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Impact of Feldspar Acidulation on Potassium Dissolution and Pea Production

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Abstract: A field experiment was carried out for two winter seasons at Ismailia Agric. Res. Station (latitude, 30^o 35' 41.901" N and longitude, 32^o 16' 45.834" E) to study impact of feldspar acidulation on potassium dissolution and pea production. Feldspar acidulation with organic acids (humic, fulvic and citric) and mineral acids (sulphoric and phosphoric) at different concentrations (5, 10 and 20%) and incubated under lab conditions followed by a field experiment.With regard to incubation experiment results indicated that organic acids were more effective on availability of potassium from feldspar as compared to mineral acids . Also data demonstrated that availability of potassium from feldspar generally increased by increasing the incubation periods. Furthermore, the present results indicated that feldspar acidulation with fulvic acid at rate 20% after 2 days incubation being the superior. While phosphoric acid treatment was the inferior.Concerning the field experement results revealed that available N and K in the experimental soil increased significantly due to feldspar acidulation with different acids especially fulvic acid at high concentration (20%). Oppositly, the pH values decreased but those of EC values increased due to feldspar acidulation with different acids (organic or mineral) with different concentrations at both studied seasons. Furthermore, results indicated that, fulvic acids at (20%) was superior for decreasing pH values and increasing EC values in soil.

Finally, Feldspar acidulation with fulvic acid at concentration (20%) had recorded the highest values of yield components (pods, straw and biological yield) as compared to either control or other treatments along with N and K total contents.
Keywords: Acidulation, Organic acids, Mineral acids, Feldspar, Soil chemical properties, Pea yield.

Introduction

Potassium is an essential plant nutrient taken up from soil in large quantity. Soil solution and exchangeable K are in equilibrium and collectively, known as the readily only a minor fraction of the total soil reserve. Only small portion of the soil K is in solution or exchangeable forms that can be easily used by plants, with the majority of soil K retained in minerals in nonexchangeable or structural forms that are slowly or less available to plants [1]. Potassium fertilizers played an important role in Egyptian agriculture. The crop production in Egypt relies greatly on imports to meet its annual requirement of potash fertilizers; besides the high cost of conventional water–soluble k fertilizers constrains their use by most of the farmers in the country.

The alternative of fertilizers depending on expensive imported fertilizers is to exploit k-bearing indigenous resources; this may give a competing capacity for Egyptian agriculture production in international markets and protecting ecological environment. The main source of K for plants growing under natural conditions comes from the weathering of K minerals and organic K- sources such as compost and plant residues. Potassium from feldspar mineral could be solubilized and transformed into available form when incorporated with organic materials such as compost or vinasse [2]. The use of natural minerals especially feldspar and compost combined with organic residues should be considered as natural alternatives and beneficial cheap sources of K fertilization for sustainable agriculture in sandy soils.

Moreover, the application of organic manure increased the uptake of K by crops. The increases in K uptake reduce the concentration of K in the soil solution and root surfaces which induce the release of K held on the external surfaces of soil particles and also a gradual release of K from the interlayer. Moreover, acidification causes K released by the roots to balance excess intake of cations under NH^{+4} nutrition generated by decomposition of organic manure might have helped in the dissolution from acid dissolving minerals[3].

So for increased plant response to rock fertilizer application it is important to characterize and evaluate the mineralogy and chemistry of the selected minerals and match the soil and plant requirements with that of the nutrient supplying capacities of the rock fertilizer. So we search about alternative resources of K –fertilizers. The main source of K for plants growing under natural conditions comes from weathering of K- mineral (K feldspar), not only for improving soil properties but also for improving growth parameters and nutrient uptake by plants[4].

Organic acids may affect mineral weathering rates by at least three mechanisms: by changing the dissolution rate through decreasing solution pH or forming complexes with cations at the mineral surface; by affecting the saturation state of the solution with respect to the mineral; and by affecting the speciation in solution of ions such as Al^{+3} that themselves affect mineral dissolution rate. The levels of organic acids are affected by a number of independent variables such as pH and redox potential influence on the dynamics of K release from silicate rocks[5]. [6] added that humic, fulvic and other organic acids have been shown to be aggressive weathering agents in soils, especially with respect to the dissolution of clay minerals.

Various organic acids can effectively dissolve minerals and chelate metallic cations. Generally, the great effect of organic acid on dissolution rocks and minerals is attributed to the presence of hydrogen ions and the formation of cation- complexes. The structural cations, released from minerals as a result of the attack of hydrogen ions, tend to form cation-organic complexes with oxalic acid, which has OH^{-1} and $COOH^{-1}$ groups in the ortho position. The chemisorptions of the cation- organic complexes on the mineral surface cause a shift of electron density toward the frame work of the mineral. This charge transfer increases the electron density of the cation-oxygen bonds and makes them more susceptible to hydrolysis[7].

Feldspar dissolution rates increased with decreasing pH below pH 4-5. Small chelating ligands such as oxalate appear to accelerate feldspar dissolution through complexation of Al at the surface of the mineral. Organic acids will influence chemical affinity by complexing Al (and possibly other elements) in solution and hence decreasing the chemical activity of Al^{+3}, while humic acid do not appear to increase feldspar dissolution rates significantly[8].

Potassium release from rocks induced transformations at the rhizosphere. Acidulation with nitric and sulphuric acid enhancing the release of K- for plant uptake through enhancing the solubility and K- release from rocks[9].

Finally, the main challenge in the use of rock fertilizers is to increase the solubility of rocks and minerals and enhance nutrient release from both multi- nutrient silicate rock fertilizers and from single nutrient fertilizers. This can be done by physically modifying (changing the surface area of the minerals through fine grinding) and / or chemically (modifying the surfaces through acidulation), for enhancing the solubility and nutrient release from minerals[10].

The objective of the present study was to use alternative resources of K- fertilizers from natural minerals (feldspar), enhance nutrient release by chemically changing of mineral through partially acidulation to enhance the K solubility, nutrient release from feldspar, and evaluate its impact on pea production in sandy soils.

Materials and Methods

To achieve the objectives of this study, incubation experiment was carried out at the lab of soil physics & chemistry section Agric. Res. Center (ARC), Giza, Egypt followed by a field experiment at El-Ismaillia Agric. Res. Station.

I- Incubation experiment:

The incubation experiment was designed to evaluate the effect of incubation period using different concentrations of organic acids (humic, fulvic and citric) and mineral acids (sulphuric, phosphoric) on potassium release from feldspar. The organic and mineral acids were used with three concentrations i.e. 5, 10 and 20 % (C1, C2 and C3). One gram of feldspar was added to bottles containing 10 ml of each acid, shaken for an hour, then incubated under laboratory conditions. The incubation periods were 0, 1, 2, 3, 4, 14 days, soluble potassium was determined to calculate the release of K from feldspar.

II- Field experiment:

The aim of this experiment was to evaluate the effectiveness of acids application on potassium release from feldspar, soil physical and chemical properties and yield production of pea. The field experiment was conducted at El- Ismaillia Agric. Res. Station, Agric. Res. Center (A.R.C), El-Ismailia Governorate during two winter seasons using pea (*Pisum Sativum L.*), crop grown on sandy soil using drip irrigation system. The soil under study was analyzed according to [11] as shown in (Table 1). Organic acids and feldspar constituents were described in (Table 2). The experiment was designed in a randomized complete block design with three replications.

All treatments received mineral fertilizers ammonium sulphate (20.6 % N), super phosphate (15 % P_2O_5) as recommended dose for pea production.

Feldspar was used as K-source in all treatments except the control where potassium sulphate fertilizer was applied as a recommended dose of pea crop. Feldspar was mixed with soil surface two weeks before pea cultivation at the rate of 48 kg K_2O fed^{-1}, the total content of potassium in feldspar (6% K_2O). And the soil surface acidulated using different concentration of acid (5, 10 and 20%).

At maturity, Pea was harvested to determine yield components (straw and pods) and nutritional status. Plant samples were oven dried at 70 C for 48 hours, up to constant dry weight, then ground and digested using H_2SO_4 and H_2O_2 mixture described by [12]. Soil physical and chemical properties of soil along with analyses for natural minerals were evaluated according to [11]. Obtained results were subjected to statistical analysis according to [13].

Table (1): Some physical and chemical properties of the experimental soil .

Soil characteristics	Values
Particle size distribution %	
Coarse Sand	50.4
Fine Sand	40.4
Silt	3.20
Clay	6.00
Texture class	Sandy
Chemical properties	
$CaCO_3$ %	1.40
pH(Suspension 1: 2.5)	7.92
EC dS/m (saturated past extract)	0.37
Organic matter %	0.40
Soluble cations and anions (meq/l)	
Ca^{++}	0.95
Mg^{++}	0.89
Na^{+}	1.51
K^{+}	0.45
CO_3^{--}	-
HCO_3^{-}	1.42
Cl^{-}	1.02
SO_4^{--}	1.36
Available nutrients (ppm)	
N	95
P	15
K	60

Table (2): Some chemical properties of humic substance, fulvic acids and feldspar used in the experiment

Characteristics	Humic substance	Fulvic acid	Feldspar
pH	5.56	1.23	7.45
EC (dSm^{-1})	61.5	64.6	0.44
O.C %	9.50	4.20	-
Total macronutrients %			
N	1.29	0.42	-
P	0.25	0.15	-
K	2.00	2.00	6.50

Table (3): Soil reaction , electric conductivity and available K from different acids.

Treatments	Conc.	PH	EC	meq l^{-1} K soluble
Humic substance	**C1**	**2.00**	**18.0**	**43.8**
	C2	**1.90**	**30.0**	**85.0**
	C3	**1.83**	**42.0**	**120**
Fulvic acid	**C1**	**2.14**	**22.0**	**58.5**
	C2	**2.00**	**36.0**	**115**
	C3	**1.80**	**48.0**	**191**
Citric acid	**C1**	**2.20**	**4.87**	**-**
	C2	**2.00**	**6.42**	**-**
	C3	**1.70**	**7.40**	**-**
Sulfuric acid	**C1**	**1.30**	**5.90**	**0.025**
	C2	**1.00**	**10.1**	**0.025**
	C3	**1.00**	**17.1**	**0.025**
Phosphoric acid	**C1**	**1.80**	**41.4**	**0.025**
	C2	**1.60**	**73.6**	**0.035**
	C3	**1.40**	**97.9**	**0.050**

Results and Discussion

I . Incubation experiment:

1. Effect of incubation periods and different acids on K release from feldspar:

In this experiment feldspar was added as source of potassium and incubated using different concentration of organic and minerals acids under laboratory condition.

Data presented in Table(4) indicated that adding different concentrations of acids increased the released potassium from feldspar as compared with control treatment.

Regarding, acid type, organic acids were superior as compared to mineral acids on availability of potassium from feldspar. These findings were observed by [14] who found that organic acids increased the dissolution rate of feldspar significantly at room temperature. Moreover, results revealed that sulphuric acid treatment is being better for K release from feldspar as compared to phosphoric acid treatment.

According to the effect of organic acids (humic, fulvic and citric) results indicated that fulvic acid treatment gave the highest values of available K from feldspar. Such results are agreement with [15] who reported that organic acids increased element release and it was the strength of the acids, rather than their complexion abilities that was causing the increased dissolution. On the other hand, the most inferior treatment for K availability was recorded for citric acid treatment. Treatments of organic acids arranged as follows: Fulvic acid >humic acid > citric acid.

With respect to acids concentration, results revealed that availability of potassium from feldspar increased significantly along with increasing the concentration of acid. The high concentration of acid (20%) being superior compared to others concentration, regardless acid type. This may be due to decrease pH by increasing acid concentration that causing the availability of K increase. Such results are confirmed by those of [16] who reported that the presence of oxalic acid increased the dissolution rate of K-feldspar at pH 4 and 9 and this dependency of dissolution upon pH decreased to approximately an order of magnitude increase with each decrease in pH by 2 pH units.

As for the effect of incubation periods, results revealed that availability of potassium from feldspar generally increased by increasing the incubation periods. Furthermore, the present results indicated that availability of potassium from feldspar increased or decreased inconsistently according to acid type.

Interaction among the influences of feldspar acidulation with different acids at different concentration and incubation periods are shown in Table (4). Results indicated that feldspar acidulation with fulvic acid at rate 20% after 2 days incubation being the superior. While phosphoric acid treatment was the inferior. This may be due to organic acids can directly enhance release K from feldspar by either protons or ligand–mediated mechanisms and or indirectly enhance dissolution by the formation of complexes in solution and as a consequence increase the chemical affinity for the overall dissolution reaction[17]. Also, many microorganisms such as potash solubilizes can play a vital role in release of potassium from rocks. Microorganisms able to solubilize unavailable forms of K-bearing minerals such as micas, illit and orthoclases by excreting organic acids like citric, tartaric and oxalic acids which either directly dissolves rock K or chelate silicon ions to bring the K into solution[18].

Table (4): Potassium release (meq/100gm) from feldspar using different acids during incubation period.

Treatments	Conc.	Incubation period (days)					
		Zero	**1 day**	**2 day**	**3 day**	**4 day**	**14 day**
Feldspar + water		**0.050**	**0.075**	**0.125**	**0.150**	**0.150**	**0.188**
Humic Substance	**C1**	109.5	109.5	137.5	156.3	100.0	118.8
	C2	212.5	225.0	256.3	287.5	171.8	222.5
	C3	300.0	418.8	456.3	559.4	257.5	418.8
Mean		**207.3**	**251.1**	**283.3**	**334.4**	**176.4**	**253.3**
Fulvic acid	**C1**	146.3	155.5	155.5	124.3	124.4	136.8
	C2	287.5	300.0	300.0	212.5	259.3	275.0
	C3	477.5	571.3	605.8	380.5	433.8	533.8
Mean		**303.8**	**342.3**	**353.8**	**239.1**	**272.5**	**315.2**
Citric acid	**C1**	0.000	2.650	0.588	2.688	2.000	2.050
	C2	0.000	2.975	2.738	2.850	2.425	2.900
	C3	0.000	3.025	3.250	4.425	2.575	3.325
Mean		**0.000**	**2.883**	**2.192**	**3.321**	**2.333**	**2.758**
Sulfuric acid	**C1**	0.063	3.138	3.313	3.313	3.563	3.638
	C2	0.063	3.63	4.113	3.488	3.638	3.863
	C3	0.063	2.863	2.988	2.538	2.863	3.688
Mean		**0.063**	**3.054**	**3.471**	**3.113**	**3.354**	**3.729**
Phosphoric acid	**C1**	0.063	0.625	0.550	0.438	0.763	0.588
	C2	0.088	0.375	0.413	0.338	0.438	0.413
	C3	0.125	0.400	0.275	0.250	0.350	0.275
Mean		**0.092**	**0.467**	**0.413**	**0.342**	**0.517**	**0.425**

II. Field experiment:

1.Soil chemical characteristics

1.1. Soil reaction (pH)

Most minerals and nutrients are more soluble or available in acid soils than in neutral or slightly alkaline soils. Soil pH provides various clues about the soil properties. So, the soil pH is great effect on the solubility of minerals or nutrients, therefore, it is necessary to monitoring pH for soil samples to know more about the nutritional status of the soil under investigation. Data presented in Table (5) indicated that pH values generally decreased due to application of different acids (organic or mineral) with different concentrations to feldspar at both studied seasons. Furthermore, results indicated that, fulvic and humic acids were superior for decreasing soil pH as compared to control and the other treatments followed by sulfuric acid. Moreover, pH values decreased gradually by increasing the concentration of acids. This may be due to the presence of acids which decrease soil pH values. This trend was true for both seasons.

1.2. Electrical conductivity (EC)

Data presented in Table (5) indicated that, feldspar acidulation with different acids caused a significantly increase in electric conductivity as compared to the control treatment this trend was true for both season. The highest EC values in soil were recorded for fulvic acid treatment as compared to control and other treatments. This may be due to the improvement of nutrients availability due to the presence of different acids, which causes more solubility of nutrients which reflection on increased EC values. Moreover, HA and FA contains more nutrients, different elements and function groups with high molecular weight and carbon contents [19]. Also, organic acids play an important role in improving bioavailability of soil nutrients which cause a significant increase in the EC of the soil for both tested seasons. Also, results revealed that mineral acids generally increased EC values as compared to control treatment. This may be due to the presence of hydrogen ion lowered the soil pH which reflection on increasing the rate dissolution of feldspar and increase the electric conductivity due to improving nutrients availability.

1.3. Macronutrient availability

With regard of availability of macronutrients (N and K) in the soil after pea harvesting, statistical analysis revealed that significant increase in the availability of nutrients due to feldspar acidulation with different acids as compared to the control treatments, this trend was true for both tested seasons. Concerning to organic acids , fulvic and humic acids were superior for increasing the availability of N and K at both tested seasons due to its contains more nutrients and function groups with high molecular weight and carbon contents[19] . Also H^+ from the weathering of rocks through acidic attack and chelation.

Moreover, feldspar acidulation with fulvic acid was superior for increasing the availability of (N and K) as compared to the other acids. While the phosphoric acid was the inferior, this may be due to presence of H^+ as a metals cation and does replacing nonexchangeable potassium (NEK) from minerals better than the other cations. Also, H^+could activate K release in soils, but the soil K activated by H^+ is mainly from the nonexchangeable part but from the structural part. nonexchangeable potassium (NEK) plays an important role in soil K supply to plants than structural K. Thus the soil NEK reserve, but not determines the total reserve soil K fertility [20].

With regard to the concentration of different acids, available N and K increased gradually along with increasing the concentration of acid, high rate of organic acid was superior. The treatments arrange as follow: fulvic acid > humic acid > sulfuric acid > citric acid > phosphoric acid.

Table (5): Effect of feldspar acidulation with different acids on some chemical properties of the tested soil for both seasons

Treatments	Conc.	First season				Second season			
		pH	EC(dSm^{-1})	Available (mg Kg^{-1})		pH	EC(dSm^{-1})	Available (mgKg-1)	
				N	K			N	K
Control		**7.60**	**0.70**	**122.0**	**105**	**7.78**	**0.78**	**124.5**	**102**
Feldspar only		**7.35**	**0.70**	**125.0**	**81.2**	**7.50**	**0.79**	**126.0**	**82.9**
Humic Substance	**C1**	7.56	0.70	133.0	87.0	7.60	0.80	131.2	85.0
	C2	7.54	0.80	135.2	90.2	7.58	0.86	136.5	89.5
	C3	7.34	1.10	139.5	100.5	7.46	1.50	141.7	102.8
Mean		**7.48**	**0.87**	**135.9**	**92.5**	**7.54**	**1.05**	**136.5**	**92.4**
Fulvic acid	**C1**	7.56	0.70	130.0	98.0	7.62	0.72	128.2	96.2
	C2	7.45	0.72	136.0	100.7	7.59	0.76	141.7	103.0
	C3	7.44	0.90	145.2	104.0	7.50	0.82	151.7	105.7
Mean		**7.48**	**0.77**	**137.0**	**100.9**	**7.57**	**0.76**	**140.5**	**101.6**
Citric acid	**C1**	7.68	0.80	122.0	84.0	7.63	0.92	126.0	82.9
	C2	7.49	1.10	125.0	86.0	7.55	1.40	128.0	92.8
	C3	7.47	1.20	126.0	95.0	7.50	1.60	130.5	97.4
Mean		**7.55**	**1.03**	**124.3**	**88.3**	**7.56**	**1.30**	**128.1**	**91.0**
Sulfuric acid	**C1**	7.37	0.70	123.2	94.5	7.40	0.70	124.2	95.2
	C2	7.32	0.70	125.0	101.0	7.38	0.76	125.9	103.0
	C3	7.30	1.20	128.9	105.2	7.33	1.10	131.2	106.0
Mean		**7.33**	**0.87**	**125.7**	**100.2**	**7.37**	**0.85**	**127.1**	**101.4**
Phosphoric acid	**C1**	7.41	0.70	123.0	80.0	7.50	0.72	124.5	82.9
	C2	7.38	1.10	124.5	86.0	7.46	1.00	127.0	89.0
	C3	7.37	1.14	124.8	91.0	7.42	1.20	127.5	90.1
Mean		**7.39**	**0.98**	**124.1**	**85.6**	**7.46**	**0.97**	**126.3**	**87.3**
L.S.D		0.05	0.03	8.2	2.10	0.03	0.12	7.10	1.30

2. Responses of pea yield components to acidulation of feldspar

Data presented in Table (6) revealed that the values of pea yield components (pods, straw and biological yield) at both studied seasons were generally increased significantly by treating soil with feldspar and different concentration of both organic and mineral acids.

With respect to acid type, results indicated that organic acids were more effective on yield components as compared to mineral acids at both growing seasons. Furthermore, results showed that application of different concentration of fulvic acid to soil treated with feldspar was superior for increasing pea yield components as compared to other acids or control treatment. While citric acid treatment was the inferior treatment. It could be due to the influence of pH and organic acids on dissolution rate it is usually interpreted on the basis of a surface-reaction, this inhancing the release of K for plant uptake, improve the translocation of nutrient and yield components of pea.

As for the effect of acids concentration, results indicated that yield components of pea increased significantly along with the application of different acid concentration (5, 10 and 20%) as compared to control treatment. High rate especially for fulvic acid being superior at both studied season. Similar results was obtained by [21] who reported that the rate of feldspar dissolution depends on the concentration of protonated (in the acid medium) and deprotonated (in the alkaline medium)complexes with participation of the surface Si-O-Si and Al-Si-O groups of the minerals lattices.

Interaction analysis revealed that values of pea yield components were most significantly as consequence of feldspar acidulation with different acids at different concentrations. Moreover, results indicated that feldspar acidulation with fulvic acid at concentration (20%) recorded the highest values of pea yield components as compared to others treatments. These increasing in biological yield of pea recorded 67.5% and 65.6% as compared to control for first and second seasons, respectively.

Possibly due to organic acids contains more nutrients, different elements and function groups with high molecular weight and carbon contents. Also , organic acids play an important role in improving bioavailability of soil nutrients and increase the uptake and yield of crops[19]. Moreover, plant roots and their associated rhizosphere produce low molecular weight organic compounds such as aliphatic acids , aldehydes, phenols, sugars and amino acids which may accelerate weathering[22]. [9] demonstrated that K release from rocks induced transformations at the rhizosphere. Acidulation with nitric and sulphuric acid enhancing the release of K- for plant uptake through enhancing the solubility and K- release from rocks.

Table (6): Effect of feldspar acidulation on pea yield during two successive season ton fed^{-1}

Treatments	Conc.	First season			Second season		
		Pods yield ton fed^{-1}	Straw yield ton fed^{-1}	Biological yield ton fed^{-1}	Pods ton fed^{-1}	Straw ton fed^{-1}	Biological yield ton fed^{-1}
Control		**1.96**	**1.80**	**3.76**	**1.90**	**1.85**	**3.75**
Feldspar		**1.82**	**1.75**	**3.57**	**1.80**	**1.60**	**3.40**
Humic Substance	**C1**	2.68	2.20	4.88	2.72	2.00	4.72
	C2	2.82	2.70	5.52	2.90	2.53	5.43
	C3	3.30	2.95	6.25	3.20	2.91	6.11
Mean		**2.93**	**2.62**	**5.55**	**2.94**	**2.48**	**5.42**
Fulvic acid	**C1**	2.90	2.62	5.52	2.85	2.50	5.35
	C2	3.36	2.94	6.30	3.20	2.80	6.00
	C3	3.72	3.10	6.82	3.60	3.00	6.60
Mean		**3.33**	**2.89**	**6.21**	**3.22**	**2.77**	**5.98**
Citric acid	**C1**	2.70	1.85	4.55	2.10	1.90	4.00
	C2	2.50	2.20	4.70	2.40	2.12	4.52
	C3	2.60	2.30	4.90	2.80	2.40	5.20
Mean		**2.60**	**2.12**	**4.72**	**2.43**	**2.14**	**4.57**
Sulfuric acid	**C1**	2.90	2.20	5.10	2.58	2.30	4.88
	C2	2.80	2.50	5.30	2.72	2.42	5.14
	C3	2.70	2.60	5.30	2.80	2.40	5.20
Mean		**2.80**	**2.43**	**5.23**	**2.70**	**2.37**	**5.07**
Phosphoric acid	**C1**	2.60	2.30	4.90	2.50	2.36	4.86
	C2	2.14	1.97	4.11	2.20	2.00	4.20
	C3	2.00	1.75	3.75	1.89	1.90	3.79
Mean		**2.25**	**2.01**	**4.25**	**2.25**	**2.01**	**4.26**
L.S.D		**0.16**	**0.14**		**0.20**	**0.23**	

3 . Response of macronutrients uptake (total content) to feldspar acidulation for pea crop

The total content of macronutrients (N and K) of pea seeds and straw are shown in Table (7). Results indicated that values of N and K total content of seeds and straw increased significantly in response to acidulation of feldspar with different acids (organic and mineral) at different concentration (5, 10 and 20%) as compared to control treatment at both studied seasons. Similar results was obtained by [23] who noticed that the efficiency of K extraction from feldspar in acidic media was better than in distilled water around three time.

With respect to type of acid, results revealed that N and K total content of pea seeds and straw increased significantly due to acidulation of feldspar with organic acids as compared to control and mineral acids. Moreover, results showed that, fulvic acid is being better for N and K total content of pea seeds and straw at both studied seasons as compared to others organic or mineral acids. These results are in agreement with those of [8] who reported that fulvic and humic acids promote mineral weathering. They suggested that , this may be pH dependence in the effect of fulvic and humic acids on dissolution. Moreover, organic acids can directly enhance dissolution by either a proton or ligand-mediated mechanism or indirectly enhance dissolution by formation of complexes in solution with reaction products and as a consequence increase the chemical affinity for the overall dissolution reaction[17].

As for the effect of mineral acids (sulphuric and phosphoric) results indicated that N and K total content of pea seeds and straw general increased due to adding sulphuric acid as compared to phosphoric acid. Similar results were obtained by [9] who demonstrated that acidulation with nitric and sulphuric acid enhancing the release of K- for plant uptake through enhancing the solubility and K- release from rocks.

With respect to concentration of different acids, data showed that N and K total content of pea seeds and straw increased significantly along with increasing different concentration of acids, high rate was superior. Of course this may due to the strength of the acid (pH effect) than a complexation effect. In addition organic acids may accelerate dissolution far from equilibrium by lowering pH and their effects as chelators. Also, most functional groups on organic acids molecule will be protonated which allows the molecule of organic acids to form only mononuclear complexes with the mineral surface. These mononuclear surface complexes enhance dissolution rates by promoting release of metal [24].

Statistical interaction analyses revealed that N and K total content of pea seeds and straw increased significantly with feldspar acidulation with fulvic at high concentration (20 %) as compared to other treatments. While phosphoric acid treatment recorded the lowest values of N and K total content of pea seeds and straw at both studied seasons. The treatments arranged as follows: Fulvic acid > humic acid > sulphuric acid > citric acid > phosphoric acid. Posibly due to differential exudation of organic compounds to facilitate release of nonexchangeable potassium (NEK) was considered as one of the mechanisms of differential K uptake efficiency. Also, organic acids such as citric acids could be released in root exudates under K sufficient or in sufficient conditions. These acids facilitate the release of (NEK) or mineral K to various extents. In plant-soil systems, root secration of organic acids or depletion of solution K to a low level in the rhizospher would be the main mechanisms that facilitate the release of nonexchangeable potassium[25]. Finelly, the dynamic release of nonexchangeable potassium (NEK) from minerals in various solution showed that the release rate of NEK was largely K-concentration dependent and some thresholds of K concentration prevented further NEK release from minerals. Also, the positive effect of H^+ on NEK release was mainly attributed to elevating the thresholds of K concentration, rather than to the effects of weathering. The main mechanisms by plant species efficiency use NEK in minerals was to the capacity of plants to absorbe K at low concentration[26].

Table (7): Effect of feldspar acidulation on macronutrient total content of seeds and straw in two successive seasons

Treatments	Conc.	Macronutrient total contents (kg fed $^{-1}$)							
		First season				Second season			
		Seeds		Straw		Seeds		Straw	
		N	K	N	K	N	K	N	K
Control		**19.52**	**9.09**	**25.55**	**17.2**	**19.84**	**9.66**	**24.80**	**16.4**
Feldspar only		**18.37**	**8.02**	**23.96**	**16.8**	**18.62**	**8.50**	**23.07**	**15.4**
Humic Substance	**C1**	30.71	14.98	20.38	19.8	29.96	12.72	20.80	19.1
	C2	34.01	16.64	32.23	21.3	30.61	14.75	33.02	20.6
	C3	32.38	18.20	37.07	21.2	33.26	16.77	38.59	20.9
Mean		**32.36**	**16.6**	**29.89**	**20.8**	**31.27**	**14.75**	**30.80**	**20.2**
Fulvic acid	**C1**	30.00	16.35	26.39	21.2	28.65	14.40	27.56	20.7
	C2	33.19	18.90	37.13	22.8	33.04	16.38	38.29	22.1
	C3	37.59	20.80	40.40	23.6	37.75	18.90	41.81	24.6
Mean		**35.26**	**18.7**	**34.64**	**22.5**	**33.15**	**16.56**	**35.88**	**22.5**
Citric acid	**C1**	17.91	11.66	22.90	16.4	19.34	11.92	26.07	17.0
	C2	24.67	12.87	26.43	17.9	25.24	13.57	27.91	17.6
	C3	27.20	11.34	28.82	17.7	27.39	11.59	29.90	17.4
Mean		**23.92**	**12.0**	**26.05**	**17.3**	**23.99**	**12.36**	**27.96**	**17.3**
Sulfuric acid	**C1**	25.31	11.26	24.02	16.6	25.31	13.44	24.02	16.8
	C2	30.33	13.20	31.85	18.3	30.33	12.88	31.85	19.6
	C3	30.81	14.87	29.83	19.6	30.81	14.49	29.83	19.5
Mean		**28.80**	**13.1**	**28.50**	**18.1**	**28.81**	**13.60**	**28.56**	**18.6**
Phosphoric acid	**C1**	26.25	10.92	25.12	15.0	26.25	10.68	26.55	17.6
	C2	21.46	10.80	27.25	16.0	21.46	11.26	26.12	15.1
	C3	21.66	9.64	22.30	16.5	20.00	9.40	22.84	16.0
Mean		**21.12**	**10.5**	**24.89**	**15.8**	**22.57**	**10.4**	**25.17**	**16.2**
L.S.D		0.07	0.09	0.13	0.11	0.05	0.08	0.15	0.17

Conclusions

Form the obtained results, it could be concluded that, feldspar acidulation with different acids (organic and mineral) at different concentration (5, 10 and 20%) increased availability of N and K in the soil and pea yield components as well as N and K total contents of grains and straw. Moreover, feldspar acidulation with organic acids especially fulvic acid at rate of (20%) recorded the highest values of available N and K in the soil and pea yield components.

Finally, organic acids effect on silicate minerals weathering particularly feldspar through enhancement of dissolution rate. Moreover, organic acids increased K release from feldspar followed by stronge mineral acid (sulfuric acid).

Thus, the importance of the use of feldspar as a slow release potassium fertilizers with organic acids acidulation (fulvic) or mineral acid (sulfuric) should be considered to utilize nonexchangeable K from mineral and increase efficiency of feldspar as natural alternatives fertilizers in sandy soils.

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