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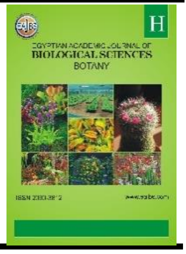

Effect of Potassium Sources on Growth and Potassium Uptake of Spinach

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Fertilizers; potassium sources, soil potassium, uptake, spinach.

ABSTRACT

To investigate the effect of potassium source and rate on soil K, growth and K uptake of spinach, a pots experiment was carried out during the winter season of 2020 at the greenhouse of the Faculty of Agriculture, Saba Basha, Alexandria, Egypt. The experiment was laid out in randomized complete block design (RCBD) with three replications. The treatments included applying 50% of recommended K in the form of potassium sulfate (PS50), 100% as potassium sulfate (PS100), 50% as potassium citrate (PC50), 100% as potassium citrate (PC100), 50% as potassium humate (PH50), 100% as potassium humate (PH100) and control (0% K). The obtained results showed that the application of potassium in the forms of potassium humate and potassium citrate improved spinach growth and K uptake compared to potassium sulfate. The application of potassium humate can minimize the potassium application rate and reduce the fertilizer requirements without significant influences on plant growth and potassium uptake.

INTRODUCTION

Potassium (K) is an essential nutrient for plant growth. Due to the large quantities of potassium being taken up by plants potassium is classified as a macronutrient. Potassium is associated with the transport of water and nutrients in plant tissue. It is vital to photosynthesis and protein synthesis. Potassium also helps to regulate the opening and closing of the stomata which regulates the exchange of water vapor, oxygen, and carbon dioxide. If potassium is not available for the plant in adequate amounts, growth is reduced and yield diminishes (Wang *et al*., 2013).

Spinach (*Spinacia oleracea* L.) is considered one of the most common leafy vegetable crops grown up in Egypt. Spinach is used fresh or preserved or frozen product. It is low in calories and a good source of vitamin C, vitamin A and minerals especially iron (Toledo *et al*., 2003). Spinach is a vegetable with a high biological value, particularly rich in antioxidants especially when fresh, steamed, or quickly boiled (Cho *et al*., 2008). It is a good source of vitamin A, C, E, K, B2, B6, B9, folic acid, minerals (Mn, Mg, Fe, K, Ca, Se), and dietary fiber. It is a good source of vitamins A, B1, B2, and C, as well as minerals such as calcium, iron, and magnesium (Kawazu *et al*., 2003). The cultivated area of spinach in Egypt was 1760 ha with a total production of 28598 tons but in Iraq the total area was 388 ha with a total production of 2684 tons. The global planting area for spinach is reported to reach 930791 ha with a total production of 30107231 tons in 2019 (FAO, 2019).

Potassium sulfate supplies soil and plants with two essential nutrients: potassium (up to 54% K_2O) and sulfur (18.4% S) (Ciceri *et al*., 2017). The presence of high chloride content

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in potassium chloride KCl, can increase the salinization of soils and accumulate the cadmium in plants (Zahedifar *et al*., 2016). For these reasons, the use of K_2SO_4 as a fertilizer is preferred for several benefits such as good solubility (120 g/l at 25 °C), low-to-0 chloride content and low salt index. It also costs half of that of the potassium nitrate (Ciceri *et al*., 2017).

The application of organic amendments, i.e., humic substances in soil with low organic matter status could be enhanced the physical, chemical and biological properties of the soil (Suddarth *et al.*, 2019; Datta *et al*., 2020). Soil characteristics vary with land use (Yadav *et al*., 2017; Marfo *et al.*, 2019). Moreover, the addition of humic substances has been found to be helpful in reducing the leaching of anion-like nitrate, sulphate and phosphate due to their high absorption capacity (Kumar *et al*., 2013). The stimulatory effects of humic substances on plant growth have been proven in many studies (Kumar and Singh, 2017; Mohsen *et al*., 2017; Burhan and AL-Taey, 2018). In this way Kadam *et al.* (2011) showed the positive effects of applied potassium humate as an increase in seed germination, the root and shoot length of wheat were recorded compared to the control. Potassium humate has the potential to increase soil properties and nutrient dynamics in soil (Turgay *et al*., 2011). In the same trend, Kumar *et al*. (2014) revealed that the application of potassium humate at 10 mg/kg soil resulted in a significant increase in plant height, the number of tillers, panicle height, panicle length and grain yield of rice.

Organic chelated forms of potassium like potassium citrate can be used as a source for potassium and it was reported by many researchers that it improved plant growth, nutrient uptake and yield as well as quality in many crops (Ebeed and Abd El-Migeed, 2005; Taha *et al.*, 2014; Behairy *et al.*, 2015; Ibrahim *et al.*, 2015). Citric acid is a tricarboxylic acid-containing β-hydroxyl functional group (CH2COOH-COHCOOH-CH2COOH). Citric acid is naturally released by plant roots in the rhizosphere, which may play an important role in weathering of soil minerals and release many nutrients including K and Si (Chatterjee *et al*., 2016).

The present study aimed to evaluate the effect of application potassium sulfate, potassium citrate and potassium humate as different sources of potassium fertilizers at different rates on K uptake and growth performance of spinach, also, the status of available potassium under the studied treats.

MATERIALS AND METHODS

Pots experiment was conducted at the Faculty of Agriculture, Saba Basha, Alexandria University, Alexandria Governorate, Egypt, during the winter season of 2020 to study the effect of potassium forms on growth, available soil K and K- uptake of spinach cv SCO-017 F1 (Denmark) grown in clay texture soil. The physical and chemical properties of the soil are presented in Table (1) (Page *et al.*, 1982).

Table 1. Physical and chemical properties of soil.

Soil properties	
Sand	37.52
Silt	30.00
Clay	32.48
Soil texture	Clay loam
pH (1:2.5)	8.25
EC (dS/m)	3.24
Available N (mg/kg)	17
Available K (mg/kg)	250.0
Available P (mg/kg)	25

The pots experiments were laid out in rondomized complete block design (RCBD) with three replications. The treatments included applying 50% of recommended K in the form of potassium sulfate (PS50), 100% as potassium sulfate (PS100), 50% as potassium citrate (PC50), 100% as potassium citrate (PC100), 50% as potassium humate (PH50), 100% as potassium humate (PH100) and control (0% K).

Spinach seeds were sown on the 22nd of November 2020 in pots with 3 liters capacity (13 cm height x 13cm diameter). Phosphorus fertilizer was added at the rate of 1g/pot in the form of triple calcium superphosphate (44 % P_2O_5) just before sowing. Mineral nitrogen fertilizer (0.6 g N/pot) as ammonium nitrate (33.5 % N) was applied at three equal doses, the first was just before sowing, the second dose was after 15 days from panting and the third dose was after 30 days from planting. All other cultural practices were followed as the recommendation of the Ministry of Agriculture and Land Reclamation recommendations.

Data obtained was exposed to the proper method of statistical analysis of variance as described by Gomez and Gomez (1984). The treatments means were compared using the least significant differences test (L.S.D.) at a 5% level of probability. The statistics analysis was carried out using CoStat 6.311 (2005) computer soft package.

RESULTS AND DISCUSSION

The results presented in Table (2) showed the effect of potassium forms on plant height (cm), root length (cm), number of leaves/plant, Chlorophyll content (SPAD unit) of spinach, available soil K and K uptake by spinach during the growing season of 2020. Concerning the effect of potassium forms, the results in Table (2) showed significant responses in plant height (cm), root length (27.7 cm), Chlorophyll content (SPAD unit) of spinach, available soil K and K uptake with different K-forms and K rate. Plant height increased significantly with potassium fertilizers with all K sources and rates over control. Application of 100 % of recommended K requirements as potassium humate recorded the highest value of plant height (27.7 cm) which was on par with 100% potassium citrate and 100% potassium sulfate. The plant height of spinach decreased significantly when 50% of the recommended K dose was applied as potassium citrate and potassium sulfate. However, no significant retraction in plant height was recorded with 50% potassium humate.

Root length increased significantly with potassium application as compared to control plants, except with 50% potassium sulfate. The number of leaves per plant increased significantly with 100% potassium humate over control. However, no significant difference between control and other treatments was registered in the number of leaves per plant. Application of potassium fertilizers improved significantly the chlorophyll content of spinach leaves (SPAD) in all treatments over control. While higher chlorophyll content was recorded with potassium humate (100% and 50% of K) and potassium citrate (100% of K) as compared to potassium sulfate treatments (100% and 50% of K).

Potassium uptake (%) also increased significantly in all potassium fertilizers treatments over control. Application of potassium humate (100% and 50% of K) and potassium citrate (100% of K) improved the K uptake (%) significantly as compared to potassium sulfate treatments (100% and 50% of K). The application of potassium fertilizers increased the available soil K significantly as compared to control. The highest available soil K was registered with 100% and 100% potassium citrate which was on par with 100% potassium sulfate treatment. These results are in agreement with those reported by Turgay *et al*. (2011), Sadak and Orabi (2015), Chatterjee *et al.* (2016), Hemida *et al.* (2017), Taha and Osman (2018) and Abdel-Baset *et al.* (2020) who reported that K fertilizers especially K- humate or K- citrate caused an increase in plant growth and soil K availability.

The accumulation of natural humic acids in the soil as a result of potassium humate application has been shown to reduce the leaching of fertilizers, improves fertilizer efficiency and reduces the need for chemical fertilizers (Kumar *et al.,* 2013). Humic substances compensate for the low content of organic matter and enhance the quality of soil (Pena-Mendez *et al.,* 2005). The promoting effect of humic substances on plant growth and yield has been noted by many investigators. Since humic acid frequently proceeds as one of the natural components of soil, it may form an enzymatically active complex that can regulate some reactions that are commonly assigned to the metabolic activity of crop roots or living organisms (Serbon and Nissenbaun, 1986).

Table 2. Effect of potassium source and rate on spinach growth, K uptake and availability during the winter season of 2020.

Treatment	Plant height (cm)	Root length (cm)	Number of leaves /plant	Chlorophyll content (SPAD unit)	Available soil K (ppm)	K uptake (%)
K- forms (B)						
Control	13.0 c	3.3 b	8.7 b	30.2 c	250.0 d	16.0 e
K- sulfate (50 %)	22.3 b	5.2 b	13.7 ab	35.6 b	316.7 c	44.4 d
K- sulfate (100 %)	23.0 ab	7.8 a	13.0 ab	36.0 b	366.7 ab	54.2 cd
K- citrate (50%)	22.3 b	8.7 a	11.7 ab	39.0 ab	333.3 bc	71.7 bc
K- citrate (100 %)	23.2 ab	8.2 a	14.3 ab	40.8 a	383.3 a	84.3 ab
K- humate (50 %)	23.5 ab	7.5 a	14.7 ab	40.9 a	316.7 c	92.2 ab
K- humate (100 %)	27.7 a	7.7 a	16.7 a	41.4 a	383.3 a	111.1 a
LSD at 0.05	5.4	2.1	6.0	4.4	49.5	26.9

Means in column (s) followed by the same letter are not significant at 0.05 level of probability.

CONCLUSION:

The obtained results concluded that the application of potassium in the forms of potassium humate and potassium citrate improved spinach growth and K uptake compared to potassium sulfate. The application of potassium humate can minimize the potassium application rate and reduce the fertilizer requirements without significant influences on plant growth and potassium uptake.

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ARABIC SUMMARY

تأثير مصادر البوتاسيوم على النمو والبوتاسيوم الممتص في السبانخ

وفاء حسن علي محمد و كرم عبد العزيز عبد الرازق الزوبي و محمود صفاء فائق الكاكي
قسم الأراضي والكيمياء الزراعية – كلية الزراعة – سابا باشا – جامعة الأسكندرية

لدراسة تأثير مصدر ومستوى البوتاسيوم على محتوى التربة من البوتاسيوم ونمو السبانخ ونسبة البوتاسيوم الممتص أجريت تجربة في اصص خلال الموسم الشتوي في عام 2020 في صوبة كلية الزراعة (سابا باشا) – جامعة الأسكندرية – مصر وصممت التجربة في تصميم القطاعات العشوائية الكاملة ووزعت المعاملات عشوائياً في ثلاثة مكررات. وشملت المعاملات اضافة 50% من جرعة البوتاسيوم الموصى بها في صورة سلفات البوتاسيوم و100% (الجرعة الموصى بها) في صورة سلفات البوتاسيوم و 50% من جرعة البوتاسيوم الموصى بها في صورة سترات البوتاسيوم و100% (الجرعة الموصى بها) في صورة سترات البوتاسيوم و 50% من جرعة البوتاسيوم الموصى بها في صورة هيومات البوتاسيوم و100% (الجرعة الموصى بها) في صورة هيومات البوتاسيوم ومعاملة الكنترول (بدون اضافة للبوتاسيوم).أوضحت النتائج المتحصل عليها أن اضافة البوتاسيوم في صورة هيومات البوتاسيوم وسترات البوتاسيوم عملت على زيادة معنوية في نمو نباتات السبانخ ونسبة البوتاسيوم الممتص مقارنة بسلفات البوتاسيوم. كما وجد أن اضافة هيومات البوتاسيوم ممكن أن تقلل معدل البوتاسيوم وتقلل من الاحتياجات السمادية بدون تأثير معنوي على نمو النبات او نسبة البوتاسيوم الممتص (%).