertilizers significantly increased early and marketable yield as well as total yield of snap bean (green pods) compared with untreated plants (Table 6). Also, the highest early and total yield were recorded when plants treated with potassium Phi followed by potassium silicate (with significant deference between them) in both seasons. Concerning the marketable yield, potassium silicate superior all K sources. Moreover, the control plants achieved the lowest values of all previous parameters in two seasons of study.

Table 6. Yield components parameters of snap bean plants as affected by foliar applications of potassium sources.

Treatments	Early yield (ton/fed)		Marketable yield (ton/fed)		Total yield (ton/fed)	
	2016	2017	2016	2017	2016	2017
Control	1.600 d	1.660 e	4.238 e	4.079 c	4.987 e	4.799 c
Potassium fulvate	1.843 abc	1.833 cd	5.093 cd	5.053 b	5.507 cd	5.464 abc
Potassium citrate	1.813 bcd	1.953 bcd	5.455 bc	5.078 b	5.866 bcd	5.460 abc
Potassium gluconate	1.696 cd	1.813 d	4.962 d	4.655 bc	5.453 d	5.116 bc
Potassium humate	1.770 bcd	1.890 bcd	5.233 bcd	4.901 b	5.689 bcd	5.328 bc
Potassium magnesium sulfate	1.810 bcd	1.973 bc	5.456 bc	5.003 b	5.931 bc	5.446 abc
Potassium nitrate	1.720 cd	1.813 d	5.074 cd	4.809 b	5.457 d	5.171 bc
Potassium phosphite	2.036 a	2.233 a	5.595 b	5.157 b	6.712 a	6.131 a
Potassium silicate	1.986 ab	2.010 b	6.376 a	5.824 a	6.028 b	5.546 b
Potassium sulfate	1.776 bcd	1.833 cd	5.077 cd	4.919 b	5.519 cd	5.347 bc

Means followed by the same letter in the same column are significantly different at the 5% level according to Duncan's multiple range test.

Green pods quality parameters:

The obtained results confirmed that exogenous foliar application of all K sources significantly affected green pods quality parameters of snap bean plants represented in chlorophylls a, b and total chlorophylls, carbohydrates, fibers, TSS, protein as well as acidity (Table 7). The check plants recorded the lowest values of all quality attributes except fiber content in both season. The collected data illustrated that, plants sprayed with potassium Phi recorded the highest values of chlorophylls a, b and total chlorophylls, carbohydrates, TSS and acidity contents in pods followed by potassium silicate. Regarding protein percentage, potassium nitrate achieved the best values followed by potassium silicate and potassium citrate. However, plants foliar sprayed with potassium Phi gave the lowest values of fiber content compared with other K fertilizers and untreated plants in both seasons.

Table 7. Green pods quality parameters of snap bean plants as affected by foliar applications of potassium sources.

Treatments	Chlorophyll a (mg/gm F. Wt.)		Chlorophyll b (mg/gm F. Wt.)		Total Chlorophylls (mg/gm F. Wt.)		Carbohydrates (%)	
	2016	2017	2016	2017	2016	2017	2016	2017
Control	1.13 b	1.21 b	1.75 c	1.55 e	2.88 b	2.76 d	15.2 f	16.9 i
Potassium fulvate	2.06 a	2.28 a	2.59 ab	1.74 cde	4.65 a	4.02 c	16.0 cd	17.5 f
Potassium citrate	2.24 a	2.15 a	2.67 a	2.23 abcd	4.91a	4.38 bc	15.8 de	17.3 g
Potassium gluconate	1.95 ab	2.25 a	2.36 abc	1.72 de	4.31 a	3.97 c	15.6 e	17.1 h
Potassium humate	2.26 a	2.25 a	2.28 abc	1.91 bcde	4.54 a	4.16 c	17.1 a	18.8 a
Potassium magnesium sulfate	1.86 ab	2.15 a	2.58 ab	2.35 abc	4.45 a	4.51 bc	16.5 b	18.1 c
Potassium nitrate	2.05 a	2.15 a	2.55 ab	1.84 bcde	4.60 a	4.00 c	16.1 cd	17.7 e
Potassium phosphite	2.36 a	2.78 a	2.75 a	2.65 a	5.11 a	5.44 a	17.4 a	18.9 a
Potassium silicate	2.28 a	2.59 a	2.70 a	2.57 a	4.99 a	5.16 ab	16.6 b	18.2 b
Potassium sulfate	2.19 a	2.05 ab	1.96 bc	2.47 ab	4.15 a	4.52 bc	16.3 bc	17.9 d

Treatments	Fiber (%)		T.S.S (%)		Protein (%)		Acidity (%)	
	2016	2017	2016	2017	2016	2017	2016	2017
Control	15.5 a	16.5 a	6.4 j	6.7 j	2.42 c	2.53 c	0.42 e	0.53 f
Potassium fulvate	11.4 e	12.4 f	6.9 g	7.1 g	3.88 bc	3.53 bc	0.45 de	0.57 ef
Potassium citrate	11.9 d	13.0 e	6.8 h	7.0 h	4.49 b	4.26 b	0.55 b	0.67 bc
Potassium gluconate	13.7 b	14.9 b	6.6 i	6.9 i	4.37 b	4.06 b	0.54 bc	0.66 bcd
Potassium humate	13.7 b	14.5 c	7.6 c	7.8 c	3.73 bc	3.66 bc	0.42 e	0.54 f
Potassium magnesium sulfate	12.3 cd	13.2 e	7.4 d	7.7 d	4.28 b	4.53 b	0.46 de	0.58 ef
Potassium nitrate	10.0 d	13.2 e	7.1 f	7.3 f	6.65 a	6.53 a	0.49 cd	0.61 de
Potassium phosphite	8.7 g	9.5 h	7.9 a	8.2 a	4.03 b	4.33 b	0.65 a	0.77 a
Potassium silicate	9.3 f	10.5 g	7.7 b	7.9 b	4.72 b	4.50 b	0.59 b	0.71 b
Potassium sulfate	12.5 c	13.5 d	7.3 e	7.5 e	3.58 bc	3.53 bc	0.49 cd	0.61 cde

Means followed by the same letter in the same column are significantly different at the 5% level according to Duncan's multiple range test.

Discussion

All obtained data indicated that the external application of potassium sources significantly accelerated snap bean plants performance represented in vegetative growth (Table 4), leaf biochemical parameters (Table 5), yield components (Table 6) as well as green pods quality (Table7) as compared with the control plants. The mentioned positive response of foliar K sources may be due to the several and various impacts of K nutrient. In this concern, K nutrient is considered as a key role in plant growth functions, metabolism in different development stages and yield maturity, have many important regulatory process and increase the minerals uptake by plant roots (Marschner, 2012). Additionally, K nutrient is the most abundant in plant tissues with high mobility within short-distance transport (between individual cells or neighbor tissues) as well as its movement within long-distance translocation through xylem and phloem in plants (Marschner, 1995). K application have stimulatory effects on photosynthetic pigments content and synthesis through regulating stomata opening and closing which allow more gas exchange with atmosphere surrounding plants, thence, K fertilization absence stimulate decomposition of new chlorophylls synthesized process. Also, K involved rabidly in most metabolism processes which related with plant growth and its ability of tolerance to both a biotic and biotic stress (Oosterhuis *et al.,* 2014). Also, K plays basic role in improving N use efficiency (Jugal and Ramani, 2017). In addition, different K sources gave high significant increase for K content (Abd El-Baky *et al.,* 2010) in snap bean leaves in both seasons

Potassium phosphite superior all K sources in recording the highest values of all growth parameters. Our results are in agreement with Glinicki *et al.,* 2010 on atrawberry and Tambascio *et al.,* 2014 on potato. Phi can act as a biocide and affect plant production and productivity. Recently, Phi has been increasingly used as a supplemental fertilizer, pesticide, fungicide and a plant bio-stimulant (Achary *et al.,* 2017 and Wu *et al.,* 2019).

Foliar fertilizers such as potassium phosphite consisting a source of nutrients that permits to correct nutritional deficiencies, improves the physiological activity of plants, while stimulating the creation of natural mechanisms of defense (Nojosa *et al.,* 2005). The positive effect of potassium Phi or potassium silicate in increasing NPK content in plant leaves may be attributed to the rapid absorption by plant surfaces especially leaves (young or mature) of the two K sources and their elements components (K, P and Si) as well as translocation within the different plant tissues (Marschner, 1995).

The findings of the present study are in accordance with the findings of Zambrosi, 2016 and Zambrosi *et al.,* 2017 indicating that Phi had a significant effect on chemical composition and nutrient status of plants which reflected on N absorption and increasing its content (Gómez- Merino and Trejo-Téllez, 2015 and 2016). Also, Phi applications could contribute to increase the total P concentration in plant tissues (Avila *et al.,* 2013 and Thao and Yamakawa, 2009).

Concerning pod yield and quality, the simulative effect of K sources on snap bean yield attributes may be due to the previous enhanced plant growth (Table 4), minerals content as well as total chlorophylls (Table 5) and translocation from leaves and shoots to pods as the final and economic yield part. Nowadays, Phi is used as a potential inducer of beneficial metabolic responses in plants and an effective agent against different stress factors and has improved crop yield and quality. Advances in molecular, biochemical and physiological approaches have confirmed the role of Phi in improving both yield and quality of different horticultural species. Also, the superior effects of both potassium Phi and potassium silicate, this confirms that increased yield attributes of snap bean plants treated with K fertilizers is associated to photosynthetic assimilations processes (sugars) and translocation of these assimilates substances towards sink tissues in plants (Zhao *et al.,* 2001). Our results are in harmony with those obtained by Estrada-ortiz *et al.,* 2013 on strawberry; El-Mogy *et al.,* 2019 on pepper and Sidiky *et al.,* 2019 on sweet potato, found that Phi increased total yield, fruit size, fresh and dry matter and number of fruit.

In such case, main benefit of K to improve quality parameters was confirmed (Marschner, 1995) reported that, K play important role in carbohydrates metabolism by its effect on glucose and starch syntheses (Hawker *et al.,* 1979), sucrose syntheses (Berg *et al.,* 2009) and pyruvate kinase activity (Matoh *et al.,* 1988). Also, enhancement of colure formation in fruits by potassium fertilization (soil/foliar) may be due to its role in many enzymes activation, plant tissue wilting reduction as well as carbohydrates and starch formation of (Fageria *et al.,* 2009).

Potassium phosphite is recommended as a bio-stimulator to improve the yield, fruit size, fresh and dry biomass and quality of a number of important crop species in modern agriculture and used as a fertilizer to supply phosphorous to plants (Gonzalez *et al.,* 2010; Gómez-Merino and Trejo-Téllez, 2015 and Estrada-ortiz *et al.,* 2016). These results revealed the positive effects of potassium phosphite that phosphite has positive effects when added as a bio stimulator to improve the yield, quality and performance of different types of crops by activating a number of biochemical, physiological, molecular and mechanisms, stimulating plant metabolism, induction of plant defense responses, secondary metabolites and phyto-hormones that are important for plant performance in general.

Additionally, significant differences were observed among the different applied sources because of the supplementary elements or groups associated with K element. The superiority of K phosphite source may be due to the known activity of its (po_3) anion, since Pi and Phi are similar, though the lack of an O atom in Phi significantly changes the nature and reactivity of the resultant molecule.

Phosphite ($H_2PO_3^-$) is an isostere of the Pi anion, in which hydrogen replaces one of the oxygen atoms bound to the P atom (Varadarajan *et al.,* 2002). The three O atoms in the Phi molecule give this anion increased mobility in plant tissues through both the xylem and the phloem, so that it can be success- fully applied throughout the plant. Because of its higher solubility, Phi and K ions are more rapidly absorbed and translocated within plants (Ratjen and Gerendas, 2009 and Jost *et al.,* 2015). Moreover, the promotive effect of potassium silicate may be attributed to it contains K plus Si which play vital roles in regulatory functions in plants (Marschner, 1995) and promote desirable both plant chemical and physiological processes (Korndorfer and Lepsch, 2001).

The control plants (without K treated) may suffer from potassium deficiencies resulting poor plant growth, lost yield and low fruits quality. Our results are in harmony with Omar *et al.,* 2020 on squash, El-Mogy *et al.,* 2019 on sweet pepper, Vinas *et al.,* 2020 on tomato and Pela *et al.,* 2020 on soybean and cotton.

REFERENCES

Abd El-Baky, M.M.H.; Ahmed, A.A.; El-Nemr, M.A. and Zaki, M.F. (2010). Effect of potassium fertilizer and foliar zinc application on yield and quality of sweet potato. Research Journal of Agriculture and Biological Sciences, 6(4): 386-394.

Abdalla, M.G. (2016). Effect of horticultural practices on fruiting of some date palm cultivars under Assiut conditions.' Ph.D. Thesis, Fac. Agric., Assiut Univ., 164 p.

Abou El-Nour, E.A.A., (2002). Can supplemented potassium foliar feeding reduce the recommended soil potassium? Pak. J. Biol. Sci. 5:259-262.

Achary, V.M.M.; Ram, B.; Manna, M.; Datta, D.; Bhatt, A.; Reddy, M. and Agrawal, P.R. (2017). Phosphite: a novel P fertilizer for weed management and pathogen control. Plant Biotechnology Journal 1-16. https://doi.org/10.1111/pbi.12803 .

Al-Khateeb, A.A.; Al-Jabr, A.M. and Al-Jabr, A.M. (2006). Date Palm in Saudi Arabia. Date Palm Research Center, Ministry of Agriculture, Al-Hassa, Saudi Arabia 138p.

AOAC (1975). Association Agricultural Chemist, Washington, D.C., 200. Official Method of Analysis 12th Ed., 44: 94-117.

AOAC. (1984). Official Methods of Analysis. (15th Ed). pp 8-14. New York.

Avila, F.W.; Faquin, V.; da Silva L.A.K.; Ávila, P.A.; Marques, D.J.; Guedes, E.M.S. and Tan, Y.D.K. (2013). Effect of phosphite supply in nutrient solution on yield, phosphorus nutrition and enzymatic behavior in common bean (*Phaseolus vulgaris* L.) plants. Aust. J. Crop Sci. 7, 713-722.

Berg, W.K.; Cunningham, S.M.; Brouder, S.M.; Joern, B.C.; Johnson, K.D. and Volenec, J.J. (2009). Influence of phosphorus and potassium on alfalfa yield, taproot C and N pools, and transcript levels of key genes after defoliation. Crop Sci. 49, 974-982.

Cantwell, M. (2004). Beans, pp. 230-233. In: K.C. Gross, C.Y. Wang, and M. Saltveit (eds.). The commercial storage of fruits, vegetables, and florist and nursery crops, Agriculture Handbook 66. U.S. Department of Agriculture, Agricultural Research Service, Beltsville, MD. http://postharvest.ucdavis.edu/Produce/ProduceFacts/Veg/greenbeans.shtml .

El-Mogy, M.M.; Salama, A.M., Mohamed, H.F.Y.; Abdelgawad, K.F. and Abdeldaym, E.A. (2019). Responding of long green pepper plants to different sources of foliar potassium fertiliser. Agriculture (Polnohospodárstvo), vol. 65(2):59-76.

Estrada-Ortiz, E.; Trejo-Téllez, L.I.; Gómez-Merino, F.C.; Nú˜nez-Escobar, R. and Sandoval-Villa, M. (2013). The effects of phosphite on strawberry yield and fruit quality. J. Soil Sci. Plant Nutr. 13, 612-620.

Estrada-Ortiz, E.; Trejo-Téllez, L.I.; Gómez-Merino, F.C.; Silva-Rojas, H.V. and Avitia-García, E. (2016). Physiological responses of chard and lettuce to phosphite supply in nutrient solution. J. Agr. Sci. Tech., 18: 1079-1090.

Fabbri, A.D.T. and Crosby. G.A. (2016). A review of the impact of preparation and cooking on the nutritional quality of vegetables and legumes. International Journal of Gastronomy and Food Science 3:2-11.

Fageria, N.K.; Filho, B.M.P.; Moreira, A. and Guimarães, C.M. (2009). Foliar fertilization of crop plants. J. Plant Nutr. 32(6): 1044-1064.

Geng, J. et al. (2015). Synchronized relationships between nitrogen release of controlled release nitrogen fertilizers and nitrogen requirements of cotton. Field Crops Res. 184, 9-16.

Glinicki, R.; Sas-Paszt, L. and Jadczuk-Tobjasz, E. (2010). The effect of plant stimulant/fertilizer resistim on growth and development of strawberry plants. J. Fruit Ornam. Plant Res. 18, 111-124.

Gomez-Merino, F.C. and Trejo-Téllez, L.I. (2015). Biostimulant activity of phosphite in horticulture, Scientia Horticulturae, 196: 82-90. https://doi.org/10.1016/j.scienta.2015.09.035 .

Gomez-Merino, F.C. and Trejo-Téllez, L.I. (2016). Conventional and novel uses of phosphite in horticulture: potentialities and challenges. Italus Hortus 23 (2), 1-13.

Gonzalez, C.; Zheng, Y. and Lovatt, C.J. (2010). Properly timed foliar fertilization can and should result in a yield benefit and net increase in grower income. Acta Hortic., 868: 273-286.

Hawker, J.S.; Marschner, H. and Krauss, A. (1979). Starch synthesis in developing potato tubers. Physiol. Plant. 46, 25-30.

Jackson, M.L. (1967). Soil Chemical Analysis, Prentice Hall of India Private Ltd., New Delhi, pp. 66-90.

Jost, R.; Pharmawati, M.; Lapis-Gaza, H.R.; Rossig, C.; Berkowitz, O.; Lambers, H. and Finnegan, P.M. (2015). Differentiating phosphate-dependent and phosphate-independent systemic phosphate-starvation response networks in Arabidopsis thaliana through the application of phosphite. J. Exp. Bot. 66, 2501-2514, http://dx.doi.org/10.1093/jxb/erv025 .

Jugal, K. and Ramani P.V. (2017). Effect of silicon on nitrogen use efficiency, yield and N and Si contents in rice under loamy sand soil. Malav. Res. J. Chem and Environ, 21(4): 110-118.

Korndörfer, G.H. and Lepsch, I. (2001). Effect of silicon on plant growth and crop yield. In: Silicon in Agriculture: Studies in Plant Science, 8: 115-131.

Lester, G.E.; Jifon, J.L. and Makus, D.J. (2006). Supplemental foliar potassium applications with or without a surfactant can enhance netted muskmelon quality. Horticultural Science, 4:741-744.

Mackinny, G. (1941). Absorption of light by chlorophyll solution. J. Biol. Chem., 140:315-322.

Magen, H. (2004). Potassium in fertigation systems, International Potash Institute (IPI), 5th Fertigation Training Course, Boading, AUH.

Malavolta, E. (2006). Manual de nutrição mineral de plantas. Agronômica Ceres.

Marchand, M. and Bourrié, B. (1999). Use of potash fertilizers through different application methods for high yield and quality crops. Developments in Plant and Soil Sciences, 86(1): 13-17.

Marschner, H. (1995): Mineral nutrition of higher plants. Academic Press, London.

Marschner, H. and Marschner, P. (2012). Marschner's mineral nutrition of higher plants: Academic press.

Marschner, P. (2012). Mineral Nutrition of Higher Plants, 3rd ed.; Academic Press: London, UK, pp. 178-189.

Matoh, T.; Yasuoka, S.; Ishikawa, T. and Takahashi, E. (1988). Potassium requirement of pyruvate kinase extracted from leaves of halophytes. Physiol. Plant. 74, 675-678.

Mengel, K. and Kirkby, E.A. (2001). Principles of Plant Nutrition. 5th ed. Kluver Academic Publishers, Netherlands.

Moody, P.W. and Bell, M.J. (2006). Availability of soil potassium and diagnostic soil tests. Soil Research, 44(3) 265-275.

Nojosa, G. B. de A., Resende, M. L. V., & Resende, A. V. (2005). Uso de fosfitos e silicatos na indução de resistência. In L. Cavalcanti, R. M. Di-Piero, S. F. Pascholati, M. L. V. de Resende, & R. da S. Romeiro (Eds.), Indução de resistência em plantas a patógenos e insetos (p. 263). Piracicaba: FEALQ.

Omar, M.M.; Taha, A.A. and Shokir, S.A. (2020). Effect of Applying Potassium Phosphite with Potassium Fulvate on Plant Growth. J. of Soil Sciences and Agricultural Engineering, Mansoura Univ., Vol. 11 (7):255-263.

Oosterhuis, D.M.; Loka, D.A.; Kawakami, E.M. and Pettigrew, W.T. (2014). Chapter Three - The Physiology of Potassium in Crop Production, Editor(s): Donald L. Sparks, Advances in Agronomy, Academic Press, Volume 126,203-233. https://doi.org/10.1016/B978-0-12-800132-5.00003-1 .

Pelá, A.; Miyazawa, M.; Gil, L.G.; Broch, D.; Arf, M.; Reis Jr, R.A. and Tiski, I. (2020). Enhanced Efficiency Potassium Fertilizer in Soybean and Cotton Crop. American Journal of Agricultural and Biological Sciences, 15(1), 118-125. https://doi.org/10.3844/ajabssp.2020.118.125 .

Piper, C.S. (1950). Soil and plant analysis. Univ. Adelied. Intersciece Published, Inc. New York, p. 258-275.

Piper, G.S. (1947). Soil and plant analysis. The Univ. of Adelaide, Adelaide.

Plummer, D.T. (1978). An introduction to practical biochemistry, 2nd Ed. McGraw-Hill Book Company (U.K.) Ltd., London.

Ratjen, A.M. and Gerendás, J. (2009). A critical assessment of the suitability of phosphite as a source of phosphorus. J. Plant Nut. Soil Sci., 172(6), 821-828.

Roemheld, V. and El-Fouly, M.M. (1999). Foliar nutrient application challenge and limits in crop production. Proceedings of the 2nd International Workshop on Foliar Fertilization, Bangkok, Thailand, 4-10.

Rosolem, C.A.; Sgariboldi, T.; Garcia, R.A. and Calonego, J.C. (2010). Potassium leaching as affected by soil texture and residual fertilization in tropical soils. Communications in soil science and plant analysis, 41(16) 1934-1943.

Salim, B.B.M.; Abd El-Gawad, H.G. and Abou El-Yazied, A. (2014). Effect of foliar spray of different potassium sources on growth, yield and mineral composition of potato (*Solanum tuberosum* L.). Middle East J. Appl. Sci., 4(4): 1197-1204.

Seif, Y.I.A.; El-Miniawy, S.D.; Abu El-Azm, N.A.I. and Hegazi, A.Z. (2016). Response of snap bean growth and seed yield to seed size, plant density and foliar application with algae extract. Ann. Agric. Sci. 61:187-199. https://doi.org/10.1016/j.aoas.2016.09.001.

Shaffer, P.A. and Hartmann, F.A. (1921). The iodometric determination of copper its use sugar analysis. II. Methods for determination of reducing sugars in blood, urine, milk and other solutions. J. Biol. Chem., 45,365.

Sidiky, B.; Zoumana, K.; E.Brice ; D.K. and Martial, K.J.H. (2019). Effect of the organic and NPK fertilizers on the growth and yield of sweet potato (*Ipomoea batatas* Lam) in the Centre of Côte d'Ivoire. Asian J. Soil Sci. Plant Nutri., 4(3):1-14.

Tambascio, C.; Covacevich, F.; Lobato, M.C.; de Lasa, C.; Caldiz, D., Dosio, G. and Andreu, A. (2014). The application of K phosphites to seed tubers enhanced emergence, early growth and mycorrhizal colonization in potato (*Solanum tuberosum*). Am. J. Plant Sci. 5, 132–137, http://dx.doi.org/10.4236/ajps.2014.51017 .

Thao, H.T.B. and Yamakawa, T. (2009) Phosphite (phosphorous acid): Fungicide, fertilizer or bio-stimulator? Soil Science and Plant Nutrition, 55:2, 228-234.

Trail, M.A.; Wahem, I.A. and Bizri. J.N. (1992). Green bean quality changed minimally when stored in low-density polyolefin film package. Journal of Food Science. 57:977-979.

Varadarajan, D.K.; Karthikeyan, A.S.; Matilda, P.D. and Raghothama, K.G. (2002). Phosphite, an analog of phosphate, suppresses the coordinated expression of genes under phosphate starvation. Plant Physiol. 129, 1232-1240.

Vinas, M.; Mendez, J.C. and Jiménez, V.M. (2020). Effect of foliar applications of phosphites on growth, nutritional status and defense responses in tomato plants, Scientia Horticulturae, 265, 109200, https://doi.org/10.1016/j.scienta.2020.109200 .

Weinbaum, S.; Niederholzer, F.; Ponchner, S.; Rosecrance, R.; Carlson, R.; Whittlesey A. and Muraoka, T. (1994). Nutrient uptake by cropping and defruited field-grown French'prune trees.' Journal of the American Society for Horticultural Science 119 (5): 925-930.

Wu, L.; Gao, X.; Xia, F.; Joshi, J.; Borza, T. and Wang-Pruski, G. (2019). Biostimulant and fungicidal effects of phosphite assessed by GC-TOF-MS analysis of potato leaf metabolome. Physiol. Mol. Plant Pathol. 106, 49-56.

Yang, G.; Tang, H.; Tang, J.; Nie, Y. and Zhang, X. (2012). Effect of fertilization frequency on cotton yield and biomass accumulation. Field Crops Res. 125, 161-166.

Zambrosi, F.C.B. (2016). Phosphite and phosphate have contrasting effects on nutrient status of plants. J. Crop Improv., 30(4), 421-432.

Zambrosi, F.C.B.; Mesquita, G.L.; Menino, G.; Tanaka, F.A.; Mattos, D. and Quaggio, J.A. (2017). Anatomical and ultrastructural damage to citrus leaves from phosphite spray depends on phosphorus supply to roots. Plant Soil, 418(1-2), 557-569.

Zhao, Z.; Chen, G. and Zhang, C. (2001) Interaction between reactive oxygen species and nitric oxide in drought-induced abscisic acid synthesis in root tips of wheat seedlings. Aust. J Plant. Physiol. 28:1055-1061.

العلاقة بين تنوع مصادر التسميد بالبوتاسيوم وتحسين جودة قرون الفاصوليا الخضراء المنتجة للتصدير

ولاء محمد السعيد سويلم[1] و عبدالبصير السيد عبدالبصير[2]

[1] قسم الخضر والزينة ـ كلية الزراعة ـ جامعة المنصورة ـ مصر.

[2] قسم بحوث محاصيل الخضر الذاتية التلقيح ـ معهد بحوث البساتين ـ مركز البحوث الزراعية ـ جيزة ـ مصر.

تزرع الفاصوليا فى العروة الشتوية بهدف الحصول على القرون الخضراء ذات المحتوى المنخفض من الألياف والعالي من المعادن والكربوهيدرات للتصدير أو للأسواق المحلية. وتستجيب الفاصوليا بشكل أفضل للأسمدة الورقية وخاصة البوتاسيوم كعنصر جودة. وفي هذا الصدد تم إجراء تجربتين لمعرفة تأثير مصادر مختلفه من الأسمدة البوتاسية المنتشرة في مصر لتحديد أنسب مصدر من أسمدة البوتاسيوم الذي يحقق أعلى كمية من المحصول وجودة القرون الخضراء تحت ظروف التربة الطينية فى أقليم الدلتا. شملت التجربة تسعة مصادر لأسمدة البوتاسيوم مرتبة في تصميم القطاعات العشوائية الكاملة بثلاث مكررات. أوضحت النتائج أن هناك فروق معنوية بين معظم مصادر البوتاسيوم في معظم الصفات المدروسة. كما أظهرت النتائج أن معاملة البوتاسيوم فوسفيت سجلت أفضل النتائج من حيث النمو الخضري والتركيب الكيماوى للأوراق والقرون يليه سيليكات البوتاسيوم (دون وجود فروق معنوية بينهما في معظم الحالات). كما تم الحصول على أقصى إنتاج مبكر وانتاج كلي من القرون الخضراء من التسميد الورقى بالبوتاسيوم فوسفيت بينما تم تسجيل أقصى إنتاجية للقرون القابلة للتسويق من استخدام سيليكات البوتاسيوم. وحيث أن التجربة أجريت في مكان واحد ولمدة موسمين لذا فإن تكرار التجربة في كثير من المواقع (أنواع تربة مختلفة) وكذلك اختبار أسمدة بوتاسيوم جديدة سيساعد على استخلاص توصيات للمزارعيين وتحقيق أفضل استخدام لوحدة التسميد بالإضافة إلى صفات القرون الممتازة الصالحة للتسويق والتخزين.

الكلمات الدالة: الفاصوليا ، البوتاسيوم فوسفيت ، التسميد ، القرون الخضراء.