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EFFECT OF POTASSIUM FERTILIZATION AND HUMIC ACID APPLICATION ON PLANT GROWTH AND PRODUCTIVITY OF POTATO PLANTS UNDER CLAY SOIL

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ABSTRACT

This experiment was carried out during the two successive summer seasons of 2008 and 2009 at Private Farm in El-Mahala El-Kobra region Ghrabia Governorate, on potato plant cv. Diamant to study the effect of potassium rates (0,50 and 100 kg K_2O/fed) and humic acid as soil application (0, 2 and 4 kg/fed. as humate potassium) as well as their interactions on growth, nutrition status and productivity of potato under clay soil.

Application of 100 kg K_2O/fed. was the superior treatment for enhancing dry weight of straw and tubers, percentage of N,P and k and total uptake by plant as well as total yield/fed.

Treated of potato plants with humic acid at 4 kg/fed. gave the maximum values of plant growth and plant nutritional statues as well as yield and its components with significant differences with 2 kg / fed. with respect to N,P and K (%) and yield and its components.

The best interaction treatment for increasing yield and its components was obtained by fertilization of potato plants with 100 kg K_2O / fed. and treated of plants with 2 kg /fed. humic acid.

Keywords: Potato, potassium, humic acid and yield and its components

INTRODUCTION

Nowadays potato (*Solanum tuberosum* L.) is a more important throughout the world between field crops. As potato is such a potassium demanding crop, it is particularly important that the potassium fertilizers used should be correctly balanced. Applying the adequate quantity of balanced K-fertilizer is the first requirement for achieving optimum yield and doing so will result in potatoes of acceptable quality (Márton László , 2010). Potato is a soil nutrients demanding crop and has a particularly high requirement for potassium. Tubers remove 1.5 times more potassium than nitrogen and 4 or 5 times the amount of phosphate. The quantity of nutrients taken up by a crop is not necessarily an indication of responsiveness to fertilizers but potato, because its root system is relativly poorly developed in relation to yield is extremely responsive to all nutrients (Márton 1984). As potato is such a demanding crop, it is particularly important that the potassium fertilizers used should be correctly balanced (Burton, 1948). Applying the adequate quantity of balanced K- fertilizer is the first requirement for achieving optimum yield and doing so will result in potatoes of acceptable quality (Márton 2000).

Many researchers recorded an increase of potato tubers yield as a result of increasing the levels of potassium (K) fertilization (El-Gamal, 1985 and Humadi 1986]. Such increases in yield of potato tubers was either due to the formation of large size tubers or increasing of the number of tubers per plant . In addition application of potassium 96 kg K_2O / fed. achieved the highest significant values of dry matter, content of N and K as well as N content in tuber. Whereas, the high values of tuber yield, protein content were obtained when 120 kg K_2O/fed. (Al-Esaily *et al.*, 2011 on sweet potato , Mahmoud and Hafez ,2010 and Abd El-Latif *et al.*, 2011 on potato).

Application of humic acids (HA) has several benefits and agriculturists all over the world are accepting humic acids as an integral part of their fertilizer program. It can be applied directly to the plant foliage in liquid form or to the soil in the form of granules alone or as fertilizer mix. Humic acid is one of the major components of humus. Humates are natural organic substances, high in humic acid and containing most of known trace minerals necessary to the development of plant life (Senn, 1991). Humic substances are an important soil component because they constitute a stable fraction of carbon and improve water holding capacity, pH buffering and thermal insulation (McDonnell *et al.*, 2001). Studies of the positive effects of humic substances on plant growth have demonstrated the importance of optimum mineral supply, independent of nutrition (Yildirim, 2007).

Humic acid increased dry weight/ plant , total yield , N,P and K contents and uptake in tubers of potato (Ezzat *et al.*, 2009 ; Mahmoud and Hafez, 2010 and El-Hefny (2010) on cowpea) with respect the effect of humic acid as soil application . Foliar spray with HA significantly increased dry weight/ plant and green pod yield of snap bean (Kaya *et al.*, 2005 ; Abou El-Khair *et al.*, 2010 on garlic El-Bassiony *et al.*, 2010) on snap bean..

Thus, this study was planned to determine the effect of potassium fertilization and humic acid , to obtain high quantity and quality of potato under the conditions of Gharbia District.

MATERIALS AND METHODS

This experiment was carried out during the two successive summer seasons of 2008 and 2009 at a Private farm in El-Mahala El-Kobra region Ghrabia Governorate, on potato plant cv. Diamant to study the effect of potassium rates and humic acid as well as their interactions on growth, nutrition status and productivity of potato under clay soil.

The physical and chemical properties of the used experimental soil in the two seasons showed in Table (1).

The experiment included 9 treatments, which were the combinations between three potassium rates (0, 50 and 100 kg K_2O/fed.) and three rates of humic acid (0, 2 and 4 kg/ fed. as humate potassium 20 % humic acid). These treatments were arranged in a split plot design with three replicates. Potassium rates were randomly arranged in the main plots and the humic acid rates were randomly distributed in the sub plots. Tuber seeds were sown at 25 cm apart on January 2^{th} and 4^{th} during the 1^{st} and 2^{nd} seasons, respectively. The experimental unit area was 12.6 m^2. It contains three rows with 6m length each and 70 cm distance between the two rows. One row was used to measure the dry weight of different organs/ plant and plant chemical analysis and the other two rows were used for yield determinations.

Potassium sulphate (48% K_2O) was used as a source of potassium. The amount of potassium fertilizer was divided into two equal portions applied at preparing the soil to planting, then 45 days after sowing. However, the amounts of humic acid was mixed by sand and then, applied to the root absorption zone of plants, 20 days after planting, just before irrigation .

All treatments received 30 m^3/FYM , 120 kg N and 80 kg P_2O_5 as ammonium sulfate (20.6 % N) and calcium super phosphate (15.5 % P_2O_5) respectively. One third of N and all P_2O_5 were added during soil preparation with FYM. The rest of N (two thirds) were added at three portions as soil application at 15 days interval beginning one month after planting. The normal agricultural practices were carried out as commonly followed in the district of this investigation.

Table 1: The physical and chemical properties of the experimental soil before growing seasons.

Physical and chemical properties	2009 season	2010 season
Sand%	6.85	6.70
Silt%	28.15	26.23
Clay%	65.00	67.07
Texture	Clay	Clay
pH	7.87	7.92
EC** dS m^{-1}	1.48	1.69
$CaCO_3$%	2.53	274
OM%	2.01	2.25
Nitrogen (N)	60.55	61.86
Phosphorus (P)	17.80	18.50
Potassium (K)	290.2	307.8

Data recorded:

Plant growth: A random samples of three plants from each plot were taken at harvest to determined dry weight of straw and tubers as well as whole plant.

4. **Percentages and Uptake of N, P and K in straw and tubers at harvest**: Total Dried represented samples of straw and tubers of the all tested treatments in both seasons were finely ground and wet digested. Then, N, P and K contents were determined according to the methods described by Bremner and Mulvaney (1982), Olsen and Sommers (1982) and Jackson (1970), respectively. The uptake of minerals and total plant uptake were calculated
5. **Yield and its components:** It included, tuber yield per plant (kg) and total yield (ton/ *fed*) .

Statistical Analysis: Collected data were subjected to statistical analysis of variance according to Snedecor and Cochran (1980), and means separation was done using L.S.D. at 5 % level of probability.

RESULTS AND DISCUSSION

1. Plant growth

Effect of K_2O

Table 2 show that K_2O application markedly increased dry weight of different organs of potato plant in both seasons.

It can be noticed that dry weight of straw and tubers as well as whole plants increased with increasing K rates and the highest mean values were recorded at the rates of 100 kg K_2O fed. (129, 51 and 131.54g for DW of straw) and (115.51 and 117.34g for DW of tubers / plant) and 261.5 and 248.88 g for total dry weight/ plant in the 1st and 2nd seasons , respectively). Evans and Wildes (1971) reported that K involved in a number of steps in protein synthesis. The increase in dry weight of straw and tubers due to mineral fertilization might be referred to the favorable effect of N, P and K on the meristematic activity of plant tissues. Gardener *et al.,* (1985) and Mengel and Kirkby (1987) reported that potassium was found to serve a vital role in photosynthesis by direct increasing in growth and leaf area index and hence CO_2 assimilation and increasing the outward translocation of photosynthates,

These results agree with those reported with Al-Esaily *et al.*(2011) on sweet potato, Mahmoud and Hafez (2010) and Abd El-Latif *et al.* (2011) on potato.

Table (2): Effect of potassium rate and humic acid soil application on dry weight of different parts of potato plants during 2008 and 2009 seasons under clay soil

Characters / Treatments	Dry weight (g/organ)					
	Straw		Tuber		Total	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
	Effect of potassium rate (kg/fed.)					
0	91.38	93.96	90.71	90.52	١٨٢.٠٩	١٨٤.٤٨
50	114.14	118.20	100.81	105.60	٢١٤.٩٥	٢٢٣.٨٠
100	129.51	131.54	115.51	117.34	٢٤٥.٠٢	٢٤٨.٨٨
LSD at 0.5 level	**2.55**	**2.90**	**2.15**	**0.74**	**3.21**	**2.51**
	Effect of humic acid (kg/fed.)					
0	99.65	101.70	97.72	95.29	١٩٧.٣٧	١٩٦.٩٩
2	113.27	116.06	103.78	106.25	٢٢٧.٠٥	٢٢٢.٣١
4	122.12	125.94	105.53	111.92	٢٢٧.٦٥	٢٣٧.٨٠
LSD at 0.5 level	**1.87**	**1.47**	**2.49**	**9.94**	**3.59**	**4.10**

Effect of humic acid

The same data in Table 2 indicate that the plant growth parameters of potato plants were significantly response to humic acid application. Results show that plant growth parameters (dry weight of straw and tubers) were significantly increased with increasing the level of humic acid soil application from 0 up to 4 kg humic acid/fed. (122.12 and 125.94 g for DW of straw) 105.53 and 111.92 g for DW of tuber, 248.07 and 237.86 g for total dry weight/ plant in the 1st and 2nd seasons, respectively. This result was true in both growing seasons. Humic substances are mostly used to remove or decrease the negative effects of chemical fertilizers from the soil and have a major effect on plant growth, as shown by many scientists (Ghabbour and Davies, 2001). also humic acid stimulate plant growth by the assimilation of major and minor elements, enzyme activation and/or inhibition, changes in membrane permeability, protein synthesis and finally the activation of biomass production (Ulukan, 2008).

These results are in line with obtained with Ezzat *et al.*, 2009 on potato and Abou El-Khair *et al.*, 2010 on garlic.

Effect of the interaction between K_2O and humic acid

Data in Table 3 show the effect of the interaction treatments between K_2O and humic acid rates on the plant growth of potato plants. Results clear that plant growth parameters were significantly affected by the interaction treatments, in the two growing seasons. Results also indicate that the highest values of both dry weight of straw, tubers and total dry weight/ plant were recorded with application of the highest rates of K_2O (100 kg /fed.) with 4 kg humic acid/fed. as soil application. However, the lowest values were recorded with 0 K_2O x 0 humic acid. These results were true in both growing seasons.

Table (3): Effect of interaction between potassium rate and humic acid soil application on dry weight of different parts of potato plants during 2008 and 2009 seasons under clay soil

Characters / Treatments		Dry weight (g/organ)					
		Straw		Tuber		Total	
K_2O rate (kg/fed.)	Humic acid (kg/fed.)	1st season	2nd season	1st season	2nd season	1st season	2nd season
0	0	71.05	72.95	84.97	81.51	١٥٦.٠٢	١٥٤.٤٦
	2	94.93	97.06	92. 17	93.35	١٨٧.١٠	١٩٠.٤١
	4	108.17	111.88	94.98	96.71	٢٠٣.١٥	٢٠٨.٥٩
50	0	106.83	109.21	98.73	100.41	٢٠٥.٥٦	٢٠٩.٦٢
	2	115.93	119.83	103.00	105.63	٢١٨.٩٣	٢٢٥.٤٦
	4	119.67	125.55	100.70	110.75	٢٢٠.٣٧	٢٣٦.٣٠
100	0	121.07	122.93	109.47	103.95	٢٣٠.٥٤	٢٢٦.٨٨
	2	128.93	131.30	116.17	119.76	٢٤٥.١٠	٢٥١.٠٦
	4	138.53	140.40	120.90	128.30	٢٥٩.٤٣	٢٦٨.٧٠
LSD at 0.5 level		3.26	2.55	4.31	17.22	6.22	7.11

2. Contents and uptake of N, P and K

Effect of K_2O

Data in Tables (4 and 5) show the effect of K_2O fertilization had significant effect on N,P and K contents and uptake in straw and tubers in both seasons .

The maximum N, P and K contents and uptake in straw and tubers significantly increased with increasing K_2O rates up to the high rate (100 kg/fed.) in both season .

Table (4): Effect of potassium rate and humic acid soil application on mineral content (%) of different parts of potato plants during 2008 and 2009 seasons under clay soil

Characters / Treatments (kg/fed.)	Straw						Tuber					
	N		P		K		N		P		K	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
	Effect of potassium rate (kg/fed.)											
0	2.93	2.98	0.378	0.378	2.67	2.64	2.15	1.81	0.320	0.314	1.22	1.15
50	3.28	3.51	0.404	0.399	2.87	2.92	2.46	2.13	0.371	0.336	1.28	1.23
100	4.02	4.02	0.442	0.476	2.98	3.03	2.62	2.36	0.400	0.438	1.35	1.30
LSD at 0.5 level	0.09	0.06	0.014	0.009	0.05	0.05	0.10	0.16	0.025	0.018	0.06	0.02
	Effect of humic acid (kg/fed.)											
0	3.11	3.14	0.377	0.388	2.69	2.71	2.18	1.92	0.316	0.330	1.25	1.17
2	3.55	3.61	0.401	0.412	2.89	2.92	2.44	2.16	0.368	0.364	1.28	1.24
4	3.58	3.77	0.446	0.452	2.93	2.97	2.61	2.22	0.408	0.393	1.32	1.28
LSD at 0.5 level	0.06	0.03	0.011	0.012	0.03	0.03	0.06	0.06	0.027	0.030	0.04	0.03

Table (5): Effect of potassium rate and humic acid soil application on N,P and K uptake by different parts of potato plants during 2008 and 2009 seasons under clay soil

Characters / Treatments (kg/fed.)	Straw						Tuber					
	N		P		K		N		P		K	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
	Effect of potassium rate (kg/fed.)											
0	2717.3	2848.0	351.6	361.9	2473.4	2513.5	1966.6	1658.5	291.7	287.6	1107.2	1050.1
50	3751.4	4150.7	461.7	472.8	3274.2	3456.8	2478.5	2249.9	374.3	354.9	1289.4	1300.8
100	5227.8	5319.1	573.5	626.6	3858.8	3988.8	3035.7	2773.8	463.7	515.6	1562.9	1533.3
LSD at 0.5 level	131.4	158.5	22.0	20.0	111.4	131.8	155.7	158.6	27.0	17.7	66.9	18.8
	Effect of humic acid (kg/fed.)											
0	3184.9	3272.9	383.1	404.8	2735.4	2808.2	2171.0	1866.7	311.2	320.2	1228.4	1125.2
2	4084.1	4244.2	458.8	483.8	3281.1	3399.3	2547.3	2310.4	384.8	392.6	1336.6	1319.5
4	4427.6	4800.7	544.9	572.6	3589.9	3751.5	2762.4	2505.0	433.6	445.3	1394.6	1439.6
LSD at 0.5 level	91.3	60.1	11.4	18.3	52.5	61.9	116.7	68.0	25.1	35.8	55.1	42.1

Table (6): Effect of interaction between potassium rate and humic acid soil application on mineral content (%) of different parts of potato plants during 2008 and 2009 seasons under clay soil

Treatments	Characters	Straw						Tuber					
		N		P		K		N		P		K	
K_2O rate (kg/fed.)	Humic acid (kg/fed.)	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
0	0	2.55	2.58	0.33	0.327	2.32	2.32	1.65	1.40	0.267	0.257	1.18	1.03
	2	3.05	3.13	0.367	0.373	2.82	2.80	2.25	2.00	0.33	0.313	1.22	1.18
	4	3.18	3.23	0.437	0.433	2.87	2.80	2.55	2.03	0.363	0.373	1.26	1.26
50	0	3.17	3.40	0.377	0.38	2.82	2.88	2.38	2.08	0.34	0.317	1.25	1.21
	2	3.40	3.47	0.387	0.387	2.87	2.90	2.41	2.09	0.357	0.347	1.27	1.23
	4	3.28	3.65	0.447	0.43	2.92	2.98	2.58	2.21	0.417	0.344	1.31	1.25
100	0	3.60	3.43	0.423	0.457	2.93	2.92	2.52	2.28	0.34	0.417	1.32	1.27
	2	4.20	4.22	0.450	0.477	2.98	3.05	2.66	2.38	0.417	0.433	1.36	1.30
	4	4.27	4.42	0.453	0.493	3.02	3.12	2.70	2.42	0.443	0.463	1.38	1.34
LSD at 0.5 level		0.10	0.06	0.020	0.021	0.07	0.06	0.16	0.11	0.047	0.053	0.07	0.06

Table (7): Effect of interaction between potassium rate and humic acid soil application on N,P and K uptake by different parts of potato plants during 2008 and 2009 seasons under clay soil

Treatments	Characters	Straw						Tuber					
		N		P		K		N		P		K	
K_2O rate (kg/fed.)	Humic acid (kg/fed.)	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
0	0	1813.5	1884.8	234.6	238.3	1646.3	1689.7	1404.7	1141.6	226.1	209.3	1000.0	836.9
	2	2895.1	3041.5	348.1	362.4	2673.4	2718.0	2073.7	1866.7	304.0	292.5	1121.4	1098.5
	4	3443.4	3617.8	472.3	485.0	3100.7	3132.7	2421.5	1967.3	345.1	361.2	1200.3	1215.2
50	0	3383.3	3713.8	402.4	414.9	3008.8	3149.2	2352.7	2091.9	335.8	318.1	1237.0	1215.2
	2	3942.0	4154.8	448.3	463.3	3323.5	3475.2	2481.0	2210.7	367.4	366.3	1312.1	1302.9
	4	3929.0	4583.5	534.5	540.2	3490.3	3746.0	2601.8	2447.4	419.7	380.5	1319.1	1384.5
100	0	4358.0	4220.2	512.4	561.4	3551.1	3585.9	2755.8	2366.8	371.9	433.3	1448.2	1323.7
	2	5415.2	5536.4	580.2	625.9	3846.6	4004.7	3087.4	2854.0	483.2	519.1	1576.3	1557.1
	4	5910.4	6200.9	628.0	692.7	4178.9	4375.9	3263.9	3100.6	536.0	594.4	1664.4	1719.2
LSD at 0.5 level		158.1	104.1	19.8	31.7	90.9	107.2	202.2	117.8	43.4	62.1	95.5	72.9

The increment in the percentage of N,P and K in the straw due to increasing of K application rate can be explained on the basis of increasing the availability of nutrients in the soil. In addition, the increment of the concentration of N,P and K in straw in responses to the high rate of potassium may be due to the high mobility of K nutrient in the plant (Marschner, , 1995).

Effect of humic acid

The same data in Tables 4 and 5 show that application of humic acid at different rates reflected a significant effect on N, P and K (%) and their uptake by straw and tubers at harvesting time during the two tested seasons. Treated of potato plants with humic acid at the rate of 4 kg/fed was the best treatment for enhancing N P and K percentages and their uptake by straw and tubers .

Humic acid has a number of potential benefits for plants: increased nutrient, increased reserve of slow release nutrients; enhanced solubility of phosphorus, zinc, iron, manganese, and copper, improved soil aggregation, enlarged root system and then increased the uptake of these elements by plant (Mikkelsen, 2005).

In this respect Randhawa and Broadbent (1965) reported that HA produces ligands capable of complexing nutrient elements and the complexed elements remain more available to plant roots as complexation shields them against immobilisation in soil

Effect of the interaction between K_2O and humic acid

Interaction treatments between potassium fertilization and humic acid (Tables 6 and 7) reveal that K_2O at 100 kg/fed. interacted with 4 kg/ fed. humic acid gave the highest values of N, P and K (%) and their uptake in different plant organs (straw and tubers) without significant differences with the interaction treatment of 100 kg K_2O/ fed. and humic acid at 2kg/fed. in most cases with respect to N,P and K in the both seasons.

3. N,P and K total uptake

Effect of K_2O

Data in Table (8) reported that N,P and K total uptake by plant was significantly influenced by potassium application in the two seasons. The heaviest N,P and K total uptake was obtained with 100 kg/fed. K_2O in both seasons.

Effect of humic acid

The same results in Table (8) indicate that, humic acid application had a significant effect on N,P and K total uptake by plant in both seasons.

The maximum values of N,P and K total uptake were obtained by treated of potato plants with 4 kg/ fed. humic acid in both seasons. The release of fixed K by humic acid (Tan, 1978) may explain its increased availability.

Russo and Berlyn (1990) reported that, humates (granular and liquid forms) can reduce plant stress that involved plant diseases as well as enhance plant nutrient uptake. Also humic substances lead to a greater uptake of nutrients into the plant root and through the cell membrane (Yildirim, 2007).

These results are in harmony with those reported with Abou El-Khair *et al.* (2010) on garlic and Mahmoud and Hafez, (2010)

Table (8): Effect of potassium rate and humic acid soil application on N,P and K uptake and total uptake by potato plants during 2008 and 2009 seasons under clay soil

Treatments \ Characters	Total uptake					
	N		P		K	
	1st	2nd	1st	2nd	1st	2nd
(kg/fed.)	Effect of potassium rate (kg/fed.)					
0	4684.0	4506.5	643.4	649.5	3580.7	3563.6
50	6230.0	6400.6	836.0	827.7	4563.6	4757.6
100	8263.6	8092.9	1037.2	1142.2	5421.8	5522.1
LSD at 0.5 level	**228.94**	**243.7**	**34.1**	**24.1**	**99.1**	**139.1**
	Effect of humic acid (kg/fed.)					
0	5356.1	5139.6	694.4	725.1	3963.8	3933.5
2	6631.5	6554.7	843.7	876.4	4617.7	4718.8
4	7190.0	7305.8	978.5	1017.9	4984.6	5191.1
LSD at 0.5 level	**119.6**	**62.9**	**25.8**	**44.3**	**66.5**	**70.3**

Effect of the interaction between K_2O and humic acid

Presented data in Table 9 show that the effect of interaction between K_2O rate and humic acid application on N,P and K total uptake by potato plant in both season. The interaction treatments reflected a significant effect on N,P and K total uptake by plant in both seasons.

The superior interaction treatment for increasing N,P and K total uptake by potato plants was obtained by fertilization of plants with 100 kg K_2O/fed and treated of potato plants with 4 kg/ fed. humic acid in both seasons.

Table (9): Effect of potassium rate and humic acid soil application on N,P and K uptake and total uptake by potato plants during 2008 and 2009 seasons under clay soil

Treatments \ Characters		Total uptake					
		N		P		K	
K_2O rate (kg/fed.)	Humic acid (kg/fed.)	1st	2nd	1st	2nd	1st	2nd
0	0	3218.3	3026.4	460.7	447.6	2646.3	2526.6
	2	4968.9	4908.2	652.1	654.9	3794.8	3816.5
	4	5864.9	5585.1	817.4	846.2	4301	4347.9
50	0	5736.1	5805.7	738.2	733.0	4245.8	4364.4
	2	6423.1	6365.5	815.7	829.6	4635.6	4778.1
	4	6530.8	7030.9	954.2	920.7	4809.5	5130.5
100	0	7113.9	6587.0	884.3	994.7	4999.3	4909.6
	2	8502.6	8390.4	1063.5	1145.0	5422.8	5561.8
	4	9174.3	9301.5	1164.0	1287.1	5843.3	6095.1
LSD at 0.5 level		**207.19**	**109.0**	**44.73**	**76.77**	**115.13**	**121.88**

4.Yield Components

Effect of K_2O

Table 10 reveal that K_2O fertilization of potato had significant effect on yield / plant and total yield /fed. in both seasons.

It is clear that K_2O application had a general marked positive trend for yield/ plant and total yield/feddan. In addition application of 100 kg /fed. K_2O gave the highest values of both yield/ plant and total yield/fed (0.466 and 0.461 g/ plant) and 11.105 and 10.565 ton/fed. in the 1^{st} and 2^{nd} seasons, respectively. The increase in total yield/ fed. was about 27.0 and 21.5 % for K_2O at 100 kg/ fed. over the control treatment (without K_2O) in the 1^{st} and 2^{nd} seasons, respectively.

Potato insufficient K can result in reduced yields and smaller-sized tubers (Tindall and Westermann, 1994). The increasing tuber yield of plants due to increasing potassium application rate can be attributed as reported by Marschner (1995) to the crucial role of potassium in the energy status of the plant, translocation and storage of assimilates and maintenance of tissue water relations.

Similar results were reported by Abd El-Baky *et al.* (2010) on and Abou El-Khair *et al.*, (2011) on sweet potato , Mahmoud and Hafez (2010.) and Abd El-Latif *et al.* (2011) on potato.

Table (10): Effect of potassium rate and humic acid soil application on yield and its components of potato plants during 2008 and 2009 seasons under clay soil

Characters / Treatments	Yield and its components					
	kg/ plant		Ton/fed.		Relative increases in total yield (%)	
	1^{st} season	2^{nd} season	1^{st} season	2^{nd} season	1^{st} season	2^{nd} season
(kg/fed.)	Effect of potassium rate (kg/fed.)					
0	0.386	0.385	8.746	8.698	100.0	100.0
50	0.414	0.415	10.493	9.965	120.0	114.6
100	0.461	0.466	11.105	10.565	127.0	121.5
LSD at 0.5 level	**0.043**	**0.034**	**0.129**	**0.209**	--	--
	Effect of humic acid (kg/fed.)					
0	0.388	0.393	9.750	9.370	100.0	100.0
2	0.417	0.422	10.230	9.991	104.9	106.6
4	0.457	0.452	10.364	9.868	106.3	105.3
LSD at 0.5 level	**0.050**	**0.039**	**0.154**	**0.144**	---	--

Effect of humic acid

Presented data in Table 10 show that the application of humic acid as soil application reflected a significant effect on yield/ plant and total yield /fed. in both seasons .

The same data in Table 10 that application of humic acid at 4 kg/fed recorded the maximum values of yield/ plant and total yield /fed. (0.457 and 0.452 kg/ plant and 10.364 and 9.868 ton/fed. in the 1^{st} and 2^{nd} seasons, respectively) without significant differences with 2 kg/fed in both season. The increase in total yield/ fed. was about 6.3 and 5.3 % for application of humic acid at 4kg /fed.. over the control treatment (without humic acid) in the 1[st] and 2[nd] seasons, respectively.

Humic materials increase the permeability plant membranes, promote the uptake of nutrients, and stimulate plant growth (higher biomass production) by accelerating net photosynthesis, consequently tuber development (Zhang *et al.*, 2003).

Results are in harmony with Seyedbagheri and Torell, 2001, Ezzat *et al.*, 2009, Mahmoud and Hafez, 2010 on potato and El-Hefny, 2010 on cowpea.

Effect of the interaction between K_2O and humic acid

Data in Table 11 show that the interaction between K_2O fertilization and application of humic acid reflected a significant effect on yield/ plant and total yield /fed. in both season of potato plants.

Application of K_2O at the highest rate 100 kg/ fed and combined with 2 kg/fed. humic acid was the superior interaction treatment for increasing yield/ plant and total yield / fed., in addition, this treatment recorded 11.370 and 11.008 ton/fed. in the 1[st] and 2[nd] seasons, respectively.

The increase in total yield/ fed. was about 35.9 and 29.5 % for application of 100 kg K_2O/ fed. and combined with 2kg /fed. humic acid over the control treatment (0 K_2O +0 humic acid) in the 1[st] and 2[nd] seasons, respectively.

Finally, it could be concluded that, the best interaction treatment for increasing yield and its components was obtained by fertilization of potato plants with 100 kg K_2O / fed. and treated of plants with 2 kg /fed. humic acid.

Table (11): Effect of interaction between potassium rate and humic acid soil application on yield and its components of potato plants during 2008 and 2009 seasons under clay soil

Treatments	Characters	Yield and its components					
		kg/ plant		Ton/fed.		Relative increases in total yield (%)	
K_2O rate (kg/fed.)	Humic acid (kg/fed.)	1[st] season	2[nd] season	1[st] season	2[nd] season	1[st] season	2[nd] season
0	0	0.337	0.334	8.369	8.503	100.0	100.0
	2	0.390	0.392	8.768	8.78	104.8	103.3
	4	0.432	0.429	9.102	8.81	108.8	103.6
50	0	0.398	0.401	9.958	9.303	119.0	109.4
	2	0.406	0.417	10.553	10.185	126.1	119.8
	4	0.439	0.428	10.967	10.408	131.0	122.4
100	0	0.429	0.443	10.922	10.303	130.5	121.2
	2	0.454	0.456	11.37	11.008	135.9	129.5
	4	0.499	0.499	11.023	10.385	131.7	122.1
LSD at 0.5 level		**0.087**	**0.069**	**0.272**	**0.255**	–	—

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تأثير التسميد البوتاسى وحمض الهيومك على النمو والإنتاجية للبطاطس تحت ظـروف الاراضى الطينية

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أجريت تجربتان حقليتان فى الموسم الصيفي لعامى ٢٠٠٨ – ٢٠٠٩ فى مزرعة خاصة بالمحلة الكبرى – محافظة الغربية على الصنف دايمونت وذلك لدراسة تأثير التسميد البوتاسى بمعدل ٠ ، ٥٠ ، ١٠٠ كجم بو٢أ / ف وحمض الهيوميك بمعدل ٠ ، ٢ ، ٤ كجم حمض هيوميك إضافة أرضية والتفاعل بينهما وذلك على النمو ومحتوى كل من العرش والدرنات من النتروجين والفوسفور والبوتاسيوم وكذلك الإنتاجية تحت ظروف الأرض الطينية

وأوضحت النتائج ما يلى :-

- إضافة معدل ١٠٠ كجم بو ٢أ للفدان هي المعاملة المتفوقة على باقي المعاملات وذلك على كل من الوزن الجاف للعرش والدرنات ومحتوى الدرنات والعرش من كل من النيتروجين والفوسفور والبوتاسيوم وكذلك المحصول للنبات والفدان .
- أدت معاملة النباتات بمعدل ٤ كيلو جرام حمض الهيوميك الى الحصول على أعلى قيم من كل من النمو والمحتوى من النيتروجين والفوسفور والبوتاسيوم ومحصول النبات والفدان عن باقي المعاملات.
- أدى التفاعل بين البوتاسيوم بمعدل ١٠٠كجم للفدان وحمض الهيوميك بمعدل ٢ كجم / ف الى الحصول على أعلى قيم للنمو وكذلك محصول النبات والفدان مقارنة بباقي المعاملات .
- وبذلك يمكن التوصية باضافة ١٠٠ كجم بو ٢ أ بالاضافة الى ٢ كجم حمض هيوميك وذلك للحصول على أعلى محصول جيد تحت ظروف الأرض الطينية .

قام بتحكيم البحث

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