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USING OF NANOTECHNOLOGY TO EVALUATE SOME POTASSIUM SOURCES AND METHODS APPLICATION ON SOIL AND PLANT

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ABSTEACT: A field experiment was conducted on clay soil at Agriculture Research Center Station, Giza, Egypt, tomato (*Solanum lycopersicum* L., var. 448) plants were grown during the winter season of 2020-2021. Nanofertilizers were prepared by ball-milling and investigated by Transmission Electron Microscopy (TEM) measuring the potassium fertilizer particle sizes. Four treatments were apply as 100% of recommended dose (traditional K fertilizer-control treatment) 60, 30, 10% K NFs and two sources of KNFs as K-humate(bio-source) and K-gluconate(organo-source), and two methods of K fertilizer apply as soil and foliar. The K-compound were sprayed with 1000g/400 liter fed^{-1}. The aim of this study improving the use of potassium fertilizers by applying nanotechnology, raising tomato yields and reducing K loss. The data appeared that tomato yield and their quality showed more response to foliar application, K-humate at rate 10% of K NFs, and showed that the KNFs foliar spray application at rate of 10% reduced losses of K through soil depths.

Key words: Potassium nanofertilizer, potassium sources, application methods, available K-losses, tomato plants, growth parameters and total yield,

INTRODCUTION

There is an urgent need to reduce the dangers arising from the excessive use of chemical fertilizers, as chemical fertilizers are applied in large quantities and with low efficiency, and this results in environmental pollution (Mir et al. 2018). Therefore, a serious agricultural technique must be applied that works to rationalize the use of fertilizers and with high efficiency, to reduce environmental damage (Mahmoud and Swaefy, 2020). The environmental pollution is increasing in developing countries where agriculture is the vertebral column of their national economy and faces many defies as the lack of new suitable soil and reduction of cultivable soil due to contend demands for economic development activities, ware reliance, penury, and malnutrition (Ditta and Arshad, 2016). Application of conventional fertilizers with low efficiency (20–50%) and heavy cost increase in use rates have due to develop and promote the use of nanofertilizer (Aziz *et al.,* 2006). Progression in the realms of science and technology could be a possible solution for raise the value in current production systems (Prasad *et al.,* 2014). A considerable increase in agricultural production could be possible through employment of current knowledge in the realm of nanotechnology for efficient nutrient system (Liu and Lal, 2015), good plant protection practices, precision agriculture, and many others (Tarafdar, *et al., 2013*).Nanofertilizer are particles lies in the range of 1-100 nm, which are more efficient than traditional chemical fertilizers due to the increase in use efficiency, reduce nutrient loss and reduce environmental pollution (Ditta and Arshad, 2016).

Potassium (K) has basic role in mitigation of biotic and abiotic stresses (Read *et al.,* 2006), also it is enter in many processes in plant such as transport, assimilation, storage in tissue protein synthesis, photosynthesis, activation of enzymes and nitrogen fixation (Cakmak, 2005, Hawkesford *et al.,* 2012 and Safavi, 2016), which affect on plant growth and yield components. Use of nano-potassium fertilizer increases the yield of the crop in soils with low fertility (Rajaei, 2010).

Tomato (*Solanum lycopersicum* L.) is one of the most widely consumed vegetable crops and grown at all world (Abdelmonaim, 2012). In Egypt, tomatoes have great economic importance in greenhouse and field production (Abuel-Heba *et al.,* 2008).

The aim of this study: improving the use of potassium fertilizers by applying nanotechnology, improving and raising tomato yields, reducing soil and groundwater pollution.

MATRIALS AND METHODES

A field experiment was conducted on clay soil at Agriculture Research Center Station, Giza, Egypt, tomato plants(*Solanum lycopersicum* L., var. 448) were grown during the winter season of 2020 -2021. A spilt split plot design with three replicates was used to study some sources of potassium nanofertilizers (KNFs) as humate and gluconate on soil and plant. potassium sources were applied in main plots. Application methods were placed in sub-pots and four applications rates were located in sub-sub plots as 100% of full recommended dose of traditional K fertilizer (control), and KNFs as 60, 30 and 10% from recommended dose, which equal 48, 28.8, 14.4 and 4.8 kg fed^{-1}, respectively). Potassium compound were sprayed with 1000 (control treatment 100% of traditional K fertilizer as potassium sulphate 48% K), and KNFs as 600(60%), 300(30%) and 100(10%) g/400 liter fed^{-1} were applied at 15, 30, 45 and 60 days after planting at randomly distributed in sub plots, followed spraying with standard methods to avoid osmosis effect on plants at early morning. Plants were transplanted into plots with an area of 12 m^2 (3×4 m) each plot had twelve plants having spacing between rows and plants were 70 and 40 cm, respectively. All agricultural practices were applied according to the recommendations of the ministry of agriculture, Egypt. Nanofertilizers were prepared by ball-milling (Eleyan *et al.,* 2018) and Transmission Electron Microscopy (TEM) used to investigated and measuring the size of potassium fertilizers particle using JEOL transmission electron microscope (TEM) HRTEM, JEOL 3010 (Wang *et al.,* 2014) as shown 1n Fig (1).

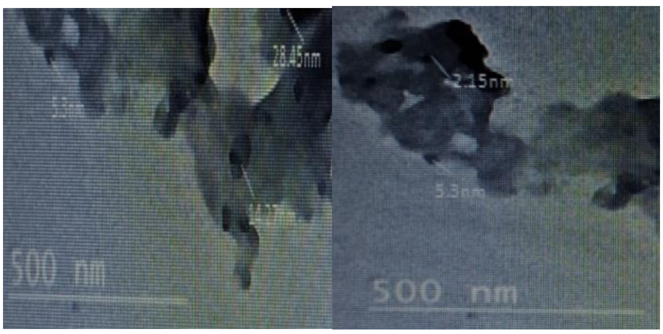

Fig (1): TEM images of (a) K-gluconate and K-humate NFs

Soil samples were collected from all the studied treatments at depth of 0-30, 30-60 and 60-90cm thoroughly homogenized, air dried and passed through 2 mm size sieve to determine organic matter according to Piper (1950). Soil pH (using pH meter model WTW Series pH 720) was determined in 1:2.5 soil water suspensions according to the standard method described by Richards (1954). Total soluble salt (using EC meter model WTW Series Cond 720) were measured in soil paste extract as method described by Jackson *et al.* (1973). Total $CaCO^3$ content and soluble cations and anions were carried out according to Jackson *et al.,* (1973). Nitrogen by the micro Kjeldahl method according to AOAC (2012). Phosphorus was determined colorimetrically using spectrophotometer (model JENWAY6705UV/Vis) and potassium was determined using Flame-photometer (model JENWAYPFP7), according to Jackson *et al.* (1973). Available micronutrients were extracted by DTPA according to Lindsay and Norvell (1978) and determined using Atomic Absorption Spectrophotometer (model, analyticjenanovAA 350). Some physical and chemical properties of the experimental soil obtained are presented in Table (1).

At harvest stage, five plant samples were collected from each treatment of plot and were oven dried at 70 °C, then fine grinded and were digested according to Jackson, (1973) to determine macro (N, P, and K), Na and micronutrients (Fe, Mn and Zn) using micro-Kjelahel method, spectrophotometer, flam photometer and atomic spectrophotometer, respectively, according to AOAC (2012). Determined some of plant growth and biochemical parameters and yield productivity, fruit quality analysis as total acidity according to the method of Wills and Ku (2002), total soluble sugars according to Stewart (1974), Vitamin C according to Pearson (1970), Brix was made on the slide of the refractometer and the lid replaced, total soluble solids (brix°) according to Owoso *et al.,* (2000), Penetrometer or Sclerometer to measuring fruit firmness to know force necessary to penetrate a plunger of known size into the pulp of the fruit. Photosynthetic pigments (chlorophyll-a, chlorophyll-b, total chlorophyll and carotenoids) were determined in fresh leaves according to Sumanta *et al.* (2014) using UV/VIS spectrophotometer (JENWAY 6705, UK).

Table (1): Some physical and chemical characteristics of the studied soil.

Soil characteristics	Value	Soil characteristics	Value
Particle size distribution%:		Soluble cations (soil paste $mmole_c l^{-1}$):	
Sand	4.05	Ca^{2+}	0.82
Silt	9.50	Mg^{2+}	0.62
Clay	86.45	Na^+	0.85
Textural class Clay		K^+	0.16
Soil chemical properties:		Soluble anions (soil paste $mmole_c l^{-1}$):	
pH (soil paste extract)	7.55	CO_3^{2-}	0.00
EC dS m^{-1} (soil paste extract)	0.24	HCO_3^-	0.36
Organic carbon %	0.21	Cl^-	1.36
$CaCO_3$ g kg^{-1}	1.33	SO_4^{2-}	0.73

Available Nutrients mg kg^{-1}

N	P	K	S	Fe	Mn	Zn
118.2	5.63	68.85	1.11	6.62	0.84	0.42

The data were statistically analyzed using one-way analysis of variance test by the least significant difference (LSD at 0.05) according to method described by Gomez and Gomez (1984) using IBM SPSS Statistics 20 program.

RESULTS AND DISCUSSION

Study was an attempt to know the best application methods (foliar or soil), improve tomato quality, productivity and least degree of pollution to the soil with some K FNs sources such as potassium humate(bio-K) and potassium gluconate (organo-K) (Shimaa, 2017). As the obtained results of winter season was not significantly different, their average was taken into consideration.

Effect of some KNFs sources application on some plant growth characteristics of tomato plant:

Data in Table (2) showed that the effect of KNFs application as soil and foliar spray addition, with different rates. The results revealed that, the K-humate NFs and K- gluconate NFs were significantly enhanced the growth parameters compared with control treatments.

As shown in the Table (2) the applied potassium in source of K-humate NFs led to enhancing the growth parameters of the tomato plant, and applied also as a spraying on the plant led to a better response on all growth parameters(Mahmoud *etal.,*2019). Also, applied K-humate as NFs at different rates under study gave a positive response at the rate of 10% K-humate NFs(Mahmoud *etal.,*2017). Azarpour *et al.* (2012) studied the different K-sources and methods of applied and found that K-humate marked increases in plant height, fresh weight and dry matter content of tomato plants and values were 102.72cm, 2899 kg fed^{-1} and 7.01%, respectively, in compare with other treatments and control treatment (100 full recommended dose as traditional fertilizer) which recorded lowest values were 62.35 cm, 1464 kg fed^{-1} and 3.57%, respectively, as the previous arrangement(Mahmoud and Swaefy, 2020).

The presented data showed that interaction analysis for K-humate NFs at foliar spray application and rate of 10% KNFs was superior to all other potassium sources and application methods used for tomato plant, where K-gluconate added as soil application and control treatment was inferior (Sher and Abdur, 2013).

Effect of some KNFs sources on some fruit characteristics of tomato plant:

The data in Table (3) indicated that adding NFs as K-humate with foliar spray application on the tomato plant gave a better result than K-gluconate organo-source with soil application in terms on the characteristics of tomato plants and yield (Farnia and Ezatollah, 2015).

However, adding fertilizers at the nano size maximize the benefit of the fertilizer unit. While, choosing the appropriate fertilizer source, dose and suitable method to add, maximize the plant response (Bidari and Hebsur, 2011).

Fruit firmness and Fruit yield were as follows 27.17, 22.47, 11.25 fruit plant^{-1}, 9.45,7.31, 6.43 kg cm^{-1}, 37.51, 29.89 and 9.63 ton fed^{-1} for each of K-humate and K-gluconate at rate 10% KNFs(in the case of adding the fertilizer foliar spray on plant) in compare with the control treatment, respectively, (Hosseini *et al.,* 2013).

Interaction analysis showed that K-humate NFs with foliar spray application at rate of 10% KNFs were superior, while application of K-gluconate NFs was

inferior at both application methods used, as showed in Fig. (2). NFs increased the productivity of all most treatments in tomato plants, this mean that NFs could promote the production of plant (Nouraein, 2019).

Table (2): Effect of some KNFs sources on some fruit characteristics of plant.

Methods(M)	K sources(S)	Rates%(R)	Plant height cm	Fresh weight Kg fed^{-1}	Dry matter %
Soil	Control	100	62.33	1359	3.55
	Humate	60	92.12	2474	4.64
		30	92.59	2475	5.11
		10	92.95	2477	5.47
		Mean	85.00	2196	4.69
	Control	100	62.33	1359	3.55
	Gluconate	60	75.82	2021	3.85
		30	76.29	2024	4.32
		10	76.41	2025	4.86
		Mean	72.71	1857	4.15
Mean			78.86	2026.75	4.42
Foliar	Control	100	62.35	1464	3.57
	Humate	60	102.24	2897	6.16
		30	102.72	2898	6.65
		10	103.07	2899	7.01
		Mean	92.60	2540	5.85
	Control	100	62.35	1464	3.57
	Gluconate	60	85.24	2104	4.80
		30	85.71	2106	4.64
		10	86.07	2108	5.63
		Mean	79.84	1946	4.66
Mean			86.22	2242.50	5.25
Mean of K sources	Humate		88.80	2367.88	5.27
	Gluconate		76.28	1901.38	4.40
Mean of rates%	100		62.34	1411.5	3.56
	60		88.86	2374.00	4.86
	30		89.33	2375.75	5.18
	10		89.63	2377.25	5.74
LSD at 0.05	M		1.5	1.8	0.5
	S		3	3.3	1.5
	R		0.9	1.1	0.6
	MS		0.7	0.8	0.7
	MR		2.2	1.3	1.5
	SR		0.9	0.7	0.7
	MSR		4.2	6.6	0.8

Table (3): Effect of some KNFs sources on some fruit characteristics of plant.

Methods(M)	K sources(S)	Rates%(R)	No. of fruit $plant^{-1}$	Fruit firmness (kg cm^{-1})	Fruit yield (ton fed^{-1})
Soil	Control	100	11.53	6.46	9.06
	Humate	60	21.82	7.50	28.31
		30	22.29	7.97	28.78
		10	22.65	8.33	29.14
		Mean	19.57	7.57	23.82
	Control	100	11.53	6.46	9.06
	Gluconate	60	18.62	6.20	26.52
		30	19.09	6.97	26.99
		10	19.45	7.33	27.35
		Mean	17.17	6.74	22.48
Mean			18.37	7.15	23.15
Foliar	Control	100	11.25	6.43	9.63
	Humate	60	26.34	8.62	36.68
		30	26.81	9.09	37.15
		10	27.17	9.45	37.51
		Mean	22.89	8.40	30.24
	Control	100	11.25	6.43	9.63
	Gluconate	60	21.64	6.48	29.05
		30	22.11	6.95	29.53
		10	22.47	7.31	29.89
		Mean	19.37	6.79	24.53
Mean			21.13	7.60	27.38
Mean of K sources	Humate		21.23	7.98	27.03
	Gluconate		18.27	6.77	23.50
Mean of rates %	100		11.39	6.45	9.35
	60		22.11	7.20	30.14
	30		22.58	7.75	30.61
	10		22.94	8.11	30.97
LSD at 0.05	M		1.7	2.0	0.9
	S		0.5	0.7	0.5
	R		0.9	1.0	0.5
	MS		1.4	1.4	1.1
	MR		1.3	0.9	1.2
	SR		0.5	0.7	0.3
	MSR		0.8	1.4	0.6

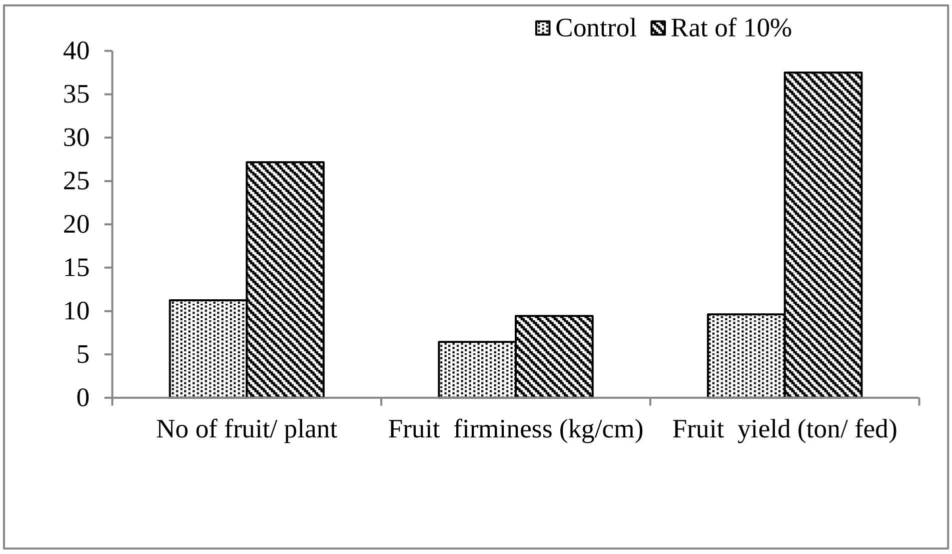

Fig (2): Compare between control and foliar application with KNFs at rate of 10%application for fruit and some yield parameters of tomato plans.

Effect of some KNFs sources on some on macro- nutrients content of tomato fruit:

The results in Table (4) show the macro-nutrients content of tomato fruits, which reflects the nutritional status of the plant.

Data was found that following the appropriate methods such as type of fertilizer source, method of addition, the appropriate fertilizer rate for adding and using nanofertilizer led to an increase in the plant's response to the accumulation of N, P and K in the vegetative parts of plant and then remobilize and translocate to the growing fruits.

The data presented Table (4) showed that the difference in the plant's response to applying potassium as K-humate or organo-fertilizer (K-gluconate) and also if the addition was soil add or foliar spray application at different rates compared to the control treatment, the K-humate NFs was the best and showed a clear superiority of tomato effects with values of 2.94, 2.21 and 3.79% for K-humate NFs while the values were 2.5, 1.60 and 3.24%tefor K-gluconate NFs using a foliar spray application at a rate of 10%, but the values of control treatment were 1.55, 1.26 and 2.85%, respectively. NFs treatments induced a significant improvement in nutrient content in tomato plants compared to control treatment (Ditta and Arshad, 2016).

Finally, the results showed that responses of N, P and K content in tomato fruit seemed to be more efficient with K- humate NFs of foliar spray application. Furthermore, the same attitude previously mentioned with tomato plant growth parameter was more rational and more related to N, P and K contents in tomato fruit (Sajyan et al., 2020).

Effect of some K NFs sources on some on micro- nutrients content of tomato fruit:

Data recorded in Table (5) revealed differences between both studied sources of KNFs, and relationship between micronutrients status and tomato fruit. The K-humate NFs seemed to be preferable. Further, the micronutrient elements content as Fe, Mn

and Zn in tomato fruits due to K-humate application as K-humate NFs treatment were considerably better than that of the organo-oneNFs (K-gluconate). The mean values were 89.67 and 63.96mg kg^{-1} for iron, 69.39 and 64.36mgkg^{-1} for manganese and 42.94 and 31.76 mg kg^{-1} for zinc, respectively (Delfani *et al.,* 2014).

Table (4): Effect of some KNFs sources on some macro- nutrients content of fruits.

Methods(M)	K sources(S)	Rates%(R)	N %	P %	K %
Soil	Control	100	1.36	1.12	2.76
	Humate	60	1.79	1.22	2.63
		30	2.26	1.49	3.10
		10	2.62	1.85	3.46
		Mean	2.01	1.37	2.99
	Control	100	1.36	1.12	2.76
	Gluconate	60	1.46	1.02	2.22
		30	1.92	1.12	2.69
		10	2.28	1.43	3.05
		Mean	1.76	1.02	2.68
Mean			1.88	1.20	2.83
Foliar	Control	100	1.55	1.26	2.85
	Humate	60	2.11	1.38	2.96
		30	2.58	1.85	3.42
		10	2.94	2.21	3.78
		Mean	2.30	1.68	3.25
	Control	100	1.55	1.26	2.85
	Gluconate	60	1.68	1.17	2.40
		30	2.14	1.24	2.87
		10	2.50	1.60	3.24
		Mean	1.97	1.22	2.84
Mean			2.13	1.45	3.05
Mean of K sources	Humate		2.15	1.52	3.12
	Gluconate		1.86	1.12	2.76
Mean of rates%	100		1.46	1.19	2.81
	60		1.79	1.20	2.55
	30		2.23	1.40	3.02
	10		2.59	1.77	3.38
LSD at 0.05	M		0.5	0.7	0.03
	S		0.5	0.6	0.2
	R		0.6	0.8	0.02
	MS		0.3	0.4	0.1
	MR		0.3	0.6	0.1
	SR		0.4	0.5	0.4
	MSR		0.4	0.6	0.04

Table (5): Effect of some KNFs sources on some micro- nutrients content of fruits.

Methods(M)	K sources(S)	Rates%(R)	Fe mg kg^{-1}	Mn mg kg^{-1}	Zn mg kg^{-1}
Soil	Control	100	46.13	52.33	23.43
	Humate	60	78.12	66.32	37.92
		30	78.59	66.79	33.39
		10	78.95	67.15	38.75
		Mean	70.45	63.15	33.37
	Control	100	46.13	52.33	23.43
	Gluconate	60	64.82	60.32	31.62
		30	65.29	60.79	32.09
		10	65.65	61.15	32.45
		Mean	60.47	58.65	29.90
Mean			65.46	60.90	31.64
Foliar	Control	100	55.23	50.53	23.63
	Humate	60	88.84	75.24	48.94
		30	89.31	75.71	49.41
		10	89.67	76.07	49.77
		Mean	80.76	69.39	42.94
	Control	100	55.23	50.53	23.63
	Gluconate	60	66.44	68.54	34.04
		30	66.91	69.01	34.51
		10	67.27	69.37	34.87
		Mean	63.96	64.36	31.76
Mean			72.36	66.88	37.35
Mean of K sources	Humate		75.61	66.27	38.16
	Gluconate		62.22	61.51	30.83
Mean of rates %	100		50.68	51.43	23.53
	60		74.56	67.61	38.13
	30		75.03	68.08	37.35
	10		75.39	68.44	38.96
LSD at 0.05	M		2.3	2.4	1.1
	S		6.0	9.2	2.5
	R		2.2	2.3	2.1
	MS		1.4	2.2	2.5
	MR		5.2	5.5	2.3
	SR		1.3	2.1	5.3
	MSR		3.2	3.4	2.2

Furthermore, foliar spray application was more suitable than that of soil application, most supposedly that occurred because ease of fertilizer absorption by the plant without loss, as occurs in soil application, this is explain the improvement occurred for both growths of plants and macro-nutrients status.Generally, the results appeared that the high contents of micronutrient in tomato fruit were with values 89.67, 76.07 and 49,77 mg kg^{-1} at 10% rate of K-humate NFs and foliar application for Fe, Mn and Zn, respectively, (Afify *et al.,* 2019).

Effect of some KNFs sources on some total soluble solids and titratable acidity of tomato fruit quality:

Usually evaluated the quality of plant production according to the purpose of using the plant. Anyway, nutrition and other environmental factors are highly affecting through effecting biochemical of physiological processes. Data in Table (6) showed that some differences between both K-humate and K-gluconate sources, but K-humate NFs was relatively considered the best treatment. Also, the results showed that the response of tomato plants to K-humate more than K-gluconate, such this response may be due to the suitability of source application for total soluble solids and titratable acidity of tomato fruit (Ferrara and Brunetti, 2010). The applied method of potassium was more effective with foliar spray being more favorable than soil application. On other hand, the values were 6.97, 5.27ºBrix,3849 and 2138 mg L^{-1} for TSS and respectively, at 10% rate of K-humate NFs with foliar application (Merghany et al., 2019).

Interaction analysis obtained in the previous Table showed that total soluble solids and titratable acidity were most affected by K-humate and K-gluconate at foliar spray application were. But, the effect of k-gluconate NFs form at a soil application method was inferior.

Effect of some K NFs sources on some biochemical parameters of tomato leaves:

Data presented in Table (7) showed the same behavior mentioned previously for all plant parameters under study. There was a positive response of plant pigments to K-source NFs and methods of application, especially K-humate, was more essential compared to organo-KNFs with all plant pigments contents under study. Whereas, the data revealed that KNFs at all sources and rates produced the highest total chlorophyll and carotenoids content values compared to the control treatment with mean ranged between 2083 to 2843 and 1089 to 1494 µg g^{-1} fresh leaves, respectively (Salama, 2012). At rate of 10%, K-humate NFs with foliar spray application recorded high positive response with value were 2843 and 289 µg g^{-1} fresh leaves for total chlorophyll and carotenoids content, respectively (Afify *et al.,* 2019).

On the other hand, applied K-humate NFs, as foliar spray was high positive response compared to soil application. Where total chlorophyll and carotenoids content increased due to the plant photothynses, rate of plant growth, protein synthesis and activated biomass production which stimulates plant growth and ultimately increases plant growth (Merghany *et al.,* 2019).

Nanoparticles improve photosynthesis and reduce respiration rate, which increases the content of tomato plants from total chlorophyll (Abdel Wahab *et al*., 2019).

Interaction analysis for the appeared data in Fig (3) stated that foliar spray application of K-humate NFs seemed to be the high response and K-gluconate NFs in soil application was less response.

Table (6): Effect of some KNFs sources on some total soluble solids and total acidity of fruit

Methods(M)	K sources(S)	Rates%(R)	TSS (Brix)	Total acidity mg l^{-1}
Soil	Control	100	3.93	1322
	Humate	60	4.42	2214
		30	4.89	2215
		10	5.25	2217
		Mean	4.62	1992.00
	Control	100	3.93	1322
	Gluconate	60	3.52	2017
		30	3.99	2018
		10	4.35	2019
		Mean	3.95	1844.00
Mean			4.29	1918.00
Foliar	Control	100	4.05	1331
	Humate	60	6.14	3846
		30	6.61	3848
		10	6.97	3849
		Mean	5.94	3218.50
	Control	100	4.05	1331
	Gluconate	60	4.44	2134
		30	4.91	2137
		10	5.27	2138
		Mean	4.67	1935.00
Mean			5.31	2576.75
Mean of K sources	Humate		5.28	2605.25
	Gluconate		4.31	1889.50
Mean of Rates %	100		3.99	1326.50
	60		4.63	2552.75
	30		5.10	2554.50
	10		5.46	2555.75
LSD at 0.05	M		6.2	7.2
	S		1.7	3.7
	R		5.4	9.1
	MS		10.5	6.6
	MR		3.5	6.5
	SR		9.2	3.7
	MSR		4.5	5.7

Table (7): Effect of some K NFs sources on some biochemical parameters (µg/ g) of leaves

Methods(M)	K sources(S)	Rates%(R)	Ch a	Ch b	Total Chl	Carotenoid
			µg g^{-1} fresh leaves			
Soil	Control	100	1003	603	1606	156
	Humate	60	1803	789	2592	276
		30	1805	792	2597	275
		10	1808	795	2603	278
		Mean	1604.75	744.75	2349.50	246.25
	Control	100	1003.00	603.00	1606.00	156.00
	Gluconate	60	1553.00	684.00	2237.00	198.00
		30	1556.00	688.00	2244.00	201.00
		10	1557.00	689.00	2246.00	204.00
		Mean	1417.25	666.00	2083.25	189.75
Mean			1511.00	705.38	2216.38	218.00
Foliar	Control	100	1005.00	610.00	1615.00	151.00
	Humate	60	1908.00	1338.00	3246.00	333.00
		30	1912.00	1341.00	3253.00	334.00
		10	1915.00	1344.00	3259.00	337.00
		Mean	1685.00	1158.25	2843.25	288.75
	Control	100	1005.00	610.00	1615.00	151.00
	Gluconate	60	1652.00	985.00	2637.00	222.00
		30	1955.00	987.00	2942.00	222.00
		10	1957.00	989.00	2946.00	225.40
		Mean	1642.25	892.75	2535.00	205.10
Mean			1662.63	410.20	1663.63	247.08
Mean of K sources	Humate		1644.88	951.50	2596.38	267.50
	Gluconate		1529.75	779.38	2309.13	451.00
Mean of rates %	100		1004.00	606.50	1610.50	153.50
	60		3458.00	1898.00	5356.00	257.25
	30		1807.00	952.00	2759.00	258.00
	10		1809.25	954.25	2763.50	261.10
LSD at 0.05		M	10.0	30.0	15.0	25.0
		S	2.5	5.3	10.0	50.0
		R	10.0	12.0	4.8	10.0
		MS	2.5	5.9	1.5	12.5
		MR	10.0	6.3	7.2	2.5
		SR	5.5	7.2	4.5	5.8
		MSR	10.0	55.0	5.2	15.0

Chl a = Chlorophyll a, Chl b= Chlorophyll b and Chl T= total Chlorophyll

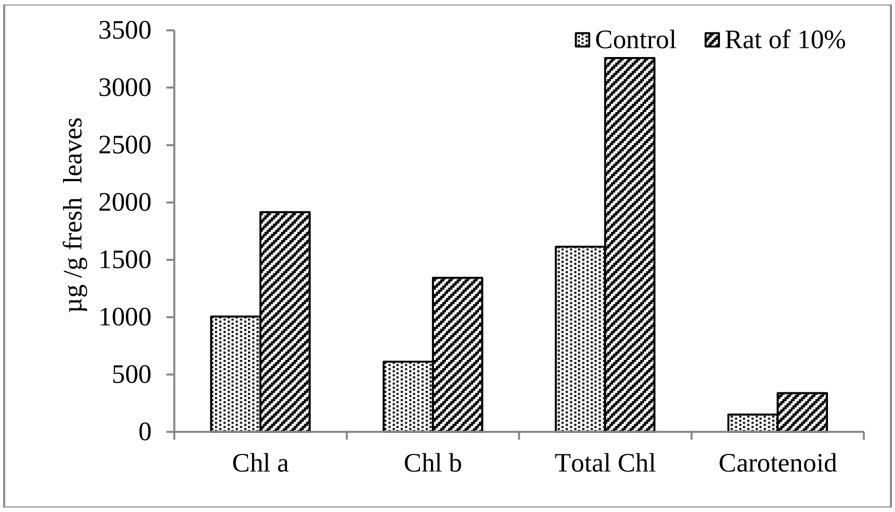

Fig. (3): Compare between control and foliar application with K-humate KNFs at rate of 10% for same biochemical plant parameters of tomato plants.

Effect of some KNFs sources on total soluble sugars and vitamin C of tomato fruit quality:

Data in Table (8) showed that significant differences between method of applied KNFs source, K-humate NFs and KNFs rate. However, data showed that K-humate sprayed at rate of 10%, total sugar and vitamin C content was more than that one produced from another source as organo-KNFs with values were 80.05mg g^{-1} dwt and 283.17 mg 100 cm^{-3} juice, respectively. Thus, the results of total soluble sugars and vitamin C appeared an expected trend for foliar spray application method which taken a suitable effect on the total sugar content and vitamin C (Chapagain and Wiesman, 2004 and Asri *et al.*, 2015). Moreover, foliar potassium application improves fruit marketable by increasing sugars content and vitamin C, this may be due to improved photosynthetic assimilation, their translocation from leaves to fruits and increased enzyme activation (Lester *et al.,* 2007).

Interaction analysis for the obtained data of total sugars of tomato fruit, revealed that K-humate as foliar spray application seemed to be superior as revealed from the significant interaction illustrated in Table (8). Anyhow, the effect of k-gluconate was more or less equal effect, obtained with total sugar content in tomato fruit, while it was more evident than control treatment.

Effect of some KNFs sources on sodium and potassium contents and K^+/Na^+ ratio in tomato fruit:

As shown in Table (9) sodium content in tomato fruit and the ratio of $K^+/Na^+$with KNFs, showed that KNFs sources made Na^+ content less intense and significantly decreased it. Therefore, K^+/Na^+ ratio increased. In this regard K sources NFs under experiment gave K^+/Na^+ ratio more than 1 with use of K-humate NFs. Factors affecting the uptake and distribution of Na^+ within the plants can have a predominant role in the response to K(Munns, 2002 and Zhu, 2003).

Generally, Na^+ content was significantly decreased more than control treatment. Data was noticeable that the ratio of potassium to sodium in all treatments was greater compared to the control treatment. Improving plant potassium absorption by using the spraying method and the appropriate

source of composting and nano-sized fertilizer at all rates led to a reduction in the competition between sodium and potassium. Potassium plays an important vital role in all cellular processes, and it is possible the presence of potassium to sodium in the plant juice gives the plant the ability to endure because the high concentration of sodium in humans of potassium leads to inhibiting the metabolism processes that depend on potassium (Abdelaziz*et al.,* 2019).

Table (8): Effect of some KNFs sources on total soluble sugars and vitamin C of tomato fruit quality

Methods(M)	K sources(S)	Rates%(R)	Total soluble sugar mg g^{-1}	Vitamin C mg 100 cm^{-3} juice
Soil	Control	100	40.56	143.48
	Humate	60	67.77	200.42
		30	68.43	202.15
		10	69.66	205.2
		Mean	61.61	187.81
	Control	100	40.56	143.48
	Gluconate	60	54.95	166.78
		30	58.09	166.98
		10	58.99	168.55
		Mean	53.15	161.45
Mean			57.38	174.63
Foliar	Control	100	44.25	154.32
	Humate	60	78.15	278.2
		30	78.85	281.33
		10	80.05	283.17
		Mean	70.33	249.26
	Control	100	44.25	154.32
	Gluconate	60	58.87	177.16
		30	61.34	177.45
		10	60.00	179.34
		Mean	56.12	172.07
Mean			63.23	210.67
Mean of K sources	Humate		65.97	218.53
	Gluconate		54.63	166.76
Mean of rates %	100		42.41	148.90
	60		64.68	205.64
	30		66.68	206.98
	10		67.18	209.07
LSD at 0.05	M		15	20
	S		10	13
	R		2.5	3
	MS		1.5	2.6
	MR		7.5	6
	SR		12.6	3.9
	MSR		6.3	7.5

Table (9): Effect of some KNFs sources on sodium and potassium contents and K^+/Na^+ ratio of fruit.

Methods	K sources	Rates %	Na^+	K^+	K^+/Na^+ ratio
Soil	Control	100	3.1	2.33	0.75
	Humate	60	2.18	3.28	1.51
		30	2.15	3.36	1.56
		10	2.11	3.45	1.64
		Mean	2.39	3.11	1.37
	Control	100	3.1	2.33	0.75
	Gluconate	60	2.17	2.75	1.27
		30	2.12	2.87	1.35
		10	2.04	2.92	1.43
		Mean	2.36	2.72	1.20
Mean			2.37	2.91	1.29
Foliar	Control	100	3.09	2.53	0.82
	Humate	60	2.22	3.4	1.53
		30	2.18	3.48	1.6
		10	2.16	3.66	1.69
		Mean	2.41	3.27	1.41
	Control	100	3.09	2.53	0.82
	Gluconate	60	2.28	2.83	1.24
		30	2.17	2.96	1.36
		10	2.12	3.12	1.47
		Mean	2.42	2.86	1.22
Mean			2.41	3.06	1.32
Mean of K sources	Humate		2.40	3.19	1.39
	Gluconate		2.39	2.79	1.21
Mean of rates %	100		3.10	2.43	0.79
	60		2.22	3.07	1.39
	30		2.16	3.17	1.47
	10		2.11	3.29	1.56

Effect of some KNFs sources on loss of available K in soil depth:

Data in Table (10) show the effect of KNFs on loss of available K in soil depth. Regard to, the results, data showed that use of KNFs at two sources, foliar spray application at different rates reduced leaching the available K at different depths of the soil under study.

Whereas, the results obtained that the control treatment (traditional K fertilizer at recommended doseat rate 100%) was the highest available K values loss in the soil with values were 220.14, 209.06 and 207.08 mg K $kg^{-1}$and 212.15, 201.45 and 199.52 mg K kg^{-1} at 0-30, 30-60 and 60-90 cm soil depths with soil and foliar spray application, respectively, (Mendes *et al.*, 2016).

Table (10): Effect of some KNFs sources on loss of available K at soil depth.

Methods(M)	K sources(S)	Rates%(R)	0-30 cm	30-60 cm	60-90 cm
Background K in soil mg kg^{-1}			68.85	65.15	62.01
Soil	Control	100	220.14	209.06	207.08
	Humate	60	120.85	104.52	103.03
		30	55.42	51.37	48.2
		10	21.31	20.3	18.44
		Mean	104.43	96.31	94.19
	Control	100	220.14	209.06	207.09
	Gluconate	60	135.75	128.41	125.22
		30	69.33	63.5	61.61
		10	33.73	31.52	28.54
		Mean	114.74	108.12	105.62
Mean			109.58	102.22	99.90
Foliar	Control	100	212.15	201.45	199.52
	Humate	60	115.86	106.91	95.47
		30	47.43	40.76	38.04
		10	9.32	5.69	4.28
		Mean	96.19	88.70	84.33
	Control	100	212.15	201.45	199.52
	Gluconate	60	128.76	119.81	118.25
		30	59.88	53.21	50.49
		10	15.77	12.14	9.73
		Mean	104.14	96.65	94.50
Mean			100.17	92.68	89.41
Mean of K sources	Humate		100.31	92.51	89.26
	Gluconate		109.44	102.39	100.06
Mean of rates %	100		216.15	205.26	203.30
	60		125.31	114.91	110.50
	30		58.02	52.21	49.59
	10		20.03	17.41	15.25
LSD at 0.05		M	1.5	2.1	0.7
		S	0.4	0.6	0.1
		R	0.6	0.8	0.5
		MS	0.6	1.3	0.1
		MR	0.9	1.7	0.4
		SR	0.2	0.5	0.1
		MSR	0.5	0.7	0.3

On the other hand, among the rates of KNFs in combined with different K sources and application methods were differ in the loss of available K with values were ranged between 4.28 to 135.75 mg K kg^{-1}at all soil depths under study (Hayyawi *et al.,* 2019).

Therefore, data also, showed that treatment of K-humate NFs as K-humate NFs (foliar spray application) was more effect in combined with rate of 10% and the values were 9.32, 5.69 and 4.28 mg K kg^{-1} at 0-30, 30-60 and 60-90 cm soil depths, respectively.

The trend of available K loss from different rates of KNFsin combined with different K NFs sources used and application methods applied on tomato plants was observed as follow: 10< 30<60<100%(control treatment)(Al-juthery et al., 2019). While, the trend of available K NFs loss from different sources KNFs in combined with different rates of KNFs and application methods(soil and foliar) applied on tomato plants was observed as follow: K-humate NFs < K-gluconate NFs< control, also, foliar spray application less lost of available K NFs than soil application.

Fig (4) showed that the compare between control treatment and 10% rate of K-humate NFs at foliar application. Potassium associated with the highly soluble sources, may lead to high losses through leaching (Silva *et al.,* 2002). So, Moraes and Dynia (1992) considered K as the most easily leached cation, due to its displacement to the soil solution and to its leaching.

So, a better conduct of the K nutrients that is essential to the plants and needful to enhance sustainable agriculture (Goulding *et al.,* 2008). One of the methods that can be applied is use of foliar spray application by KNFs (Shehata *et al.,* 2019 and Afify *et al.,* 2019).

Using of the traditional potassium fertilizers with soil application, the spread of potassium to the roots is more complicated so potassium is subject to competition and interaction with other positive ions such as calcium, magnesium, sodium and hydrogen, which affects the movement and distribution of potassium (Fulton *et al.,* 2010). While the nanofertilizers is characterized by slow release, accuracy of targeting, rapid absorption by roots, penetration into living tissues, avoiding sedimentation and adsorption reactions (Qureshi *et al.,* 2018).

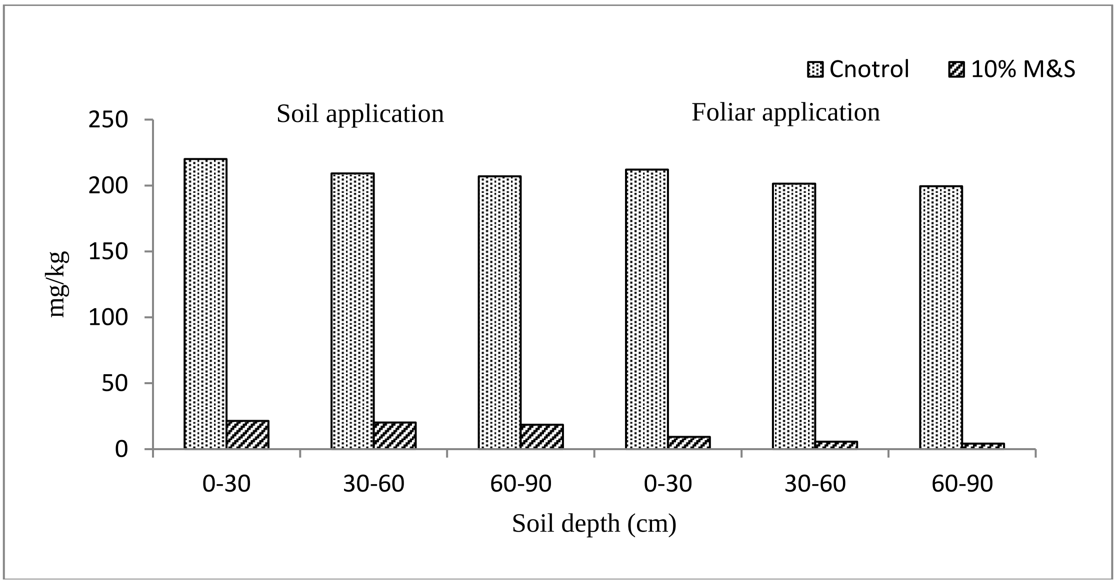

Fig (4): Compare between control, soil and foliar spray application with K-humate at rate of 10% for available K content loess in soil depth after tomato plants harvesting.

CONCLUSSION

Could be concluded that, use of KNFs have been successful for better nutrition of crop plants compared to the conventional fertilizers. Use of KNFs as a foliar spray application on tomato plants leads to reduced in the amount of KNFs by 10% of recommended dose, use of k-humate NFs as K-humate of potassium fertilizer was more responsive to all plant parameters and use of KNFs as foliar spray application on the plant reduced available potassium loss through soil depths.

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استخدام تقنية النانو لتقييم بعض مصادر البوتاسيوم وطرق تطبيقها على التربة والنبات

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معهد بحوث الأراضي والمياه والبيئة –مركز البحوث الزراعية –الجيزة –مصر

الملخص العربي

أجريت تجربة حقلية على تربة طينية بمحطة مركز البحوث الزراعية، الجيزة، مصر، تمت زراعتها بنباتات الطماطم (*Solanum lycopersicum* L. var. 448)، خلال فصل الشتاء ٢٠٢٠-٢٠٢١ . تم تحضير الأسمدة النانوية بالطحن الكروي وفحصها بواسطة المجهر الإلكتروني الناقل (TEM) لقياس أحجام حبيبات سماد البوتاسيوم. تم تطبيق أربعة معالجات وهى ١٠٠٪ للمقارنة سواء للإضافة الأرضية أو الورقية (سماد سلفات البوتاسيوم التقليدي ٤٨% بو$_2$أ جرعة كاملة حسب وزارة الزراعة)، ٦٠، ٣٠ ،١٠ ٪ سماد بوتاسيوم النانوى) واثنين من مصادر سماد البوتاسيوم النانوى كمصدر حيوي (هيومات بوتاسيوم) ومصدر عضوي (جلوكونات بوتاسيوم)، وطريقتين لإضافة السماد البوتاسي كإضافة أرضية وأخرى ورقية. يتم رش مركبات البوتاسيوم بمعدل ١٠٠٠ جم /٤٠٠ لتر/ فدان على فترات مختلفة كل ٤٥،٣٠،١٥و٦٠يوم بعد الزراعة. تهدف هذه الدراسة إلى تحسين استخدام الأسمدة البوتاسية من خلال تطبيق تقنية النانوتكنواوجى، وتحسين وزيادة محصول الطماطم، والحد من تلوث التربة والمياه الجوفية. وقد أظهرت النتائج أن محصول الطماطم وجودته أظهر استجابة أكبر للتطبيق الورقي، والمصدر الحيوي هيومات البوتاسيوم بمعدل ١٠ ٪ من سماد البوتاسيوم النانوى، وأظهرت النتائج أيضا أن الرش الورقي من السماد النانوى بمعدل ١٠ ٪ قلل من فقد البوتاسيوم الميسر خلال أعماق التربة المختلفة تحت الدراسة.

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