Journal of Horticultural Science & Ornamental Plants 13 (2): 124-133, 2021
ISSN 2079-2158

DOI: 10.5829/idosi.jhsop.2021.124.133

Effect of Potassium Humate and Levels of Potassium Fertilization on Growth, Yield and Nutritional Status of Tomato Plants

[1]M.H. Mohammed, [2]Hanaa A. Abd-Alrahman, [3]Hanan H. Abdel-Kader and [1]Fatma Sayed Aboud

[1]Central Laboratory for Agriculture Climate, Agriculture Research Center, Giza, Egypt
[2]Department of Vegetable Research, National Research Centre, Dokki, Cairo, Egypt
[3]Plant Nutrition Dept., National Research Centre, Dokki, Giza, Egypt

Abstract: Field experiments were conducted in sandy soil opened field at Nubaria, Egypt under drip irrigation system. The study aimed to rationalize rates mineral potassium fertilizer by partial replacing it with low quantities by spraying organic potassium fertilizer contains a high concentration of potassium. So, the effect of soil and foliar potassium fertilization on vegetative growth, total yield and nutritional status of tomato plants were studied. Three levels of potassium fertilization were applied using 60, 90 and 120 Kg K_2O per feddan which represent 50, 75 and 100 % of the recommended fertilizer. In addition, three concentrations of K-humate (20 % K_2O) using 0.5, 1 and 1.5 g/L were applied as foliar spray. Results showed that the reduction in the added potassium fertilizer (50 and 75 % of the recommended dose) significantly decreased growth characteristics, quality and quantity of tomato yield. Increasing the concentration of sprayed potassium humate on tomato plants led to improve growth and yield of tomato. Also, reducing potassium fertilizer rate has an effect on the uptake of nitrogen, phosphorus and potassium in tomato leaves at the two growing seasons. Similarly increasing the concentration sprayed of potassium humate increased the amount of nutrients uptake inside tomato leaves. It can be said that potassium in the form of an organic chelate (humate) can be used as a partial supplement inexpensive source for potassium fertilization and it can be used as a spray on the leaves, as it greatly and morally helps the growth and different yield characteristics of tomato plants grown in sandy soil.

Key words: Potassium fertilization · Potassium humate · Tomato plants · Growth · Yield · Nutrients uptake

INTRODUCTION

Tomato (*Solanum Iycopersicum* L.) is one of the most paramount vegetable crops in Egypt. It is one of the industrial crops that contributes significantly to the Egyptian national agricultural income [1]. Tomato is rich source of minerals and vitamins, its distinctive nutritional attributes play an important role in reducing risk of cardiovascular and associated diseases through their bioactivity in modulating disease process pathways [2, 3]. Moreover, it is an important source of lycopene, which is a powerful antioxidant that acts as an anticarcinogen [4]. Tomato fruits are also an outstanding source of ascorbic acid and are main source of vitamin C next to citrus [5, 6].

Potassium presents more abundantly in the soil and most plants required it in large amounts, being the second most concentrated nutrient in plant tissues after nitrogen [7]. Potassium plays a serious role in tomato fruit quality by involved in metabolic processes, like the enzyme activation, synthesis of proteins and membrane transport processes [8]. potassium is one of the vital elements required for plant growth and physiology. Potassium is not only a constituent of the plant structure but it also has a regulatory function in several biochemical processes related to protein synthesis, carbohydrate metabolism and enzyme activation.

Potassium humate is a promising natural resource to improve growth, yield and nutritional state. It is a natural material that can improve soil physical and chemical properties and nutrient dynamics [9]. It can be used as an organic potassium fertilizer to supply the plants with high levels of soluble potassium in a readily available form. Humic acid combined with potassium led to rapidly absorbed and incorporated potassium into plants, whether via soil addition or foliar application methods [10]. Faten *et al*. [11] studied the effect of potassium

Corresponding Author: M.H. Mohammed, Central Laboratory for Agriculture Climate, Agriculture Research Center, Giza, Egypt.

humate (0, 3, 6 and 12 L/fed) of onion plants. They found that potassium humate (KH) had significant effects on growth characters, total yield and components as well as it was caused an increment in TSS, N, P, K and Fe in bulbs tissues. Dhanasekarm [12] found that spraying tomato plants with humic acid as based substance improved total yield as compared to control treatment (without humic spraying). Potassium humate increases production and quality of a crop, plant tolerance to drought stress and salinity [13, 14].

The aim of the research is to use potassium humate that contains a high percentage of potassium nutrients (20% K_2O) and use it as an alternative to fertilizing with mineral potassium fertilizer to reduce the use of high-priced potassium mineral fertilizers and their effect on the growth, yield and nutritional status of tomato plants in two consecutive growing seasons.

MATERIALS AND METHODS

Field experiments were carried out in the two successive winter seasons of 2018/2019 and 2019/2020 in the Experimental Station of the National Research Centre in El-Nubaria region, Behira Governorate. Standard agricultural practices for tomato nurseries were carried out.

Tomato seedlings "hybrid Marwa" were used in these experiments. Seedlings were transplanted on 7th and 20st of November in the first and second seasons, respectively when plants were 40 days old. All agriculture practices were performed as recommended by Egyptian Ministry of Agriculture and Land Reclamation for tomato cultivation under open field conditions. Figures 1 and 2 showed to average temperatures and humidity per week in Nubaria region during two seasons.

Treatments: Proposed treatments were different levels of the potassium soil rates combined with different concentrations of K-humate foliar application. The rates of K fertilization were 60, 90 and 120 Kg K_2O per feddan (the recommended fertilizer dose 120 kg K_2O fed^{-1}). The concentrations of K-humate (20 % K_2O) application were 0.5, 1 and 1.5 g/ L. First spray of K-humate was done when the seedlings reached the stage of 6 true fully expanded leaves (about two weeks after transplanting). From the second to the fourth sprays, the application was carried out every three weeks later from the previous one. Total number of foliar applications was four times.

Physical and chemical properties of the cultivated soil were evaluated in samples taken before tomato planting according to standard procedures reported by Chapman and Pratt (15) presented in (Table 1).

The Experimental Design

Experimental Design: The experiment was laid out in a split- plot design with three replicates. Potassium rates were assigned in the main plots, whereas potassium humate were allotted in the sub-plots. The area of the experimental plot was 22.5 m^2 consisted of one row with 15 m length and 1.5 m width and the plants were transplanted 50 cm spaced in the rows.

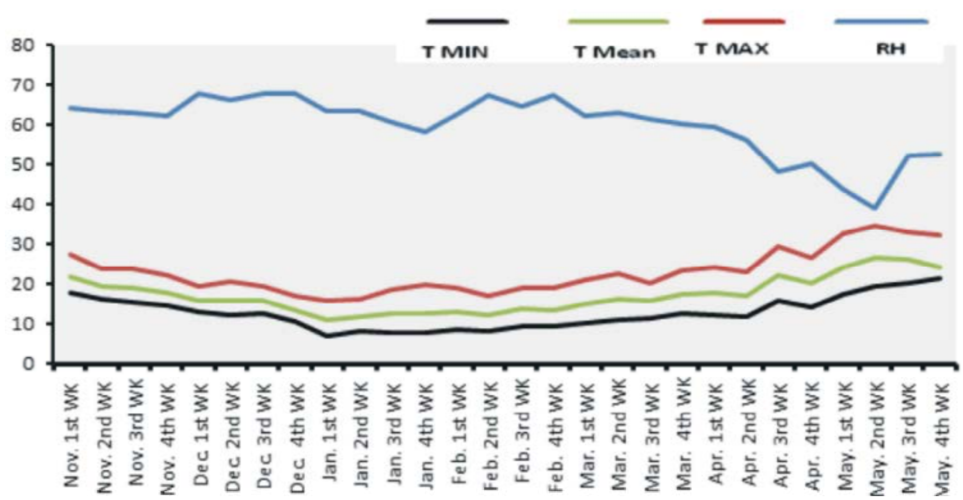

Fig. 1: Average temperatures and humidity per week in Nubaria region during 2018 and 2019 seasons.

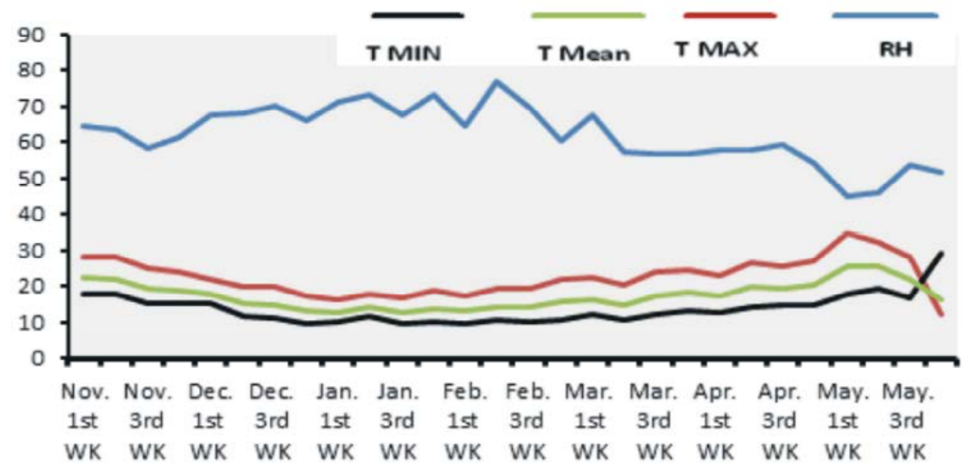

Fig. 2: Average temperatures and humidity per week in Nubaria region during 2019 and 2020 seasons

Table 1: Physical and chemical properties of the experimental soil

				Physical properties					
	Sand %		Clay %			Silt %			Texture
	72.15		6.6			21.25			Sandy
Chemical properties									
	Cations (Meq/l)				Anions (Meq/l)				
E.C.(dS/m^{-1})*	pH**	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO^{-}	Cl^{-}	SO_4^{--}
1.5	7.9	4.65	3.4	5.35	1.6	nd	1.85	5.3	7.85
					Available nutrient (ppm)				
			N			P			K
			18.60			69.87			155.38

* Soil paste extract ** 1:2.5 soil suspension

Studied Characteristics: Samples of three plants were chosen at random from every plot at the end of the growing season and directly transferred to the Laboratory. The following data were recorded.

- Plant height (cm): Plant height was measured from soil surface to the longest leaf.
- Number of leaves: Total number of leaves of the three selected plants was counted and their mean was recorded as the number of leaves per plant.
- Number of branches per plant.
- Leaves fresh weight (g).
- Dry weight per plant (g).
- Average weight of fruit (g).
- Weight of fruits in total yield was recorded from the whole plot.

Fruit samples were taken from the 3rd harvest at red ripe stage from each experimental plot to determine fruit quality parameters, *i.e.,* total soluble solids (TSS) using hand held Brix meter and ascorbic acid as described by A.O.A.C. [16]. Leaves were taken from the fourth upper of tomato stem of eight randomly collected plants after 90 days from transplanting, washed with distilled water, dried with paper towels, then dried at 70°C and wet digested [17] for the determination of N, P and K [16].

Economic Evaluation: Total cost is the sum of total fixed cost and total variable cost (L.E/fed.) were calculated. Total revenue was calculated as the sum of the fresh yield weight for the two seasons multiplied by the number of plants in one square meter multiplied by the average market price (L.E./kg). The following Table (2) illustrates the market price of the experiment constituents by Egyptian pound as recorded during the years of 2018/2019 and 2019/2020. The revenue and total cost ratio was determined according to [18].

Table 2: Price of the experiment constituents (L.E.)

Fixed cost	
Item	Price (L.E.)
Land Preparation	500
Irrigation	3000
Fertilization	1700
Weeding	400
Pest Control	700
Harvesting	1500
Transportation	1000
Other Expenses	1000
Rent	3000
Variable Cost	
Item	Price (L.E.)
potassium humate (3kg)	240
potassium sulfate's (50kg)	400
Tomato Market prices kg	1.5

- Net Revenue = Revenue (L.E/fed.)- Total cost (L.E/fed.)
- The Revenue to total Cost (R/C) ratio was calculated to represent the profit percentage.

All data were subjected to statistical analysis using Mstatc software. The comparison among means of the different treatments was determined, as illustrated by Snedecor and Cochran [19]. Means of the treatments were compared by Duncan Test.

RESULTS AND DISCUSSION

Vegetative Growth

Effect of Different Rates of Mineral Potassium Fertilizer: It can be shown in Table (3), the effect of adding different rates of potassium fertilization on the growth of tomato plants(plant height, leaves and branches numbers, as well as leaves fresh and dry weights).Results showed that the lack of potassium levels to (60 and 90 kgK_2O fed^{-1}) has a significant effect on plant growth and reduced plant height, number of leaves and branches, as well as leaves fresh and dry weights. The application of 120 Kg K_2O/fed. (the recommended fertilizer rate) recorded the highest values of the prementioned parameters compared to the other treatments in both seasons.

Effect of Concentrations of Potassium Humate: Table 4 illustrates that using potassium humate enhanced the vegetative growth of tomato plants, especially foliar application of potassium humate at concentrations of (1.5 g/L). However, the lowest values of vegetative growth parameters were recorded by plants treated with potassium humate at concentration (0.5 g/L).

Effect of Concentrations of Potassium Humate and its Interactions with Different Rates of Mineral Potassium Fertilizer: With the substitution of low quantities of mineral potassium fertilization by spraying the plants with potassium humate, it led to a significant increase in growth characteristics of tomato plants, during the two growing seasons. The highest values of growth characteristics of tomato plants were recorded by spraying them at a concentration of 1.5 g l^{-1} of K-humate combined with the highest rate of potassium fertilization (120 Kg K_2O fed^{-1}), followed by plants that treated by 90 kg K_2Ofed^{-1} (75%) of the recommended fertilizer unit with foliar applications of potassium humate at concentrations of (1.5 g/L) without any significant differences between them as shown in Table, 5. On the other hand, the lowest values of tomatoes plant growth were recorded in plants that received 60 kg K_2O/fed with potassium humate at concentrations 0.5 g/L.

Yield and Quality

Effect of Different Rates of Mineral Potassium Fertilizer: Concerning potassium levels, data in Table 6 showed that there were significant increase in the fruit weight, fruit yield/plant, total yield per fed., TSS and ascorbic acid percentages by increasing potassium fertilization up to the highest level (120 kg K_2O/fed) followed by plants fertilized with application of 90 Kg K_2O/fed (75%) of the recommended fertilizer rate without any significant differences between them. However, the lowest values of the pre mentioned parameters were obtained in plants treated with 60 Kg K_2O/fed in both seasons.

Effect of Concentrations of Potassium Humate: It is clear from the data in Table 7 that quality and total yield were significantly affected by the concentrations of potassium humate in both seasons. Plants receiving potassium humate at 1.5 g/l gave the highest values of fruit weight, fruit yield/plant, total yield per fed., TSS and ascorbic acid percentages. Whereas, the lowest values were obtained by plants receiving 0.5 g/L potassium humate in both seasons.

Effect of Concentrations of Potassium Humate and its Interactions with Different Rates of Mineral Potassium Fertilizer: Regarding the interaction between the different rates of potassium with different concentrations of potassium humate, data indicated that in Table 8 the highest values of fruit weight, fruit yield/plant,

Table 3: Effect of different rates of mineral potassium fertilizer on vegetative growth of tomato plants during 2018/2019 and 2019/2020

	Plant height (cm)		Leaves number/plant		Branches number/plant		Leaves fresh weight (g)		Leaves dry matter (%)	
Rates of potassium (Kg/fed.)	1^{st} season	2^{nd} season	1^{st} season	2^{nd} season	1^{st} season	2^{nd} season	1^{st} season	2^{nd} season	1^{st} season	2^{nd} season
60	65.00^{C}	65.67^{C}	62.67^{C}	64.00^{C}	5.44^{C}	6.00^{C}	371.89^{C}	377.39^{C}	30.19^{C}	31.64^{C}
90	69.00^{B}	70.00^{B}	88.00^{B}	91.11^{B}	6.22^{B}	7.00^{B}	420.13^{B}	415.92^{B}	41.87^{B}	40.66^{B}
120	72.00^{A}	72.00^{A}	93.33^{A}	101.33^{A}	7.11^{A}	8.00^{A}	427.58^{A}	423.51^{A}	43.08^{A}	42.60^{A}

Values followed by the same letter (s) within column are not significantly different ($P<0.05$).

Table 4: Effect of different concentrations of potassium humate on vegetative growth of tomato plants during 2018/2019 and 2019/2020.

	Plant height (cm)		Leaves number/plant		Branches number/plant		Leaves fresh weight (g)		Leaves dry matter (%)	
Potassium humate (g/L)	1^{st} season	2^{nd} season	1^{st} season	2^{nd} season	1^{st} season	2^{nd} season	1^{st} season	2^{nd} season	1^{st} season	2^{nd} season
0.5	66.00^{B}	66.67^{C}	73.67^{C}	78.67^{C}	5.67^{B}	6.22^{B}	391.40^{C}	388.10^{C}	34.03^{C}	33.91^{C}
1	69.33^{A}	69.67^{B}	84.00^{B}	86.00^{B}	6.00^{B}	6.67^{B}	406.70^{B}	406.40^{B}	38.97^{B}	38.76^{B}
1.5	70.67^{A}	71.33^{A}	86.33^{A}	91.78^{A}	7.11^{A}	8.11^{A}	421.50^{A}	422.40^{A}	42.14^{A}	

Table 5: Effect of interaction between different rates of mineral potassium fertilizer and different concentrations of potassium humate on vegetative growth of tomato plants during 2018/2019 and 2019/2020

		Plant height (cm)		Leaves number/plant		Branches number/plant		Leaves fresh weight (g)		Leaves dry matter (%)	
Rates of K (Kg/fed.)	K humate (g/L)	1^{st} season	2^{nd} season	1^{st} season	2^{nd} season	1^{st} season	2^{nd} season	1^{st} season	2^{nd} season	1^{st} season	2^{nd} season
60	0.5	63.0^{f}	64.0^{f}	59.0^{g}	58.0^{g}	4.33^{d}	4.67^{c}	357.9^{g}	360.4^{g}	26.53^{g}	27.67^{g}
	1	65.0^{ef}	65.0^{ef}	64.0^{f}	64.0^{f}	5.33^{cd}	5.67^{bc}	373.9^{f}	378.7^{f}	30.90^{f}	32.40^{f}
	1.5	67.0^{de}	68.0^{d}	65.0^{f}	70.0^{e}	6.67^{ab}	7.67^{a}	383.8^{e}	393.1^{e}	33.13^{e}	34.87^{e}
90	0.5	66.0^{e}	67.0^{de}	72.0^{e}	80.0^{d}	5.67^{bc}	6.33^{b}	403.5^{d}	397.5^{d}	37.83^{d}	36.93^{d}
	1	70.0^{c}	71.0^{bc}	94.0^{c}	92.0^{c}	5.67^{bc}	6.33^{b}	419.6^{c}	417.0^{c}	41.77^{c}	40.33^{c}
	1.5	71.0^{bc}	72.0^{ab}	96.0^{a}	101.3^{a}	7.33^{a}	8.33^{a}	437.3^{a}	433.2^{a}	46.51^{a}	46.70^{a}
120	0.5	69.0^{cd}	69.0^{cd}	90.0^{d}	98.0^{b}	7.00^{a}	7.67^{a}	412.8^{cd}	406.3^{cd}	37.73^{e}	37.13^{e}
	1	73.0^{ab}	73.0^{ab}	94.0^{c}	102.0^{a}	7.00^{a}	8.0^{a}	426.6^{b}	423.3^{b}	44.23^{b}	43.53^{b}
	1.5	74.0^{a}	74.0^{a}	98.0^{a}	104.0^{a}	7.33^{a}	8.33^{a}	443.4^{a}	440.9^{a}	47.27^{a}	47.14^{a}

Values followed by the same letter (s) within column are not significantly different ($P<0.05$).

Table 6: Effect of different rates of mineral potassium fertilizer on quality and yield of tomato plants during 2018/2019 and 2019/2020

	Fruit weight (g)		Fruit yield/plant (Kg)		Total yield (ton/fed.)		Total soluble solids (%)		Ascorbic acid (%)	
Rates of potassium (Kg/fed.)	1^{st} season	2^{nd} season	1^{st} season	2^{nd} season	1^{st} season	2^{nd} season	1^{st} season	2^{nd} season	1^{st} season	2^{nd} season
60	82.5^{C}	82.7^{B}	3.2^{B}	3.2^{B}	26.6^{B}	27.1^{B}	6.3^{C}	6.09^{C}	1.63^{C}	1.65^{C}
90	84.8^{B}	85.3^{A}	3.9^{A}	3.9^{A}	32.4^{A}	32.4^{A}	6.5^{B}	6.26^{B}	2.03^{B}	2.06^{B}
120	86.3^{A}	86.4^{A}	3.9^{A}	3.9^{A}	32.5^{A}	32.7^{A}	6.50^{A}	6.44^{A}	2.18^{A}	2.29^{A}

Values followed by the same letter (s) within column are not significantly different ($P<0.05$).

Table 7: Effect of different concentrations of potassium humate on quality and yield of tomato plants during 2018/2019 and 2019/2020.

	Fruit weight (g)		Fruit yield/plant (Kg)		Total yield (ton/fed.)		Total soluble solids (%)		Ascorbic acid (%)	
Potassium humate (g/L)	1^{st} season	2^{nd} season	1^{st} season	2^{nd} season	1^{st} season	2^{nd} season	1^{st} season	2^{nd} season	1^{st} season	2^{nd} season
0.5	75.7^{C}	75.58^{C}	3.32^{B}	3.36^{C}	27.9^{B}	28.20^{C}	6.18^{C}	6.07^{C}	1.87^{B}	1.92^{C}
1	87.7^{B}	87.45^{B}	3.52^{B}	3.56^{B}	29.5^{B}	29.93^{B}	6.47^{B}	6.26^{B}	1.93^{B}	2.00^{B}
1.5	90.3^{A}	91.25^{A}	3.71^{b}	3.80b	34.0^{A}	34.08^{A}	6.57^{A}	6.46^{A}	2.04^{A}	2.08^{A}

Values followed by the same letter (s) within column are not significantly different ($P<0.05$).

Table 8: Effect of interaction between different rates of mineral potassium fertilizer and foliar applied potassium humate on quality and yield of tomato plants during 2018/2019 and 2019/2020

Rates of potassium (Kg/fed.)	K humate (g/L)	Fruit weight (g) 1st season	Fruit weight (g) 2nd season	Fruit yield/plant (Kg) 1st season	Fruit yield/plant (Kg) 2nd season	Total yield (ton/fed.) 1st season	Total yield (ton/fed.) 2nd season	Total soluble solids (%) 1st season	Total soluble solids (%) 2nd season	Ascorbic acid (%) 1st season	Ascorbic acid (%) 2nd season
60	0.5	72.6^{g}	73.41^{e}	2.78^{c}	2.79e	23.35^{c}	23.44^{e}	6.25^{c}	6.02^{d}	1.52^{d}	1.54^{i}
	1	86.04^{d}	85.75^{c}	3.00^{c}	3.08d	25.20^{c}	25.87^{d}	6.30^{bc}	6.07^{d}	1.66^{c}	1.68^{h}
	1.5	88.97^{bc}	88.78^{b}	4.05^{A}	4.06^{A}	31.16^{b}	31.92^{b}	6.20^{c}	6.18^{c}	1.70^{c}	1.74^{g}
90	0.5	76.21^{f}	75.91^{d}	3.59^{b}	3.64c	30.16^{b}	30.58^{c}	6.30^{bc}	6.09^{d}	2.00^{b}	2.01^{f}
	1	87.70^{c}	87.97^{bc}	3.77^{b}	3.79b	31.67^{b}	31.84^{b}	6.40^{b}	6.18^{c}	2.02^{b}	2.05^{e}
	1.5	90.39^{ab}	91.87^{a}	4.21^{a}	4.15a	35.36^{a}	34.86^{a}	6.70^{a}	6.50^{b}	2.07^{b}	2.11^{d}
120	0.5	78.35^{e}	77.41^{d}	3.60^{b}	3.64c	30.24^{b}	30.58^{c}	6.00^{d}	6.10^{cd}	2.08^{b}	2.20^{c}
	1	89.24^{bc}	88.63^{b}	3.78^{b}	3.82b	31.75^{b}	32.09^{b}	6.70^{a}	6.52^{b}	2.11^{b}	2.28^{b}
	1.5	91.42^{a}	93.10^{a}	4.23^{a}	4.22^{a}	35.53^{a}	35.45^{a}	6.81^{a}	6.71^{a}	2.36^{a}	2.40^{a}

Values followed by the same letter (s) within column are not significantly different (P<0.05)

Table 9: Effect of different rates of mineral potassium fertilizer on nutrients uptake (mg/Kg) of tomato plants during 2018/2019 and 2019/2020

Rates of potassium (Kg/fed.)	N (mg/Kg) 1st season	N (mg/Kg) 2nd season	P (mg/Kg) 1st season	P (mg/Kg) 2nd season	K (mg/Kg) 1st season	K (mg/Kg) 2nd season
60	55.70^{C}	56.77^{C}	8.61^{C}	8.90^{B}	47.26^{C}	40.33^{C}
90	81.47^{B}	81.83^{B}	10.06^{B}	11.73^{A}	72.88^{B}	73.43^{B}
120	84.67^{A}	87.50^{A}	11.97^{A}	11.97^{A}	75.77^{A}	75.93^{A}

Values followed by the same letter (s) within column are not significantly different (P<0.05)

Total yield per fed., TSS and ascorbic acid percentages recorded in plants that treated by 120 Kg K_2O/fed with foliar spraying of potassium humate at 1.5 g/L. On the other hand, the lowest values were recorded in plants that treated by combination of 60 Kg K_2O plus 0.5 g/L potassium humate in both seasons as shown in Table, 8. The decrease in the rates of added potassium fertilization was treated by spraying plants with potassium humate, whose potassium content was 20%. as it reduced the decrease in the tomato yield and the quality of the fruits.

Nutrients Uptake

Effect of Different Rates of Soil Applied Potassium Fertilizer: The results in Table (9) indicated the effect of different rates of potassium sulfate on uptake of nitrogen, phosphorus and potassium in tomato leaves. The results showed that the importance of potassium fertilization in increasing the absorbed amount of the three nutrients in tomato leaves at the two growing seasons, as it was found that by increasing each of the rates of potassium fertilization from 60 to 120 K_2O Kg per feddan which led to a significant increase in uptake of nitrogen, phosphorus and potassium.

Effect of Different Concentrations of Foliar Applied Potassium Humate: Spraying potassium humate enhanced the absorption of the nutrients, especially the potassium uptake. The highest values of N, P and K uptake were recorded with plants which treated by foliar spraying of potassium humate at 1.5 g/L as shown in Table 10. However, the lowest values of nutrients uptake were recorded by plants which treated by foliar spraying of potassium humate at 0.5 g/L.

Effect of Concentrations of Potassium Humate and its Interactions with Different Rates of Mineral Potassium Fertilizer: Nutrients uptake of tomato plants was statistically influenced by different rates of mineral potassium fertilizer and concentrations of potassium humate. The highest values of N, P and K uptake were recorded with plants which treated by higher mineral potassium fertilizer (120 Kg K_2O/fed) combined with potassium humate at 1.5g/L as shown in Table 11. However, the lowest values of nutrients uptake were recorded by plants which treated by 60 Kg K_2O/fed +foliar spraying of potassium humate at 0.5 g/L in both seasons.

Economic Evaluation: Economic evaluation could be used as one of the criteria that are consistent with the conditions of the field trials and the economic logic of first. Farm net revenue is the difference between revenues and costs. A project is economically profitable when the net revenue is positive. Secondly, the ratio of the revenue to the total cost (R/C) when it is greater than one, the project is profitable.

Table 10: Effect of different concentrations of potassium humate on nutrients uptake (mg/Kg) of tomato plants during 2018/2019 and 2019/2020

	N (mg/Kg)		P (mg/Kg)		K (mg/Kg)	
Potassium humate (g/L)	1st season	2nd season	1st season	2nd season	1st season	2nd season
0.5	60.37C	63.27C	8.14C	9.09C	51.90C	51.47C
1	75.63B	76.03B	10.84B	11.27B	68.93B	66.07B
1.5	85.83A	86.80A	11.66A	12.24A	75.08A	72.17A

Values followed by the same letter (s) within column are not significantly different (P<0.05)

Table 11: Effect of interaction between different rates of mineral potassium fertilizer and different concentrations of potassium humate on nutrients uptake (mg/Kg) of tomato plants during 2018/2019 and 2019/2020

		N (mg/Kg)		P (mg/Kg)		K (mg/Kg)	
Rates of potassium (Kg/fed.)	Potassium humate (g/L)	1st season	2nd season	1st season	2nd season	1st season	2nd season
60	0.5	52.10g	52.40h	7.93f	7.96h	39.89h	38.10i
	1	54.40f	54.80g	8.73de	8.82f	48.77g	39.40h
	1.5	60.60e	63.10e	9.18d	9.92e	53.12f	43.50g
90	0.5	61.40e	61.60f	8.09f	10.90d	52.83f	53.20f
	1	84.80c	85.50c	10.90c	12.10c	77.00d	77.60d
	1.5	98.20a	98.40a	11.20c	12.20c	83.30b	83.50b
120	0.5	67.60d	75.80d	8.40ef	8.42g	62.99e	63.10e
	1	87.70b	87.80b	12.90b	12.90b	81.03c	81.20c
	1.5	98.70a	98.90a	14.60a	14.60a	88.81a	89.50a

Values followed by the same letter (s) within column are not significantly different (P<0.05).

Table 12: Economic evaluation of field experiment (fruits of tomato crop) under drip irrigation system (L.E./fed.)

Treatment		Input			Output			
Rates of potassium (Kg/fed.)	K humate (l/fad.)	Fixed Cost (L.E/fed)	Variable Cost (L.E/fed)	Total cost (L.E/fed)	Revenue (L.E/fed)	Net Revenue (L.E/fed)	Revenue/Total cost ratio	Treatment Order
60	----------	12800	5480	18280	40275	21995	2.20	11
90		12800	5720	18520	48600	30080	2.62	3
120		12800	5960	18760	48900	30140	2.61	4
---------------	0.5	12800	5024	17824	42075	24251	2.36	10
	1	12800	5048	17848	44573	26725	2.50	7
	1.5	12800	5072	17872	47310	29438	2.65	3
60	0.5	12800	5504	18304	35093	16789	1.92	13
	1	12800	5528	18328	38303	19975	2.09	12
	1.5	12800	5552	18352	51060	32708	2.78	2
90	0.5	12800	5744	18544	45555	27011	2.46	8
	1	12800	5768	18568	47633	29065	2.57	5
	1.5	12800	5792	18592	52665	34073	2.83	1
120	0.5	12800	5984	18784	45615	26831	2.43	9
	1	12800	6008	18808	47880	29072	2.55	6
	1.5	12800	6032	18832	53235	34403	2.83	1

Table (12) and Fig. (3) represents the results of conducted economic feasibility study for the investigated treatments. It is clear that all treatments are economically feasible however, the highest R/C ratio, values were recorded with plants which treated by mineral potassium fertilizer (90 Kg K_2O/fed) combined with potassium humate at 1.5g/L as indicated by the treatment order column in Table (12) and the same mineral potassium fertilizer (120 Kg K_2O/fed) combined with potassium humate at 1.5g/L and the ratio of revenue to total cost estimated 2.83, decreased in the treatments respectively.

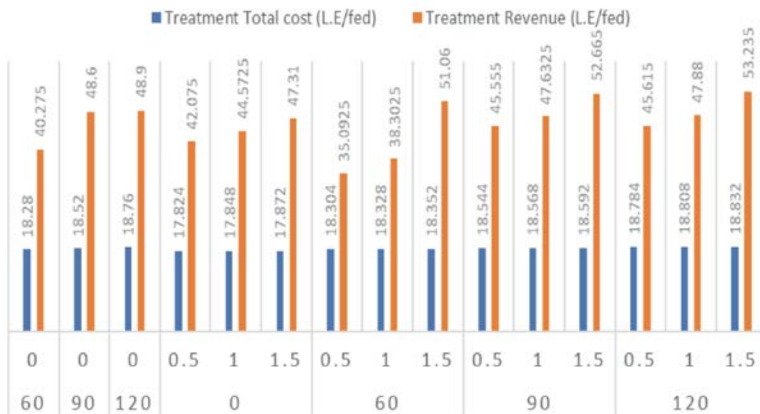

Fig. 3: Total costs and revenue (L.E./ fed) for the application of different treatments on tomato crop

DISCUSSION

Results showed that vegetative growth of tomato plants expressed as plant height, leaves and brunches number, as well as leaves fresh and dry weights were statistically influenced by different rates of potassium fertilization. Linear relationship was obtained between the above-mentioned characteristics and the increased potassium levels up to its highest level. The highest values growth were obtained by the addition of the high potassium level. Enhancement growth by potassium application may be due to its wide role in enzyme activation, protein synthesis, photosynthesis, osmoregulation and cell extension. Also, these increases in fruit weight, fruit yield might be also due to the resulting increases in the vegetative growth. Since fruit yield is the function of the growth, photosynthetic activity, nutrients uptake and dry matter accumulations. The higher content of K in plant tissue explains the higher quality of tomato fruits due to the presence of K which acts on photosynthate translocation from the leaves to the storage organs. Potassium plays mainly role as a charge transporter of high mobility that forms only weak complexes in which it is readily commutable [20]. Kasinath *et al*., [21] found that application of potassium increased plant height by up to 65%. It may be due to reason that K has increased the leaves number and photosynthesis process and thus ultimately enhanced the plant height of tomato plants [22]. Potassium used in various ways within the plant and involved in the stimulation of early growth in a plant was reported by [23]. The role of potassium in increasing the growth during early phases of growth could have induced the production of more number of branches [24].

Potassium humate can be used as an organic potash fertilizer to supply the plants with high levels of soluble potassium in a readily available form. when K combine with humic acid, potassium can be rapidly absorbed and incorporated into plants, whether via soil or foliar application methods. Enhancement of plant growth through using K-humate had been attributed to the increased uptake of many nutrients [25]. Meanwhile, K-humate increases photosynthesis, chlorophyll density and plant root respiration which resulted in greater plant growth [26].

Potassium is the nutrient most absorbed by tomato plants and is essential for many physiological processes, such as enzymatic activation and soluble solids [27]. Potassium deficiency limits photosynthesis in the leaves and the transport of metabolic substances to the tomato fruits, causing reduction in fruit quality [28]. Vasilenko [29] and Yildirim [30] have reported a significant enhancement in tomato fruit diameter and length as a result of K-humate application compared to control. El-Tohamy *et al*. [31] found that foliar application of K significantly improved the total soluble solids in carrot roots. The improvements in the total soluble solids in roots as a result of K-humate foliar application could be attributed to the mode of action of K in enhancing the photosynthetic activity and enzymes of carbohydrates transformation. The enhancement of nutrient uptake in the presence of K-humate could be due to its positive effect on membrane permeability of plants. This is due to the presence of hydrophilic and hydrophobic sites that enhance surface [32]. Therefore, the humic substances interact with structures of the cell membranes and react as nutrient carrier. Furthermore, root volume increases with humic substances application which considers an important factor in nutrient uptake [33].

CONCLUSION

This study indicated the possibility of partial substitution of soil applied K by foliar applied K humate without affecting tomato yield and quality and improved growth and yield, as well as the nutritional status of tomato plants grown in sandy soil. Foliar fertilization is more economical than root fertilization due to the efficiency and lower cost. The foliar method of fertilizer application is usually preferred because very small amounts of fertilizers are applied per feddan. It is recommended to use a concentration of potassium sulfate at rate 90 kg/fed combined with foliar applied K humate for increasing tomato production and the economically feasible for the crop.

REFERENCES

1. Glala A.A., A.M. Hoda and Z.F. Fawzi, 2005. Improving Tomato Plant Growth, Health, Earliness, Productivity and Fruit Quality by Chemically Induced Systematic Resistance. Journal of Applied Sciences Research, 1: 362-372.
2. Vallverdú-Queralt, A., A. Medina-Remón, M. Martínez-Huélamo, O. Jáuregui, C. Andres-Lacueva and R.M. Lamuela-Raventos, 2011. Phenolic profile and hydrophilic antioxidant capacity as chemotaxonomic markers of tomato varieties. J. Agric. Food Chem., 59: 3994-4001.
3. Dias, J.S., 2012. Nutritional Quality and Health Benefits of Vegetables: A Review. Food and Nutrition Sciences, 3: 1354-1374. http://dx.doi.org/10.4236/fns.2012.310179.
4. Burton-Freeman, B. and K. Reimers, 2011. Tomato Consumption and Health: Emerging Benefits. American Journal of Lifestyle Medicine, 5(2): 182-191. https://doi.org/10.1177/1559827610387488.
5. Rao, A.V. and L.G. Rao, 2007). Carotenoids and Human Health. Pharmacological Research, 55(3): 207-216. https://doi.org/10.1016/j.phrs. 2007.01.012.
6. Ramyabharathi, S.A., V. Shanthiyaa, K. Sankari Meena and T. Raguchander, 2014. Nutrient deficiencies management for tomato and potato. An ebook on nutrient disorder. Smash words, Inc. USA.
7. Lester, G. E., J.L. Jifon and G. Rogers, 2005. Impact of Potassium Nutrition on Food Quality of Fruits and Vegetable. J. Amer. Soc. Hort. Sci., 130: 649-653.
8. Dorais, M., D.L. Ehret and A.P. Papadopoulos, 2001. Tomato (*Solanum lycopersicum*) health components: from the seed to the consumer. Phytochem. Rev., 7: 231-250.
9. Kumar, D., AP. Singh, P. Raha, A. Rakshit, P. Kishor and C.M. Singh, 2013. Potassium Humate: A Potential soil conditioner and plant growth promoter. Inter. J. Agric. Environ. Biotech., 6: 441-446.
10. Abd El-Aal H.A., N.I. Abo El-Fadl and S.A.M. Moussa, 2010. Effect of mineral and organic potassium fertilization on sweet potato crop grown in the newly reclaimed land. Alexandria Science Exchange Journal, 31: 266-278.
11. Faten, S., M.R. Shafeak, A.A. Ahmed and A.M. Shaheen, 2005. Response of growth yield of onion plants to potassium fertilizers. J. Agric. Sci. Mansoura Univ., 30(1): 441-452.
12. Dhanasekarm, K., 2006. Effect of foliar application of enriched humic substances on the yield and quality of tomato (*Lycopersicon esculentum* Mill). Adv. In Plant Sci., 19: 539-542.
13. Jalilm, A., F.P. Saeid, R.A. Mohammad and K. Ali, 2013. Effect of potassium humate on yield and yield components of different potato varieties as a second crop after barley harvest in Ardabil region, Iran. Ann. of Biol. Res., 4(2): 85-89.
14. Ismail, A.F., S.M. Hussien, S.A. El-Shall and M.A. Fathi, 2007. Effect of irrigation and humic acid on "Le-Conte" Pear. J. Agric. Sci. Mansoura Univ., 32(9): 7589-7603.
15. Chapman, H.D. and P.E. Pratt, 1978. Methods of analysis for soil and waters. University of California. Dep. of Agric. Sci. USA, pp: 1-309.
16. A.O.A.C., 1990. Official Methods of Analysis, Association of Officinal Analytical Chemists. 16th Ed., Washington. D. C., U.S.A.
17. Van Schouwenberg, J.Ch., 1968. International Report of Soil and Plant Analysis. Lab. of Soil and Fert. Agric., Wageningen Univ., Netherlands.
18. Nahed, M.M. El-Shimi, El-Sayeda H.M. El-Badawy and Hager I. Tolba, 2015. Response of Sweet Pepper Plants to some Organic and Bio-fertilizers and its Effect on Fruit Yield and Quality, 04(03): 435-445.
19. Snedecor, G.W. and W.G. Cochran, 1982. Statistical Methods. 7th ed. Iowa State Univ. Press, Iowa, U.S.A.
20. Wyn Jones, R.G., C.J. Brady and J. Speirs, 1979. Ionic and osmotic relations in plant cells. In "Recent Advances in the Biochemistry of Cereals" (D.L. Laidman and R. G. Wyn Jones, eds.), pp: 63-103. Academic Press, London and Orlando.

21. Kasinath, B., A. Ganeshmurthy and N. Nagegowda 2014. Critical limit of soil and plant magnesium in tomato-growing soils of South Karnataka. Journal of Horticultural Science, 9: 209-212.
22. Majumdar, S. and D. Jayas, 2000. Classification of cereal grains using machine vision: II. Color models. Transactions of the ASAE, 43: 1677-1679.
23 Rehm, G. and M. Schmitt, 2002. Potassium for crop production. Retrieved, 2011: 2.
24. Kaur, H., J. Thakur and N. Chawla, 2003. Effect of nitrogen and potassium on growth, yield and quality of tomato (*Lycopersicon esculentum* Mill.) cv. Punjab Upma. Haryana Journal of Horticultural Sciences, 32: 286-287.
25. Nardi, S., D. Pizzeghello, A. Muscolo and A. Vianello, 2002. Physiological effects of humic substances on higherplants. Soil Bio. Bioche, 34: 1527-1536.
26. Chapagain, P.B. and Z. Wiesman, 2004. Effect of potassium agnesium chloride in the fertigation solution as partial sourceof potassium on growth, yield and quality of greenhouse tomato. Scientia Horticulturae*,* 99: 279-288.
27. Blanco, F.F. and M.V. Folegatti, 2008. Doses de N e K no tomateiro sob estressesalino: III. Produção e qualidade de frutos. Revista Brasileira de Engenharia Agrícola e Ambiental, 12: 122-127.
28. Dorais, M., L.E. David and A.P. Papadopoulos, 2008. Tomato (*Solanum lycopersicum*) Health components: From the seed to the consumer. Phytochemistry Reviews, 7: 231-250.
29. Vasilenko, V., 2002. Hydroponics and Humates: Ancient Acids for Modern Agriculture. The Best of the Growing Edge International, 2000-2005: Select Cream-of-The-Crop Articles for Soilless Growers. New Moon Publishing, pp: 373-375.
30. Yildirim, E., 2007. Foliar and soil fertilization of humic acid affect productivity and quality of tomato. Acta Agriculturae Scandinavica Section B-Soil Plant Science, 57: 182-186.
31. El-Tohamy, W.A., H.M. El-Abagy, M.A. Badr, S.D. Abou-Hussein and Y.I. Helmy, 2011. The influence of foliar application of potassium on yield and quality of carrot (*Daucuscarota*L.) plants grown under sandy soil conditions. Aust. J. Basic & Appl. Sci., 5: 171-174.
32. Canellas, L., F.A. Olivares, Olofrokovha-Facanha and A. Facanha, 2002. Humic acids isolated from earth worm compost enhance root elongation, lateral root emergence and plasma membrane H^+ ATPase activity in maize roots. Plant Physiol., 130: 1951-1957.
33. Eyheraguibel, B., 2004. Characterization of humic substances derived from organic waste enhancements- Effects on plants. Doctoral Dissertation, Institut National Poly technique de Toulouse, Toulouse, France.