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EFFECT OF RATES AND SOURCES OF POTASSIUM FERTILIZATION ON DRY WEIGHT, MINERAL UPTAKE, POTASSIUM USE EFFICIENCY AND PRODUCTIVITY OF EGGPLANT

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ABSTRACT: Two field experiments were carried out during the two successive summer seasons of 2019 and 2020 in the private Farm at Keshek Village, Abou- Hamad district, Shahrkia Governorate, to study the effect of potassium rates (45, 60, 75 and 90 kg K_2O/fad.) as soil applications and different sources of potassium, *i.e.* potassium citrate ($K_3C_6H_5O_7$) at 1 ml/l, potassium humate ($C_9H_8K_2O_4$) at 3 g/l, potassium thiosulfate ($K_2S_2O_3$) at 1ml/l and potassium silicate (K_2SiO_3) at 3 ml/l, beside sprayed with water (control treatment) as foliar application on dry weight, mineral uptake and yield and its components of eggplant (cv. long black). The interaction between K_2O at 90 kg/fad. and foliar spray with $K_3C_6H_5O_7$at 1 ml/l significantly increased dry weight of branches, leaves and shoots/plant, N, P and K uptake by shoots, average fruit weight, yield/plant, and total yield with no significant differences with K_2O at 75 kg /fad., and spraying with $K_3C_6H_5O_7$at 1 ml/l, followed by the interaction between 90 kg K_2O/fad., and spraying with potassium humate at 3g/l in both seasons. In the same time, total yield /fad. (14.649 and 14.768 ton/fad.) produced from 75 kg K_2O and spraying with $K_3C_6H_5O_7$at 1 ml/l treatment were more than total yield/fad. (12.320 and 12.290 ton/fad.) produced from 90 kg K_2O and unsprayed (spraying with water) in the 1st and 2nd seasons, respectively. As for potassium use efficiency (KUE), the highest values of KUE were recorded with the interaction between 45 kg K_2O/fad. and $K_3C_6H_5O_7$at 1 ml/l foliar spray (245.3 and 247.2 kg fruit/kg K_2O) in the 1st and 2nd seasons, respectively.

Key words: Eggplant, potassium rates and sources, soil and foliar application, dry weight, mineral uptake and yield.

INTRODUCTION

Eggplant (*Solanum melongena* L.) is generally enlisted as classical commodity for both local consumption and exportation. It is grown in most cultivated area in Egypt. Eggplant is one of the most popular vegetables in many parts of the subtropical regions. As eggplant's fruit contains low calories, they are regarded as a healthy food by many dietitians. They also represent good sources of vitamin C, potassium and calcium. One hundred grams of fresh fruit flesh contains around 24 calories, 1 gram of protein, zero fat, zero cholesterol and 239 milligrams of sodium.

The total area devoted in Egypt for the production of eggplant in 2019 was 109545 fed. which produced 1180240 tons with average 10.770 ton/fad. (According to FAO, 2020).

Most agricultural practices assess the productivity of eggplant yield among these firstly selected high yielding cultivars and use optimum level of mineral potassium fertilization as soil application as well as foliar application with micronutrient.

Potassium fertilization became an important factor for eggplants production under Egyptian soils. However, farmers minimized the used amount to the minimum dose or ignored using it because chemical potassium fertilizer became a high expensive fertilizer in Egypt. In addition to use any other newly and cheapest potassium

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sources through foliar application to overcome such problem and to maximize their net return to cover the additional cost of this K fertilizer source.

Many authors showed that increasing potassium fertilizer rates gave the best results for enhancing dry weight **(Fawzy *et al*., 2007** on eggplants**, El-Bassiony *et al.*, 2010** on sweet pepper and **Efnan *et al.*, 2013** on tomato), mineral uptake **(Ortas 2013; Ahmad *et al*., 2015 and Sultana *et al.*, 2015** on tomato) and best productivity (**El-Miniawy, 2015, Kakahy *et al*., 2020** and **Manimegala and Gunasekaran, 2020** on eggplants**).**

Foliar fertilization is more economical than root fertilization due to the efficiency and lower cost. The foliar application of different sources of potassium are usually preferred because very small amounts of fertilizers are applied per units. It also reduces the number of passes of the applicant, thereby reducing problem of soil compactness. Foliar application is also less likely to result in ground water pollution. Potassium in organic cheated form (potassium citrate, Humate) can be used as a inexpensive source for potassium and it could be used as foliar application.

As for, spraying plants with different sources of potassium effects on plant growth (**Fawzy *et al*., 2007; Rakha, 2014** on eggplant, **Hussein *et al.*, 2012** on pepper), plants nutrient uptake (**Kamal, 2013)** on pepper, **Ramadan** and **Shalaby 2016** on eggplant, **Zakher and Elashry, 2016** on tomato) and total yield **Hussein** and **Muhammed, 2017** on eggplants**, Abdel-Aziz, and Geeth, 2018** on sweet pepper, **Abd Elwahed, 2018** on tomato and **Khalil *et al.* 2018** on sweet pepper). All indicated that spraying plants with potassium, citrate, humate, thiosulpahte and silicate had significant effects on plant growth, mineral uptake and yield and its components than unsprayed plants.

The aim of this research was to determine the appropriate rate of potassium fertilizer as a soil application individually or in combination with foliar application with some potassium sources for optimizing growth and yield of eggplant.

MATERIALS AND METHODS

Two field experiments were carried out during the two successive summer seasons of 2019 and 2020 in the private Farm at Keshek Village, Abou-Hamad District, Shahrkia Governorate, to study the effect of potassium rates as soil applications and different sources of potassium as foliar application on plant growth and yield and its components of eggplant (cv. long black).

The physical and chemical properties of the experimental soil are presented in Table 1.

This experiment included 20 treatments which were the combinations between four K_2O rates (45, 60, 75 and 90 kg K_2O/fed.) as soil applications in the form of potassium sulphate and four sources of potassium as foliar spray potassium citrate ($K_3C_6H_5O_7$) at 1 ml/l, potassium humate ($C_9H_8K_2O_4$) at 3 g/l, potassium thiosulfate ($K_2S_2O_3$) at 1ml/l, potassium silicate (K_2SiO_3) at 3 ml/l, beside spraying with water (control treatment).

These treatments were arranged in a split plot design with three replicates. Potassium rates as soil application were randomly arranged in the main plots and potassium sources as foliar application were randomly distributed in the sub plots.

K_2O rates were added as soil application of potassium sulphate at three equal portions monthly beginning one month after transplanting. Potassium citrate, potassium humate, and potassium thiosulfate as well as potassium silicate were added as foliar application four times at 45, 60, 75 and 90 days after transplanting.

Potassium thiosulfate is a neutral to basic, clear liquid solution, containing 36% K_2O and 25% sulfur, imported by the International Company for Fertilizers and Chemicals-Aga-Dakahlia, Governorate, Egypt.

Potassium citrate containing 36.5 %K_2O and produced by Agricultural Company of Modern Pesticides, Apartment 8, Building 119, District 3-4, Fifth District, Cairo, potassium humate and potassium silicate were obtained from Technogen Company, El-Dokky, Giza, Egypt.

Seeds of eggplant were sown in nursery on May 10th and 12th in 2019 and 2020 seasons, respectively. Eggplant transplants were transplanted at 40 cm apart on one side of the ridge in July 10th and 14th in the first and second seasons, respectively. All experimental units' area was 18 m^2 and it contained three ridges with

Table 1. The physical and chemical properties of the experimental soil at 2019 and 2020 seasons

Soil property	1st season	2nd season
Physical properties		
Clay (%)	30.91	32.00
Silt (%)	10.29	11.81
Sand (%)	58.6	57.03
Texture	Sandy loam	Sandy loam
Chemical properties		
E.C. (mmhos/cm)*	2.89	3.01
pH**		
Organic matter (%)	1.49	1.52
Available N (ppm)	9.18	9.37
Available P_2O_5 (%)	0.037	0.036
Available K_2O (%)	0.57	0.58

Samples of the soil were obtained from 25 cm soil surface. *E.C: Electric conductivity, ** pH (1: 2.5 suspension).

6 m length and 1.0 m in width. One ridge was used to measure vegetative growth and the other two ridges were used for yield determination.

All plots received the recommended rate of N and P as ammonium sulphate (20.5%N) and calcium super phosphate (15.5 % P_2O_5). The normal agricultural practices in both experiments were carried out as commonly followed in the district.

Data Recorded

A random sample of five plants from each experimental unit was randomly taken at 110 days after transplanting in both seasons to determine dry weight of leaves/plant (g), dry weight of branches /plant (g) and total dry weight of shoots (leaves + branches/plant (g).

The N, P and K uptake by shoot was computed at 110 days after transplanting in both seasons after the determination of nitrogen, phosphorus and potassium contents in leaves and branches according to the methods described by **Bremner and Mulvaney (1982), Olsen and Sommers (1982) and Jackson (1970**), respectively.

At harvest stage, the mature fruits of eggplant for each plot were collected (twice every week). Total picked fruits /plot during the whole harvesting season were weighted, counted and the total yield per plant and per fad. and average fruit weight were calculated.

Potassium use Efficiency (NUE)

It was determined by dividing the yield/fad., by the potassium quantity/fad., and expressed as kg fruits /kg K_2O according to **Clark (1982**).

Statistical Analysis

Collected data were subjected to proper statistical analysis of variance according to **Snedecor and Cochran (1980)** and the differences among treatments were compared using Duncans' multiple range test (**Duncan, 1958**), where means had different letters were statistically significant, and those means followed by the same letter were statistically insignificant.

RESULTS AND DISCUSSION

Dry Weight

Effect of potassium levels as soil application

Fertilizing eggplants with K_2O at 90 kg/fad., significantly increased dry weight of branches, leaves and shoots at 110 days after transplanting in both seasons, followed by K_2O at 75 kg/fad. (Table 2).

Table 2. Effect of potassium levels as soil application on dry weight of different parts of eggplant after 110 days from transplanting during 2019 and 2020 seasons

Treatments Potassium levels (kg/fad.)	Dry weight of branches/plant (g)	Dry weight of leaves /plant (g)	Dry weight of shoots (branches + leaves) (g)
		2019 season	
45	30.13 c	15.33 c	45.46 c
60	37.98 b	21.33 b	59.31 b
75	40.42 ab	23.82 ab	64.24 ab
90	42.51 a	25.69 a	68.20 a
		2020 season	
45	32.22 c	16.77 d	49.00 c
60	38.55 b	21.61 c	60.22 b
75	40.44 b	24.55 b	65.00 b
90	45.55 a	26.88 a	72.44 a

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

The increases in shoot dry weight were about 13.85 and 11.22 g/plant for 60 kg K_2O/fad., 18.78 and 16.0 g/plant for 75 Kg K_2O/fad., and 22.74 and 22.44 g/plant for 90 kg K_2O/fad., over the 45 kg K_2O/fad., in the 1st and 2nd seasons, respectively.

This result may be due to the role of potassium in the activation of many enzymes that has the responsibility of regularity of various metabolic processes within plants, the construction of vital compounds such as starch and protein, as well, stimulating the growth of meristematic tissue, also promote the photosynthesis and transport of the carbohydrates to the storage organs (**Marschner, 1995**). Substantially, potassium is one of the building blocks in plant physiology and which could contribute significantly to the superiority of the dry weight content of eggplant plants (**Gardener *et al.*, 1985**).

Similar results were obtained by **Fawzy *et al.* (2007)** on eggplants**, El-Bassiony *et al.* (2010)** on sweet pepper and **Efnan *et al.* (2013)** on tomato. They found that fertilizing plants with the highest rate of potassium recorded the best dry weight of different organs/plant than other rates.

Effect of potassium sources as foliar application

Spraying eggplant plants with different potassium sources increased dry weight of branches, leaves and shoots of eggplant at 110 days after transplanting compared to unsprayed (spraying with water) in both growing seasons as shown in Table 3.

Foliar spray with potassium citrate at 1 ml/l increased dry weight of branches, leaves and shoots of eggplant in both seasons, followed by spraying with potassium humate at 3 g/l.

The increases in shoot dry weight were about 24.73 and 23.20 g/plant for potassium citrate at 1 ml/l, 20.83 and 22.36 g/plant for potassium humate at 3g/l., 15.64 and 16.25 g/plant for potassium thiosulfate at 1ml/l and 13.50 and 13.75 g/plant for potassium silicate at 3 ml/l over control (unsprayed) in the 1st and 2nd seasons, respectively.

Potassium citrate is potassium salt of citric acid which considered one of the most important organic acids in the respiratory pathways into plant cell. The mitochondrial citric acid cycle provides the energy for ATP synthesis which is

Table 3. Effect of potassium sources as foliar application on dry weight of different parts of eggplant after 110 days from transplanting during 2019 and 2020 seasons

Treatments Potassium sources	Dry weight of branches/plant (g)	Dry weight of leaves /plant (g)	Dry weight of shoots (branches + leaves) (g)
		2019 season	
Unsprayed	30.94 c	13.41 d	44.36 d
$K_3C_6H_5O_7$at 1 ml/l	42.61 a	26.50 a	69.11 a
$C_9H_8K_2O_4$ at 3 g/l	40.69 a	24.50 ab	65.19 ab
$K_2S_2O_3$ at 1 ml/l	37.61 b	22.39 bc	60.00 bc
K_2SiO_3 at 3 ml/l	36.94 b	20.91 c	57.86 c
		2020 season	
Unsprayed	30.69 c	14.72 e	45.55 d
$K_3C_6H_5O_7$at 1 ml/l	45.97 a	27.77 a	73.75 a
$C_9H_8K_2O_4$ at 3 g/l	42.08 b	25.86 b	67.91 b
$K_2S_2O_3$ at 1 ml/l	38.61 b	23.17 c	61.80 c
K_2SiO_3 at 3 ml/l	38.61 b	20.74 d	59.30 c

$K_3C_6H_5O_7$= Potassium citrate (36.5 % K_2O), $C_9H_8K_2O_4$ = potassium humate (12 % K_2O), $K_2S_2O_3$= potassium Thiosulfate (36% K_2O), and K_2SiO_3 = potassium silicate (10 % K_2O)
Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

essential for different biochemical and physiological processes (**Taiz and Zeiger, 2002**). Additionally, citric acid plays an important role in plant metabolism, it's as non-enzymatic antioxidant in chelating free radicals and protecting plant from injury could result in prolonging the shelf life of plant cells and improving growth characters (**Sadak and Orabi, 2015**).

These results were in agreement with findings of **Fawzy *et al*. (2007), Rakha, (2014)** on eggplant and **Hussein *et al.* (2012)** on pepper, all indicated that spraying plants with potassium, citrate, humate, thiosulpahte and silicate had significant effects on plant growth than unsprayed plants.

Effect of the interaction

The obtained results in Tables 4 and 5 show that the interaction between K_2O at 90 kg /fad. and foliar spray with potassium citrate at 1 ml/l significantly increased dry weight of branches, leaves and shoots/plant, with no significant differences with the interaction between 75 kg K_2O/fad. and spraying with potassium citrate at 1 ml/l in the 1^{st} season.

This means that dry weight of shoots for the interaction between 75 kg K_2O/fad. and spraying with potassium citrate at 1ml/l were more than dry weight of shoots for 90 kg /fad. K_2O and unsprayed (spraying with water).

The obtained results are in good harmony with those of **El-Bassiony *et al*. (2010)** which showed that, the highest values dry weights of leaves of sweet pepper were obtained with the interaction between 200 kg/fad. K_2O and spraying with potassium humate at 4 gm/liter as compared to other interaction treatment.

Nitrogen, Phosphorus and Potassium

Effect of potassium levels as soil application

Fertilizing eggplant with K_2O at 90 kg/fad., significantly increased N,P and K uptake by shoots at 110 days after transplanting in both seasons (Table 6). The stimulating effect of potassium fertilization on the absorption of N, P and K in shoots may be due to the increased dry weight of shoots due to potassium fertilization (Table 2).

These results may be due to the role of potassium in plant metabolism. Moreover,

Table 4. Effect of the interaction between potassium levels as soil application and potassium sources as foliar application on dry weight of different parts of eggplant after 110 days from transplanting during 2019 season

Treatments		Dry weight of branches/plant (g)	Dry weight of leaves /plant (g)	Dry weight of shoots (branches +leaves) (g)
Potassium levels (kg/fad.)	Potassium sources			
45	Unsprayed	23.33 j	9.00 g	32.33 i
	$K_3C_6H_5O_7$at 1 ml/l	36.33 e-h	20.44 c-e	56.78 d-g
	$C_9H_8K_2O_4$ at 3 g/l	33.11 g-i	17.11 d-f	50.23 f-h
	$K_2S_2O_3$ at 1 ml/l	29.11 ij	14.89 e-g	44.00 h
	K_2SiO_3 at 3 ml/l	28.78 ij	15.23 e-g	44.00 h
60	Unsprayed	30.67 hi	12.44 fg	43.11 hi
	$K_3C_6H_5O_7$at 1 ml/l	43.23 a-c	25.78 a-c	69.00 a-c
	$C_9H_8K_2O_4$ at 3 g/l	41.67 a-f	24.89 a-c	66.56 a-d
	$K_2S_2O_3$ at 1 ml/l	37.67 c-g	23.11 b-d	60.78 c-f
	K_2SiO_3 at 3 ml/l	36.67 d-g	20.44 c-e	57.11 d-g
75	Unsprayed	33.67 g-i	15.33 e-g	49.00 gh
	$K_3C_6H_5O_7$at 1 ml/l	44.44 ab	29.11 ab	73.56 ab
	$C_9H_8K_2O_4$ at 3 g/l	43.00 a-c	27.56 a-c	70.56 a-c
	$K_2S_2O_3$ at 1 ml/l	41.00 a-f	24.00 a-d	65.00 b-d
	K_2SiO_3 at 3 ml/l	40.00 b-f	23.11 b-d	63.11 b-e
90	Unsprayed	36.11 f-h	16.89 d-f	53.00 e-h
	$K_3C_6H_5O_7$at 1 ml/l	46.44 a	30.67 a	77.11 a
	$C_9H_8K_2O_4$ at 3 g/l	45.00 ab	28.44 ab	73.44 ab
	$K_2S_2O_3$ at 1 ml/l	42.67 a-d	27.56 a-c	70.23 a-c
	K_2SiO_3 at 3 ml/l	42.33 a-e	24.89 a-c	67.23 a-d

$K_3C_6H_5O_7$= Potassium citrate (36.5 % K_2O), $C_9H_8K_2O_4$ = potassium humate (12 % K_2O), $K_2S_2O_3$= potassium Thiosulfate (36% K_2O), and K_2SiO_3 = potassium silicate (10 % K_2O)

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

Table 5. Effect of the interaction between potassium levels as soil application and potassium sources as foliar application on dry weight of different parts of eggplant after 110 days from transplanting during 2020 season

Treatments		Dry weight of branches/plant (g)	Dry weight of leaves/plant (g)	Dry weight of shoots (branches + leaves) (g)
Potassium levels (kg/fad.)	Potassium sources			
45	Unsprayed	26.67 h	11.11 k	37.78 i
	$K_3C_6H_5O_7$ at 1 ml/l	37.78 d-f	20.56 fg	58.33 de
	$C_9H_8K_2O_4$ at 3 g/l	33.33 e-h	19.44 gh	52.78 e-g
	$K_2S_2O_3$ at 1 ml/l	33.33 e-h	16.67 i	50.00 f-h
	K_2SiO_3 at 3 ml/l	30.00 gh	16.11 i	46.11 gh
60	Unsprayed	29.44 gh	13.61 j	43.33 hi
	$K_3C_6H_5O_7$ at 1 ml/l	47.23 ab	27.23 cd	74.44 b
	$C_9H_8K_2O_4$ at 3 g/l	43.33 b-d	25.56 de	68.89 bc
	$K_2S_2O_3$ at 1 ml/l	35.00 e-g	22.23 f	57.23 d-f
	K_2SiO_3 at 3 ml/l	37.78 d-f	19.44 gh	57.23 d-f
75	Unsprayed	32.23 f-h	16.11 i	48.33 gh
	$K_3C_6H_5O_7$ at 1 ml/l	46.11 a-c	30.56 b	76.67 b
	$C_9H_8K_2O_4$ at 3 g/l	44.44 b-d	28.94 bc	73.33 b
	$K_2S_2O_3$ at 1 ml/l	38.89 c-f	24.83 e	63.89 cd
	K_2SiO_3 at 3 ml/l	40.56 b-e	22.33 f	62.78 cd
90	Unsprayed	34.44 e-g	18.06 hi	52.78 e-g
	$K_3C_6H_5O_7$ at 1 ml/l	52.78 a	32.73 a	85.56 a
	$C_9H_8K_2O_4$ at 3 g/l	47.23 ab	29.53 b	76.67 b
	$K_2S_2O_3$ at 1 ml/l	47.23 ab	28.97 bc	76.11 b
	K_2SiO_3 at 3 ml/l	46.11 a-c	25.11 e	71.11 bc

$K_3C_6H_5O_7$= Potassium citrate (36.5 % K_2O), $C_9H_8K_2O_4$ = potassium humate (12 % K_2O), $K_2S_2O_3$= potassium Thiosulfate (36% K_2O), and K_2SiO_3 = potassium silicate (10 % K_2O)

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

Table 6. Effect of potassium levels as soil application on N, P and K uptake by shoots (mg) of eggplant after 110 days from transplanting during 2019 and 2020 seasons

Treatments Potassium levels (kg/fad.)	N	P	K
		2019 season	
45	1198.5 c	107.14 d	982.1 c
60	1618.3 b	150.71 c	1312.3 b
75	1837.0 a	176.81 b	1513.9 a
90	1973.2 a	206.00 a	1632.5 a
		2020 season	
45	1278.6 d	128.00 d	1064.2 c
60	1664.1 c	171.68 c	1342.6 b
75	1868.4 b	196.08 b	1525.6 b
90	2138.3 a	240.81 a	1739.6 a

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

potassium is involved in numerous step in protein synthesis (**Edmond *et al*., 1977**). Also the important roles of potassium in plants such as the osmotic adjustment (**Lindhauer, 1985**), enzyme activation, cell turgor maintenance, ion homeostasis, photosynthesis and transport of outputs to the storage organs (**Marschner, 1995**) which led to increased mineral values of the leaves.

In this regard, **Eleiwa *et al*. (2012)** found that increasing the supplied K levels significantly increased pigments content in potato shoots. Increased leaf activities stimulate the need of water uptake and consequently, it increases the nutrients uptake from the soil**.** The obtained results are in accordance with those reported by **Ortas (2013), Ahmad *et al*. (2015) and Sultana *et al.* (2015)** on tomato.

Effect of potassium sources as foliar application

Spraying with potassium sources increased N,P and K uptake by shoots compared to control (unsprayed) in both seasons. Foliar spray of eggplant with potassium citrate at 1 ml/l increased N, P and K uptake by shoots at 110 days after transplanting in both seasons compared to other treatments (Table 7).

In addition, **Böhme and Thi Lua (1997)** reported that K-humate had beneficial effects on nutrient uptake by plants and was particularly important for the transport and availability of micro nutrients needed for optimal plant growth and development than unsprayed plants.

Similar results were obtained by **Kamal (2013)** on pepper, **Ramadan and Shalaby (2016)** on eggplant and **Zakher, and Elashry (2016)** on tomato. All indicated that spraying plants with potassium, citrate, humate, thiosulpahte and silicate had significant effects on mineral uptake in shoots than unsprayed plants.

Effect of the interaction

The interaction between K_2O at 90 kg /fad. as soil application and potassium citrate at 1 ml/l as foliar application significantly increased N,P and K uptake by shoots at 110 days after transplanting in both seasons, with no significant differences with the interaction between 75 kg K_2O/fad., and spraying with potassium citrate at 1 ml/l in both seasons (Tables 8 and 9). This means that the interaction between 75 kg/fad. K_2O and potassium citrate at 1ml/l gave the highest values of N,P and K uptake by shoots.

Table 7. Effect of potassium sources as foliar application on N, P and K uptake by shoots (mg) of eggplant after 110 days from transplanting during 2019 and 2020 seasons

Treatments Potassium sources	N	P	K
		2019 season	
Unsprayed	940.2 d	98.21 e	667.9 d
$K_3C_6H_5O_7$at 1 ml/l	2234.0 a	221.90 a	1815.5 a
$C_9H_8K_2O_4$ at 3 g/l	2071.9 b	183.14 b	1639.1 b
$K_2S_2O_3$ at 1 ml/l	1518.9 c	156.81 c	1314.1 c
K_2SiO_3 at 3 ml/l	1518.8 c	140.76 d	1364.4 c
		2020 season	
Unsprayed	929.4 d	112.51 e	832.2 d
$K_3C_6H_5O_7$at 1 ml/l	472.6 a	261.36 a	1840.2 a
$C_9H_8K_2O_4$ at 3 g/l	164.3 b	209.86 b	1680.1 b
$K_2S_2O_3$ at 1 ml/l	603.4 c	176.40 c	1357.1 c
K_2SiO_3 at 3 ml/l	517.1 c	160.60 d	1380.4 c

$K_3C_6H_5O_7$= Potassium citrate (36.5 % K_2O), $C_9H_8K_2O_4$ = potassium humate (12 % K_2O), $K_2S_2O_3$= potassium Thiosulfate (36% K_2O), and K_2SiO_3 = potassium silicate (10 % K_2O)

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

Table 8. Effect of the interaction between potassium levels as soil application and potassium sources as foliar application on N, P and K uptake by shoots (mg) of eggplant after 110 days from transplanting during 2019 season

Treatments Potassium levels (kg/fad.)	Potassium sources	N	P	K
45	**Unsprayed**	636.9 k	59.81 m	452.6 m
	$K_3C_6H_5O_7$at 1 ml/l	1658.0 efg	157.85 gh	1425.2 g-i
	$C_9H_8K_2O_4$ at 3 g/l	1431.6 h	123.57 jk	1250.7 j
	$K_2S_2O_3$ at 1 ml/l	1108.8 i	99.00 l	910.8 k
	K_2SiO_3 at 3 ml/l	1157.2 i	95.48 l	871.2 k
60	**Unsprayed**	909.6 j	89.67 l	616.5 lm
	$K_3C_6H_5O_7$at 1 ml/l	2152.8 cd	215.28 cd	1731.9 de
	$C_9H_8K_2O_4$ at 3 g/l	2036.7 d	173.72 fg	1617.4 d-f
	$K_2S_2O_3$ at 1 ml/l	1507.3 f-h	145.26 h-j	1276.4 ij
	K_2SiO_3 at 3 ml/l	1484.9 gh	129.64 i-k	1319.2 h-j
75	**Unsprayed**	1053.5 ij	109.27 kl	754.6 kl
	$K_3C_6H_5O_7$at 1 ml/l	2449.6 b	252.31 ab	2022.9 ab
	$C_9H_8K_2O_4$ at 3 g/l	2300.3 c	203.21 de	1764.0 cd
	$K_2S_2O_3$ at 1 ml/l	1696.5 e	171.60 fg	1482.0 f-h
	K_2SiO_3 at 3 ml/l	1685.0 ef	147.68 hi	1546.2 e-g
90	**Unsprayed**	1160.7 i	134.09 ij	848.0 k
	$K_3C_6H_5O_7$at 1 ml/l	2675.7 a	262.17 a	2082.0 a
	$C_9H_8K_2O_4$ at 3 g/l	2519.0 b	232.07 bc	1924.1 bc
	$K_2S_2O_3$ at 1 ml/l	1762.8 e	211.39 d	1587.2 d-g
	K_2SiO_3 at 3 ml/l	1748.0 e	190.26 ef	1721.1de

$K_3C_6H_5O_7$= Potassium citrate (36.5 % K_2O), $C_9H_8K_2O_4$ = potassium humate (12 % K_2O), $K_2S_2O_3$= potassium Thiosulfate (36% K_2O), and K_2SiO_3 = potassium silicate (10 % K_2O)

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

Table 9. Effect of the interaction between potassium levels as soil application and potassium sources as foliar application on N, P and K uptake by shoots (mg) of eggplant after 110 days from transplanting during 2020 season

Treatments		N	P	K
Potassium levels (kg/fad.)	Potassium sources			
45	**Unsprayed**	748.0 l	78.96 k	778.7 f
	$K_3C_6H_5O_7$at 1 ml/l	1793.2 f	182.57 fg	1297.4 d
	$C_9H_8K_2O_4$ at 3 g/l	1514.8 gh	145.67 hi	1266.7 d
	$K_2S_2O_3$ at 1 ml/l	1193.3 ij	124.00 ij	1005.0 ef
	K_2SiO_3 at 3 ml/l	1143.5 j	108.82 j	972.9 ef
60	**Unsprayed**	870.9 kl	103.13 jk	749.6 f
	$K_3C_6H_5O_7$at 1 ml/l	2404.4 bc	257.56 c	1875.9 b
	$C_9H_8K_2O_4$ at 3 g/l	2114.9 d	201.85 ef	1680.9 bc
	$K_2S_2O_3$ at 1 ml/l	1493.7 gh	150.51 h	1201.8 de
	K_2SiO_3 at 3 ml/l	1436.5 hi	145.36 hi	1204.8 de
75	**Unsprayed**	995.6 jk	122.27 ij	850.6 f
	$K_3C_6H_5O_7$at 1 ml/l	2629.8 b	284.45 b	1962.8 ab
	$C_9H_8K_2O_4$ at 3 g/l	2397.9 c	225.86 de	1840.6 b
	$K_2S_2O_3$ at 1 ml/l	1686.7 fg	181.45 fg	1486.4 cd
	K_2SiO_3 at 3 ml/l	1632.3 f-h	166.37 gh	1487.9 cd
90	**Unsprayed**	1103.1 jk	145.67 hi	950.0 ef
	$K_3C_6H_5O_7$at 1 ml/l	3063.1 a	320.85 a	2224.6 a
	$C_9H_8K_2O_4$ at 3 g/l	2629.8 bc	266.04 bc	1932.1 b
	$K_2S_2O_3$ at 1 ml/l	2039.8 de	249.64 cd	1735.3 bc
	K_2SiO_3 at 3 ml/l	1856.0 ef	221.86 e	1856.0 b

$K_3C_6H_5O_7$= Potassium citrate (36.5 % K_2O), $C_9H_8K_2O_4$ = potassium humate (12 % K_2O), $K_2S_2O_3$= potassium Thiosulfate (36% K_2O), and K_2SiO_3 = potassium silicate (10 % K_2O)
Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

The results obtained by **Fawzy *et al.* (2007)** who reported that, the interaction between 250 kg applied by soil dressing and foliar application of K_2O had a significant effect on N and K uptake in leaves of eggplant. Also, **Ali *et al.* (2021)** showed that the interaction between fertilizing potato plants with 100 % K and spraying with potassium citrate gave the highest values of N, P and K uptake by shoots than other interaction treatments.

Yield and its Components

Effect of potassium levels as soil application

Data in Table 10 show that, the average of fruit weight, yield/plant, and total yield/fad. increased with increasing K_2O up to 90 kg/fad., with no significant differences with K_2O at 75 kg/fad., with respect to yield/plant in both seasons and total yield in the 1st season. This means that K_2O at 75 kg/fad., increased yield/ plant and early yield /fad., whereas K_2O at 90 kg /fad., increased total yield/fad.

Concerning potassium use efficiency (KUE) data show that K_2O at 45 kg /fad. gave the highest KUE in both seasons. KUE decreased with increasing K_2O up to 90 kg /fad. in both seasons. The increases in total yield/fad. were about 1.543 and 0.360 ton/fad. for 60 kg K_2O /fad., 3.539 and 3.817 ton/fad. for 75 Kg K_2O/fad. and 3.817 and 3.407 ton/fad. for 90 kg K_2O/fad., over the 45 kg K_2O/fad. in the 1st and 2nd seasons, respectively.

The stimulative effect of 90 kg K_2O/fad. on total yield/fad., may be due to that 90 kg K_2O/ fad., increased shoot dry weight (Table 2), N,P and K uptake by shoots (Table 6), yield/plant and

Table 10. Effect of potassium levels as soil application on yield and its components and potassium use efficiency (KUE) of eggplants during 2019 and 2020 seasons

Treatments Potassium levels (kg/fad.)	Average fruit weight (g)	Yield / plant (kg)	Total yield (ton/fad.)	K UE (kg fruits/one kg K_2O)
		2019 season		
45	46.04 c	0.961 c	9.566 c	212.6 a
60	49.26 b	1.116 b	11.109 b	185.2 b
75	52.02 a	1.317 a	13.105 a	174.7 c
90	53.77 a	1.344 a	13.383 a	148.7 d
		2020 season		
45	44.98 b	1.027 b	10.225 d	227.2 a
60	45.00 b	1.063 b	10.585 c	176.4 b
75	53.35 a	1.340 a	13.335 b	177.8 c
90	53.58 a	1.368 a	13.632 a	151.5 d

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

average fruit weight (Table 10). These increases may be attributable to the beneficial position of the potassium used in the production of pigments, activation of photosynthesis and assimilation of carbohydrates redirected to the fruits representing the economic part of plant (**Hilman and Asandhi, 1987**).

The obtained results are in good harmony with those to **El-Miniawy (2015),** Kakahy ***et al*****. (2020)** and **Manimegala and Gunasekaran (2020)** on eggplants. They showed that, fertilizing eggplants with the highest rate of potassium gave the best results for yield and its composts..

Effect of potassium sources as foliar application

Spraying eggplant with different potassium sources increased average fruit weight, yield / plant, total yield and KUE compared to control (unsprayed) in both seasons (Table 11). Spraying eggplant with potassium citrate at 1 ml/l increased average fruit weight, yield/plant and total yield as well as KUE, followed by spraying with potassium humate at 3 g/l in both seasons. The increases in total yield /fad., were about 3.067 and 1.830 ton/fad. for potassium citrate at 1ml/l, 1.883 and 0.950 ton/fad., for potassium humate at 3 g/l., 0.643 and 0.810 ton/fad., for potassium thiosulfate at 1ml/l and 1.796 and 1.065 ton/fad., for potassium silicate at 3 ml/l over control (unsprayed) in the 1st and 2nd seasons, respectively.

The stimulative effect of potassium citrate at 1 ml/l on total yield/fad., may be due to that potassium citrate increased shoot dry weight (Table 3), N,P and K uptake by shoots (Table 7), yield/plant and average fruit weight (Table 11).

In this respect, many other investigators had results in good harmony with those obtained by **Hussein and Muhammed (2017)** on eggplants**, Abdel-Aziz and Geeth (2018)** on sweet pepper, **Abd Elwahed (2018)** on tomato and **Khalil *et al.* (2018)** on sweet pepper. All showed that spraying plants with potassium, citrate, humate, thiosulpahte and silicate had significant effects on yield and its components than unsprayed plants.

Table 11. Effect of potassium sources as foliar application on yield and its components and potassium use efficiency (KUE) of eggplants during 2019 and 2020 seasons

Treatments / Potassium sources	Average fruit weight (g)	Yield / plant (kg)	Total yield (ton/fad.)	K UE (kg fruits/one kg K_2O)
			2019 season	
Unsprayed	45.95 d	1.032 c	10.323 d	156.1 d
$K_3C_6H_5O_7$at 1 ml/l	55.39 a	1.344 a	13.339 a	204.9 a
$C_9H_8K_2O_4$ at 3 g/l	50.04 bc	1.227 b	12.206 b	186.9 b
$K_2S_2O_3$ at 1 ml/l	48.54 c	1.103 c	10.966 c	167.7 c
K_2SiO_3 at 3 ml/l	51.43 b	1.217 b	12.119 b	185.9 b
			2020 season	
Unsprayed	45.13 c	1.103 c	11.030 c	167.6 c
$K_3C_6H_5O_7$at 1 ml/l	53.16 a	1.295 a	12.860 a	197.4 a
$C_9H_8K_2O_4$ at 3 g/l	49.29 b	1.196 b	11.898 b	182.0 b
$K_2S_2O_3$ at 1 ml/l	48.64 b	1.190 b	11.840 b	182.7 b
K_2SiO_3 at 3 ml/l	49.92 ab	1.214 b	12.094 b	186.4 b

$K_3C_6H_5O_7$= Potassium citrate (36.5 % K_2O), $C_9H_8K_2O_4$ = potassium humate (12 % K_2O), $K_2S_2O_3$= potassium Thiosulfate (36% K_2O), and K_2SiO_3 = potassium silicate (10 % K_2O)

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

Effect of the interaction

The interaction between K_2O at 90 kg/fad., as soil application and potassium citrate at 1 ml/l as foliar application increased the average of fruit weight, yield / plant, and total yield with no significant differences with K_2O at 75 kg /fad. and spraying with potassium citrate at 1 ml/l, followed by the interaction between 90 kg K_2O/fad. and spraying with potassium humate at 3g/l in both seasons, (Tables 12 and 13).

Yield/ plant (1.476 and 1.486 kg) and total yield /fad. (14.649 and 14.768 ton/fad.) produced from 75 kg K_2O and spraying with potassium citrate at 1 ml/l treatment were more than yield / plant (1.232 and 1.329 kg) and total yield/fad. (12.320 and 12.290 ton/fad.) produced from 90 kg K_2O and unsprayed (spraying with water) in the 1st and 2nd seasons, respectively.

As for KUE, the same data in Tables 12 and 13 indicate that, the highest values of KUE were recorded with the interaction between 45 kg K_2O/fad. and spraying with potassium citrate at 1 ml/l (245.3 and 247.2 kg fruit / kg K_2O) in the 1st and 2nd seasons, respectively.

In this regard, **Fawzy *et al.* (2007)** showed that, the highest amount of total yield was found by using 150 and 200 K_2O/fad., with foliar spray of potassium. On the contrary, the lowest fruit weight and total yield of eggplant fruit was given by using 50 K_2O/fed. without foliar spray of potassium. Also, **El-Bassiony *et al*. (2010)** indicated that using 200 kg /fad. K_2O and spraying with potassium humate at 4 gm/ liter recorded the highest values of fruit weight and total yield (ton/fad) as compared to other interaction treatment of sweet pepper.

Conclusion

From the foregoing results, it could be concluded that fertilizing with K_2O at 75 kg/fad. and spraying with potassium citrate at 1 ml/l increased average fruit weight, yield/plant and total yield/fad. This treatment reduces potassium quantity for about 15 kg K_2O/fad. and increase total yield about 2.401 ton/fad. (average of two seasons) over 90 kg K_2O/fad. Also, this treatment could reduce the costs of eggplant production and environment pollution. From the foregoing results, it could be concluded that, fertilizing eggplant cv Balady during summer plantation in clay soil with K_2O at 75 Kg/fad. and spraying with potassium citrate at 1 ml/l increased the productivity of eggplant.

Table 12. Effect of the interaction between potassium levels as soil application and potassium sources as foliar application on yield and its components and potassium use efficiency (KUE) of eggplants during 2019 and 2020 seasons

Treatments		Average fruit weight (g)	Yield/ plant (kg)	Total yield (ton/fad.)	K UE (kg fruits/one kg K_2O)
Potassium levels (kg/fad.)	Potassium sources				
45	Unsprayed	42.43 m	0.776 j	7.760 m	172.4 f-i
	$K_3C_6H_5O_7$ at 1 ml/l	49.75 f-i	1.112 f-h	11.037 ij	245.3a
	$C_9H_8K_2O_4$ at 3 g/l	45.68 j-m	1.021 g-i	10.155 k	225.7b
	$K_2S_2O_3$ at 1 ml/l	47.18 h-l	0.888 ij	8.821 l	196.0c
	K_2SiO_3 at 3 ml/l	45.19 k-m	1.010 g-i	10.056 k	223.5b
60	Unsprayed	44.84 lm	0.968 hi	9.680 kl	161.3h-g
	$K_3C_6H_5O_7$ at 1 ml/l	53.00 c-f	1.297 b-e	12.873 d-f	214.6b
	$C_9H_8K_2O_4$ at 3 g/l	47.85 g-l	1.126 fg	11.199 hi	186.7c-f
	$K_2S_2O_3$ at 1 ml/l	49.29 f-j	1.044 g-i	10.371 jk	172.9e-i
	K_2SiO_3 at 3 ml/l	51.32 d-g	1.147 e-g	11.420 g-i	190.3c-e
75	Unsprayed	46.23 i-m	1.153 e-g	11.530 g-i	153.7g-k
	$K_3C_6H_5O_7$ at 1 ml/l	59.73 a	1.476 a	14.649 ab	195.3c-e
	$C_9H_8K_2O_4$ at 3 g/l	51.23 d-g	1.356 a-d	13.487 cd	179.8c-g
	$K_2S_2O_3$ at 1 ml/l	48.76 g-k	1.262 b-f	12.537 ef	167.2g-j
	K_2SiO_3 at 3 ml/l	54.15 c-e	1.338 a-d	13.321 c-e	177.6d-h
90	Unsprayed	50.33 e-h	1.232 c-f	12.320 fg	136.9kl
	$K_3C_6H_5O_7$ at 1 ml/l	59.09 ab	1.491 a	14.798 a	164.4g-j
	$C_9H_8K_2O_4$ at 3 g/l	55.41 bc	1.406 ab	13.984 bc	155.4i-j
	$K_2S_2O_3$ at 1 ml/l	48.94 g-k	1.218 d-f	12.135 f-h	134.8 l
	K_2SiO_3 at 3 ml/l	55.08 cd	1.374 a-c	13.680 cd	152.0 g-l

$K_3C_6H_5O_7$= Potassium citrate (36.5 % K_2O), $C_9H_8K_2O_4$ = potassium humate (12 % K_2O), $K_2S_2O_3$= potassium Thiosulfate (36% K_2O), and K_2SiO_3 = potassium silicate (10 % K_2O)

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

Table 13. Effect of the interaction between potassium levels as soil application and potassium sources as foliar application on yield and its components and potassium use efficiency (KUE) of eggplants during 2019 and 2020 seasons

Treatments		Average fruit weight (g)	Yield/ plant (kg)	Total yield (ton/fad.)	K UE (kg fruits/one kg K_2O)
Potassium levels (kg/fad.)	Potassium sources				
45	Unsprayed	42.80 g	0.856 f	8.560 h	190.2cd
	$K_3C_6H_5O_7$ at 1 ml/l	47.64 c-g	1.121 de	11.126 cd	247.2a
	$C_9H_8K_2O_4$ at 3 g/l	44.97 e-g	1.005 e	9.996 g	222.1b
	$K_2S_2O_3$ at 1 ml/l	44.29 fg	1.071 de	10.639 d-g	236.4ab
	K_2SiO_3 at 3 ml/l	45.21 e-g	1.085 de	10.802 d-f	240.0ab
60	Unsprayed	43.34 g	1.071 de	10.710 d-f	178.5c-e
	$K_3C_6H_5O_7$ at 1 ml/l	50.13 b-f	1.115 de	11.066 c-e	184.4cd
	$C_9H_8K_2O_4$ at 3 g/l	42.49 g	1.050 de	10.443 e-g	174.1d-f
	$K_2S_2O_3$ at 1 ml/l	45.24 e-g	1.035 de	10.282 fg	171.4d-j
	K_2SiO_3 at 3 ml/l	43.84 fg	1.047 de	10.424 e-g	173.7d-f
75	Unsprayed	47.93 c-g	1.156 d	11.560 c	154.1f-h
	$K_3C_6H_5O_7$ at 1 ml/l	56.21 ab	1.488 a	14.768 a	196.9c
	$C_9H_8K_2O_4$ at 3 g/l	54.59 a-c	1.368 abc	13.606 b	181.4c-e
	$K_2S_2O_3$ at 1 ml/l	53.34 a-d	1.318 c	13.093 b	174.6d-f
	K_2SiO_3 at 3 ml/l	54.71 ab	1.371 a-c	13.650 b	182.0c-e
90	Unsprayed	46.48 d-g	1.329 c	13.290 b	147.7h
	$K_3C_6H_5O_7$ at 1 ml/l	58.69 a	1.459 ab	14.481 a	160.9e-h
	$C_9H_8K_2O_4$ at 3 g/l	55.14 ab	1.362 a-c	13.546 b	150.5gh
	$K_2S_2O_3$ at 1 ml/l	51.70 b-e	1.338 bc	13.345 b	148.3h
	K_2SiO_3 at 3 ml/l	55.93 ab	1.356 bc	13.500 b	150.0gh

$K_3C_6H_5O_7$= Potassium citrate (36.5% K_2O), $C_9H_8K_2O_4$ = potassium humate (12 % K_2O), $K_2S_2O_3$= potassium Thiosulfate (36% K_2O), and K_2SiO_3 = potassium silicate (10 % K_2O)

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

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تأثير معدلات ومصادر التسميد البوتاسى على الوزن الجاف وامتصاص العناصر وكفاءة استخدام البوتاسيوم وإنتاجية الباذنجان

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أجريت تجربتان حقليتان خلال موسمي الصيف المتتاليين لعامي 2019 و 2020 في مزرعة خاصة بقرية كشك، أبو حماد، بمحافظة الشرقية لدراسة تأثير معدلات البوتاسيوم (45 ، 60 ، 75 ، 90 كجم بو$_2$أ / فدان) كإضافات أرضيه وبعض المصادر المختلفة للبوتاسيوم (سترات البوتاسيوم بمعدل 1 مل/لتر، هيومات البوتاسيوم بمعدل 3 جم/لتر، ثيوسلفات البوتاسيوم بمعدل 1 مل/لتر وسيليكات البوتاسيوم بمعدل 3 مل/لتر، بجانب معاملة الكنترول للمقارنة (الرش الورقي بالماء) كإضافه ورقية، على الوزن الجاف للنبات، الممتص من العناصر محصول الثمار ومكوناته للباذنجان (صنف طويل أسود). سجلت معامله التفاعل بين التسميد بو$_2$أ بمعدل 90 كجم/ فدان. والرش الورقي مع سترات البوتاسيوم بمعدل 1 مل/لتر أعلى القيم من الوزن الجاف للأفرع ، الأوراق والعرش/النبات، الممتص الكلى من النتيروجين والفوسفور والبوتاسيوم بواسطة المجموع الخضرى للباذنجان، متوسط وزن الثمره، محصول/النبات، والمحصول الكلي وبدون فروق معنويه بين التسميد بو$_2$أ بمعدل 75 كجم / فدان والرش الورقي مع سترات البوتاسيوم بمعدل 1 مل/لتر، يليه يليه التفاعل بين 90 كجم بو$_2$أ والرش بـهيومات البوتاسيوم بمعدل 3 جم/لتر في كلا الموسمين. فى نفس الوقت كان المحصول الكلى الناتج من معامله التفاعل بين التسميد بو2أ بمعدل 75 كجم/فدان والرش الورقي مع سترات البوتاسيوم تساوى 14.649 ، 14.768 طن/فدان بينما المحصول الكلى الناتج من التفاعل بين التسميد بأكسيد البوتاسيوم بمعدل 90 كجم/فدان والرش الورقي بالماء تساوى 12.320 ، 12.590 طن/فدان خلال الموسم الأول والثانى على التوالى. بالنسبة إلى كفاءه استخدام البوتاسيوم، تم تسجيل أعلى القيم مع التفاعل بين 45 كجم/فدان من بو$_2$أ والرش بسترات البوتاسيوم بمعدل 1 مل/لتر (245.3 و 247.2 كجم ثمار/كجم بو$_2$أ) خلال الموسم الأول والثاني على التوالى.

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