Effect of Potassium Bearing Rock on the Growth and Quality of Potato Crop (*Solanum tuberosum*)

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Abstract

The main target of this research work is to evaluate the possibility of substituting partly or totally the expensive potassium fertilizers by natural deposits of feldspars bearing rocks.
A field experiment was conducted to grow potatoes on poorly sandy soils. Four treatments were followed: control using K-sulfate only; ½ K-sulfate +½ K-feldspar; ¼ K-sulfate + ¾ K-feldspars and K-feldspars only (according to the crop requirements of this element). Management and fertilization requirement of NPK were followed for potato crop.
The total yield weight of vegetative plants as well as tubers could be arranged in the following order: 2nd treatment> 1st > 3rd > 4th. The K- content of the plants was significantly higher in the second treatment while the minor elements (Fe, Mn, Zn, and Cu) have no significant differences among the four treatments. High quality of potato tubers (morphological parameters) were observed in the fourth treatment in spite of the lower yield.
The addition of equal rates of K-feldspar and K-sulfate resulted in the highest content of starch, monosucrose, protein and both vitamin C and A of potatoes.
The advantages of applying K- bearing rock on poor fertility sandy soil can be related to their improvement of physical and chemical conditions particularly when combined with organic amendment. Also, the excessive application of relatively soluble chemical fertilizers has hazardous impact on environmental conditions since considerable proportions are usually lost through drainage and cause pollution of water channels. From economical point of view, the price of potassium sulfate fertilizer is about 7000 LE/ton while K- feldspar rock is about 600-800 LE/ton.

Key words: Potassium bearing rock, K-feldspar, potato crop, sandy soil.

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1- Introduction

There are many areas and ways to increase the yield and productivity of various crops and consequently the agricultural income in every region.

In Egypt, there is a great need to optimize the use of the natural resources to continue the development and sustainability of agriculture. The amendment of the required nutrients to each specific crop is one of the main factors to reach the optimum yield. The sources of plant nutrients are mainly from chemical or organic fertilizers to substitute the deficiency in the soils. The prices of chemical fertilizers are tremendously increasing nowadays which enhance the cost of production and put burden on the farmers and the national authorities who subsidize the prices of these chemical fertilizers.

For all these considerations attention has been directed to the use of natural deposits which exist in many localities with large amounts. Potassium is one of the essential elements which is required for many crops, vegetables and fruits, and added to the soil as potassium sulphate or potassium chloride. Potassium bearing minerals are mainly as K-feldspars mica and illite.

Many experiments and research works have been carried in various countries emphasizing the importance of applying the K-bearing rocks to substitute chemical fertilizers.

Manning (2010), stated, according to the current knowledge of alternative sources, that potassium is the seventh most abundant element in the earth's continental crust present in feldspars and much less commonly in feldspathoid minerals including nepheline and leucite. However, experimentally, nepheline dissolves 100 times more quickly than potassium feldspar. He added that, under conditions where soils are rapidly leached with low capacity toretain soluble nutrients, the use of potassium feldspar does give a yield response, although not greater than for conventional fertilizers.

Kleiv and Thornhill (2007), showed that high intensive dry grinding could be implemented to increase the release of potassium from K-feldspar containing minerals by more than an order of magnitude. When subjected to planetary milling, less than 10 minutes of milling was required to make the K-feldspar mineral more reactive than the intrinsically more soluble nepheline.

In a large area of savannah in Colombia, Scovino and Rowell (1988), used finely ground sanidine feldspar (< 100 mesh, largely sanidine, 7 % K) as fertilizers in a pasture experiment, they concluded that the feldspars may be valuable as a slow release fertilizer in low input agricultural system particularly on leached soils of low CEC.

Bakken et al. (2005), proved that a rock-based fertilizer containing biotite as its main K-bearing mineral and between 5 and 20% carbonate, will release K at a slower rate than soluble K fertilizer do. The results obtained by Girgis et al. (2008), showed that inoculcation with selected strains having a variable degrees of metabolic effectiveness led to partial degradation of minerals resulting in release of higher amounts of soluble K and P in the culture media compared to control.

In the same respect, Badr (2006), found that inoculation with SDB (silicate dissolving bacteria) into the composition mass appears to enhance the percentage of available K in the mature compost. Similarly the response of tomato plants was dramatically enhanced in sandy soil of low K content and its effect was higher than potassium sulfate.

Sugiyama and Ae (2006), found that potato showed severe K deficiency without K application and yielded poorly while wheat was not affected under similar conditions. Total K uptake by crops was much higher than exchangeable soil K, indicating that crops may have utilized insoluble forms of K in these soils.

Also, Priyono and Gilkes (2008), evaluated the effectiveness of intensively milled gneiss and potassium feldspars as K-fertilizers through a glasshouse experiment with ryegrass. They found that the application of K-silicate rock fertilizer (K-SRFs) will be most advantageous for amending K-deficient soils.

Recently, a comprehensive review is published by Manning (2010), on mineral sources of potassium for plant nutrition. He concluded that the present high cost of environmental potassium fertilizers justifies further investigation of potassium silicate minerals and their host rocks.

The target of this research work was to evaluate the possibility of substituting partly or totally of the expensive K. fertilizers by natural deposits feldspars bearing rocks. Experiment has been carried on potato crop and its content of major and minor elements as well as the quantity and quality of potato tubers.

2- Materials and Methods

A field experiment was conducted on the sandy soil of the Research and Production Station of the National Research Centre, El-Nubaria Region, Egypt, to grow potato under the following four treatments of full required K:

1- The first treatment: Potassium sulfate only (Control)

2- The second treatment: 1/2 Potassium sulfate + 1/2 K-feldspar

3- The third treatment: 1/4 Potassium sulfate + 3/4 K- feldspar

4- The fourth treatment: K-feldspar only

The experiment was carried out in triplicates and designed as Randomized Complete Blocks where, it formed of three blocks each one was composed of four plots. Each treatment was assigned at random to one plot in each block. The plot size was 10x4 m where the seeds were planted within the rows which had 50 cm width and 30 cm spacing in between.

Sponta cultivar of potatoes was selected where the seeds were planted at the rate of 400 kg/fed (ha = 2.38 feddan).

Organic compost as well as phosphate and nitrogen fertilizers were applied as recommended.

K-feldspar rock (total K of about 10%) was added (at a rate of 300kg/fed) and K-sulfate fertilizer was used (112kg/fed).

The soil was investigated to determine its main characteristics where:

Total soluble salts were determined in the saturated soil paste extract as dS/m at 25 °C according to Black et al, (1982), pH measured in in the saturated soil paste following Rhodes (1982), total carbonates were estimated as $CaCO_3$ % after Nelson (1982), total N, P and K contents of the soil were determined according to Black et al, 1982.

The morphological parameters (including: shoots, roots, number of branches and weight) of the potato plant were measured as well the yield and morphological parameters of the potato tubers.

The major (N, P and K) and minor elements (Fe, Mn, Zn and Cu) of the potato tubers were determined as well as their quality which includes; starch, sugars, proteins and vitamin A, according to AOAC, (2000).

3- Results and Discussion

The experiment was carried on virgin sandy soil, very poor in organic material and tend to alkalinity (pH 8.25), free of salts (EC 0.15-0.28 dS/m) and low $CaCO_3$ content (1.7-2.8%). The soil of the experiment was classified as Typic Quartzipsamments after USDA, (2010). Due to the soil low nutrient content (N: 38.8-48.6, P: 36.7-42.8 and K: 2.6-12.2 ppm) the necessity of fertilizers amendment was regarded.

3-1- The morphological parameters of potato plants which are recorded in table 1 indicated the variations among the four treatments. The total yield weight can be arranged in the following order: the second treatment > first > third > fourth, (Photos 1- 4).

Photo 1: Treatment

Photo 2: Treatment (2)

Photo 3: Treatment (3)

Photo 4: Treatment (4)

Table 1: The morphological parameters of potato plants

Treatments	Shoots (g)		Roots (g)		No. of branches	Weight / plant (g)	Total Weight (kg)
	Fresh	Dry	Fresh	Dry			
1-1	200	45	40	15	15	795	83.5
1-2	300	49	45	17	13	1115	80.5
1-3	215	46	20	9	16	980	82.9
Mean	**238.3**	**46.7**	**35**	**13.7**	**15**	**963**	**82.3**
2-1	295	48	35	13	17	630	86.5
2-2	335	57	25	10	16	1305	84.2
2-3	200	41	40	16	15	1300	87.1
Mean	**276.7**	**48.7**	**33.3**	**13**	**16**	**1078.3**	**85.9**
4-1	200	43	25	12	9	865	63.0
4-2	260	50	20	10	11	890	62.1
4-3	115	30	15	9	10	670	65.0
Mean	**191.7**	**41**	**20**	**10.3**	**10**	**808.3**	**63.68**

3-2- The major elements in the potato plants were estimated as percentage (Table 2) and it was found that the variations between treatments were limited; the high figures were noticed in the second treatment which received half of the potassium requirement as chemical fertilizer and half from K-feldspar rock. Regarding the minor elements (Mn, Zn and Cu), it can be stated that the type of K-fertilizer has no influence on the uptake by potato plants. Iron content has the highest value (379 ppm) on the first treatment with potassium sulfate only.

Table 2: The major and minor elements of potato plants

Treatments	Major elements (%)			Minor elements (ppm)			
	N	P	K	Fe	Mn	Zn	Cu
1-1	4.82	0.85	5.80	385	30	22	21
1-2	4.69	0.81	5.68	379	29	19	19
1-3	3.21	0.74	5.06	375	26	17	17
Mean	**4.24**	**0.80**	**5.49**	**379**	**28**	**20**	**20**
2-1	4.80	0.88	6.32	366	36	24	21
2-2	5.42	0.85	5.69	361	30	21	18
2-3	5.91	0.79	5.24	358	24	20	16
Mean	**5.11**	**0.84**	**5.75**	**362**	**30**	**22**	**18**
3-1	5.44	0.82	5.19	362	30	24	21
3-2	4.82	0.82	5.00	362	28	23	20
3-3	4.14	0.75	4.89	359	26	22	18
Mean	**4.80**	**0.80**	**5.03**	**361**	**28**	**23**	**20**
4-1	4.22	0.74	4.95	360	30	24	21
4-2	4.01	0.69	4.68	357	30	24	20
4-3	3.89	0.65	4.09	351	27	20	18
Mean	**4.04**	**0.69**	**4.57**	**356**	**29**	**23**	**19**

3-3- The main characteristics of potato tubers are recorded in table 3 and photo 5 a & b. It is clear that the second treatment gave the highest values of length and diameter of tubers, fresh and dry weight and moisture content. It is worthy to mention that addition of K-feldspar rock only in the fourth treatment had a positive effect on the quality of tubers due to its action as slow release fertilizer through the growth stages of potato plants.

Table 3: The main characteristics of potato tubers

Treatments	Length of tubers (cm)	Diameter of tubers (cm)	Fresh weight (g)	Dry weight (g)	Moisture (%)	Dry matter (%)
1-1	8.0	15.5	167	39.3	76.5	23.5
1-2	7.2	14.2	161	37.2	76.8	23.2
1-3	7.2	14.0	157	35.4	77.5	22.5
Mean	**7.4**	**14.6**	**162**	**37.0**	**76.9**	**23.1**
2-1	11.0	19.0	265	50.7	81.1	18.9
2-2	11.6	19.5	273	52.1	80.7	19.3
2-3	11.6	21.0	280	53.0	81.1	18.9
Mean	**11.4**	**19.8**	**273**	**52.0**	**81.0**	**19.0**
3-1	9.0	16.5	195	44.4	77.2	22.8
3-2	8.5	15.2	178	41.7	76.6	23.4
3-3	8.0	15.0	170	38.9	77.1	22.9
Mean	**8.5**	**15.0**	**181**	**42.0**	**77.0**	**23.0**
4-1	10.2	18.0	226	47.9	78.8	21.2
4-2	9.7	17.5	201	45.6	77.3	22.7
4-3	8.5	16.5	189	41.0	78.3	21.7
Mean	**9.5**	**17.3**	**205**	**45.0**	**78.0**	**22.0**

3-4- The results of the chemical constituents of potato tubers are recorded in table 4. It was observed that slight variation in the content of soluble solid material among the four treatments, while the starch and mono sucrose contents were the highest in the second treatment. With respect to proteins, it can be arranged as follows: 2^{nd} treatment> 4^{th} >3^{rd} >1^{st}. The obtained results proved that the chemical constituents of potato tubers were higher in the 4^{th} treatment (K-feldspar rock) than the 1^{st} one with potassium sulfate fertilization, particularly vitamin C.

3-5- The major elements (N, P, K) in the potato tubers (Table 5) have the same trend as the whole plant (Table 2) with slight fluctuation among the four treatments, since they received the same requirements of ammonium nitrate (400kg/fed), super phosphate 50kg/fed) and organic compost (1/2 m^3). The 2^{nd} treatment has given slightly higher values in Fe content while Mn, Zn and Cu have almost the same content. These results refer that the type of K-fertilization has no influence on major and minor elements on potato tubers.

Photo 5 (a): Morphology of potato tubers under different treatments

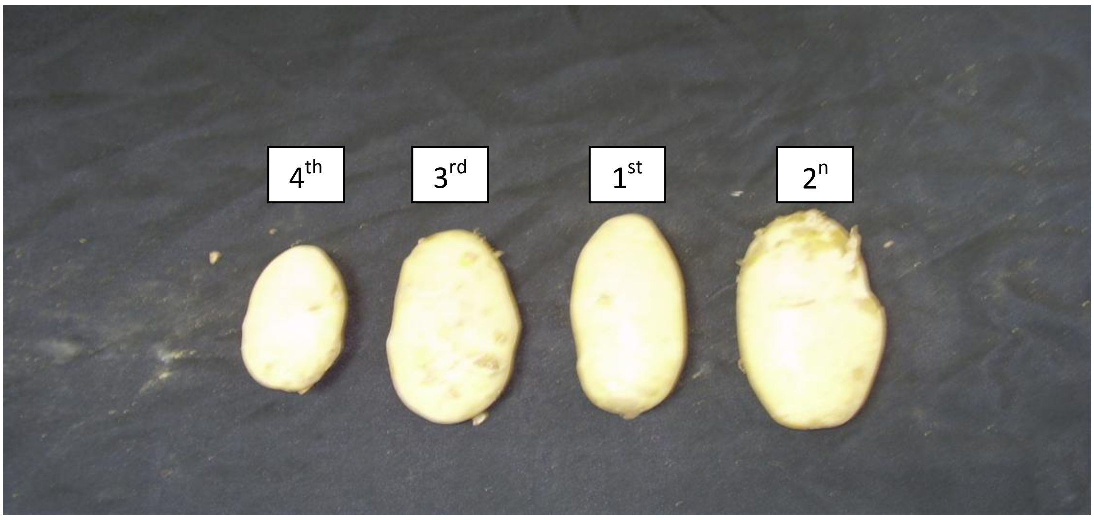

Photo 5 (b): Close up to the morphology of a potato tuber under different treatments

Table 4: The chemical constituents of potato tubers

Treatments	(%)				mg/100g fresh tissue	
	Soluble Solid material	Starch	Mono sucrose	Proteins	Vitamin A	Vitamin C
1-1	3.65	66.9	3.11	6.18	1.61	16.55
1-2	3.61	65.2	3.11	6.11	1.57	16.40
1-3	3.56	64.6	3.09	6.02	1.54	16.23
Mean	**3.61**	**65.0**	**3.10**	**6.20**	**1.57**	**16.39**
2-1	3.90	72.3	3.80	7.49	1.88	19.72
2-2	3.96	72.5	3.82	7.55	1.94	19.64
2-3	3.98	73.0	3.85	7.70	1.98	19.58
Mean	**3.95**	**72.6**	**3.80**	**7.60**	**1.93**	**16.65**
3-1	3.72	68.0	3.22	6.68	1.75	17.54
3-2	3.69	66.5	3.19	6.79	1.71	17.75
3-3	3.64	65.6	3.13	6.88	1.69	17.90
Mean	**3.70**	**66.7**	**3.18**	**6.78**	**1.72**	**17.73**
4-1	3.89	69.8	3.47	7.30	1.82	18.24
4-2	3.82	69.0	3.41	7.19	1.76	18.19
4-3	3.77	67.7	3.38	7.03	1.72	18.04
Mean	**3.83**	**68.8**	**3.42**	**7.17**	**1.77**	**18.16**

Table 5: The major and minor elements of potato tubers

Treatments	Major elements (%)			Minor elements (ppm)			
	N	P	K	Fe	Mn	Zn	Cu
1-1	5.14	0.66	5.51	354	21	15	12
1-2	5.01	0.59	5.49	350	20	15	12
1-3	4.92	0.54	511	346	15	15	12
Mean	**5.02**	**0.60**	**5.37**	**350**	**18**	**15**	**12**
2-1	5.32	0.68	5.64	362	20	15	13
2-2	5.27	0.65	5.60	360	20	15	12
2-3	4.79	0.59	5.09	357	20	15	13
Mean	**5.13**	**0.64**	**5.44**	**360**	**20**	**15**	**13**
3-1	5.21	0.63	5.62	359	20	15	12
3-2	4.90	0.62	5.54	354	20	15	12
3-3	4.85	0.55	4.89	354	20	15	11
Mean	**4.99**	**0.60**	**5.35**	**356**	**20**	**15**	**12**
4-1	5.25	0.64	5.59	356	20	15	12
4-2	5.22	0.59	5.20	351	20	15	12
4-3	4.78	0.55	4.80	349	19	15	11
Mean	**5.08**	**0.59**	**5.20**	**352**	**20**	**15**	**12**

3-6- Statistical analysis

The statistical analysis, after CoHort (1986), had been focused on three components, namely; the vegetative part, tuber and yield of potato, (Tables 6a-6h). The results showed that there were no significant differences of the nitrogen content of the vegetative part at 0.01 and 0.05 levels. However, phosphorus content had a significant difference between the fourth treatment and others at 0.05 level. Potassium content of the vegetative part, also had only significant differences at 0.05 level between the second and the fourth treatment, however both first and third treatments had no significant differences with previous ones.

As trace elements are concerned, there were no significant differences in Mn, Zn and Cu contents of the vegetative part. However, highly significant difference (0.01 level) was found between the first treatment and all others in the Fe content of the vegetative part. The tuber weight had highly significant difference (0.01 level) between the second treatment and all other ones. Moreover, highly significant difference was found between the fourth and the first treatments, while the third had non-significant difference with both fourth and first ones. Tuber starch content showed highly significant difference between the second treatment and all other treatments at 0.01 level. Tuber NPK contents, however, had non significant differences between the treatments at both 0.01 and 0.05 levels. While tuber Fe content showed a significant difference only between the second and first treatment at 0.05 level, no significant differences were occurred either between the other treatments or for tuber Mn, Zn and Cu contents. Highly significant differences were recorded in the yield between second, third and fourth treatments at 0.01 level and no significant difference between second and first treatments as well as between first and third treatments. However, significant differences between the second, fourth and both first and third treatments were observed for the potato yield at 0.05 level.

Finally, it should be noticed that the second K-treatment had superior effect on potato crop than other treatments.

Table 6a: LSD for potato vegetative part P content

Ranking	Treatment	Mean	Non–significant range
1	2	0.84	a
2	1	0.80	a
3	3	0.797	a
4	4	0.69	b
LSD 0.05 = 0.085			

Table 6b: LSD for potato vegetative part K content

Ranking	Treatment	Mean	Non–significant range
1	2	5.75	a
2	1	5.51	ab
3	3	5.02	ab
4	4	4.57	b
LSD 0.05 = 0.770			

Table 6c: LSD for potato vegetative part Fe content

Ranking	Treatment	Mean	Non–significant range
1	1	379.6	a
2	2	361.6	b
3	3	361.0	b
4	4	356.5	b
LSD 0.01 = 11.100			

Table 6d: LSD for potato tuber weight

Ranking	Treatment	Mean	Non–significant range
1	2	272.66	a
2	4	205.33	b
3	3	1.81.0	bc
4	1	161.66	c
LSD 0.01 = 33.582			

Table 6e: LSD for potato tuber starch content

Ranking	Treatment	Mean	Non–significant range
1	2	72.60	a
2	4	68.83	b
3	3	66.70	b
4	1	65.57	b
LSD 0.01 = 2.789			

Table 6f: LSD for potato tuber Fe content

Ranking	Treatment	Mean	Non–significant range
1	2	359.7	a
2	3	355.7	ab
3	4	352.0	ab
4	1	350.0	b
LSD 0.05 = 6.221			

Table 6g: LSD for potato yield

Ranking	Treatment	Mean	Non–significant range
1	2	85.94	a
2	1	82.31	ab
3	3	81.32	b
4	4	63.69	c
LSD 0.01 = 2.789			

Table 6h: LSD for potato yield

Ranking	Treatment	Mean	Non–significant range
1	2	85.94	a
2	1	82.31	b
3	3	81.32	b
4	4	63.69	c
LSD 0.05 = 2.639			

Conclusions

The valuable results obtained from the field experiment on the application of K- feldspar rock, partly or totally**,** to be the source of K for potato crop to substitute the potassium sulfate fertilizers have given the following important conclusions:

- The application of half the K- requirement as K- feldspar rock and the other half as potassium sulfate resulted in the optimum growth of the plants as well as the weight of the potato tubers.

- There was a significant increase in potassium content, in the 2nd treatment, while the minor elements Fe, Mn, Zn and Cu did not show any variations among the four treatments.

- The addition of K-feldspar only, in the fourth treatment, showed high morphological quality of potato tubers, with respect to high diameter and solid material in spite of the lower yield obtained. This can be explained by the slow and long release of K from feldspar rock through stages of growth.

- The chemical constituents of potato tubers showed the highest content in the 2nd treatment in which equal rates of K-feldspar and potassium sulfate were added, particularly starch, mono sucrose, protein and both vitamin C and A. These parameters indicate the high quality of the obtained potato tubers.

- The application of K-feldspar rock on the poor fertility sandy soil, will improve their physical and chemical conditions particularly when combined with organic source and silicate dissolving bacteria, (as recommended by other research works).
- From economic point of view, this approach of using the naturally deposited materials instead of chemical fertilizers will be very beneficial for both the farmers as well as the national authorities who subsidize the high costs of chemical. The price of potassium sulfate is about 7000 LE /ton while K- feldspar rock about 600-800 LE/ton.
- It is well known that the excessive applications of chemical fertilizers have hazardous impact on environmental conditions since considerable proportions are usually lost through drainage and cause pollution of water channels.

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