Journal of Soil Sciences and Agricultural Engineering

Journal homepage: www.jssae.mans.edu.eg
Available online at: www.jssae.journals.ekb.eg

Effect of Applying Potassium Phosphite with Potassium Fulvate on Plant Growth

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ABSTRACT

A pot experiment was conducted to study the response of squash (*cucurbita pepo L.*) to potassium phosphite and potassium fulvate as single treatments or in a combination with each other. The treatments included: potassium phosphite as a single treatment at four concentrations (C1: 0, C2: 0.1, C3: 0.2 and C4: 0.4 ml plant^{-1}), potassium fulvate as a single treatment at four concentrations (C1: 0, C2: 6, C3: 9 and C4: 12 kg fed^{-1}), and the combined treatment of potassium phosphite with potassium fulvate at four concentrations (C1:0, C2: 0.05+3, C3: 0.1+4.5 and C4: 0.2 ml plant^{-1}+6 kg fed^{-1}, respectively using soil and foliar applications. The results indicated that the combined treatment of potassium phosphite with potassium fulvate was more effective in increasing of all investigated parameters. At the flowering stage, the highest values of fresh weight (214.96g), dry weight (13.31g), plant length (70.83cm), total leaf area (2547.12cm^2) and the nutrients concentrations of (N, P and K%) (5.17,0.72 and 6.50%) were achieved with the combined treatment at C3 using soil application. At the harvesting stage, the highest values of fresh, dry weigh, total leaf area and (N, P and K) were 346.87g, 29.00g, 4720.56cm^2 and (3.95, 0.62 and 4.43%), respectively, using the combined treatment at C2 as soil application, while the value of plant length was (88.67cm) with the combined treatment at C3 using soil application. The highest values of total yield, dry weight and the characteristics of squash fruit (length, diameter and weight) were 475.67g,19.13g and (16.30cm, 3.63cm and 115.95g), respectively using the combined treatment as foliar application at C3, the combined treatment at C2 as soil application gave the highest values of N,P and K in fruits, these values were 4.12,0.71 and 5.99%. Also, the highest values of available N, P and K mg kg^{-1} and OM content gkg^{-1} were 70.70, 12.83 and 423.73 mg kg^{-1} and 13.5 gkg^{-1}, respectively with the combined treatment at C4 using soil application.

Keywords: Potassium phosphite, Potassium fulvate, Squash plant

INTRODUCTION

Squash (*cucurbita pepo L .*) is a very important crop because it is the richest source of macro- and micro-nutrients, in addition to natural antioxidants such as phenols, beta-carotene and vitamins c. Squash grows at all four seasons, the total cultivated area reached by 91 thousands fed, producing about 699 thousand tons with an average 7.67 tons/fed (Abd El-Aal *et al*., 2010; Eissa *et al*., 2013). Potassium phosphite: KPhi (KH_2PO_3) 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, as a bio-stimulator to enhance resistance against abiotic stress factors such as drought or water-logged soils, in addition to enhance resistance against biotic stress factors caused by various species of plant pathogens through improving the defense responses of plants, including the production of hormones, enzymes and antibodies involved in defense. Additionally, KPhi used as a fertilizer to supply phosphorous to plants (Gonzalez *et al*., 2010; Gonçalves *et al*., 2015; Gómez-Merino and Trejo-Téllez, 2015; Estrada-ortiz *et al*., 2016). Phosphite (Phi) is a less oxidized form of phosphorus than phosphate (Pi) with one less oxygen (O) than Pi. Phosphorous is bonded with four oxygen atoms to form Pi molecule, while Phi has three oxygen atoms. Phosphite salts are more soluble than Pi, the three O atoms in the phi molecule give this anion increased mobility in plant tissues, phi is easily absorbed and transported through both the xylem and the phloem to all areas of the plant, as it is usually formulated as a soluble form, which increases its mobility in soil (McDonald *et al*., 2001; Gómez-Merino and Trejo-Téllez, 2016). KPhi product resulting from the neutralization of phosphoric acid with the base of KOH (Ratjen and Gerendas, 2009).

Fulvic acid (FA) is slightly polymerized form of humic acid, also known as humic materials with a high oxygen content and low molecular weight. Fulvic acids are compounds with aromatic organic acids and weak aliphatic chains that are soluble in water in all pH conditions (alkaline, neutral and acidic). Fulvic acid has an oxygen content twice that of humic acid and has many hydroxyl (-OH) and carboxyl (-COOH) groups, which make it more chemically reactive. FA can easily enter plant roots, stems, and leaves due to the comparatively little size of the molecules (Pettit, 2004; Wang *et al*., 2015). Humates are mineral salts of fulvic acid or humic acid, which are products rich in carbon, produced by treating FA or HA with KOH or NaOH (Bremner & Harada, 1959; Pettit, 2004). Humic substances have many positive effects on crops, including reducing mineral fertilizers application, replacing synthetic plant regulators, improving seedling health, early growth and flowering, enhancing tolerance to abiotic and

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DOI: 10.21608/jssae.2020.109423

biotic stress factors, and increasing nutrient uptake and utilization, yield and quality of plants. Benefits of HS due to their ability to form complex metal ions and form aqueous complexes with micronutrients and can also form an enzymatically active complex, which can be performed on reactions that are assigned to microorganisms metabolic activity (Peňa-Méndez *et al*, 2005; Selim and Mosa, 2012; Naidu *et al*., 2013; Denre *et al*., 2014; Canellas *et al*., 2015). Humic subctances absorbed by the roots and transported to shoots, promoting the growth of the whole plant through the actions of plant growth promoting hormones, including auxins, cytokinins, and gibberellins. The effects of HS may be depended on several factors, including the normal source and rates of HS, soil pH and plant species (Karaca *et al*., 2006). Also, HS have many positive roles in soil as stable aggregates formation, soil surface protection and high water holding capacity, nutrients immobilization and release, increasing ion exchange capacity and activity of microorganisms in the soil, and reducing the emissions of CO_2 (Walsh and McDonnell, 2012; Wright and Lenssen, 2013; Farid *et al*., 2018).

This research aimed to study the response of squash plant grown to potassium phosphite with potassium fulvate as single treatments or in a combination with each other at different levels using foliar and soil applications as well as to study their effects on plant growth parameters, yield, fruit characteristics, nutrients content (NPK %) and soil properties.

MATERIALS AND METHODS

To achieve the previous aim, a pot experiment was carried out on squash (*Curcurbita pepo L.*) plant grown on alluvial soil at the Experimental Farm of the Faculty of Agriculture, Mansoura University to evaluate response of squash to different levels of potassium phosphite with potassium fulvate as single treatments or in a combination with each other at different levels using foliar and soil applications. Soil samples were collected from the surface layer (0-30 cm) from the experimental of the Faculty of Agric., Mansoura to represent an alluvial soil; the collected samples were air-dried, crushed and passed through a 2 mm. These samples were analyzed for their physical and chemical properties according to Klute (1986) and Sparks *et al*., (1996) and the results are presented in table 1.

Table 1. Physical and chemical characteristics of the studied soil.

Soil characteristics	Values	Soil characteristics			Values
Sand (%)	22.65	Soluble ions**	Soluble cations (mmolc L^{-1})	Ca^{++}	5.50
Silt (%)	24.65			Mg^{++}	2.90
Clay (%)	52.70			Na^+	4.60
Soil texture	clay			K^+	2.00
Field capacity (%)	36.0		Soluble anions (mmolc L^{-1})	$CO_3^{=}$	0.00
Saturation (%)	72.0			HCO_3^-	0.90
Calcium carbonate (g kg^{-1})	30			Cl^-	7.90
OM (g kg^{-1})	11			$SO_4^{=}$	6.20
pH*	7.80				
EC** (dSm^{-1})	1.50	Available (mg.kg^{-1})		N	60.70
				P	10.91
				K	284.30

***Soil pH was determined in soil paste.**
****Soil electrical conductivity (EC) and soluble ions were determined in soil paste extract.**

The used experimental design was a split – split plot design with three replicates. The main treatments were two methods of application (foliar and soil applications). Sub treatments were potassium phosphite as a single treatment, potassium fulvate as a single treatment and potassium phosphite with potassium fulvate as a combined treatment. Sub sub treatments were four concentrations for each treatment (0,0 (control), 0.1 ml $plant^{-1}$, 0.2 ml $plant^{-1}$ and 0.4 ml $plant^{-1}$ of potassium phosphite as a single treatment), (0,0 (control), 6 kg fed^{-1}, 9 kg fed^{-1} and 12 kg fed^{-1} of potassium fulvate as a single treatment), and (0,0 (control), 0.05 ml $plant^{-1}$+ 3 kg fed^{-1}, 0.1 ml $plant^{-1}$+4.5 kg fed^{-1} and 0.2 ml $plant^{-1}$+6 kg fed^{-1} of potassium phosphite with potassium fulvate, respectively as a combined treatment). Irrigation water was applied to reach the field capacity and the assumed field capacity was readjust two times every week. Mineral fertilizers were applied at rates of 100 kg fed^{-1} ammonium nitrate, 50 kg fed^{-1} super phosphate and 100 kg fed^{-1} potassium sulphate.

RESULTS AND DISCUSSION

1- Fresh, dry weight, plant lengeth, total leaf area and nutrients content of squash plant as affected by different levels of potassium phosphite and potassium fulvate as single treatments or as a combined treatment using soil and foliar applications.

Data illustrated in Table 2 show the effect of potassium phosphite and potassium fulvate as single treatments or as a combined treatment on the values of fresh, dry weight (g pot^{-1}), length (cm), total leaf area (cm^2) and nutrients content (%) of squash plant grown on alluvial soil using soil and foliar applications at the flowering stage after 40 days from planting. Generally, the fresh & dry weight, total leaf area and nutrients content of squash plant increased significantly with the combined treatment of potassium phosphite with potassium fulvate compared to other single treatments and controls. The soil application was more effective on studied parameters of squash plant than foliar application.

From data in Table 2, it was found that the highest values of plant fresh weight, dry weight and total leaf area were achieved by the combined treatment of potassium phosphite with potassium fulvate at C3 (0.1 ml $plant^{-1}$+4.5 kg fed^{-1}), they were (214.96g) & (207.69g) for fresh weight, (13.31g) & (12.66g) for dry weight and (2547.12 cm^2) & (2545.03 cm^2) for total leaf area using soil and foliar methods of application, respectively. The highest values of plant length were (70.83cm) & (62.67cm) with the combined treatment of potassium phosphite with potassium fulvate at C3 (0.1 ml $plant^{-1}$+4.5 kg fed^{-1}) as soil and foliar applications, respectively, and they were (71.00cm) & (61.67cm) with potassium fulvate as a single treatment at C2 (6 kg fed^{-1}) as soil application and at C3 (9 kg fed^{-1}) as foliar application, respectively. With potassium phosphite as a single treatment, the highest values of plant length were (63.67cm) at C2 (0.1 ml $plant^{-1}$) as soil application and (59.00 cm) at C3 (0.2 ml $plant^{-1}$) as foliar application, compared with controls.

Table 2. Fresh, dry weight, plant length, total leaf area plant^{-1} and nutrients content of squash plant as affected by different levels of potassium phosphite and potassium fulvate as single treatments or as a combined treatment at the flowering stage after 40 days from planting using soil and foliar applications.

Char. Treat.	Concentration (C)	Fresh Weight (g)	Dry weight (g)	Plant length (cm)	Total leaf area plant^{-1} (cm^2)	Nutrients content of squash plant (%) N (%)	P (%)	K (%)
Foliar spray application (B)								
Potassium phosphite	C1, control	94.45	7.65	48.00	1267.64	3.77	0.45	5.16
	C2, (0.1 ml plant^{-1})	119.79	7.80	50.33	1503.58	3.98	0.49	5.25
	C3, (0.2 ml plant^{-1})	177.71	11.23	59.00	2156.33	4.47	0.54	5.38
	C4, (0.4 ml plant^{-1})	157.42	9.78	53.67	2125.72	4.11	0.50	4.79
Mean		137.34	9.12	52.75	1763.32	4.08	0.49	5.14
Potassium fulvate	C1, control	113.19	7.47	57.00	1382.72	3.97	0.49	5.30
	C2, (6 kg fed^{-1})	205.67	12.45	60.00	2458.12	5.03	0.49	6.36
	C3, (9 kg fed^{-1})	156.70	9.69	61.67	2060.43	4.75	0.52	5.65
	C4, (12 kg fed^{-1})	133.13	8.05	57.67	1629.61	4.75	0.48	5.38
Mean		152.17	9.41	59.08	1882.72	4.63	0.50	5.67
Potassium phosphite with Potassium fulvate	C1, control	76.60	5.15	51.33	1054.72	3.04	0.48	5.25
	C2, (0.05 ml plant^{-1} + 3 kg fed^{-1})	182.58	10.16	61.00	1605.71	4.37	0.53	5.57
	C3, (0.1 ml plant^{-1} +4.5 kg fed^{-1})	207.69	12.66	62.67	2545.03	5.09	0.58	6.45
	C4, (0.2 ml plant^{-1} +6 kg fed^{-1})	153.82	10.09	56.00	2069.82	4.83	0.56	5.01
Mean		155.17	9.52	57.75	1818.82	4.33	0.54	5.57
Soil application (B)								
Potassium phosphite	C1, control	176.66	9.84	60.00	1744.31	4.07	0.51	5.30
	C2, (0.1 ml plant^{-1})	180.73	10.03	63.67	2162.80	4.99	0.69	5.89
	C3, (0.2 ml plant^{-1})	173.81	9.37	61.33	1746.14	4.81	0.57	5.18
	C4, (0.4 ml plant^{-1})	132.51	8.36	54.67	1607.02	4.55	0.53	5.26
Mean		165.93	9.40	59.92	1815.07	4.61	0.58	5.41
Potassium fulvate	C1, control	124.55	7.21	56.33	1460.29	3.87	0.47	5.28
	C2, (6 kg fed^{-1})	212.85	13.22	71.00	2470.68	5.11	0.58	6.31
	C3, (9 kg fed^{-1})	202.89	11.29	70.67	2299.51	4.81	0.57	6.41
	C4, (12 kg fed^{-1})	187.93	10.64	60.00	2251.52	4.51	0.52	5.48
Mean		182.06	10.59	64.50	2120.50	4.58	0.54	5.87
Potassium phosphite with Potassium fulvate	C1, control	98.22	6.49	52.33	1645.41	3.87	0.49	5.13
	C2, (0.05 ml plant^{-1} + 3 kg fed^{-1})	193.33	10.83	66.67	2244.91	4.65	0.59	6.22
	C3, (0.1 ml plant^{-1} +4.5 kg fed^{-1})	214.96	13.31	70.83	2547.12	5.17	0.72	6.50
	C4, (0.2 ml plant^{-1} +6 kg fed^{-1})	155.27	9.94	55.33	2112.52	4.85	0.61	5.23
Mean		165.45	10.14	61.29	2137.49	4.64	0.60	5.77
L.S.D. at 5%								
Treatments (A)		21.86	1.21	2.27	201.23	0.12	0.03	0.18
Application methods (B)		28.66	0.70	6.63	107.11	0.24	0.07	0.33
Concentration (C)		21.15	1.22	3.53	217.48	0.21	0.04	0.24
Interaction (ABC)		51.80	3.00	8.64	532.72	0.50	0.11	0.59

These results reveal the positive effects of potassium phosphite and potassium fulvate, which can be explained as mentioned by Gómez-Merino and Trejo-Téllez, (2015; 2016) who stated that phosphite has positive effects when added as a biostimulator to improve the yield, quality and performance of different types of crop, by activating a number of molecular, biochemical and physiological mechanisms, induction of plant defense responses, stimulating plant metabolism and phytohormones and secondary metabolites that which are important for plant growth and increasing P content in the whole plant (Lovatt and Mikkelsen 2006). Likewise, Wright and Lenssen, (2013) reported that fulvic acid can be used as plant biostimulants to enhance nutrient uptake and utilization, seedling health, crops quality, plant height, yield, and dry or fresh weight, due to FA has high oxygen content, low molecular weight, oxygen content twice that of humic acid and many hydroxyl (-OH) and carboxyl (-COOH) groups, which make it more chemically reactive and increased its exchange capacity. In addition, it is soluble in water in all pH conditions and can easily enter plant roots, stems, and leaves due to the comparatively little size of the molecules (Pettit, 2004; Wang *et al*., 2015). Also, Benefits of humic substances (HS) due to their ability to form complex metal ions and form aqueous complexes with micronutrients and can also form an enzymatically active complex (Peňa-Méndez *et al*, 2005; Naidu *et al*., 2013; Denre *et al*., 2014). HS absorbed by the root and transported to shoots, promoting the growth of the whole plant through the actions of plant growth promoting hormones, including auxins, cytokinins, and gibberellins (Karaca *et al*., 2006). Also, Phi contains one less oxygen (O) than Pi. Phosphorous is bonded with three oxygen atoms to form Phi molecule, These three O atoms in the phi molecule give this anion increased mobility in the whole plant tissues, also phi is easily absorbed and transported through both the xylem and the phloem to all areas of the plant because of its high solubility, Non-biological oxidation of Phi to Pi gradually in plant (McDonald *et al*., 2001; Gómez-Merino and Trejo-Téllez, 2016). The finding of the present study is in agreement with Glinicki *et al*., (2010); Tambascio *et al*., (2014); Constán-Aguilar *et al*., (2014) who found that phi-containing products stimulated the parameters of growth, leaf area, fresh and dry weight when adding under sufficient conditions for P in the medium of growth. Also, these results are in harmony with the finding of Sharaf El-Dine *et al*., (2011); Suh *et al*., (2014); Esringü *et al*., (2015); Taha *et al*., (2016); Abdel-Baky *et al*., (2019) who found that fulvic acid increased all parameters of plant growth.

With soil application, the highest values of (N, P and K %) were (5.17,0.72 and 6.50 %, respectively) with the combined treatment of potassium phosphite with potassium fulvate at C3 (0.1 ml plant^{-1}+ 4.5 kg fed^{-1}), followed by (5.11, 0.58 and 6.31%, respectively) with potassium fulvate as a single treatment at C2 (6 kg fed^{-1}), and (4.99, 0.69 and 5.89 %, respectively) with potassium phosphite as a single treatment at C2 (0.1 ml plant $^{-1}$). With foliar application, the highest values of N, P and K % were 5.09, 0.58 and 6.45 %, respectively with the combined treatment of at C3 (0.1 ml plant^{-1}+ 4.5 kg fed $^{-1}$), followed by 5.03, 0.49 and 6.36 % with potassium fulvate as a single treatment at C2 (6 kg fed $^{-1}$), and 4.47, 0.54 and 5.38 %, respectively with potassium phosphite as a single treatment at C3 (0.2 ml plant^{-1}). Therefore, it can be concluded that the addition of potassium phosphite in a combination with potassium fulvate induced positive effects on N, P and K (%) content in squash plant. The finding of the present study is in accordance with Constán-Aguilar *et al*., (2014); Estrada-ortiz *et al*., (2016); Zambrosi *et al*., (2016); Zambrosi *et al*., (2017) who found that Phi had a significant effects on nutrient status of plants under Pi-sufficient supply, which they attributed to stimulatory effects of Phi on N absorption, and increasing of total tissue P concentration is due to the greater mobility of Phi within the plant and phi-absorption by Pi transporters (Gómez-Merino and Trejo-Téllez, 2015;2016). These results are also consistent with the results of Khalil *et al* ., (2011); Samavat and Samavat, (2014); Taha *et al*., (2016); Diab *et al*., (2017) who found that fulvic acid increased nutrients concentration in all plant studied.Data of Table 3 show that soil application was more effective than foliar application on squash plant parameters at the harvesting stage after 70 days from planting. The results under the combined treatment were higher than the results under potassium fulvate and potassium phosphite as single treatments, while the lower values for studied parameters of squash plant were obtained at controls (without potassium fulvate or potassium phosphite).

As shown in Table 3, with soil application, the highest values of fresh, dry weight, total leaf area and (N, P and K%) of squash plant were achieved by the combined treatment of potassium phosphite with potassium fulvate at C2 (0.05 ml plant^{-1}+ 3 kg fed^{-1}), these values were (346.87g), (29.00 g) and (4720.56 cm^2), (3.95, 0.62 and 4.43 %) respectively, while the highest value of plant length was (88.67 cm) with the combined treatment at C3 (0.1 mm plant^{-1}+4.5 kg fed^{-1}). On the other hand, with foliar application, the highest values were (333.30 g) for fresh weight, (23.80 g) for dry weight, (87.67 cm) for length (3526.64 cm^2) for total leaf area and (3.67, 0.62 and 4.13 %) for (N, P and K%), with the combined treatment of potassium phosphite with potassium fulvate at C3 (0.1 ml plant^{-1}+4.5 kg fed^{-1}).

Results in Table 3 show that potassium fulvate as a single treatment increased significantly the values of plant growth parameters, the values were (341.83g) & (286.66g) for fresh weight, (27.58g) & (21.81g) for dry weight, (87.67cm) & (80.67cm) for plant length, (4351.50 cm^2) & (3205.57cm^2) for total leaf area and (3.72, 0.58 and 4.28 %) & (3.61, 0.59 and 4.11 %) for (N, P and K%) using soil application at C2 (6 kg fed $^{-1}$) and foliar application at C3 (9 kg fed $^{-1}$), respectively. Potassium phosphite as a single treatment was more effective on all plant growth parameters using soil method of application than foliar application, the highest values of fresh weight, dry weight, plant length, total leaf area and (N, P and K%) were (331.09 g), (21.91 g), (87.33 cm), (3943.95 cm^2) and (3.59, 0.61 and 4.04 %), respectively at C2 (0.1 ml plant^{-1}) as soil application. However, with foliar application, potassium phosphite alone was effective at C3 (0.2 ml plant $^{-1}$) as it increased the value of fresh, dry weight, plant length, total leaf area and (N, P and K%) to (248.94 g), (17.78 g), (69 cm), (2924.22 cm^2) and (3.00, 0.55 and 4.10 %), respectively. Also data in Table 3 show that the values of plant growth parameters of squash decreased significantly with the high level of potassium phosphite as a single treatment at C4 (0.4 ml plant^{-1}) using soil application, compared with the control.

These results reveal the positive effects of the combined treatment, these positive effects can be explained as mentioned by Wright and Lenssen, (2013); Gómez-Merino and Trejo-Téllez, (2015;2016). The addition of Phi and FA as biostimulators can enhance nutrient uptake, health, quality and yield of many plants. The present results agree with those obtained by Glinicki *et al*., (2010); Tambascio *et al*., (2014); Constán-Aguilar *et al*., (2014); Estrada-ortiz *et al*., (2016); Zambrosi, (2016); Zambrosi *et al*., (2017) who found that phi-containing products stimulated the traits and nutrient status of plants under Pi-sufficient supply. Also, these results are in harmony with the finding of Sharaf El-Dine *et al*., (2011); Khalil *et al* ., (2011); Suh *et al*., (2014); Samavat and Samavat, (2014); Esringü *et al*., (2015); Taha *et al*., (2016); Diab *et al*., (2017); Abdel-Baky *et al*., (2019) who found that FA increased all the parameters of plant growth in addition to nutrients concentration in plants, these positive effects may be attributed to improve productivity of squash yield as indirectly result to use the combined treatment and improved chemical properties of the soil as well as direct the positive effect on plant physiological resulting from the improved conditions of absorption of required nutrients for plant growth, and increasing of enzymatic activities and photosynthesis of plant, and due to the better developed root systems or by their effects on plant growth regulators.

2- Total yield, dry weight of yield, characteristics (length, diameter and weight) and nutrients content of squash fruits as affected by different levels of potassium phosphite and potassium fulvate as single treatments or combined treatment using soil and foliar applications.

Data illustrated in Table 4 show the effect of different levels of potassium phosphite and potassium fulvate as single treatments or as a combined treatment using soil and foliar applications on the values of total yield (g pot^{-1}), dry weight of yield (g), characteristics (length (cm), diameter (cm) and weight (g)) and nutrients content (%) of squash fruits. Generally, adding of potassium phosphite in a combination with potassium fulvate induced positive effects on N, P and K (%) contents in fruit of squash. The combined treatment of potassium phosphite with potassium fulvate achieved the highest values of minerals content (%), especially with soil application followed by foliar application compared to controls and other treatments.

From data in Table 4, it was found that the highest values of total yield, dry weight of yield were (475.67 g) and (19.13 g), respectively in addition to the highest values of squash fruit characteristics (length , diameter and weight) that were (16.30 cm, 3.63 cm and 115.95 g) using the combined treatment of potassium phosphite with potassium fulvate as foliar application at C3 (0.1 ml plant $^{-1}$+4.5 kg fed $^{-1}$), followed by the values of total yield and dry weight (425.31 g) and (16.44 g), respectively and (15.67 cm), (3.07 cm) and (109.49 g) for (length), (diameter) and (weight), respectively that recorded with potassium fulvate as a single treatment at C3 (9 kg fed $^{-1}$) using foliar application.

Table 3. Fresh, dry weight, length, total leaf area and nutrients content of squash plant as affected by different levels of potassium phosphite and potassium fulvate as single treatments or as a combined treatment at the harvesting stage after 70 days from planting using soil and foliar applications.

Characters Treat. (A)	Concentration (C)	Fresh weight (g)	Dry weight (g)	Plant length (cm)	Total leaf area $plant^{-1}$ (cm^2)	Nutrients content of squash plant (%) N (%)	P (%)	K (%)
	Foliar spray application (B)							
Potassium phosphite	C1, control	226.48	15.91	62.33	2615.09	2.37	0.40	3.29
	C2, (0.1 ml $plant^{-1}$)	227.49	17.54	68.33	2697.93	2.59	0.45	3.76
	C3, (0.2 ml $plant^{-1}$)	248.94	17.78	69.00	2924.22	3.00	0.55	4.10
	C4, (0.4 ml $plant^{-1}$)	204.72	14.72	62.00	2508.17	2.63	0.49	3.71
Mean		226.91	16.49	65.42	2686.35	2.65	0.47	3.72
Potassium fulvate	C1, control	162.19	14.54	64.33	2165.00	2.48	0.42	3.29
	C2, (6 kg fed^{-1})	207.20	15.11	71.67	2685.58	3.05	0.53	3.79
	C3, (9 kg fed^{-1})	286.66	21.81	80.67	3205.57	3.61	0.59	4.11
	C4, (12 kg fed^{-1})	231.67	19.32	72.33	2979.46	3.24	0.47	3.70
Mean		221.93	17.70	72.25	2758.90	3.10	0.50	3.72
Potassium phosphite with Potassium fulvate	C1, control	196.5	15.71	67.67	2684.72	2.56	0.45	3.22
	C2, (0.05 ml $plant^{-1}$ + 3 kg fed^{-1})	260.55	18.94	86.33	3052.53	3.14	0.51	3.90
	C3, (0.1 ml $plant^{-1}$ +4.5 kg fed^{-1})	333.30	23.80	87.67	3526.64	3.67	0.62	4.13
	C4, (0.2 ml $plant^{-1}$ +6 kg fed^{-1})	242.14	20.59	71.00	2977.16	3.07	0.44	3.75
Mean		258.12	19.76	78.17	3060.26	3.11	0.50	3.75
	Soil application (B)							
Potassium phosphite	C1, control	263.32	19.38	71.67	3400.77	2.67	0.44	3.65
	C2, (0.1 ml $plant^{-1}$)	331.09	21.91	87.33	3943.95	3.59	0.61	4.04
	C3, (0.2 ml $plant^{-1}$)	236.10	18.27	79.67	2944.73	3.42	0.51	3.74
	C4, (0.4 ml $plant^{-1}$)	199.58	17.98	64.33	2723.61	3.12	0.40	3.61
Mean		257.52	19.39	75.75	3253.26	3.2	0.49	3.76
Potassium fulvate	C1, control	189.26	18.78	70.67	2740.41	2.58	0.46	3.38
	C2, (6 kg fed^{-1})	341.83	27.58	87.67	4351.50	3.72	0.58	4.28
	C3, (9 kg fed^{-1})	289.71	23.27	83.00	3117.05	3.39	0.53	3.80
	C4, (12 kg fed^{-1})	235.25	17.34	68.67	2975.78	3.39	0.48	3.72
Mean		264.01	21.74	77.5	3296.19	3.27	0.51	3.80
Potassium phosphite with Potassium fulvate	C1, control	189.67	15.47	63.67	2764.73	2.43	0.42	3.26
	C2, (0.05 ml $plant^{-1}$ + 3 kg fed^{-1})	346.87	29.00	82.33	4720.56	3.95	0.62	4.43
	C3, (0.1 ml $plant^{-1}$ +4.5 kg fed^{-1})	312.20	22.00	88.67	4258.37	3.52	0.56	4.05
	C4, (0.2 ml $plant^{-1}$ +6 kg fed^{-1})	285.59	21.82	82.00	3542.40	3.10	0.46	3.87
Mean		283.58	22.07	79.17	3821.51	3.25	0.51	3.90
	L.S.D. at 5%							
Treatments (A)		17.07	1.23	2.48	356.57	0.14	0.05	0.16
Application methods (B)		36.79	3.80	4.81	724.02	0.29	0.15	0.35
Concentration (C)		25.76	2.28	4.24	508.75	0.14	0.06	0.29
Interaction (ABC)		63.11	5.58	10.38	1246.19	0.34	0.14	0.70

With soil application, the combined treatment of potassium phosphite with potassium fulvate at C3 (0.1 ml plant $^{-1}$+4.5 kg fed $^{-1}$) significantly increased the values of total yield and dry weight that were (392.71 g) and (15.01 g), respectively while total yield and dry weight were (346.39 g) and (14.18 g) with potassium fulvate as a single treatment at C3 (9 kg fed $^{-1}$). Also with soil application, the combined treatment of potassium phosphite with potassium fulvate gave the highest values of fruit characteristics (length), (diameter) and (weight), followed by potassium fulvate and potassium phosphite as single treatments, respectively. So it can be said that the combined treatment was the most effective on total yield, dry weight, characteristics of squash fruits, especially with foliar application.

Potassium phosphite as a single treatment significantly increased the values of total yield and dry weight of yield (325.10 g) and (12.78 g), respectively using foliar application at C3 (0.2 ml $plant^{-1}$), while with soil application increased the values of total yield and dry weight 301.21 g and 12.73 g, respectively at C2 (0.1 ml plant $^{-1}$). The present results agree with those obtained by Gonzalez *et al*., (2010); Cicore *et al*., (2011); Silva *et al*., (2011); Monsalve *et al*. , (2012); Pinto *et al*., (2013); Estrada-ortiz *et al*., (2013) who found that Phi increased total yield, fruit size, fresh & dry matter and number of fruit, these positive effect are due to activation the synthesis of antioxidant metabolites and internal hormonal and chemical changes by phi application. Also, Similar results were also concluded by Khalil *et al* ., (2011); Selim and Mosa, (2012); Patti *et al*., (2013); Suh *et al*., (2014); Diab *et al*., (2017); Farid *et al*., (2018) who found that FA increased the yield and all physical and chemical characteristics of fruits.

With soil application, the combined treatment of potassium phosphite with potassium fulvate at C2 (0.05 ml plant $^{-1}$+3 kg fed $^{-1}$) gave the highest values of N, P and K %, they were 4.12, 0.71 and 5.99 %, respectively, followed by 4.10, 0.66 and 5.43 %, respectively) with potassium fulvate as a single treatment at C2 (6 kg fed $^{-1}$), and (4.06, 0.65 and 5.22 %, respectively with potassium phosphite as a single treatment at C2 (0.1 ml plant $^{-1}$). With foliar application, the highest values of N, P and K % were (4.01, 0.7 and 5.74 %, respectively) that were achieved using the combined treatment of potassium phosphite with potassium fulvate at C2 (0.05 ml plant $^{-1}$+ 3 kg fed $^{-1}$), followed by (3.94, 0.65 and 5.34 %, respectively) with potassium fulvate as a single treatment at C3 (9 kg fed $^{-1}$), and

(4.00, 0.64 and 5.06 %) with potassium phosphite as a single treatment at C3 (0.2 mm plant $^{-1}$). The finding of the present study is in accordance with Constán-Aguilar *et al*., (2014); Estrada-ortiz *et al*., (2016); Zambrosi (2016) and Zambrosi *et al*., (2017) who found that Phi had a significant effect on nutrient status of plants under Pi-sufficient supply. These results are also consistent with the results of Khalil *et al* ., (2011); Wright and Lenssen, (2013); Samavat and Samavat, (2014); Taha *et al*., (2016); Diab *et al*., (2017); who found that fulvic acid significantly increased nutrients concentration (%).

Table 4. Total yield (g pot^{-1}), dry weight of yield (g), characteristics (length (cm) , diameter (cm) and weight (g)) and nutrients content (%) of squash fruits as affected by different levels of potassium phosphite and potassium fulvate as single treatments or as a combined treatment using soil and foliar applications.

Characters Treat. (A)	Concentration (C)	Total yield (g/pot)	Dry weight of yield (g)	Characteristics of squash fruit per plant: Length (cm)	Diameter (cm)	Weight (g)	Nutrients content of squash fruits (%): N (%)	P (%)	K (%)
				Foliar spray application (B)					
	C1, control	248.72	9.32	12.83	3.23	79.92	3.38	0.51	4.34
Potassium	C2, (0.1 ml plant $^{-1}$)	290.57	11.72	12.83	3.07	94.73	3.77	0.61	4.74
phosphite	C3, (0.2 ml plant $^{-1}$)	325.10	12.78	14.83	3.00	99.95	4.00	0.64	5.06
	C4, (0.4 ml plant $^{-1}$)	199.95	6.68	13.60	2.80	86.06	3.65	0.61	4.25
Mean		266.08	10.12	13.53	3.03	90.16	3.70	0.59	4.60
	C1, control	207.05	8.02	12.97	2.83	82.43	3.50	0.52	4.32
Potassium	C2, (6 kg fed $^{-1}$)	381.51	15.04	15.17	2.93	104.20	3.69	0.62	4.48
fulvate	C3, (9 kg fed $^{-1}$)	425.31	16.44	15.67	3.07	109.49	3.94	0.65	5.34
	C4, (12 kg fed $^{-1}$)	299.06	11.61	13.83	2.83	98.40	3.56	0.63	5.34
Mean		328.23	12.78	14.41	2.92	98.63	3.67	0.61	4.87
Potassium	C1, control	198.69	8.88	13.33	3.07	76.33	3.21	0.60	4.25
phosphite	C2, (0.05 ml plant $^{-1}$+ 3 kg fed $^{-1}$)	394.35	15.17	15.73	3.53	104.42	4.01	0.70	5.74
With Potassium	C3, (0.1 ml plant $^{-1}$+4.5 kg fed $^{-1}$)	475.67	19.13	16.30	3.63	115.95	3.62	0.63	5.07
fulvate	C4, (0.2 ml plant^{-1}+6 kg fed $^{-1}$)	310.70	13.06	15.50	3.23	98.46	3.36	0.61	4.30
Mean		344.85	14.06	15.22	3.37	98.79	3.55	0.63	4.84
				Soil application (B)					
	C1, control	171.16	6.90	14.07	2.73	74.47	3.45	0.60	4.12
Potassium	C2, (0.1 ml plant $^{-1}$)	301.21	12.73	14.30	2.73	95.45	4.06	0.65	5.22
phosphite	C3, (0.2 ml plant $^{-1}$)	246.71	12.27	13.57	3.27	91.44	3.43	0.63	4.26
	C4, (0.4 ml plant $^{-1}$)	203.04	9.50	14.67	2.90	88.45	3.30	0.62	4.04
Mean		230.53	10.35	14.15	2.91	87.45	3.56	0.62	4.41
	C1, control	198.85	8.03	12.93	2.87	79.87	3.52	0.55	4.10
Potassium	C2, (6 kg fed $^{-1}$)	296.95	12.16	14.67	2.97	96.62	4.10	0.66	5.43
fulvate	C3, (9 kg fed $^{-1}$)	346.39	14.18	15.33	3.10	100.96	3.92	0.65	4.97
	C4, (12 kg fed $^{-1}$)	253.62	10.8	13.80	3.10	95.55	3.75	0.65	4.33
Mean		273.95	11.29	14.18	3.01	93.25	3.82	0.63	4.71
Potassium	C1, control	87.01	3.60	12.33	2.40	55.64	3.58	0.57	3.93
phosphite	C2, (0.05 ml plant $^{-1}$+ 3 kg fed $^{-1}$)	287.73	10.78	15.27	3.17	100.76	4.12	0.71	5.99
With Potassium	C3, (0.1 ml plant $^{-1}$+4.5 kg fed $^{-1}$)	392.71	15.01	14.17	3.37	104.56	4.04	0.65	5.39
fulvate	C4, (0.2 ml plant $^{-1}$+6 kg fed $^{-1}$)	293.18	11.14	14.50	3.20	95.44	3.69	0.61	4.47
Mean		265.16	10.13	14.07	3.03	89.10	3.86	0.63	4.94
				L.S.D. at 5%					
Treatments (A)		29.61	1.11	0.83	0.18	11.67	0.34	0.02	0.58
Application methods (B)		45.19	2.53	1.27	0.23	21.41	0.34	0.004	2.01
Concentration (C)		46.43	1.52	0.88	0.23	13.74	0.25	0.01	0.54
Interaction (ABC)		113.7	3.72	2.15	0.57	33.65	0.60	0.04	1.31

3- Available N, P and K (mg kg^{-1}) and organic matter content (OM %) in soil after harvesting as affected by different levels of potassium phosphite and potassium fulvate as single treatments or as a combined treatment using soil and foliar methods of application.

Regarding to the effect of all treatments on studied soil it can be observed that soil application was superior for increasing the available N, P and K (mg kg^{-1}) in soil and the content of organic matter (OM g kg^{-1}) followed by foliar application, especially with the combined treatment, while the lowest content was recorded with control treatments.

The average available values of N, P and K (mg kg^{-1}) and organic matter content (g kg^{-1}) in soil after harvesting of squash plant in Table 5, showed positive stimulation effect in all treatments on the absorption of N, P and K by squash plant which, reflected on the traits of squash plant and fruits. With soil application, the highest values of available N, P and K (mg kg^{-1}) in the soil after harvesting of squash plant were 70.70, 12.83 and 423.73, respectively with the combined treatment of potassium phosphite and potassium fulvate at C4 (0.2 ml plant^{-1}+6 kg fed^{-1}) followed by 69.74, 12.34 and 412.48 with potassium fulvate as a single treatment at C3 (9 kg fed $^{-1}$), while potassium phosphite as a single treatment significantly increased the values of available N, P and K (mg kg^{-1}) that were 69.74, 12.09 and 404.38, respectively at C3 (0.2 ml plant $^{-1}$).With foliar application, the highest values of available N, P and K (mg kg^{-1}) in the soil after harvesting of squash plant were 68.20, 12.17 and 408.33, respectively with the combined treatment at C4 (0.2 ml plant $^{-1}$+6 kg fed $^{-1}$) followed by 68.07, 12.01 and 398.05, respectively with potassium fulvate as a single treatment at C3 (9 kg fed $^{-1}$), while potassium phosphite as a single treatment significantly increased the values of available N, P and K (mg kg^{-1}) that were 65.20, 11.69 and 394.59, respectively at C3 (0.2 ml plant $^{-1}$).

Table 5. Available N, P and K (mg kg^{-1}) and OM (g kg^{-1}) in soil after harvesting as affected by different levels of potassium phosphite and potassium fulvate as single treatments or as a combined treatment using soil and foliar applications.

Char. Treat. (A)	Concentration (C)	Available N, P and K (mg kg^{-1}) N	P	K	OM (g kg^{-1})
	Foliar spray application (B)				
Potassium phosphite	C1, control	62.34	11.06	284.44	11.1
	C2, (0.1 ml plant $^{-1}$)	63.57	11.29	327.85	11.7
	C3, (0.2 ml plant $^{-1}$)	65.20	11.69	394.59	11.9
	C4, (0.4 ml plant $^{-1}$)	64.05	11.62	361.25	11.8
Mean		63.79	11.41	342.03	11.6
Potassium fulvate	C1, control	61.73	11.07	315.85	11.7
	C2, (6 kg fed $^{-1}$)	64.62	11.65	343.69	12.6
	C3, (9 kg fed $^{-1}$)	68.07	12.01	398.05	12.7
	C4, (12 kg fed $^{-1}$)	65.67	11.94	398.05	12.5
Mean		65.02	11.67	363.91	12.4
Potassium phosphite with Potassium fulvate	C1, control	62.9	11.12	306.43	12.2
	C2, (0.05 ml plant $^{-1}$+ 3 kg fed $^{-1}$)	65.40	11.73	345.74	12.6
	C3, (0.1 ml plant $^{-1}$+4.5 kg fed $^{-1}$)	67.43	11.98	367.74	12.8
	C4, (0.2 ml plant $^{-1}$+6 kg fed $^{-1}$)	68.20	12.17	408.33	12.5
Mean		65.98	11.75	357.01	12.5
	Soil application (B)				
Potassium phosphite	C1, control	63.68	11.12	311.67	11.2
	C2, (0.1 ml plant $^{-1}$)	66.26	11.69	347.34	11.8
	C3, (0.2 ml plant $^{-1}$)	69.74	12.09	404.38	11.9
	C4, (0.4 ml plant $^{-1}$)	67.26	11.97	380.79	11.8
Mean		66.73	11.72	361.04	11.7
Potassium fulvate	C1, control	62.01	11.09	296.04	11.1
	C2, (6 kg fed $^{-1}$)	68.08	11.9	368.38	12.8
	C3, (9 kg fed $^{-1}$)	69.74	12.34	412.48	13.2
	C4, (12 kg fed $^{-1}$)	69.25	12.33	412.48	12.6
Mean		67.27	11.92	372.34	12.4
Potassium phosphite with Potassium fulvate	C1, control	61.21	11.12	308.89	11.2
	C2, (0.05 ml plant $^{-1}$+ 3 kg fed $^{-1}$)	67.00	12.08	368.24	12.7
	C3, (0.1 ml plant $^{-1}$+4.5 kg fed $^{-1}$)	69.37	12.31	384.01	13.1
	C4, (0.2 ml plant $^{-1}$+6 kg fed $^{-1}$)	70.70	12.83	423.73	13.5
Mean		67.07	12.09	371.22	12.7
	L.S.D. at 5%				
Treatments (A)		1.80	0.10	24.30	0.04
Application methods (B)		4.27	0.14	35.54	0.04
Concentration (C)		4.60	0.09	25.99	0.03
Interaction (ABC)		11.27	0.22	63.67	0.06

From the data in Table 5, it was found that the highest value of organic matter content (OM g kg^{-1}) were (13.5 g kg^{-1}) with the combined treatment of potassium phosphite with potassium fulvate at C4 (0.2 ml plant $^{-1}$+ 6 kg fed $^{-1}$) followed by (13.2 g kg^{-1}) with potassium fulvate as a single treatment at C3 (9 kg fed $^{-1}$) using soil application. Also with foliar application , the value of organic matter content (OM g kg^{-1}) increased significantly with the combined treatment of potassium phosphite and potassium fulvate, it was (12.8 g kg^{-1}) at C3 (0.1 ml plant^{-1}+4.5 kg fed^{-1}), followed by (12.7 g kg^{-1}) with potassium fulvate as a single treatment at C3 (9 kg fed $^{-1}$).

While potassium phosphite as a single treatment had no significant effect on the content of OM (g kg^{-1}) compared to other treatments. From these results it is clear that the values of available N, P, K and OM content in soil under soil application are greater than that of foliar application, especially with the combined treatment at C4 (0.2 mm plant^{-1}+6 kg fed^{-1}). These results are in harmony with the finding of Khalil *et al* ., (2011); Habashy and Ewees., (2011); Selim and Mosa (2012); Yang *et al*., (2013); Merwad (2018) who found that adding of fulvic acid alone or with one of phosphorous fertilizers to the soil significantly improved the chemical properties (pH, EC, organic matter and availability of macronutrients (NPK) and micronutrients (Fe, Zn and Mn), physical properties (bulk density, total porosity, moisture constants) and microbial population of soil. The increase in available N, P, K and OM content might be attributed to the enhanced microbial activity, the high complexing power and the lower molecular weight fractions of fulvic acid and the high solubility and mobility of Phi in soil (Pettit, 2004; Gómez-Merino and Trejo-Téllez, 2016).

CONCLUSION

Based on the obtained results of this study it could be concluded that the addition of potassium phosphite in combination with potassium fulvate is considered the most suitable treatment as a biostimulate to increase the growth , parameters and minerals content of squash plant , in addition to yield, characteristics and minerals content of squash fruit. Also the combined treatment of potassium phosphite with potassium fulvate has positive effects on chemical properties of the studied soil.

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تأثير إضافة فوسفيت البوتاسيوم مع فلفات البوتاسيوم علي نمو النبات

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أجريت تجربة أصص خلال موسم الخريف 2017 بصوبة كلية الزراعة- جامعه المنصورة لدراسة مدي استجابة نبات الكوسا للمعدلات المختلفة من فوسفيت البوتاسيوم و فلفات البوتاسيوم كإضافات منفردة او في تركيبة مع بعضهم البعض تحت طرق إضافة مختلفة. اشتملت معاملات التجربة علي فوسفيت البوتاسيوم كإضافة منفردة عند اربع تركيزات مختلفة (صفر (كنترول) و0.1 و0.2 و 0.4 مل نبات-1) و كذلك فلفات البوتاسيوم كإضافة منفردة عند اربع تركيزات مختلفة (صفر(كنترول) و 6 و 9 و12كجم/فدان) والإضافة المشتركة لفوسفيت البوتاسيوم مع فلفات البوتاسيوم عند أربع تركيزات أخري (صفر(كنترول) و 0.05 مل نبات-1 +3 كجم/ فدان و 0.1 مل نبات-1 + 4.5 كجم/ فدان و 0.2 مل نبات -1 + 6 كجم/ فدان علي التوالي). وذلك باستخدام طريقتين للإضافة وهي :الإضافة الأرضية و الإضافة الورقية .ولقد أجريت التجربة باستخدام تصميم القطع المنشقة مرتين في ثلاث مكررات. ولقد أشارت النتائج إلي أن أعلي القيم للوزن الطازج(214.96جم) والوزن الجاف (13.31جم) والمساحة الورقية لنبات الكوسا (2547.12 سم^2) ومحتوي العناصر الغذائية (النيتروجين والفوسفور والبوتاسيوم %) (5.17 و0.72 و6.50 %) تم تحقيقه مع إضافة المركب لفوسفيت البوتاسيوم مع فلفات البوتاسيوم عند (0.1 مل نبات-1 + 4.5 كجم/ فدان علي التوالي) كما تم تسجيل أعلي قيم لطول النبات (70.83سم)&(71.00سم) مع إضافة المركب لفوسفيت البوتاسيوم مع فلفات البوتاسيوم عند (0.1 مل نبات-1 + 4.5 كجم/ فدان) و فلفات البوتاسيوم كإضافة منفردة عند (6 كجم/فدان) علي التوالي في مرحله الإزهار بعد 40 يوم من الزراعة باستخدام تطبيق الإضافة الأرضية. بالإضافة الي أن أعلي القيم للوزن الطازج (346.87جم) والوزن الجاف (29.00جم) و المساحة الورقية لنبات الكوسا (4720.56سم^2) ومحتوي العناصر الغذائية (النيتروجين والفوسفور والبوتاسيوم %) (3.95 و0.62 و4.43 %) تم الحصول عليها مع إضافة المركب لفوسفيت البوتاسيوم مع فلفات البوتاسيوم عند (0.05 مل نبات-1 + 3 كجم/ فدان علي التوالي). بينما اعلي قيمه لطول النبات (88.67سم) تم تحقيقها مع إضافة المركب لفوسفيت البوتاسيوم مع فلفات البوتاسيوم عند (0.1 مل نبات-1 + 4.5 كجم/ فدان علي التوالي) في مرحله الحصاد بعد 70 يوم من الزراعة باستخدام تطبيق الإضافة الأرضية وكذلك تم تحقيق اعلي القيم للمحصول الكلي (475.67جم) والوزن الجاف (19.13جم) وصفات ثمار الكوسا (الوزن والقطر والطول) (115.95 جم و3.63 سم و16.30 سم) مع إضافة المركب لفوسفيت البوتاسيوم مع فلفات البوتاسيوم عند (0.1 مل نبات-1 + 4.5 كجم/ فدان علي التوالي) باستخدام تطبيق الإضافة الورقية بينما أعلي القيم لمحتوي العناصر الغذائية في ثمار الكوسا (النيتروجين والفوسفور والبوتاسيوم %) (4.12 و0.71 و 5.99 %) تم الحصول عليها مع إضافة المركب لفوسفيت البوتاسيوم مع فلفات البوتاسيوم عند (0.05 مل نبات-1 + 3 كجم/ فدان علي التوالي) باستخدام تطبيق الإضافة الأرضية. تم تسجيل أعلي القيم للعناصر المتاحة النيتروجين والفوسفور والبوتاسيوم (مجم كجم-1) (70.70 و12.83 و423.73 مجم كجم-1) ونسبه المادة العضوية جم كجم-1 (13.5 جم كجم-1) في التربة بعد الحصاد مع إضافة المركب لفوسفيت البوتاسيوم مع فلفات البوتاسيوم عند (0.2 مل نبات-1 + 6 كجم/ فدان علي التوالي) باستخدام تطبيق الإضافة الأرضية.