

## **Abstract**

This study was carried out for the investigation of plant available potassium. Seven soilsamples were collected from three areas within Khartoum state from the depths of 0 – 30cm. The areas are, selit-north agricultural scheme(4 samples), suba(2 samples), and western Omdurman(1 sample).

The soilsamples were chemically and physically analyzed. The amount of available potassium varied from (0.5 to 2 mEq/100g), the status of plant available potassium in whole samples classified as sufficient (class1).

## الملخص:

أجريت هذه الدراسة للتحقيق في نبات البوتاسيوم المتاح. تم جمع سبعة عينات من ثلاث مناطق داخل ولاية الخرطوم من أعماق تتراوح بين 0 و 30 سم. أما المناطق فهي مخطط الزراعة السيلية الشمالية (4 عينات) و سوبا (2 عينة) وغرب أم درمان (عينة واحدة).

تم تحليل عينات التربة كيميائيا وجسديا. وتراوحت كمية البوتاسيوم المتاح من (0.5 إلى 2 ميق / 100 غم)، وحالة النبات البوتاسيوم المتاح في عينات كاملة مصنفة على أنها كافية.  
(.class1)

# CHAPTER ONE

## **Introduction:**

As a major constituent within all living cells, potassium ( $K^+$ ) is an essential nutrient, and is required in large amounts by plants, animals, and human. Humans obtain the majority of their potassium either directly from plants or indirectly through the animal products in their diet.

Potassium is classified as a macronutrient due to the large quantities being taken up by plants during their life cycle. (Troeh&Thomposon,2005)

A unique aspect of K is that it is not a part of any structural component of plant and occurs as a soluble ion in the plant sap. It is associated with the movement of water, and carbohydrates in plant tissue. Potassium is involved in enzyme activation within the plant which affects protein, starch and adenosine tri-phosphate (ATP) production. The production of (ATP) can regulate the rate of photosynthesis.

Potassium also helps to regulate the opening and closing of the stomata which regulates the exchange of water vapor, oxygen, and carbon dioxide. (Singh, 2009)

If K is deficient or not supplied in adequate amounts, growth is stunted and yield is reduced. For perennial crops such as alfalfa, potassium has been shown to play a role in stand persistence through the winter. (Rose,2017)

Available K is estimated from sum of both exchangeable and soluble potassium.

**The objectives:**

The aim of this study is to investigate the level of available potassium in soils of three areas in Khartoum state.

## **CHAPTER TWO**

### **2.0 Literature review:**

#### **2.1 Potassium K:**

Potassium is one of the macronutrients and usually present in plants in quantities larger than those of any other mineral nutrients taken from soil with the exception of hydrogen and nitrogen.(Willy & Sons,1968)

#### **2.2 Potassium in nature:**

Potassium is a relatively abundant and widely distributed constituent of the surface rocks, making up an estimated amount of 2.6% of the earth crust by weight.(Willy& sons,1968).

#### **2.3 Potassium requirements:**

The K requirement of plants varies widely depending on plant species.

-The average of potassium contents in plants tissues may reaches 1.5%. Some plant tissues accumulate much potassium. Tobacco leaves, for example may contain as much as 8% potassium on dry weight basis and may show symptoms of potassium deficiency if the content falls much below 3%.

-Tree crops such as pecans, peaches, apples, etc. have relatively low K requirements.

-The critical value for K in tree leaves ranges from 0.75 to 1.25%.

-For grasses, the K requirement is higher with the critical value in leaves ranging from 1.20 to 2.00%.

-For legumes, the critical value generally ranges from 1.75 to 2.00%.

-Young plants may contain 3.00 to 5.00%, although the actual requirement may not be that high, because of its mobility in plant.

<http://aesl.ces.uga.edu/publications/plant/nutrient.asp>

## **2.4 Potassium availability in soils:**

Although potassium is removed from soil continually, most soils continue to supply potassium for a long time. Consequently, relatively few soils are so low in potassium that cropping is entirely dependent on fertilization. (Willy & Sons, 1968).

## **2.5 Potassium percentages in soils:**

In most soil except those that are extremely sandy in high rainfall regions total potassium content are high. Similar to nitrogen and phosphorus, not all of the total potassium is available. Therefore, soils containing relatively large amount of total potassium usually respond to potassium fertilization.

The percentages of K in soils range from less 0.1% by weight to over 4%.

## **2.6 Mineralogical forms:**

Most of potassium in soils is present in minerals classified as feldspars and micas. The most important of these are orthoclase and microcline feldspar, biotite mica, and micaceous clay mineral known as illite.

### **2.6.1 Feldspars:**

Feldspars occur almost exclusively in the fine sand and silt fractions of soils but are found occasionally in the coarse clay.

## 2.6.2 Biotite and muscovite mica:

These minerals also occur mainly in the silt and sand fractions.

## 2.6.3 Illite:

Illite is the principal potassium bearing mineral in the clay fraction of soils. Its cation exchange capacity ranges from (20-40).

**Table No.1 Potassium contents of primary and secondary minerals:**

Mineral	K <sub>2</sub> O%
1. Alkali feldspars	4–15
2. Ca-Na-feldspars	0–3
3. Muscovite (K-Mica)	7–11
4. Biotite (Mg-Mica)	6–10
5. Illite	10
6. Vermiculite	0–2
7. Chlorite	0–1
8. Montmorillonite	0 – 0.5

(الشبيني، 2007)

## 2.7 Chemical forms:

### 2.7.1 Relatively Unavailable Potassium

From 90-

98 percent of the total potassium present in soils is found in insoluble primary minerals such as feldspars and micas. These minerals consist of potassium-aluminum

silicates which are resistant to chemical breakdown. They release potassium slowly, but in small quantities compared to total needs of growing crops.

(Singh, 2009)

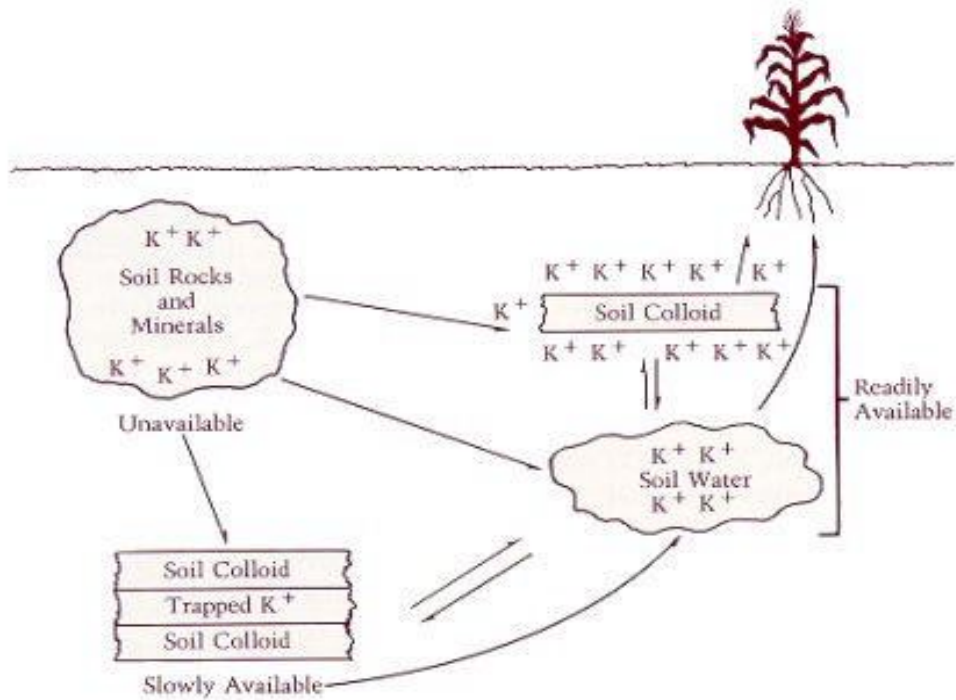
### **2.7.2 Slowly Available Potassium:**

This form comprises 1-10 percent of the total potassium supply and may originate from dissolved primary minerals or from potassium fertilizers. This potassium is attracted to the surface of clay minerals where it may be firmly bound or fixed between the clay layers in a form slowly available to plants. The actual amount available depends on the type and amount of clay present. (Singh, 2009)

### **2.7.3 Readily Available Potassium:**

Readily available forms of potassium comprise only 0.1 to 2 percent of the total potassium in the soil and consist of potassium dissolved in the soil solution and held on the exchange positions of the clay and organic matter. This potassium is referred to as "exchangeable" because it can be replaced by other positively-charged ions (cations) such as hydrogen, calcium, and magnesium. This exchange happens rapidly and frequently. The potassium in the soil solution may be taken up by the plant or lost from the soil by leaching, especially on sandy coarse-textured soils in regions of high rainfall. (Singh, 2009)





**Figure No.1:** Relationship among unavailable, slowly available and readily available potassium in the soil-plant system (Rehm G. & Schmitt M., 2002).

## 2.8 The role of potassium in plant growth:

While K does not become a part of the chemical structure of plants, it plays many important regulatory roles in plant development.

### 2.8.1 Enzyme activation:

Potassium activates at least 60 different enzymes involved in plant growth. Potassium (K<sup>+</sup>) changes the physical shape of the enzyme molecule, exposing the appropriate chemically active sites for reaction.

The amount of potassium present in the cell determines how many enzymes can be activated and the rates at which chemical reactions can proceed.

### **2.8.2 Stomatal activity:**

Plants depend upon potassium to regulate the opening and closing of stomates. When K is into the guarded cells around the stomates, the cells accumulate water and swell, causing pores to open and allowing gases to move freely in and out.

### **2.8.3 Photosynthesis:**

The role of K in photosynthesis is complex. The activation of enzymes by K and its involvement in adenosine triphosphate (ATP) production is probably more important in regulating the rate of photosynthesis than stomatal activity.

### **2.8.4 Transport of sugars:**

Sugars produced in photosynthesis must be transported through the phloem to other parts of the utilization and storage. The plant transport system uses energy in the form of ATP. If  $K^+$  is inadequate, less ATP is available, and the transport system breaks down.

### **2.8.5 Starch synthesis:**

The enzyme responsible for synthesis of starch (starch synthetase) is activated by  $K^+$ . Thus, with inadequate  $K^+$ , the level of starch declines while soluble carbohydrates and N compound accumulate. Photosynthetic activity also affects the rate of sugar formation for ultimate starch production. Under high  $K^+$  levels, starch is efficiently moved from sites of production to storage organs.

### **2.8.6 Water and nutrients transport:**

Potassium also plays a major role in the transport of water and nutrients throughout the plant xylem. When  $K^+$  supply is reduced, translocation of nitrates, phosphates, calcium, magnesium, and amino acids is depressed. As with phloem transport systems, the role of  $K^+$  in xylem transport is often in conjunction with specific enzymes and plant growth hormones. An ample supply of  $K^+$  is essential to efficient operation of these systems.

### **2.8.7 Protein synthesis:**

Potassium is required for every major step of protein synthesis. The reading of the genetic code in plant cells to produce proteins and enzymes that regulate all growth processes would be impossible without adequate amount of  $K^+$ .

### **2.8.8 Crop quality:**

Potassium plays a significant role in enhancing crop quality. High levels of available  $K^+$  improve the physical quality, disease resistance, and shelf life of fruits and vegetables used for human consumption and the feeding value of grain and forage crops. Fiber quality of cotton is also improved.

The effects of  $K^+$  deficiency can cause reduced yield potential and quality long before visible symptoms appear. This hidden hunger robs profits from the farmer who fails to keep soil  $K^+$  levels in the range high enough to supply adequate  $K^+$  at all times during the growing season. Even short periods of deficiency, especially during critical developmental stages, can cause serious losses.(Prajapati and Modi,2012)

## **2.9 Potassium fixation:**

The potassium fixation is the result of re-entrapment of  $K^+$  ions between the layers of 2:1 minerals especially illite. Alternate wetting and drying of 2:1 type clay minerals may aid in slow release of fixed potassium. In the presence of vermiculite, illite and other 2:1 type minerals, the potassium of such fertilizers as potassium chloride not only became absorbed but also may become definitely fixed by the soil colloids.(Singh, 2009)

## **2.10 Factors affecting K fixation:**

### **2.1.1 Clay minerals:**

The soils containing 2:1 type of clay minerals like illite vermiculite and montmorillonite can fix considerable amounts of potassium.(Tan,1998).

### **2.10.2 Potassium concentration:**

An increase in K concentration is likely to increase K fixation because more K goes into the exchange complex by mass action.

### **2.10.3 Wetting and drying:**

The  $K^+$  fixation is strongly influenced by wetting and drying of soils. Fixation occurs when initial level of exchangeable and soluble  $K^+$  is high and release occurs when the level of such K is low. Thus, the process of drying favours attainment of equilibrium in distribution of  $K^+$  in soils.

### **2.1.:4 Temperature**

Higher temperature favours dehydration and contraction of the crystal lattice resulting in higher K fixation.

### **2.10.5 Soil pH**

Increase in soil pH leads to higher fixation of potassium.

### **2.1.6 Exchangeable cations**

The size of K and other ions replacing K is important in K fixation. The cations of smaller size of the hydrated ions can easily enter into clay lattices and replace some of the fixed potassium.

### **2.10.7 Texture:**

The finer the texture the more is the K fixation.

### **2.10.8 Organic matter:**

The addition of organic matter decreases the k fixation by inorganic colloids. (Rose, 2017)

### **2.11 Soil potassium problems:**

2.11.1 Not all of the potassium in soil is available for plant.

2.11.2 The losses of K<sup>+</sup> by leaching.

2.11.3 Crop removal.

2.11.4 Fixation. (Willy & Sons, 1968)

2.12 Potassium deficiency symptoms:

Plants absorb potassium as the potassium ion (K<sup>+</sup>). Potassium is a highly mobile element in the plant and is translocated from the older to younger tissue. Consequently, potassium deficiency symptoms usually occur first on the lower leaves of the plant and progress toward the top as the severity of the deficiency increases.

1. One the most common sign of potassium deficiency is the yellow scorching or firing “chlorosis” along the leaf margin. In severe cases of potassium deficiency the fired margin of the leaf may fall out. However, with broadleaf crops, such as soybeans and cotton, the entire leaf may shed resulting in premature defoliation of the crop.
2. Potassium deficient crops grow slowly and have poorly developed root systems.
3. Stalks are weak and lodging of cereal crops such as corn and small grain is common.
4. Legumes are not strong competitors for soil potassium and are often crowded out by grasses in grass-legume pasture.
5. When potassium is not sufficient, winter-killing of perennial crops such as alfalfa and grasses can occur.
6. Seeds from potassium deficient plants are small, shriveled, and are more susceptible to diseases.
7. Fruit is often lacking in normal coloration and is low in sugar content.
8. Vegetables and fruits deteriorate rapidly when shipped and have a short shelf-life in the market.(Rehm&Schmitt,1997)

### **2.13 The toxicity of potassium:**

There is no level at which potassium becomes toxic to plants. But when plants get too much potassium, the absorption of other nutrients is inhibited, which leads to symptoms caused by the deficiency of these nutrients.

**TableNo.2 The relative levels of potassium:**

<b>Potassium in mEq/100g</b>	<b>Relative levels</b>
>0.4	Class1
0.4 – 0.2	Class2
0.2 – 0.1	Class3
<0.1	Class4

### **2.14Na and K:**

At higher levels of sodium, plant will preferentially take up sodium in place of potassium.(Singh, 2009)

### **2.15Fertilizers contain potassium:**

#### **2.15.1 Potassium chloride:**

Accounts for approximately 95% of all potassium fertilizers used in agriculture because it is the cheapest per ton and most widely obtainable. As fine crystals it can be compacted into suitable sized particles to be spread by machine or used in blends.The percentage of K<sup>+</sup> is 50% (K<sub>2</sub>O,62%), chloride (47-50%),NaCl (2.8-2.9%).

#### **2.15.2 Potassium sulphate:**

Potassium sulphate is more expensive per ton than potassium chloride, as it contains two nutrients, potassium (43%) and sulphur(17-18.5%). Also it contains Na<sup>+</sup> (0.1-2.5%) and Cl<sup>-</sup> (1-2.5%).

### **2.15.3 Potassium nitrate:**

Potassium nitrate is considered as one of the best complex potassium fertilizers as a simple salt containing two nutrients. Nitrogen as nitrate, which is readily available for crops (13-14%). And potassium counts for (44%  $K_2O$ ). (الشبيني، 2007).



## CHAPTER THREE

### 3.0 Materials and methods:

#### 3.1 Location:

The three areas are within Khartoum state which is bordered by the following coordinates: 15° 48' 0.00" N 33° 00' 0.00" E.

The three areas are:

- selit-north agricultural project (sample No.1,2,3 and 4).
- suba first terrace and upper terrace (sample No.5 and 6).
- western Omdurman (sample No.7)

<http://latitude.to/map/sd/sudan/regions/khartoum-state>

#### 3.2 Climate of Khartoum state:

The climate in Khartoum state is semi-arid with average annual rainfall of 135mm. the average annual air temperature is 29.6C°.

<https://en.climat-data.org/location/549/>

#### 3.3 Samples:

Seven composite soil samples were collected from the three study areas using soil auger from the depths of 0 – 30cm.

#### 3.4 Date of sampling:

The field work started in 2\8\2017 and completed in 5\8\2017.

### **3.5 Soil analysis:**

All chemical and physical analysis of the soil samples were carried out in the soil laboratory of soil and water department, Sudan university of science and technology (shambat).

### **3.6 Samples preparation:**

The samples were air-dried and crushed to pass a 2mm mesh sieve to obtain the fine earth.

### **3.7 Physical analysis procedures:**

#### **3.7.1 Moisture content:**

The moisture contents of the soils were determined by the gravimetric method. (Wide, 1979)

#### **3.7.2 Saturation percentages:**

The saturation percentage was determined by adding the soil to a known amount of water with stirring until a soil paste is prepared. The moisture content of the soil used is added to the initial volume of water. The saturation percentage was then calculated as follows:

$$S.P \equiv (V_w \times 100) / W_s.$$

$V_w$   $\equiv$  total water volume.

$W_s$   $\equiv$  soil weight.

#### **3.7.3 Mechanical analysis:**

The particle size distribution was obtained by adopting the hydrometer method. 50 ml of a Calgon solution was added to a known amount of

soil(50g) in a beaker. Then the soil was heated with stirring for five minutes, and was then transferred into a liter measuring cylinder by adding small amount of water and stirring. The volume completed to 1 liter by adding tap water, an automatic manual plunger was used for mixing(10 times).

$R_1$  is measured after 40 seconds,  $R_2$  is measured after 2 hours. The temperature was measured at  $R_1$  and  $R_2$ , using a thermometer and represented by  $T_1$  and  $T_2$  respectively. The percentages of sand, silt, and clay were calculated as follows:

$$\text{Silt+clay\%} = (R_1 + (T_1 - 19.4) \times 0.39 \times 100) / S_w$$

$$\text{Clay\%} = (R_2 + (T_2 - 19.4) \times 0.39 \times 100) / S_w$$

$$\text{Sand\%} = 100 - (\text{Silt+clay\%})$$

The soil texture obtained from the triangles of the texture using the percentage of sand, silt, and clay as determined from the hydrometer readings.

### **3.8 Chemical analysis:**

#### **3.8.1 Soil reaction:**

A pH meter was used in measuring the soil pH in a soil water suspension 1:5.

#### **3.8.2 Electrical conductivity:**

It was measured by an EC meter in a soil water suspension 1:5. The EC was then corrected as follows:

$$\text{E.C. at saturation} = \text{E.C.}(1:5) \times (500/S.P)$$

S.P≡ Saturation percentage.

### **3.8.3 Soluble cations and anions:**

Sodium and potassium measured using flame photo meter. Calcium and magnesium titrated against EDTA.

Carbonate and bicarbonate were determined by the titration against 0.01 hydrochloric acid. Chloride was titrated against 0.05 silver nitrate. And sulphate was obtained by difference as follows:

$$SO_4^{2-} = (\sum Na^+, K^+, Ca^{++}, Mg^{++}) - (\sum CO_3^{2-}, HCO_3^-, Cl^-).$$

(Wilde, 1979)

### **3.8.4 Exchangeable cations:**

Exchangeable sodium and potassium were determined by the displacement of adsorbed cations by ammonium acetate and measured using flame photo meter. The values obtained were then corrected for the soluble part.

### **3.8.5 Phosphorus:**

Phosphorus was determined spectrophotometrically adopting Olsen method.

### **3.8.6 Organic matter:**

Walkley and black (wet oxidation) method was used. And organic matter was obtained from the relationship:

$$\% \text{Organic matter} = \% \text{O.C} \times 1.72.$$

## **3.9 Correction of the results:**

The results of the EC and the soluble cations and anions were corrected by multiplying the results of a soil suspension 1:5 by a correction factor depending on its saturation percentage. This was applied for every soil as follows:

Correction factor=  $500/S.P$

S.P≡ Saturation percentage.

## CHAPTER FOUR

### 4:0 Results and discussion:

**Table No.3: pH, ECe and soluble cations (MEq/L):**

Sample NO.	Depth	pH	ECe	Na <sup>+</sup>	K <sup>+</sup>	Ca <sup>++</sup>	Mg <sup>++</sup>
1	0 – 30	8.2	6.2	25	6.25	25	18
2	0 – 30	8.1	6.4	26	3.85	30.6	26
3	0 – 30	8.5	7.5	27	11.25	30	19.5
4	0 – 30	8.3	8.7	32	3.07	24.6	23.3
5	0 – 30	8.3	2.8	6	8.75	14.7	14
6	0 – 30	8.4	4.7	16	2.31	23.9	17.5
7	0 – 30	7.7	6.4	10	5.85	27.3	31.5

The results on the above table show the similarity of the seven samples in their pH. Which range from 7.7 to 8.5 pH. That means all of the studied soils are weakly alkaline reaction.

It is observable that the total salts content (ECe, ds/m) is high in all the samples with the exception of sample No.5 first terrace soil.

The amount of water soluble potassium is positively related to the soil ECe. With the exception of sample No.5, despite it has a lower ECe than in the samples 6 and 7, but it has a higher amount of water soluble potassium. This can be explained by the higher clay content (table.7) and organic matter (table.6).

**Table No.4 Soluble anions:**

Sample NO.	CO <sub>3</sub> <sup>=</sup> mEq/L	HCO <sub>3</sub> <sup>-</sup> mEq/L	Cl <sup>-</sup> mEq/L	SO <sub>4</sub> <sup>=</sup> mEq/L
1	13.75	12.5	31	17
2	15.3	15.3	38.3	17.5
3	24	18	45	2.3
4	14.7	12.3	30.7	25
5	10.5	9.1	11.2	12.6
6	15.6	13.8	30.3	0.8
7	23.1	21	23.6	6.9

The results of the soluble anions analysis in table.3 show the wide variation between the studied soils in their soluble salts. Carbonate varies from (10.5–24mEq/L), Bicarbonate varies from (9.1–21mEq/L), Chloride varies from (11.2–45mEq/L) and Sulphate varies from (0.8-25mEq/L).

Those high ranges of carbonate and bicarbonate were found to be a result of the calcium carbonate accumulation in arid soils.

**Table No.5 Exchangeable Na<sup>+</sup> and K<sup>+</sup> and available k<sup>+</sup>:**

Sample NO.	Exch. Na <sup>+</sup> mEq/100g	Exch. k <sup>+</sup> mEq/100g	Available k <sup>+</sup> mEq/100g
1	18.2	0.4	1.0
2	9.56	0.1	0.5
3	7.81	0.3	1.5
4	6.95	0.7	1.0
5	1.73	1.1	2

6	5.21	0.3	0.5
7	1.73	0.4	1.0

The results of the analysis of the exchangeable potassium for the seven samples (table5) show a positive relationship when comparing with the results of water soluble potassium (table3). The positive relationship between exchangeable k<sup>+</sup> and soluble k<sup>+</sup> was pointed by Rehm&Schmitt(2002).

The available potassium ranges from 0.5 to 2 mEq/100g. The highest level of available potassium is in sample 1, this was the reflection of the higher clay content and organic matter. The lowest level of available potassium was in the samples 2 and 6. That is because of the lower clay contents.

The available potassium in whole samples is sufficient for crops production and its status can be classified as class 1.

**Table No.6 Organic matter and phosphorus:**

Sample No.	O.M %	P (P.P.M)
1	0.6	5
2	0.7	6
3	0.5	6
4	0.85	6
5	1.9	9
6	1.2	5
7	0.09	4



The organic matter contents of the samples 1, 2, 3, and 4 are very low, varied (0.5–0.85%). The O.M content of the samples 5 and 6 are comparatively higher.

The sample No.7 is extremely low in its O.M content (0.09%), that's because of the absence of vegetation and cultivation in western Omdurman area.

**Table No.7 Soil particle size distribution, saturation percentages and moisture content:**

<b>Sample NO.</b>	<b>Sand %</b>	<b>Silt %</b>	<b>Clay %</b>	<b>Textural group</b>	<b>S.P %</b>	<b>M.C %</b>
1	51.92	5.6	42.48	Sandy clay	40	3.2
2	61.92	5.6	32.48	Sandy clay loam	32.4	3
3	40.08	22.4	37.52	Clay loam	33	2.8
4	50.08	8.4	41.52	Clay	40.6	3
5	25.92	9.6	64.48	Clay	71.5	7
6	63.92	3.6	32.48	Sandy clay loam	54	4
7	55.92	5.6	38.48	Sandy clay	23.4	1

The sand and silt fraction can contain potassium in primary minerals like, feldspar and mica. But they are very resistant to chemical break-down therefore, release potassium very slowly.(Singh, 2009)

The clay fraction is known to effect the amount of available potassium.(Troeh&Thomposon,2005)

That can be noticed in the results of the soil clay fraction when it is compared to the amount of exchangeable potassium.

The clay contents are positively related to the saturation percentages and also the moisture contents of the soils.

### **Recommendations:**

1. According to the results of the study the level of the available potassium in the soils of the three areas (selit-north, suba, and western Omdurman) is sufficient for producing crops. And the need for K fertilization is unlikely.
2. The contact exchange phenomenon is the main process for plant to get its needs of K. The contact exchange is strongly affected by clay, aeration and root respiration, therefore enhancing soil drainage is required.
3. The levels of available k in poor-drained soils should be raised higher than those of well-drained soils.
4. wetting and drying are found to affect K fixation consequently, the maintenance of soil moisture is important.
5. The replacement of K by Na in plant when Na is higher in a soil requires specified study especially in selit and suba soils.

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