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Response of Potato Cultivars to Different Potassium Sources

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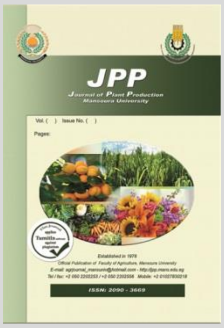

ABSTRACT

Potassium plays a pivotal role in improving potato quality and yield. Field experiment was conducted during fall seasons of 2018/2019 and 2019/2020 at the experimental facilities of Minia University, Egypt, in order to study effects of different organic and inorganic sources of potassium (Potassium Sulfate - Potassium Humate - Potassium Nitrate - Potassium Silicate) on growth and yield performance of potato cultivars of (Lady Balfour and Cara). After 75 days from planting, maximum plant height and number of branches was obtained with cultivar Lady Balfour fertilized with potassium humate. Use of potassium humate with Lady Balfour gave superlative results in terms of length of branches, number of stems and weight of branches, while the leaf area was increased in the Lady Balfour with potassium silicate treatment. The greatest amount of tubers/plant in both seasons were achieved by Cara fertilized with potassium silicate, while the weight of tubers/plant was recorded by Lady Balfour with potassium humate treatment in the second season. The greatest tuber yields for both seasons were achieved by Cara with potassium silicate and Lady Balfour with potassium humate. Tuber's texture, TSS and contents of chlorophyll a, b and carotene were higher with Cara cultivar fertilized potassium humate and potassium silicate. The results of experiment showed that the highest contents of nitrogen, phosphorous and potassium in potatoes leaves obtained by humic acid with both cultivars. Positive impacts of potassium humate followed by potassium silicate over other examined potassium sources on potato growth and quality were confirmed.

Keywords: Potassium humate, Potassium silicate, Potato Cara cultivar.

INTRODUCTION

Potato (*Solanum tuberosum* L.) plays a vital role in human diet worldwide and ranks the fourth crop as in terms of consumption at the level of the world. Potato cultivation needs adequate fertilization and organic and inorganic nutrients as considered the main source for producing maximizing tubers yield (Abd El-Azeim *et al*., 2020). Potato is a high potassium consuming crop and applying adequate quantity of balanced K- fertilizer is critical for achieving highly acceptable quality tubers (Márton László 2010). Humic substances (humic acid) increase the soil's water-holding capacity, which helps plants to withstand drought stress, and also stimulates potato growth (Abdel-Monaim *et al*., 2011). Also, humic substances play dynamic roles in chemical, physical and soil biological functions essential to plant growth and soil health. Therefore, humic acid application increases crop productivity and improving soil fertility (Rajpar *et al*., 2011). In sweet potato, humic acid applications significantly increased the total yield and all growth parameters and significantly improved total nitrogen, potassium and phosphorous contents (Abd- All *et al* 2017).

Potato monoculture in Egypt is a common practice in most provinces of the country being monocropped in fertile soils and ends with intensive organic and inorganic fertilization. Accordingly, soil quality could have been degraded since potato productivity has been decreasing despite high rates of fertilizers applied and high yielding cultivars (Abd El-Azeim *et al*., 2020). Egypt is the largest African country producing potato, and ranks 14th in the world, therefore, authorities and farmers has the scope of increasing the intensification of crop production using intensive fertilization systems as the agricultural year is divided into three planting successive seasons; summer, fall, and winter. Intensive agricultural practices necessitate high fertilizers inputs to achieve high yields and hence improper agricultural intensification joined with careless use of fertilizers has deteriorated soil health. Thus, there is a rising awareness on the use of eco-friendly sustainable fertilizers that place stress on soil health conservation on short and long-term bases (Rinot *et al*., 2019). In addition, current methods of fertilization significantly contribute to greenhouse gas emissions from agricultural sectors therefore, nanoscience and nanotechnology are being exploited for producing nanofertilizers to ensure nutrients use efficiency even though enhancing crop yields (El-Ramady *et al*. 2018; Abdelsalam *et al*. 2019; and Eissa 2019).

Fertilizers are organic and inorganic products applied to soil agroecosystems for recompensing or satisfying the essential nutrients needs for plant growth and soil health. Inorganic fertilizers play an important role in achieving crop yield targets, yet latent inefficiencies in conventional fertilizer use management can lead to disastrous environmental and economic concerns. Much of the NPK fertilizers applied to farming systems are lost to water and air resulting in harmful environmental impacts such as leached nitrate and phosphates runoff into aquatic ecosystems causing eutrophication and release of N-oxides into the atmosphere (El-Ramady *et al*., 2018). Organic

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fertilizers for instance humic substances trigger continual nutrient availability, microbial activity and growth due to high content of labile carbon (C) and nitrogen (N) (Akimbekov, *et al*., 2020). Organic fertilizers are progressively decayed in soils providing a continual release of nutrients including C, P, S and N compared to fast release of nutrient when inorganic fertilisers are used.

Four leonardite doses (0, 200, 400, 600 kg ha^{-1}) and four potato cultivars were tested by (Sanli 2013) who concluded that, leonardite had improved number of tubers per plant by 22%, total tuber yield by 15% and marketable tuber yield by 38% compared with the control. Humic acid affects moisture retention therefore it can increase irrigation efficiency. In addition, Humic acid can increase the nutrient content of soil, which is revealed in increasing fertilizer use efficacy as reported by (Ahmed and Mosa 2012; Akimbekov, *et al*., 2020). Also, they reported that application of humic acid to potato production systems can play a significant role in increasing plant resistance against common potato diseases and can boost both qualitative and quantitative characteristics of tubers, and can also improve soil fertility and quality. Potassium fertilization improved K content in potato roots and application of KCl decreased N content in surface layer of soil (Neshev *et al* 2016). An experiment was conducted to study the effects of foliar potassium application by (Besma Ben Dkhil 2011) on sandy clay soil, tubers and yield parameters indicated significant effect ($p < 0.05$) in increasing potassium nitrate on both tuber number and tuber yield. Also, it is concluded that potassium can be sufficient for potatoes over fertigation and the optimum rate was 60 kg potassium.

Nazli *et al* (2018) reported that plant height had increased with the addition of potassium to the soil. Meanwhile, plant height is a genetic factor that can be used as indicator of crop yield. Also, results of this study showed that potassium fertilization enhanced leaf area of potato crop and the leaf area is used as an indicator of photosynthesis efficiency so an increase in leaf area causes an increase in the rate of photosynthesis and chlorophyll content as the true food processing plant. In addition, the experiment showed that potassium significantly increased the chlorophyll content, tuber yield and tuber dry matter contents with increasing the rate of potassium fertilizer. Also, their results showed that improving growth parameters like leaf area, chlorophyll and plant height contents clearly had increased potato tuber yield (Nazli *et al*., 2018). The effect of mineral fertilization on potatoes is affected by the cultivated cultivar, Spunta acted better with reference to the number of photosynthetic leaves under optimum NPK rates, then deficiency treatment, while Daifla Cv. produced the maximum number of real leaves under excess of NPK doses (Mokrani *et al* 2018).

Abd El-Gawad *et al*., (2017) showed that spraying potassium silicate stimulates plant growth in terms of increase the chlorophyll content, leaves area and osmolytes contents. Cultivar Lady Balfour had the highest significant values of vegetative growth traits (Leaf area - fresh weight – number of branches for the plant) as well as the chemical contents of the tuber's potassium, protein and dry mater as compared to cultivar Valor. Also, the results indicated that there is a positive and significant correlation between mineral fertilizer concentrations and growth parameters. However, Elsharkawy (2013); Ahmed *et al* (2017) and Della Lucia *et al*., (2021) reported that correct management of nutrients has an essential role in obtaining the highest yield from the crop as shown by that the highest yield per hectare was obtained with recommended dose of chemical fertilizer. Misgina (2016) showed that growth parameters, yield components and yield of potato were responded positively to PK fertilizers either applied as sole or in combination. Number of tubers per plant, number of stems, the highest tuber yield and average tuber weight were obtained from application of a combined PK (Misgina 2016).

Potatoes supplied with K_2SO_4 had a higher yield compared to those fertilized with KCl and a positive effect on reducing sugar content, but it increases the starch content, and specific gravity as reported by (Nikardi Gunadi 2009). It could be confirmed from the aforementioned literature that providing the plant with potassium ensures optimum plant growth and yields. Thus, the aim of the present study was to investigate the effect of four potassium fertilizer sources on potato growth and yield of two recommended cultivars i.e., (Cara and Lady Balfour) grown under El–Minia Governorate conditions of middle Egypt, Egypt.

MATERIALS AND METHODS

Description of the study area.

Field experiments were carried out during the full seasons of 2018/2019 and 2019/2020, at the Experimental Farm of Horticulture Department, Faculty of Agriculture, Minia University (28º18'16"N latitude and 30º34'38"E longitude), EL- Minia Governorate, Egypt, in order to investigate effects of the application of 4 sources of potassium fertilizer on productivity, yield and economic values of two potato cultivars (Cara and Lady Balfour). The experimental soil site had a clay texture and classified as an alluvial soil according to Abd El-Azeim *et al*., (2016). Prior to the initiation of the field experiment, clay soil detailed in Table 1 was collected, air dried, sieved to < 2.0 mm, and composite sub-samples were used to determine the basic soil physicochemical properties using standard methods derived from Black (1965), Jackson (1973), Avery and Bascomb (1982), and Page *et al*., (1982).

Table 1. Physicochemical properties of the soil investigated.

Soil Property			
Soil Chemical Properties		**Soil Physical Properties**	
pH (1:2.5 water)	7.7 (7.4)[a]	F.C %	42.45
$CaCO_3$ (g kg^{-1})	17.9	PWP %	13.78
CEC ($cmol_c$ kg^{-1})	37.87	WHC %	48.76
O.M (g kg^{-1})	28.61[b]	A.V (F.C – PWP) %	28.67
Total N (g kg^{-1})	1.29	A.V (WHC – PWP) %	34.98
Total C/N Ratio	22.18	Bulk Density (BD) g/cm^3	1.31
S.O.C g kg^{-1}	18.48	Particle Density (PD) g/cm^3	2.22
Organic N (g kg^{-1})	0.76	Clay (%)	56.45
Organic C/N Ratio	24.31	Sand (%)	17.76
Mineral N (mg kg^{-1})	58.46	Silt (%)	25.79
Total P (g kg^{-1})	0.56	Soil texture	Clay
Available P (mg kg^{-1})	13.11		
Total K (g kg^{-1})	4.37		
C_{-mic} (mg kg^{-1})	112.89		
N_{-mic} (mg kg^{-1})	22.45		
C_{-mic}: N_{-mic}	5.03		
EC (dS m^{-1} at 25 °C)	1.35		

[a] Figures in parentheses are pH values obtained for soil by $CaCl_2$ extraction ratio of 1:2.5.

[b] Organic matter determined by loss on ignition.

Experimental design, materials and procedures.

The experiments were conducted in a randomized complete block design (RCBD) with three replicates in split plots. Each plot consisted of five rows (each row was 3 m long × 3.5 m wide) with plant distance of 30 cm apart on one side of the row in a plot area of 10.5 m^2.

The treatments of fertilization were therefore as follows:

1- K1 (Potassium Sulfate,160 kg/feddan).
2- K2 (Potassium Nitrate, Bitasol, 130 kg/feddan).
3- K3 (Potassium Humate, 20 kg/feddan).
4- K4 (Potassium Silicate, 20 L/feddan).

Potassium sulfate was added at 160 kg/feddan and potassium humate was added at 20 kg/feddan, potassium nitrate was added at 130 kg/feddan, and potassium silicate was added at 20 L/feddan. All the amount of potassium fertilizer sources were divided into 2 equal portions and applied at 30 and 45 days after tuber implanting. The amount of each source of potassium fertilizer were calculated at the recommended rates, of each source as reported in previous studies (Abd El-Gawad *et al*., 2017; Ahmed *et al*., 2017). All other agronomic activities were conducted in accordance with the recommendation of Egyptian Agriculture ministry.

Harvesting was done after 120 days from planting dates for Cara, whereas the type Lady Balfour was harvested after 105 days from planting, in both seasons**.** Samples of five plants from each replicate were randomly taken. During the experimental period and after harvesting of both growing seasons, five plant samples from each replicate were randomly taken after 60 and 75 days from planting the tubers and the following data were recorded.

Growth and yield parameters:

Plant height (cm), number of branches, weight of fresh branches, number of aerial stems, number of tubers, weight of tubers, weight of tubers after curing. Also, Chlorophyll A, Chlorophyll B, Carotene were measured, average weights of collected leaves of five plants from each treatment were recorded to calculate leaf area using area-leaf and leaf weight relationship following the methodology of (Wallace and Munger, 1965). Mineral elements were analyzed using 0.2 g of dried ground leaves of the tested plants were digested in H_2SO_4 (concentrated) and H_2O_2 (5:1) for chemical analysis of nitrogen (N), phosphorus (P) and potassium (K) contents on the leaves and tubers according to AOAC (1990).

Tuber yield and quality:

Total yield per feddan (Kg/fed) was estimated and (Humidity%, Tuber length (cm), Tuber width (cm), pH, Textures, NPK percentage, as well as total soluble solid percentage) was determined as described by AOAC (1990). Total soluble solids (T.S.S.) was determined using refractometer according to AOAC (1990). Leaf chlorophyll a, b, and carotene contents were measured on the fifth fully developed leaf counted from the top of the five marked plants (After 75 days of planting). Fresh leaf samples (0.5 g) were extracted using 95% methanol and were determined spectrophotometrically according to (Nagata and Yamashita, 1992). The supernatant absorbance of chlorophyll a, b, and carotene were determined at wavelengths of 662, 645, and 470 nm, respectively. Leaf chlorophyll a, b, and carotene contents were calculated in mg/L according to the following formulas, (Nagata and Yamashita, 1992; Dinu *et al*., 2018)

Chlorophyll a = 11.75 A662 – 2.350 A645

Chlorophyll b = 18.61 A645 – 3.960 A662

Carotene = Cx + c = 1000 A470 – 2.270 Ca – 81.4 Cb / 227

Ca = Chlorophyll a; Cb = Chlorophyll b; Cx + c = Total carotene

Statistical analysis:

Data of all parameters were statistically analyzed using GLM procedure of SAS software program, version 9.2 (SAS Institute, 2008) to conduct the analysis of variance. Differences between the treatment means as well as between the different interactions were tested using the orthogonal comparisons of Duncan's New Multiple Range at 0.05 significance level.

RESULTS AND DISCUSSION

Potato vegetative growth parameters:

Potato cultivars in Table (2) showed significant differences in plant height and number of branches per potato plant, in both seasons. Lady Balfour cultivar showed significantly higher plant height as well as number of branches per plant as compared with Cara cultivar, in both seasons. The differences between both cultivars in plant height and number of branches per plant may due to genetic variation (Nazli *et al*., 2018). Among the four sources of potassium, potassium humate (K3) showed the highest values of plant height and number of branches per plant, in both seasons. Humic acid applications significantly increased the total yield and all growth parameters, as reported by (Abd- All *et al* 2017). Nazli *et al*., (2018) reported that Plant height had increased with the addition of potassium to the soil. In the same time potassium silicate (k4) was ranked as the second, whereas, Bitasol (k2) showed the lowest values of both characters as compared with other potassium sources, in both seasons. Concerning the interactions effect between potato cultivars and potassium sources, significant response was obtained, in both seasons. The most significant increases of both vegetative characters were obtained from the interaction of V2 × k3 followed by V2 × K4, in both seasons. On the other hand, the lowest values were obtained from the interaction of V1 × K2, in both seasons. The interactions of Lady Balfour and Potassium humate (K3) showed an additive value since the presence of both factors had increased the vegetative values as compared with single factor, in both seasons.

Both potatoes cultivars in Table (3) showed significant differences in length of branches, weight of branches, leaf area and number of stems in both seasons. Lady Balfour cultivar (V2) showed significantly higher length of branches, weight of branches, leaf area and number of stems in both seasons, compared to the other cultivar. (Bista and Bhandari, 2019) reported that application of potassium increased leaf area and number of stems of potato. Among different sources of potassium, significant response was obtained, in both seasons. Potassium humate (K3) showed the highest significant values of length of branches, weight of branches in both seasons. In the same time potassium silicate (k4) was ranked as the second, whereas Bitasol (k2) showed the lowest values of these characters as compared with other sources, in both seasons.

Regarding, the interactions effect of potato Cvs. and potassium sources, significant responses were obtained, in both seasons. The highest significant values of length and weight of branches were obtained from the interaction of Lady Balfour cultivar (V2) with potassium humate (K3), while the lowest values of the interactions were obtained from Cara cultivar (V1) with K2, in both seasons. Humic acid can increase the nutrient content of soil, which is revealed in increasing fertilizer use efficiency as reported by (Ahmed and Mosa, 2012). Also, they reported that application of humic acid to potato production systems can increase humic acid which can play a significant role in increasing plant resistance against common potato diseases and enhance the qualitative and quantitative characteristics of tubers, also improve soil fertility and quality, as well as, humic acid affects moisture retention therefore it can increase irrigation efficiency. Akimbekov *et al.* (2020) revealed that humic substances originating from different organic matter can improve soil properties, stimulate plant growth, and improve nutrient uptake. Their results highlighted the importance of modifying Leonardite-based humic products to maintain soil biochemical stability, to maintain healthy microbial community structure, and to increase agricultural productivity of potato plants.

Table 2. Effect of different potassium fertilizer sources on growth characteristics of potato cultivars.

	After 60 day from planting				After 75 day from planting			
	Plant height (cm)		Number of branches		Plant height (cm)		Number of branches	
	1st season	2nd season	1st season	2st season	1st season	2nd season	1st season	2st season
Cara (V1)	53.94 b	55.80 b	1.97 b	1.83 b	60.57 b	63.76 b	3.07 b	2.75 b
Lady B (V2)	60.71 a	60.87 a	2.68 a	2.69 a	69.77 a	69.58 a	3.90 a	3.84 a
Mean of cultivars	57.33	58.34	2.33	2.26	65.17	66.67	3.49	3.30
Potassium sulfate (K1)	55.28 c	56.06 c	2.28 c	2.18 c	65.54 b	65.61 c	3.48 c	3.20 c
Potassium Nitrate Bitasol (K2)	56.12 c	55.01 c	2.01 d	1.93 d	62.74 c	63.40 d	3.26 c	2.97 d
Potassium humate (K3)	64.24 a	66.63 a	2.99 a	2.77 a	72.43 a	75.43 a	4.18 a	3.82 a
Potassium silicate (K4)	59.76 b	61.68 b	2.71 b	2.62 b	66.87 b	68.77 b	3.75 b	3.60 b
Control (K0)	51.22 d	52.29 d	1.63 e	1.80 e	58.25 d	60.14 e	2.76 d	2.88 d
Mean of treatments	57.32	58.33	2.32	2.26	65.17	66.67	3.49	3.29
V1 K1	51.85 de	52.50 de	1.96 cde	1.77 f	61.83 d	61.50 e	3.07 ef	2.50 e
V1 K2	50.67 ef	51.48 e	1.87 de	1.70 f	57.67 e	59.33 e	2.90 f	2.67 e
V1 K3	61.67 b	65.53 ab	2.50 b	2.03 de	67.00 c	72.33 b	3.83 bc	3.17 cd
V1 K4	56.50 c	60.00 c	2.07 cd	2.00 e	62.83 d	67.00 d	3.43 de	3.03 d
V1 K0	49.00 f	49.50 e	1.47 f	1.63 f	53.50 f	58.64 e	2.13 g	2.37 e
V2 K1	58.70 c	59.62 c	2.59 b	2.59 c	69.24 bc	69.73 bcd	3.90 bc	3.91 b
V2 K2	61.58 b	58.54 c	2.16 c	2.16 d	67.81 c	67.46 cd	3.63 cd	3.27 cd
V2 K3	66.82 a	67.73 a	3.48 a	3.51 a	77.87 a	78.53 a	4.53 a	4.47 a
V2 K4	63.01 b	63.36 b	3.36 a	3.24 b	70.91 b	70.54 bc	4.07 b	4.16 ab
V2 K0	53.43 d	55.09 d	1.80 e	1.97 e	63.00 d	61.63 e	3.39 de	3.40 c

Table 3. Effect of different potassium fertilizer sources on growth characteristics of potato cultivars.

	Length of branches		Weight of branches		Leaf area		Number of stem	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Cara (V1)	73.3 b	72.5 b	257.3 b	261.3 b	117.38 b	118.08 b	4.31 b	4.34 b
Lady B (V2)	88.4 a	88.9 a	387.2 a	397.5 a	126.60 a	127.61 a	5.35 a	5.43 a
Mean of cultivars	80.85	80.7	322.25	329.4	121.99	122.845	4.83	4.88
Potassium sulfate (K1)	80.5 b	79.1 c	287.3 c	296.4 c	115.94 b	117.21 b	4.45 b	4.58 b
Potassium Nitrate Bitasol (K2)	77.7 c	77.2 cd	272.8 d	298.8 c	119.75 b	120.31 b	4.43 b	4.42 b
Potassium humate (K3)	90.7 a	89.1 a	410.2 a	414.5 a	131.42 a	131.25 a	5.83 a	5.88 a
Potassium silicate (K4)	81.9 b	82.6 b	368.6 b	371.9 b	132.46 a	133.46 a	5.53 a	5.63 a
Control (K0)	73.5 d	75.5 d	272.3 d	265.5 d	110.37 c	111.99 c	3.90 c	3.92 c
Mean of treatments	80.86	80.7	322.24	329.42	121.98	122.84	4.82	4.88
V1 K1	73.8 f	70.2 ef	232.3 e	241.2 f	112.44 d	112.96 ef	4.23 cd	4.40 d
V1 K2	70.8 g	69.4 ef	213.3 f	227.3 f	113.71 cd	112.98 ef	3.90 de	3.83 e
V1 K3	85.9 cd	82.9 d	330.0 b	337.7 c	128.15 b	128.98 bc	5.13 b	5.17 b
V1 K4	72.2 fg	73.2 e	263.3 d	265.2 e	126.33 b	126.66 c	4.83 b	4.83 bc
V1 K0	63.6 h	66.6 f	247.7 de	235.3 f	106.24 e	108.80 f	3.47 e	3.47 f
V2 K1	87.1 c	88.0 bc	342.3 b	351.7 c	119.44 c	121.45 d	4.67 bc	4.77 c
V2 K2	84.5 de	85.0 cd	332.3 b	370.3 b	125.79 b	127.65 c	4.97 b	5.00 bc
V2 K3	95.6 a	95.3 a	490.3 a	491.3 a	134.69 a	133.51 b	6.53 a	6.60 a
V2 K4	91.6 b	91.9 ab	473.8 a	478.7 a	138.59 a	140.26 a	6.23 a	6.43 a
V2 K0	83.3 e	84.4 cd	297.0 c	295.7 d	114.49 cd	115.19 e	4.33 cd	4.37 d

Both potato cultivars in Table (4) showed significant differences in yield characteristics, the highest significant values of weight of tubers, tuber length and yield/feddan were showed with Lady Balfour cultivar in both seasons. On the other hand, the highest significant values of number of tubers per plant and tuber diameter were showed with Cara cultivar. Among different sources of potassium, potassium silicate (k4) showed the highest significant values of number of tubers per plant, weight of tubers per plant and yield/feddan. In addition, the highest tuber length and diameter were showed with potassium humate (K3) compared with other sources of potassium. Bista and Bhandari (2019) showed that application of potassium increased potato yield. Abd El Latif *et al*., (2011), and

Nazali *et al*., (2018), reported that maximum potato tuber yield and quality of potato obtained by potassium fertilization and the highest significant potato yield was attained by high levels of potassium.

The interaction between potato cultivars and sources of potassium showed the highest significant values of tuber length, yield/fedd. and tuber diameter with Lady Balfour cultivar (V2) with Potassium humate (K3) compared with the others interaction.

The two cultivars in Table (5) showed significant differences in humidity, pH, textures and TSS. Cara cultivar (V1) showed high significant values of pH, textures and TSS in both seasons compared with Lady Balfour cultivar (V2). While Lady Balfour cultivar (V2) showed heigh significant humidity in the first season compared with Cara cultivar (V1). Sources of potassium showed significant values with humidity, pH, textures and TSS in both seasons. Potassium sulfate (K1) high values of humidity in both seasons, while the lowest values showed with Potassium silicate (K4). In the other hand, potassium humate (K3) showed the high significant values of pH, texture and TSS compared with the other sources. Abd El Latif *et al*, (2011) reported that the highest TSS in tubers was showed with application of potassium.

The interaction between potato cultivars and potassium sources showed high values of humidity percentage with Balfour cultivar (V2) x (K0) while, the lowest humidity showed in the first season between Cara cultivar (V1) x (K3). Cara cultivar (V1) showed high pH with (K2) and (k3) in both seasons as well as the high textures showed with Cara cultivar (V1) x (K3) but the higher values of TSS obtained by Cara cultivar (V1) x (K1 and K3).

Table 4. Effect of the four different potassium fertilizer sources on yield characteristics of two potato cultivars.

	Number of tubers/plant		Weight of tubers / plant		Tuber length (cm)		Yield ton /feddan		Tuber diameter (cm)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Cara (V1)	6.3 a	6.6 a	646.1 b	640.6 b	8.59 b	8.59 b	12.922 b	12.812 b	5.18 a	5.35 a
Lady B (V2)	5.4 b	5.5 b	680 a	682.9 a	10.07 a	10.16 a	13.600 a	13.658 a	5.18 a	5.29 b
Mean of cultivars	5.85	6.05	663.05	661.75	9.33	9.375	13.261	13.235	5.18	5.32
Potassium sulfate (K1)	5.7 c	5.8 d	630.8 d	631.3 d	9.48 bc	9.32 c	12.616 d	12.626 d	5.02 c	5.10 c
Potassium Nitrate Bitasol (K2)	5.9 bc	6.0 c	663 c	659.2 c	8.99 c	9.12 c	13.260 c	13.184 c	5.35 b	5.27 bc
Potassium humate (K3)	6.1 b	6.4 b	735.7 b	729.3 b	10.68 a	10.8 a	14.714 b	14.586 b	5.80 a	6.10 a
Potassium silicate (K4)	6.5 a	6.7 a	753.6 a	747.8 a	9.96 b	9.86 b	15.072 a	14.956 a	5.28 b	5.30 b
Control (K0)	5.2 d	5.4 e	532.3 e	541.1 e	7.52 d	7.79 d	10.646 e	10.822 e	4.48 d	4.81 d
Mean of treatments	5.88	6.06	663.08	661.74	9.326	9.378	13.261	13.234	5.18	5.32
V1 K1	6.0 cd	6.0 c	556.5 e	556.0 f	8.98 de	8.67 e	11.130 e	11.120 f	5.02 b	5.09 bc
V1 K2	6.7 b	6.9 b	663.0 d	661.7 e	8.32 e	8.56 e	13.260 d	13.234 e	5.35 b	5.32 b
V1 K3	6.1 c	6.8 b	701.0 c	684.2 d	9.51 cd	9.64 cd	14.020 c	13.684 d	5.8 a	6.17 a
V1 K4	7.2 a	7.5 a	777.8 a	762.3 a	9.42 cd	9.12 de	15.556 a	15.246 a	5.28 b	5.37 b
V1 K0	5.6 de	5.9 c	532.3 f	538.8 f	6.69 f	6.98 f	10.646 f	10.776 f	4.48 c	4.78 d
V2 K1	5.5 e	5.5 d	705.0 c	706.7 c	9.98 bc	9.97 c	14.100 c	14.134 c	5.02 b	5.12 bc
V2 K2	5.0 f	5.1 e	663.0 d	656.7 e	9.66 cd	9.68 c	13.260 d	13.134 e	5.35 b	5.23 b
V2 K3	6.1 c	6.1 c	770.3 a	774.3 a	11.86 a	11.96 a	15.406 a	15.486 a	5.80 a	6.03 a
V2 K4	5.9 cd	5.9 c	729.3 b	733.3 b	10.5 b	10.59 b	14.586 b	14.666 b	5.28 b	5.23 b
V2 K0	4.7 f	4.8 e	532.3 f	543.3 f	8.36 e	8.59 e	10.646 f	10.866 f	4.48 c	4.85 cd

Table 5. Effect of different potassium fertilizer sources on Humidity%, pH, Textures, and TSS contents in tubers.

	Humidity%		pH		Textures		TSS	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Cara (V1)	79.25 b	79.6 a	7.0 a	7.0 a	10.6 a	10.7 a	7.4 a	7.4 a
Lady B (V2)	81.41 a	80.75 a	6.5 b	6.4 b	9.6 b	9.4 b	7.1 b	7.3 a
Mean of cultivars	80.33	80.17	6.75	6.70	10.10	10.05	7.25	7.35
Potassium sulfate (K1)	80.97 b	80.65 a	6.5 d	6.5 c	10.1 b	10.1 b	7.5 a	7.4 ab
Potassium Nitrate Bitasol (K2)	80.12 bc	80.3 a	6.6 c	6.6 c	9.8 b	9.9 bc	7.0 bc	7.2 bc
Potassium humate (K3)	78.35 c	81.24 a	7.0 a	6.9 a	11.1 a	11.0 a	7.7 a	7.7 a
Potassium silicate (K4)	78.59 c	78.35 b	6.8 b	6.8 b	10.0 b	10.0 b	7.4 ab	7.6 ab
Control (K0)	83.64 a	80.34 a	6.6 c	6.6 c	9.5 c	9.5 c	6.7 c	6.8 c
Mean of treatments	80.33	80.18	6.7	6.68	10.10	10.10	7.26	7.34
V1 K1	79.42 cd	79.44 cde	6.9 b	6.9 b	10.7 b	11.0 b	7.8 a	7.8 a
V1 K2	80.22 bc	81.24 bc	7.1 a	7.1 a	10.5 bc	10.7 bc	7.2 abc	7.3 abc
V1 K3	76.47 e	82.94 ab	7.2 a	7.1 a	11.8 a	11.8 a	7.7 ab	7.7 ab
V1 K4	77.34 de	77.53 ef	6.9 b	6.9 b	10.2 cd	10.2 cd	7.3 abc	7.4 ab
V1 K0	82.81 a	76.87 f	6.8 b	6.8 b	10.0 d	10.0 cd	7.0 bcd	7.0 abc
V2 K1	82.52 ab	81.86 b	6.2 d	6.1 e	9.4 e	9.1 ef	7.2 abc	7.2 abc
V2 K2	80.02 bc	79.35 cde	6.1 d	6.1 e	9.1 e	9.1 ef	6.9 cd	7.0 bc
V2 K3	80.22 bc	79.55 cd	6.8 b	6.7 c	10.4 bc	10.2 cd	7.7 ab	7.7 ab
V2 K4	79.83 cd	79.16 de	6.8 b	6.6 c	9.9 d	9.8 de	7.5 abc	7.7 ab
V2 K0	84.47 a	83.81 a	6.4 c	6.3 d	9.0 e	8.9 f	6.4 d	6.6 c

Both cultivars in Table (6) showed significant differences in chlo. A, chlo. B and carotene, the high significant values showed with Cara cultivar compared with Lady Balfour cultivar. Among four sources of potassium,

potassium silicate (K4) showed the highest significant values of chlo. A, chlo. B and carotene compared with the other sources of potassium. Cao and Tibbittis (1991) found that different K concentrations gave significant concentration of chlorophyll in potato leaves compared to control treatment. In general, the interaction between potato cultivars and sources of potassium showed significant values. Cara cultivar (V1) with potassium silicate (K4) showed significant higher values compared to the other interactions.

Both potatoes cultivars in Table (7) showed differences in NPK in tubers and leaves of potato plants in both seasons. Lady Balfour cultivar showed significantly higher N in tubers compared with Cara cultivar in both seasons, while, Cara cultivar showed significantly higher of P and K in tubers compared with Lady Balfour cultivar in both seasons. Among the four sources of potassium, Potassium humate (K3) showed the highest significant values of NPK in tubers and leaves in both seasons. In the same time potassium silicate (k4) was ranked as the second, whereas, Bitasol (k2) showed the lowest values of both nutrients as compared with the three other sources, in both seasons. Salim *et al*., (2014) found that application of k increases the content of NPK in potato leaves. Concerning the interactions effect of potato Cvs. and potassium sources, significant responses were obtained, in both seasons. Cara cultivar (V1) with potassium humate (K3) showed high significant values of P, K in tubers and N, K in leaves compared with the other interactions. Whereas, Lady Balfour cultivar (V2) with potassium humate (K3) showed high significant values of N in tubers and P in leaves in both seasons.

Table 6. Effect of different potassium fertilizer sources on quality characteristics of potato cultivars.

	Chlo. A		Chlo. B		Carotene	
	1st season	**2nd season**	**1st season**	**2nd season**	**1st season**	**2nd season**
Cara (V1)	4.17 a	4.14 a	3.74 a	3.78 a	3.92 a	4.12 a
Lady B (V2)	3.88 a	3.95 a	3.16 b	3.24 b	3.48 b	3.58 b
Mean of cultivars	4.03	4.05	3.45	3.51	3.70	3.85
Potassium sulfate (K1)	3.77 d	3.84 d	3.20 d	3.33 d	3.48 d	3.67 d
Potassium Nitrate Bitasol (K2)	4.05 c	4.07 c	3.52 c	3.53 c	3.69 c	3.81 c
Potassium humate (K3)	4.28 b	4.26 b	3.66 b	3.74 b	3.97 b	4.11 b
Potassium silicate (K4)	4.59 a	4.62 a	3.85 a	3.90 a	4.21 a	4.33 a
Control (K0)	3.45 e	3.44 e	3.02 e	3.05 e	3.15 e	3.35 e
Mean of treatments	4.03	4.05	3.45	3.51	3.70	3.85
V1 K1	3.93 d	3.91 d	3.41 d	3.48 cd	3.73 d	3.94 c
V1 K2	4.12 c	4.19 c	3.86 c	3.86 b	3.92 c	4.03 c
V1 K3	4.35 b	4.30 c	4.08 b	4.12 a	4.23 b	4.39 b
V1 K4	4.79 a	4.72 a	4.22 a	4.23 a	4.46 a	4.65 a
V1 K0	3.64 e	3.56 f	3.15 e	3.21 ef	3.28 f	3.59 e
V2 K1	3.61 e	3.77 e	3.00 f	3.19 f	3.23 f	3.40 f
V2 K2	3.97 d	3.95 d	3.17 e	3.19 f	3.47 e	3.58 e
V2 K3	4.20 c	4.21 c	3.24 e	3.36 de	3.72 d	3.82 d
V2 K4	4.39 b	4.52 b	3.48 d	3.57 c	3.96 c	4.02 c
V2 K0	3.26 f	3.32 g	2.90 f	2.90 g	3.01 g	3.10 g

Table 7. Effect of different potassium fertilizer sources on NPK in tubers and leaves of potato cultivars.

	NPK in potato on the tubers						NPK in potato on the leaves					
	N %		P %		K %		N %		P %		K %	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Cara (V1)	1.94 b	1.92 b	0.44 a	0.44 a	3.63 a	3.62 a	1.88 a	1.74 b	0.41 a	0.40 a	6.18 a	6.20 a
Lady B (V2)	2.25 a	2.23 a	0.42 b	0.44 a	3.37 b	3.34 b	1.75 b	1.76 a	0.41 a	0.42 a	6.09 a	6.18 a
Mean of cultivars	2.095	2.075	0.43	0.44	3.50	3.48	1.82	1.75	0.41	0.41	6.13	6.19
Potassium sulfate (K1)	2.08 b	2.09 bc	0.41 c	0.42 c	3.50 c	3.57 c	1.85 c	1.77 c	0.40 c	0.40 c	6.27 bc	6.30 bc
Potassium Nitrate Bitasol (K2)	1.93bc	1.83cd	0.40 d	0.41 c	3.14 d	3.12 d	1.81 c	1.73 c	0.37 d	0.37 d	6.97 c	6.09 c
Potassium humate (K3)	2.50 a	2.55 a	0.53 a	0.53 a	4.03 a	4.05 a	2.03 a	1.97 a	0.50 a	0.50 a	6.83 a	6.87 a
Potassium silicate (K4)	2.20 b	2.13 b	0.46 b	0.47 b	3.82 b	3.81 b	1.95 b	1.89 b	0.44 b	0.45 b	6.40 b	6.43 b
Control (K0)	1.76 c	1.78 d	0.36 e	0.36 d	3.00 d	2.88 e	1.44 d	1.40 d	0.33 e	0.34 e	5.20 d	5.27 d
Mean of treatments	2.094	2.076	0.432	0.438	3.498	3.486	1.82	1.75	0.41	0.41	6.33	6.19
V1 K1	1.93bcd	1.92bcde	0.42 e	0.42 c	3.80 bc	3.82 b	1.93 cd	1.76 c	0.40 c	0.39 de	6.33bcd	6.34 bcd
V1 K2	1.81 cd	1.83 de	0.39 f	0.39 d	3.14 d	3.08 c	1.90 d	1.71 c	0.37 d	0.36 f	6.00cd	5.94 d
V1 K3	2.20 bc	2.25 bcd	0.55 a	0.53 a	4.19 a	4.21 a	2.09 a	1.96 a	0.50 a	0.48 b	6.93 a	6.92 a
V1 K4	2.12bc	1.95bcde	0.47 c	0.48 b	4.01 ab	3.97 ab	2.00 b	1.86 b	0.44 b	0.45 c	6.44abc	6.46 abc
V1 K0	1.63d	1.65 e	0.36 g	0.36 e	3.00 d	3.04 c	1.49 f	1.40 d	0.32 f	0.33 g	5.24 e	5.33 e
V2 K1	2.23bc	2.26 bc	0.41 ef	0.42 c	3.21 d	3.31 c	1.77 e	1.78 c	0.40 c	0.41 d	6.22 cd	6.26 cd
V2 K2	2.04bcd	1.84 cde	0.40 f	0.42 c	3.14 d	3.15 c	1.73 e	1.74 c	0.37 d	0.38 e	5.93 d	6.23 cd
V2 K3	2.81a	2.84 a	0.51 b	0.53 a	3.88 b	3.90 ab	1.97 bc	1.98 a	0.50 a	0.51 a	6.77 ab	6.81 ab
V2 K4	2.27b	2.30 b	0.44 d	0.46 b	3.63 c	3.64 b	1.90 d	1.91 ab	0.44 b	0.45 c	6.36bcd	6.40bcd
V2 K0	1.88bcd	1.91bcde	0.35 g	0.36 e	3.00 d	2.72 d	1.40 g	1.41 d	0.34 e	0.35 f	5.16 e	5.21 e

These results indicated stimulating effects of potassium humate on plant growth and tuber yield over other inorganic potassium sources. Among the different four sources of organic and inorganic potassium, potassium humate (K3) showed the highest significant improvements in potato vegetative growth and tuber quality parameters, in both seasons. In the same time potassium silicate (k4) was ranked as the second, whereas, Bitasol (k2) showed the lowest values as compared with the three other sources, in both seasons. The humic acid compounds from potassium humate may provide useful options in developing sustainable agricultural technologies for soil amendments and organic fertilizers in an ecologically responsible manner for monoculture of potato production.

Humic acids originating from potassium humate in the soil, may represent an enzymatically active complex, which can trigger various reactions that are usually assigned to the microbial metabolic activity. The observed effects of potassium humate supplement may probably be ascribed to (a) declining of soil pH; (b) increasing availability of nitrogen-containing functional groups; (c) improving nutrient-exchange capacity; (d) improving soil water retention; (e) and enabling of certain biochemical reactions, etcetera (Akimbekov, *et al.*, 2020)

CONCLUSION

In conclusion, the present study suggests positive impacts of potassium humate as an organic source of potassium on potato plant growth and tuber quality parameters compared to inorganic sources of potassium. According to these results, the soil fertilized with potassium humate exhibited high nutrient availability and fertility compared to inorganic sources of potassium and control. In addition, results demonstrated that both plant vegetative growth parameters and tuber yield were significantly affected by potassium humate followed by potassium silicate compared to other sources of potassium especially with Lady Balfour cultivar of potato. Some limitations must be assigned in the future studies in order to magnificently implement the positive effects of different organic and inorganic potassium resources on potato plant growth and yield. The central features for future studies include the variation, and complexity of different organic and inorganic potassium fertilizers; dearth of valid field pilot studies on a potassium fertilizer dosage depending on soil type, potassium fertilizer resource, potato cultivar and climate. The need for a better understanding of the fundamental mechanism of potassium in potato plant growth promotion and yield quality is critical.

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إستجابة صنفين من البطاطس لمصادر البوتاسيوم المختلفة

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يلعب البوتاسيوم دورًا محوريًا في تحسين جودة وإنتاجية البطاطس. أجريت تجربة حقلية خلال موسمي زراعة نيلي ٢٠١٩/٢٠١٨ و ٢٠٢٠/٢٠١٩ في المزرعة البحثية بجامعة المنيا بمصر ، بهدف دراسة تأثيرات المصادر العضوية وغير العضوية المختلفة للبوتاسيوم (كبريتات البوتاسيوم - هيومات البوتاسيوم - نترات البوتاسيوم - سيليكات البوتاسيوم) على نمو وإنتاجية أصناف البطاطس (ليدي بلفور وكارا). بعد ٧٥ يومًا من الزراعة ، تم الحصول على أقصى ارتفاع للنبات وعدد الأفرع مع الصنف ليدي بلفور المخصب بهيومات البوتاسيوم و أعطى استخدام هيومات البوتاسيوم مع الليدي بلفور نتائج ممتازة من حيث طول الأفرع وعدد السيقان ووزن الأفرع ، بينما زادت مساحة سطح الورقة في ليدي بلفور بمعاملة سيليكات البوتاسيوم و تم الحصول على أكبر قدر من الدرنات / نبات في كلا الموسمين مع الصنف كارا المعامل بسيليكات البوتاسيوم ، بينما سجل الصنف ليدي بلفور مع وزن الدرنات بمعاملة هيومات البوتاسيوم في الموسم الثاني. تم تحقيق أعلى إنتاجية لمحصول الدرنات لكلا الموسمين بواسطة الصنف كارا مع سيليكات البوتاسيوم وليدي بلفور مع هيومات البوتاسيوم وكان محتوي الدرنات من المواد الصلبة الكلية و الكلوروفيل a و b والكاروتين أعلى مع هيومات البوتاسيوم وسيليكات البوتاسيوم مع الصنف كارا وأظهرت نتائج التجربة أن أعلى محتوى من النيتروجين والفوسفور والبوتاسيوم في أوراق البطاطس مع كلا الصنفين المعاملة مع هيومات البوتاسيوم. تم تأكيد التأثيرات الإيجابية لهيومات البوتاسيوم تليها سيليكات البوتاسيوم على مصادر البوتاسيوم الأخرى التي تم فحصها على نمو البطاطس وجودتها.