INFLUENCE OF ADDITION METHODS OF FULVIC ACID AND FOLIAR SPRAY WITH POTASSIUM SOURCES ON PRODUCTIVITY AND QUALITY OF POTATO CROP

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ABSTRACT

Two field experiments were carried out during the two successive winter seasons of 2015/2016 and 2016/2017 in a private farm at meet Faris village, Dekarns, Dakhlia Governorate, to study the effect of fulvic acid as application methods (without, soil application at 4 kg /fed. and foliar application at 5 g / l) and some sources of potassium (potassium sulphate, potassium silicate, potassium chloride and potassium citrate) at 1% K_2O as foliar spray and the interaction between them on growth, yield and quality of potato tuber cv. Spunta under clay soil conditions using follow irrigation system .

Results indicated that, the interaction of fulvic acid at 4 kg/fed. as soil application (SA) with K silicate as foliar spray recorded the highest values of plant height, number of leaves and dry weights of potato plants. It also exerted superior recorded of N, P and K concentration in shoots and its uptake after 70 days from planting , number of tuber/ plant, yield (kg)/ plant and total yield (ton) /fed., dry matter content in tuber, TSS, starch and K content in tuber at harvesting time. In this connection, it was followed by the interaction between fulvic acid at 5 g/liter as (FS) and silicate potassium in both seasons. Meanwhile, the lowest values of abovementioned traits were recorded with the interaction between treatments of fulvic acid non addition and spraying potato plants with K sulphate in both seasons.

In this regard, the increases in total yield/fed. were about 38.90 and 45.14% for the interaction between fulvic acid as soil application and foliar application of K silicate, followed by 32.66 and 36.33 % for the interaction between fulvic acid as soil application and K citrate foliar application and 31.95 and 36.67 for the interaction between fulvic acid as foliar application at 5 g/l and K silicate foliar application than that plants which sprayed plants with K sulphate only in the 1st and 2nd seasons, respectively.

Key words. Potato, fulvic acid soil and foliar application, potassium sources, yield and its components .

INTRODUCTION

Potato (*Solanum tuberosum* L.) is a crop of major significance in human nutrition, ranking fourth in food production, after wheat, corn (maize), and rice. It is the first in energy production, and second in carbohydrate and protein production (**Nieder, 1992**).

Fulvic acid is very effective because of its least molecular weight, it has necessary and capacity to readily bond minerals and elements into its molecular structure causing them resolve and be become mobilized fulvic complexes, Fulvic acid usually loads 70 or more mineral and effect elements as bit of its molecular

complexes, **Aiken and McKnight (1985**) reported that Fulvic acids are key ingredients of enhance quality foliar fertilizers. As they can help the permeation to the plant parts, stimulate the absorption uptake of mineral from plant surfaces into plant tissues.

Once applied to leaves, fulvic acid bearer transport traces minerals directly to metabolic locations inside plant cells. Subsequently, foliar spray using at specific plant growth stages, containing mineral chelated can be used as a primary technique for maximizing plants productive capacity (**Chen *et al*., 2004).**
Some researchers showed that treated plants with fulvic acid as soil application or foliar application increased plant growth, chemical constituents, yield and its quality (**Khang, 2011** o radish , **Elattar 2012 on palm , Suh *et al.*2014a and b** on tomato and potato, **El-Borai *et al*., 2015** on grapevine , **Abou El Hassan and Husein , 2016** on tomato, **El-Hassanin *et al*., 2016** on sugar beat and **El-Kenawy,2017 on grapevine**).

Foliar nutrition is ideally designed to provide many elements in conditions that may be limiting production at a time when nutrient uptake from the soil is inefficient or nonexistent (**Hiller, 1995**). Large applications of fertilizers and soil amendments for potato production may cause the accumulation of heavy metals in tubers and eventually become toxic in the soil environment. It self, foliar sprays are effective for most nutrients in correcting foliar deficiencies, but not effective to correct tuber nutritional problems if the nutrient is not mobile in the phloem (**Westennann, 2005**). Therefore, foliar feeding of nutrients has become an established procedure in crop production to increase yield and quality of crop products (**Roemheld and El-Fouly, 1999**) and it also minimizes environmental pollution and improves nutrient utilization through reducing the amounts of fertilizers added to the soil (**Abou-El-nour, 2002**).

Spraying potato plants with different sources of potassium showed differences between them regarding plant growth, plant chemical constituents, yield and its tuber quality (**Awad *et al*., 2010, Khan *et al. 2010*, Habib *et al*., 2011, Jasim *et al*., 2013, Salim *et al*. 2014** , **Neshev and Manolov , 2016 and Abou zeid and Abd El-Latif, 2017**) on potato.

The target of this study is to improve vegetative growth, yield, tuber quality of potato by using addition methods of fulvic acid and different sources of potassium under clay soil.

MATERIALS AND METHODS

Two field experiments were carried out during the two successive winter seasons of 2015/2016 and 2016/2017 in a private farm at meet Faris village, Dekarns Dakhlia Governorate, to study the effect of fulvic acid (without, soil application at 4 kg /fed. and foliar application at 5 g/l) and some sources of potassium (potassium sulphate, potassium silicate, potassium chloride and potassium citrate) at 1% K_2O on growth, tuber yield and quality of potato under clay soil conditions using follow irrigation system .

The physical and chemical analyses of the experimental soil are presented in Tables 1.

Table 1a: The physical and chemical properties of the experimental soil

Soil properties	1st season	2nd season
Physical properties		
Sand (%)	25.66	25.23
Silt (%)	25.50	25.98
Clay (%)	48.71	48.96
O.M (%)	1.91	2.02
Chemical properties		
pH	7.60	7.30
Total N (%)	0.15	0.15
Available P_2O_5 (%)	0.030	0.031
Available K_2O (%)	0.52	0.53

This experiment included 12 treatments, which were the combinations between two application methods of fulvic acid , beside control treatments and four sources of potassium as foliar spray as follows:

a. Fulvic acid: without, 4 kg/fed. as soil application and 5g/ l as foliar application

b. Potassium sources as foliar spray were used at 1 % K_2O

1. Potassium sulphate (48.5 % K_2O)
2. Potassium silicate (10 % K_2O)
3. Potassium chloride (60 % K_2O)
4. Potassium citrate (46 % K_2O)

These treatments were arranged in a split plot design with three replicates. The Fulvic acid treatments were randomly arranged in the main plots and potassium sources were randomly distributed in the sub plots.

The plots area was 21 m^2 including three tows at 10 m long and 0.7 m wide. One row was used to measure plant growth traits and the other two rows were used to measure yield and its components traits.

Tuber seed of potato cultivar (Spunta) was sown at 20 cm apart on the 10th and 12th of October in the 1st and 2nd seasons, respectively.

All experimental units, received 120 kg N and 80 kg P_2O_5 as ammonium sulfate (20.6 % N) and triple superphosphate (37 % P_2O_5), respectively. One third of N and all P_2O_5 were added at soil preparation time with FYM at the rate of 40 m^3/feddan. The rest of nitrogen (two thirds) was applied in three equal split applications after 30 days from planting and 15 days intervals.

Fulvic acid was added as soil application after 30 days from planting, while Fulvic acid as foliar spray and potassium sources were added twice at 45 and 55 days after planting in both seasons.

Other recommended agricultural practices for commercial potato production were followed.

DATA RECORDED

1.Growth parameters

A random sample of five plants was taken from every plot at 70 days after planting, in both seasons of study, for measuring the growth characters of potato plants expressed as follows:

1. Plant height (cm)
2. Number of leaves/plant
3. Dry weight of shoots/plant (gm)

2. Nitrogen , phosphorus and potassium contents and its uptake

The dry matter of shoots at 70 days after planting in both seasons were finely ground and wet digested for N,P and K determination. Total Nitrogen, phosphorus and potassium were determined according to the methods described by **Bremner and Mulvaney (1982), Olsen and Sommers (1982) and Jackson (1970),** respectively. N,P and K uptake were calculated .

3. Yield and its components

At harvest; i.e., at 105 days after planting, tubers from each plot were calculated, weighed and counted, and the following parameters were calculated :

1. Number of tubers/plant,
2. Tuber yield per plant (gm),
3. Total yield (ton/*fed*),
4. Relative yield (%).

4. Tuber Quality

4.1. **Dry Matter (%)**: One hundred grams of the grated mixture were dried at 105 ^{0}C till constant weight and DM (%) was recorded .

4.2.Total soluble solids concentration (TSS %): were determined by using the hand refractometer

4.3.Starch concentration (%): It was determined according to the method reported by **A.O.A.C. (2000).**

4.4. Potassium concentration (%): It was determined according to the method as described by **A.O.A.C. (2000).**.

Statistical analysis:

Statistical Analysis: Recorded data were subjected to the statistical analysis of variance according to **Snedecor** and **Cochran (1980**), and means were compared according LSD at 5 % level.

RESULTS AND DISCUSSION

1. Plant Growth

a. Effect of fulvic acid application methods

Data in Table (2) indicate that **,** treating potato plants with 4 kg /fed. fulvic acid as soil application (SA) recorded the maximum values of plant height, number of leaves / plant and dry weight / plant in both seasons, followed by that plants which sprayed with fulvic acid at 5 g /liter in both seasons, while control treatment recorded the lowest values of all plant growth in both seasons.

The increases in dry weight of shoot/ plant were about 16.82 and 14.43% for fulvic acid (SA) and 6.10 and 7.47 % for fulvic acid (FA) than untreated plants in the 1st and 2nd seasons, respectively.

The beneficial effect of fulvic acid on shoot length and leaf area may be explained as of its least molecular weight, it has necessary and capacity to readily bond minerals and elements into its molecular structure causing them resolve and be mobilized fulvic complexes, Fulvic acid usually loads carries 70 or more mineral and effect elements as bit of its molecular complexes **(Aiken and McKnight 1985**).

These results are in agreement with those reported by **Khang (2011)** on radish and **Abou El Hassan and Husein (2016)** on tomato.

b. Effect of potassium sources

Such data in Table (2) show that foliar spray with different potassium sources at 1% K_2O had significantly effect on plant height, number of leaves and dry weights of potato plants in both seasons. Sprayed potato plants with potassium silicate (K silicate) recorded the highest values of plant height, number of leaves, and dry weights of shoot/plant in both seasons, followed by sprayed plants with potassium citrate (K citrate), while sprayed plants with potassium sulphate recorded the lowest values of all plant growth measurements in both seasons.

The increases in dry weight of shoot/ plant were about 48.42 and 39.33 % for K silicate and 30.59 and 25.18 for K citrate than that plants which sprayed with K sulphate in the 1st and 2nd seasons, respectively.

Potassium plays a vital role in maintaining the turgidity of plant cells. Because of its very importance in turgor maintenance, potassium is essential to obtain maximum leaf extension and stem elongation. (**Abd El-Latifa, *et al.*, 2011**).

The previous positive action of potassium silicate on growth characters may be explained as it contains higher amounts of silicon (25%) and its important roles in protecting plants against drought, cold, diseases and fungal attack, alleviating abiotic stress (heavy metals toxicity and salinity)and improving root development, uptake of water and nutrients and plant pigments (**Qin and Tian 2009**).

Results are in harmony with those reported by **Al-Hamzawi, 2010** on cucumber**, Kazemi, 2014** on tomato and **Helal and AbdElhady, 2015** on potato.

Table (2): Effect of fulvic acid application methods and potassium sources on plant growth at 70 days after planting of potato plants during winter plantation of 2015/2016 and 2016/2017 seasons

Treatments / Main effect	Plant height (cm)		Number of leaves/plant		Shoot dry weight(g)	
	2015/2016 season	2016/2017 season	2015/2016 season	2016/2017 season	2015/2016 season	2016/2017 season
	Fulvic acid application methods					
Without	75.16	75.66	25.50	25.16	36.85	38.38
Fulvic acid SA (4 kg/fed.	93.50	90.25	28.83	29.08	43.05	43.92
Fulvic acid FA (5 g/l)	85.75	83.75	27.66	28.00	39.10	41.25
LSD at 0.05 level	**3.54**	**1.40**	**1.71**	**0.61**	0.78	0.51
	Potassium sources					
K Sulphate	75.55	75.77	24.44	24.22	31.80	34.42
K Silicate	92.77	90.77	30.11	30.66	47.20	47.96
K chloride	83.00	80.88	26.55	26.55	38.13	39.25
K citrate	87.88	85.44	28.22	28.22	41.53	43.09
LSD at 0.05 level	**1.98**	**1.11**	**1.06**	**0.71**	1.06	0.56

SA=Soil application , FA= foliar application

c. Effect of the interaction between fulvic acid application methods and potassium sources

Data in the same Table (3) show that the interaction between fulvic acid application methods and potassium sources had significant effect on plant height, number of leaves and dry weights of potato plants in both seasons.

Treated potato plants with fulvic acid as soil application (SA) at 4 kg /fed. and sprayed plants with K silicate increased plant height, number of leaves and dry weight of potato plants, followed by the interaction between fulvic acid at 5 g/liter as (FA) and sprayed plants with the same source of potassium (K Slicate) in both seasons. On the other side, the lowest values of all plant growth parameters were obtained with the interaction between without fulvic acid and the plants which sprayed with K sulphate in both seasons.

The increases in dry weight of shoot/ plant were about 63.22 and 54.46% for the interaction between fulvic acid as soil application (SA) at 4 kg /fed. and sprayed plants with K silicate, followed by 50.96 and 42.66 % for the interaction between fulvic acid at 5 g/liter as (FA) and sprayed plants with K silicate than that plants which sprayed with K sulphate only in the 1st and 2nd seasons, respectively.

Table (3): Effect of interaction between fulvic acid application methods and potassium sources on plant growth at 70 days after planting of potato plants during winter plantation of 2015/2016 and 2016/2017 seasons

Treatments		Plant height (cm)		Number of leaves/ plant		Shoot dry weight (g)	
Fulvic acid application methods	Potassium sources	2015/2016 season	2016/2017 season	2015/2016 season	2016/2017 season	2015/2016 season	2016/2017 season
Without	K Sulphate	64.33	69.00	24.33	23.66	31.00	33.56
	K Silicate	83.67	83.66	26.66	27.33	44.20	44.16
	K chloride	76.00	73.66	25.33	24.33	33.60	36.60
	K citrate	76.67	76.33	25.66	25.33	38.60	39.20
Fulvic acid SA (4g/fed.)	K Sulphate	82.33	81.00	24.66	24.66	33.20	36.28
	K Silicate	101.67	97.00	32.33	33.00	50.60	51.84
	K chloride	93.00	89.66	28.00	28.66	42.60	41.52
	K citrate	97.00	93.33	30.33	30.00	45.80	46.04
Fulvic acid FA (5 g/l)	K Sulphate	80.00	77.33	24.33	24.33	31.20	33.44
	K Silicate	93.00	91.66	31.33	31.66	46.80	47.88
	K chloride	80.00	79.33	26.33	26.66	38.20	39.64
	K citrate	90.00	86.66	28.66	29.33	40.20	44.04
LSD at 0.05 level		3.44	1.93	1.85	1.23	1.84	0.98

SA=Soil application , FA= foliar application

2. N, P and K concentration and their uptake by shoots

a. Effect of fulvic acid application methods

Data in Tables (4) and (5) show that treated potato plants with fulvic acid as (SA or FA) had significant effect on N, P and K concentration and their uptake by shoots at 70 days after planting in both seasons. However, treating potato plants with fulvic acid as (SA) gave the highest values of all mineral contents in shoots and their uptake without any significant differences due to spraying potato plants with fulvic acid as (FA) respecting N and P concentration in shoot in both seasons.

Fulvic acid is key ingredients of high quality foliar spray fertilizers. As they can help the penetration to the plant parts, stimulate the uptake of elements from plant surfaces into plant tissues (**Chen *et al*., 2004**).

The present findings are in agreement with the results obtained by **Yildirim and Unay (2011)** who indicated that foliar application of fulvic acid enhances the nutritional status of tomato plants**.** Also**, Ameri and Tehranifar (2012)** investigated that spraying of humic acid on strawberry plants enhanced N, P and K uptake**.**

b. Effect of potassium sources

Data presented in Tables (4) and (5) illustrate that foliar spray with potassium sources had significant effect on N,P and K concentration and their uptake by shoots at 70 days after planting in both seasons. Spraying potato plants with K silicate recorded the maximum values of N, P and K concentration in shoots and their uptake, without any significant differences with K citrate regarding P concentration in shoots in both seasons. On the other hand, spraying

plants with K sulphate gave the lowest values of mineral contents and their uptake in both seasons.

Potassium silicate is considered as a rich source of potassium. Since potassium is directly involved in the nutrients absorption through the process of phloem loading as a counter ion to H^+ (**Komor *et al.*, 1980**) and so enhancing the mineral content of plant foliage.

The increasing nitrogen percent due to potassium fertilizer application may be due to the role of potassium on plant nutrition, i.e. promotion of enzyme activity and enhancing the translocation of assimilates and protein synthesis (**El-Said, 1999**).

These results are in agreement with those reported with **Kamal (2013)** who found that foliar application with potassium silicate to sweet pepper significantly increased NPK uptake by foliage. Also, **Salim *et al*. (2014)** came to the same result on potato. They found that foliar application of different sources of potassium gave the highest values for leaf biochemical composition as compared with control treatment.

Table (4): Effect of fulvic acid application methods and potassium sources on N,P and K concentration in shoots at 70 days after planting of potato plants during winter plantation of 2015/2016 and 2016/2017 seasons

Treatments	N (%)		P (%)		K (%)	
	2015/2016 season	2016/2017 season	2015/2016 season	2016/2017 season	2015/2016 season	2016/2017 season
Main effect	**Fulvic acid application methods**					
Without	2.83	2.80	0.323	0.353	2.42	2.49
Fulvic acid SA (4 kg/fed.)	3.49	3.63	0.354	0.404	2.85	3.06
Fulvic acid FA (5 g/l)	3.47	3.55	0.355	0.396	2.62	2.84
LSD at 0.05 level	**0.11**	**0.22**	**0.025**	**0.018**	**0.12**	**0.14**
	Potassium sources					
K Sulphate	2.78	3.09	0.299	0.330	1.94	2.14
K Silicate	3.89	3.59	0.374	0.413	3.27	3.42
K chloride	3.13	3.20	0.343	0.386	2.42	2.70
K citrate	3.26	3.42	0.361	0.410	2.89	2.91
LSD at 0.05 level	**0.14**	**0.15**	**0.014**	**0.011**	**0.15**	**0.12**

SA=Soil application , FA= foliar application

Table (5): Effect of fulvic acid application methods and potassium sources on N,P and K uptake (mg/ shoot) by shoots at 70 days after planting of potato plants during winter plantation of 2015/2016 and 2016/2017 seasons

Treatments	N		P		K	
	2015/2016 season	2016/2017 season	2015/2016 season	2016/2017 season	2015/2016 season	2016/2017 season
Main effect	**Fulvic acid application methods**					
Without	1060.1	1081.1	120.42	136.15	913.5	970.3
Fulvic acid SA (4 kg/fed.)	1529.8	1617.1	154.47	180.13	1260.6	1372.4
Fulvic acid FA (5 g/l)	1383.8	1466.2	140.22	165.40	1055.0	1196.9
LSD at 0.05 level	**47.04**	**93.01**	**9.43**	**7.65**	**49.37**	**51.04**
	Potassium sources					
K Sulphate	885.3	1067.3	95.37	113.60	620.2	740.4
K Silicate	1845.8	1737.8	177.07	199.80	1555.3	1655.4
K chloride	1204.6	1263.2	130.93	151.80	926.1	1066.1
K citrate	1362.5	1484.3	150.12	177.03	1203.8	1257.5
LSD at 0.05 level	**57.84**	**65.82**	**5.00**	**5.27**	**60.79**	**44.60**

SA=Soil application , FA= foliar application

c. Effect of the interaction between fulvic acid application methods and potassium sources

It is obvious from the data in Tables (6) and (7) that the interaction between fulvic acid application methods and potassium sources had significant effect on N, P and K concentration in shoots and their uptake in both seasons

The highest values of N, P and K contents in shoots and their uptake were obtained with the interaction between fulvic acid as (SA) at 4 kg /fed. and sprayed potato plants with K silicate in both seasons, without any significant differences between the interaction between fulvic acid as (FA) at 5 g/l and sprayed potato plants with K silicate concerning N content in shoot in the 1st season.

3. Yield and Its Components

a. Effect of fulvic acid application methods

Treated potato plants with fulvic acid as soil application or foliar application had significant effect on number of tubers /plant, yield (kg) /plant and total yield (ton)/fed. in both seasons, except number of tuber/ plant in the 2nd season. However, addition of 4 kg/fed. fulvic acid as soil application significantly increased number of tubers /plant, yield /plant and total yield/ fed. in both seasons without any significant differences with fulvic acid as (FA) at 5 g /l in the 1st season respecting number of tubers/ plant in the 1st season.

The increases in total yield /fed. were about 12.82 and 15.22% for fulvic acid as soil application and 10.45 and 10.80 % for fulvic acid as foliar application than untreated plants in the 1st and 2nd seasons, respectively.

Fulvic acid is particularly preferred in that it allows surrounding stress to decrease, helps absorb other minerals and positively contributes to yield and its components (**Bethke *et al.*, 1987**).

The present findings are in agreement with the results obtained by **Suh *et al.* (2014), Abou El Hassan and Husein (2016)** on tomato and **El-Hassanin *et al*. (2016)** on sugar beet .

Table (6): Effect of interaction between fulvic acid application methods and potassium sources on N, P and K concentration in shoots at 70 days after planting of potato plants during winter plantation of 2015/2016 and 2016/2017 seasons

Treatments		N (%)		P (%)		K (%)	
Fulvic acid application methods	Potassium sources	2015/2016 season	2016/2017 season	2015/2016 season	2016/2017 season	2015/2016 season	2016/2017 season
Without	K Sulphate	2.51	2.62	0.273	0.312	1.73	1.83
	K Silicate	3.38	3.02	0.310	0.344	2.83	2.91
	K chloride	2.71	2.61	0.316	0.367	2.42	2.47
	K citrate	2.74	2.95	0.343	0.392	2.73	2.75
Fulvic aciFA(4g/fed.)	K Sulphate	2.94	3.24	0.396	0.330	2.26	2.43
	K Silicate	4.18	4.27	0.383	0.465	3.66	3.85
	K chloride	3.27	3.38	0.333	0.403	2.47	2.91
	K citrate	3.57	3.64	0.343	0.418	3.03	3.05
Fulvic acid FA (5 g/l)	K Sulphate	2.89	3.43	0.353	0.348	1.84	2.17
	K Silicate	4.12	3.48	0.346	0.431	3.34	3.52
	K chloride	3.43	3.61	0.368	0.388	2.39	2.74
	K citrate	3.47	3.68	0.369	0.420	2.91	2.93
LSD at 0.05 level		0.24	0.27	0.023	0.020	0.26	0.21

SA=Soil application , FA= foliar application

Table (7): Effect of interaction between fulvic acid application methods and potassium sources on N, P and K uptake by shoots (mg/ shoot) at 70 days after planting of potato plants during winter plantation of 2015/2016 and 2016/2017 seasons

Treatments		N		P		K	
Fulvic acid application methods	Potassium sources	2015/2016 season	2016/2017 season	2015/2016 season	2016/2017 season	2015/2016 season	2016/2017 season
Without	K Sulphate	778.1	879.3	84.60	104.70	536.3	614.1
	K Silicate	1494.0	1333.6	151.60	151.90	1250.9	1285.1
	K chloride	910.6	955.3	111.90	134.30	813.1	904.0
	K citrate	1057.6	1156.4	133.57	153.70	1053.8	1078.0
Fulvic acid SA (4g/fed.)	K Sulphate	976.1	1175.5	102.90	119.70	750.3	881.6
	K Silicate	2115.1	2213.6	200.40	241.10	1852.0	1995.8
	K chloride	1393.0	1403.4	146.10	167.30	1052.2	1208.2
	K citrate	1635.1	1675.9	168.50	192.40	1387.7	1404.2
Fulvic acid FA (5g/l)	K Sulphate	901.7	1147.0	98.60	116.40	574.1	725.6
	K Silicate	1928.2	1666.2	179.20	206.40	1563.1	1685.4
	K chloride	1310.3	1431.0	134.80	153.80	913.0	1086.1
	K citrate	1394.9	1620.7	148.30	185.00	1169.8	1290.4
LSD at 0.05 level		100.18	114.01	8.67	9.13	105.30	77.25

SA=Soil application , FA= foliar application

b. Effect of potassium sources

Spraying potato plants with K silicate produced the highest values of number of tubers /plant, yield (kg) /plant and total yield (ton)/fed. in both seasons , followed by in this connection K citrate , while sprayed plants with K chloride came in the third rank, as spraying plants with K sulphate gave the lowest values in this respect in both seasons (Table 8).

The increases in total yield/fed. were about 23.89 and 24.83 % for K silicate , 19.37 and 18.15 % for K citrate application , 12.34 and 15.68 % for K chloride than that plants which sprayed with K sulphate in the 1st and 2nd seasons, respectively.

The role of K in increasing the yield and its components might be attributed to its function in plants which include energy metabolism and enzyme activation on exchange rate and nitrogen activity as well as enhanced carbohydrates movement from shoot to storage organs **(Mengel 1997).**

It could be concluded that increasing productivity of potato plants as a result of foliar fertilizer, may be due to increasing weight and numbers of tubers/plant which in turn increased the total tubers yield (ton/h.). This effect might be due to that potassium plays an important role in the transport of assimilates and nutrients towards tubers as storage organs (**Allison *et al.*, 2001**).

These results are in harmony with those reported with **Awad *et al.* (2010), Khan *et al.* (2010), Habib *et al.*, (2011), Jasim *et al.*, (2013), Salim *et al.* (2014)** , **Neshev and Manolov , (2016) and Abou zeid and Abd El-Latif, (2017)** on potato**.**

Table (8): Effect of fulvic acid application methods and potassium sources on yield and its components of potato during winter plantation of 2015/2016 and 2016/2017 seasons

Treatments	Number of tubers/plant		Yield / plant (kg)		Yield (ton/fed.)		Relative increses in total yield	
	2015/2016 season	2016/2017 season	2015/2016 season	2016/2017 season	2015/2016 season	2016/2017 season	2015/2016 season	2016/2017 season
Main effect	**Effect of fulvic acid application methods**							
Without	2.91	2.83	0.367	0.384	13.482	13.357	00.00	00.00
Fulvic acid SA(4kg/fed.)	3.75	3.58	0.493	0.485	15.211	15.391	12.82	15.23
Fulvic acid FA (5 g/l)	3.75	3.58	0.447	0.453	14.89 2	14.800	10.46	10.80
LSD at 0.05 level	**0.49**	**Ns**	**0.016**	**0.018**	**0.115**	**0.171**	--	--
	Effect of potassium sources							
K Sulphate	2.55	2.44	0.293	0.323	12.758	12.659	00.00	00.00
K Silicate	4.55	4.66	0.572	0.562	15.806	15.803	23.89	24.84
K chloride	3.11	2.88	0.416	0.406	14.333	14.644	12.35	15.68
K citrate	3.66	3.33	0.462	0.473	15.230	14.957	19.38	18.15
LSD at 0.05 level	**0.54**	**0.41**	**0.030**	**0.018**	**0.136**	**0.108**	--	--

SA=Soil application , FA= foliar application

c. Effect of the interaction between fulvic acid application methods and potassium sources

Data in Table (9) show that the interaction between fulvic acid application methods and potassium sources had significant effect on yield and its components in both seasons.

Application of fulvic acid at 4 kg /fed. as soil application and sprayed plants with K silicate increased number of tuber/ plant, yield (kg)/plant and total

yield (ton) /fed. in both seasons**,** followed by the interaction between fulvic acid as foliar spray at 5 g/l and sprayed potato plants with K silicate or with the interaction between fulvic acid as soli application at 4 kg /fed. and sprayed potato plants with K citrate with regard total yield in both seasons.

The increases in total yield/fed. were about 38.90 and 45.14% for the interaction between fulvic acid as soil application and sprayed potato plants with K silicate, followed by 32.66 and 36.33% for the interaction between fulvic acid as soil application and sprayed potato plants with K citrate and 31.95 and 36.67 for the interaction between fulvic acid as foliar application and sprayed potato plants with K silicate than that plants which sprayed plants with K sulphate only in the 1st and 2nd seasons, respectively.

Table (9): Effect of interaction between fulvic acid application methods and potassium sources on yield and its components of potato during winter plantation of 2015/2016 and 2016/2017 seasons

Treatments		Number of tubers /plant		Yield / plant (kg)		Yield (ton/fed.)		Relative increases in total yield (%)	
Fulvic acid application methods	Potassium sources	2015/2016 season	2016/2017 season	2015/2016 season	2016/2017 season	2015/2016 season	2016/2017 season	2015/2016 season	2016/2017 season
Without	K Sulphate	2.33	2.00	0.261	0.296	12.073	11.690	00.0	0.00
	K Silicate	3.33	3.66	0.455	0.438	14.717	14.467	21.90	23.75
	K chloride	2.66	2.66	0.345	0.385	13.233	13.373	09.60	14.39
	K citrate	3.33	3.00	0.410	0.420	13.923	13.897	15.32	18.87
Fulvic acidSA(4g/fed.)	K Sulphate	2.66	2.66	0.318	0.359	13.077	13.097	08.31	12.03
	K Silicate	5.33	5.33	0.683	0.660	16.770	16.967	38.90	45.14
	K chloride	3.33	3.00	0.481	0.434	14.993	15.563	24.18	33.13
	K citrate	3.66	3.33	0.490	0.490	16.017	15.937	32.66	36.33
Fulvic acid FA(5 g/l)	K Sulphate	2.66	2.66	0.300	0.313	13.123	13.190	08.69	12.83
	K Silicate	5.00	5.00	0.578	0.590	15.931	15.977	31.95	36.67
	K chloride	3.33	3.00	0.421	0.400	14.773	14.997	22.36	28.28
	K citrate	4.00	3.66	0.488	0.511	15.750	15.037	30.45	28.63
LSD at 0.05 level		0.94	0.71	0.052	0.031	0.237	0.187	--	--

SA=Soil application , FA= foliar application

4. Tuber quality

a. Effect of fulvic acid application methods

It is clear from the data in Table (10) that, treating potato plants with 4 kg /fed. fulvic acid as (SA) significantly increased dry matter ,TSS, starch contents and K content in tuber at harvesting time in both seasons, except TSS in the 2nd season without any significant differences with fulvic acid as (FA) concerning DM and TSS in the 1st season .

The increases in dry matter content in tuber was about 9.86 and 12.22% for fulvic acid as (SA) and 5.84 and 8.63 % for fulvic acid as (FA) than untreated plants in the 1st and 2nd seasons, respectively. Also, The increases in starch content in tuber was about 7.26 and 7.90% for fulvic acid as (SA) and 4.38 and 4.49 % for fulvic acid as (FA) than untreated plants in the 1st and 2nd seasons, respectively. However, the increases in K content in tuber was about 65.06 and 57.54% fulvic acid as (SA) and 54.21 and 43.01 % for fulvic acid as (FA) than untreated plants in the 1st and 2nd seasons, respectively.

This led to enhancing morphological characters, plant height number of leaves and shoot dry weight of plant (Tables 2 and 3) this reflected positively on yield and its components.

These results are in harmony with those of **Yildirim and Unay (2011)** and **Abou El Hassan and Husein (2016)** they found that foliar application of fulvic acid enhance fruit quality of tomato on tomato.

b. Effect of potassium sources

Data in Table (10) show that spraying potato plants with different sources of potassium had significant effect on dry matter, TSS, starch and K concentrations in tuber at harvesting time in both seasons. Sprayed plants with K silicate caused significant increases in dry matter, TSS, starch and K concentrations in tuber than other potassium sources without any significant differences with K citrate regarding TSS in both seasons.

The increases in dry matter content in tuber were about 22.65 and 18.68% for K silicate as (FA) and 12.57 and 13.08 % for K citrate that plants which sprayed with K sulphate in the 1st and 2nd seasons, respectively. Also, the increases in starch concentration in tuber was about 12.99 and 15.13% for K silicate and 9.67 and 11.37 % for K citrate than that plants which sprayed with K sulphate in the 1st and 2nd seasons, respectively.

Moreover ,the increases in K concentration in tuber were about 71.25 and 59.55% for K silicate and 52.69 and 44.38 % for K citrate than that plants which sprayed with K sulphate in the 1st and 2nd seasons, respectively.

Potassium plays an important role in functions of enzymes needed for the vital in plants. Many studies proved that K plays a major role in many physiological and biochemical processes such as cell division and elongation, enzyme activation, stabilization of the native conformation of enzymes and possibly turgor, metabolism of carbohydrates and protein compounds (**Awad, *et al*., 2010**).

Obtained results contradicted with those reported by **Salim *et al*. 2014** , **Neshev and Manolov , 2016 and Abou zeid and Abd El-Latif, 2017**) on potato.

Table (10): Effect of fulvic acid application methods and potassium sources on tuber quality of potato at harvesting time during winter plantation of 2015/2016 and 2016/2017 seasons

Treatments	Dry matter (%)		TSS (%)		Starch content (%)		K (%)	
	2015/2016 season	2016/2017 season	2015/2016 season	2016/2017 season	2015/2016 season	2016/2017 season	2015/2016 season	2016/2017 season
Main effect	**Fulvic acid application methods**							
Without	18.66	18.41	5.16	5.20	14.59	14.67	1.66	1.79
Fulvic acid SA (4 kg/fed.)	20.50	20.66	5.54	5.41	15.65	15.83	2.74	2.82
Fulvic acid FA (5 g/l)	19.75	20.00	5.29	5.37	15.23	15.33	2.56	2.56
LSD at 0.05 level	0.88	0.59	0.25	NS	0.21	0.16	0.05	0.08
	Potassium sources							
K Sulphate	17.66	17.88	5.11	5.11	14.16	14.07	1.67	1.78
K Silicate	21.66	21.22	5.61	5.66	16.00	16.20	2.86	2.84
K chloride	19.33	19.44	5.22	5.16	14.94	15.17	2.21	2.37
K citrate	19.88	20.22	5.38	5.38	15.53	15.67	2.55	2.57
LSD at 0.05 level	**0.54**	**0.59**	**0.24**	**0.31**	**0.17**	**0.16**	0.03	0.07

SA=Soil application , FA= foliar application

c. Effect of the interaction between fulvic acid application methods and potassium sources

The interaction between fulvic acid application methods and potassium sources had significant effect on dry matter %, TSS, starch and K concentrations in tuber at harvesting time in both seasons (Table 11).

The highest values of dry matter (%), TSS, starch and K concentrations in tuber were obtained with the interaction between fulvic acid at 4 kg /fed. as soil application and sprayed plants with K silicate in both seasons. On the other hand sprayed plants with K sulphate gave the lowest values in tuber quality in both seasons.

The increases in dry matter content in tuber was about 32.71% and 33.29 % and 22.91and 25.77% in starch concentration and 202.63 and 161.13% in K concentration for the interaction between fulvic acid at 4 kg /fed. as soil application and sprayed plants with K silicate than sprayed plants with K sulphate only in the 1st and 2nd seasons, respectively.

Generally, it could be concluded that, the interaction between fulvic acid at 4 kg/fed. as soil application and K silicate at 1% K_2O was the best interaction for enhancing yield and tuber quality under the same condition .

Table (11): Effect of interaction between fulvic acid application methods and potassium sources on tuber quality of potato at harvesting time during winter plantation of 2015/2016 and 2016/2017 seasons

Treatments		Dry matter (%)		TSS (%)		Starch content (%)		K (%)	
Fulvic acid application methods	Potassium sources	2015/2016 season	2016/2017 season	2015/2016 season	2016/2017 season	2015/2016 season	2016/2017 season	2015/2016 season	2016/2017 season
Without	K Sulphate	17.33	17.00	5.00	5.00	13.79	13.58	1.14	1.32
	K Silicate	20.33	19.66	5.33	5.50	15.06	15.35	1.96	2.03
	K chloride	18.33	18.00	5.16	5.16	14.62	14.73	1.65	1.84
	K citrate	18.66	19.00	5.16	5.16	14.90	15.02	1.90	1.96
Fulvic acid A(4g/fed.)	K Sulphate	18.00	18.33	5.16	5.16	14.56	14.49	1.98	2.11
	K Silicate	23.00	22.66	6.00	5.83	16.95	17.08	3.45	3.45
	K chloride	20.33	20.33	5.33	5.16	15.09	15.73	2.66	2.77
	K citrate	20.66	21.33	5.66	5.50	16.02	16.03	2.86	2.96
Fulvic acid FA(5 g/l)	K Sulphate	17.66	18.33	5.16	5.16	14.13	14.13	1.90	1.90
	K Silicate	21.66	21.33	5.50	5.66	16.00	16.18	3.16	3.03
	K chloride	19.33	20.00	5.16	5.16	15.13	15.04	2.32	2.50
	K citrate	20.33	20.33	5.33	5.50	15.66	15.96	2.88	2.81
LSD at 0.05 level		0.94	1.03	1.03	0.42	0.55	0.29	0.064	0.12

SA=Soil application , FA= foliar application

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تأثير طرق اضافة حمض الفولفيك والرش بمصادر البوتاسيوم على انتاجية وجوده محصول البطاطس

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اجريت تجربتان حقليتان خلال موسمى شتاء ٢٠١٥/٢٠١٦ ، ٢٠١٦/٢٠١٧ بمزرعة خضر خاصة بقرية ميت فارس – دكرنس – محافظة الدقهلية وذلك لدراسة تأثير طرق اضافة حمض الفولفيك (بدون، ٤ كجم/فدان اضافة أرضية، الرش بمعدل ٥ جم/لتر) وبعض مصادر البوتاسيوم (سلفات البوتاسيوم، سليكات البوتاسيوم، كلوريد البوتاسيوم، سترات البوتاسيوم) بمعدل ١% اوكسيد بوتاسيوم عن طريق الرش والتفاعل بينهم على النمو، المحصول وجوده الدرنات للبطاطس تحت ظروف الارض الطينية واستحدام الرى بالغمر. وقد أوضحت النتائج أن التفاعل بين معاملة نباتات البطاطس بحمض الفولفيك بمعدل ٤ كجم/ فدان اضافة أرضية والرش بسليكات البوتاسيوم قد سجلت أعلى القيم لكل من ارتفاع النبات، عدد الاوراق/ نبات، الوزن الجاف للعرش/محتوى العرش من النيتروجين والفوسفور والبوتاسيوم والممتص منهم بواسطة العرش بعد ٧٠ يوم من الزراعة، عدد الدرنات/ نبات، محصول النبات، المحصول الكلى للفدان، النسبه المئويه لمحتوى الدرنات من المادة الجافة والمواد الصلبة الذائبة والنشا وكذلك من البوتاسيوم عند الحصاد، يليها معامله التفاعل بين الرش بحمض الفولفيك بمعدل ٥ جم/لتر والرش بسليكات البوتاسيوم فى كلا الموسمين. بنينما كانت أقل القيم للصفات السابقة قد لوحظت مع معاملة التفاعل بين بدون حمض فولفيك ورش النباتات بسلفات البوتاسيوم فقط فى كلا الموسمين.

وفى هذا الخصوص كانت الزيادة فى المحصول الكلى قد تراوحت بين ٣٨.٩٠ ، ٤٥.١٤% بالسبة لمعاملة التفاعل بين معاملة التفاعل بين اضافة حمض الفولفيك بمعدل ٤ كجم/ فدان كاضافة أرضية والرش بسليكات البوتاسيوم، يليها ٣٢.٦٦، ٣٦.٦٦ % بالنسبة لمعاملة التفاعل بين معاملة نباتات البطاطس بحمض الفولفيك بمعدل ٤ كجم/ فدان كإضافة ارضيه والرش بسترات البوتاسيوم، ٣١.٩٥ ، ٣٦.٦٧% بالنسبة لمعاملة التفاعل بين معاملة رش نباتات البطاطس بحمض الفولفيك بمعدل ٥ جم/ لتر والرش بسليكات البوتاسيوم بالمقارنة بالنباتات التى تم رشها بسلفات البوتاسيوم فقط خلال الموسم الاول والثانى على التوالى.