Improving Ionic Exchange Process of Potassium in Poor Soils by Bentonite

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Abstract. The current study was carried out to improve ionic exchange for potassium in sandy and gypsiferous soils to obtain an increase in absorption of potassium ions in NPK fertilizers, the improving process includes two stages; The first is adding NPK fertilizer with concentrations (0.020%, 0.040%, and 0.070%) by weight for two samples, the exchange potassium concentration was measured and notice the increasing from 124 ppm to 140 ppm in sandy soil and from 156 ppm to 180 ppm in gypsiferous soil when using the highest concentration (0.070%), the second stage included adding grinded bentonite ore (10%, 20%, 30%) by weight to the two samples after treated with NPK fertilizer in same concentrations above, potassium exchange increased to 340 ppm in sandy soil and to 450 ppm in gypsiferous soil by using NPK fertilizer and bentonite ore concentrate (0.070% & 30%) respectively.

1. Introduction
One of the important problems in the dry land is the little efficiency of potassium absorption relatively; Dependent on nutrients from the ground alone is not enough for the needs of plants. so, should give plants additional nutrients, in form of fertilizers, the maximum benefit from fertilizers can be achieved by using the right amount, the right time, way, and reaching balance according to the requirements of plants [1]. Poor land is characterized by little fertility and production because it is affected by human activities upon the land which indirectly affects such as floods and bush fires, industries, and became desert land [2]. Desertification is defined as land degradation in arid, semi-arid regions, resulting from human activities and climatic variations [3], Iraq is considered among the countries affected by this phenomenon for several reasons, including low rates of rainfall, badly irrigation, and unsustainable cultivation methods [4]. Fertilizers are food ingredients given to plants for increasing the nutrients substances for the soil [5]. poor soil can be treated by inorganic fertilizing which appears increased productivity in a short time [6], on the other side, the soils fertilized with organic fertilizer have enough soil organic matter content and a good soil structure, in which the ability of the soil to bind water is greater. Potassium is an active element that does not exist in pure form but in combination with other elements; and is considered the basis of animal and plant life and represents the higher concentration of dissolved positive ions in the plant cell solution [7].
Four sources of potassium are found in the soil, first, the minerals in the soil like mica and feldspar, the second source is the non-exchangeable potassium that considers as a reserve source of potassium in the soil, the third source is exchangeable potassium that found in the cation exchange sites. Finally, the fourth source is the potassium contained in organic matter and within the soil microbial population which provides a very little amount of potassium that is needed for plant growth [8].

The reactive oxygen species (ROS) generation in plants will decrease by the regulated potassium, oxidases and retains the photosynthetic, which helps to reduce ROS. Potassium deficiencies can decrease the photosynthetic CO2 fixation [9]. Sandy soil has poor physical properties and a single-grained structure leading to a low water-holding capacity [10] and greater porosity, resistance to penetration, water retention than coarse sand, they exhibit lower permeability [11] which leads to restricted plant growth and regional economic expansion [12]. Gypsum is a mineral and rock is a soluble salt widely distributed in sedimentary rocks of various geologic formations of different ages. Gypsum minerals or rocks that contain gypsum (CaSO4.2H2O) more than (3%) within the root layer [13] may be present in the form of hydrated calcium sulphate (CaSO4.2H2O) or as anhydrous form which is called anhydrite (CaSO4) [14]. Two types of gypsum in Iraq, primary gypsum, formed as a result of the evaporation of water from closed seas and lakes containing saltwater and secondary gypsum which form as a result of the activity of soil formation processes, many methods for reclaiming gypsum soil available, include: reducing gypsum solubility by adding potassium, phosphate, and ammonium carbonate to convert gypsum into low-soluble compounds by encapsulating its granules or by the addition of organic materials and chemical fertilizers, or bentonite ore, that is crushed and added with the purpose of improving soil construction [15]. Bentonite is naturally structured with phyllosilicate minerals, described by ion adsorption capacity and high cation exchange [16]. Several applications of natural soil conditioners were carried out to improve the physical-biochemical properties of sandy soils [17]. The Bentonite clay addition to sandy soil increased the retention and availability of soil moisture and reduced the velocity of downward water movement, and restricted the deep percolation [18]. Sieving technology is used to separate different particles in size, the coarse or large particles are disintegrated by colliding with each other causing their fragmentation; the fine particles can easily pass through these holes [19]. This research will study the possibility of improving the exchange of potassium in sandy and gypsiferous soils in Saladin governorate, to obtain soil characterized with a higher absorbent for potassium that found in NPK fertilizer.

2. Location of Study Area

The samples were brought from Saladin governorate in Iraq and the samples brought from two positions, the first located near the city of Baiji, represents sand dunes transported by winds, the thickness of it is about 1.5 meters the second located east of Tikrit about 20 km represent gypsiferous soils about 3.0 m. thickness [20], ‘figure 1’ shows the location.
3. Materials and Methods

3.1. Materials

3.1.1. Bentonite

Bentonite clays used in experiments characterized with high-quality calcium, brought from Bashera valley, western desert in Iraq, grinded on sieves to (150 microns).

3.1.2. NPK fertilizer

NPK Fertilizer added was make in the General Phosphate Company and according to the applicable specification and appropriate for the Iraqi environment.

3.2. Methods

3.2.1. Preparation of samples

Two samples (sandy & gypsiferous soils) were chosen to represent the study area, the samples were divided, squared and take for chemical analysis shown in table 1, grain size analysis was necessary to know the proportions of sand, silt, and clay so sieves were used to determine the proportions of each other shown in table 2.

| Samples       | SiO$_2$ | Al$_2$O$_3$ | Fe$_2$O$_3$ | TiO$_2$ | CaO  | MgO  | SO$_3$ | Na$_2$O | K$_2$O | Cl   | L.O.I |
|---------------|---------|-------------|-------------|---------|------|------|--------|--------|-------|------|------|
| Sandy soil    | 64.75   | 7.84        | 2.00        | 0.36    | 10.12| 1.16 | < 0.06 | 1.69   | 1.70  | 0.05 | 8.85 |
| Gypsumiferous soil | 25.23  | 6.17        | 2.5         | 0.35    | 22.71| 5.18 | 19.26  | 0.92   | 0.74  | 0.19 | 16.76 |

Figure 1. Studied area
Table 2. Grain size analysis of soil samples

| samples         | Sand | Silt | Clay |
|-----------------|------|------|------|
| sandy soil      | 88.5 | 11.5 | -    |
| Gypsiferous soil| 42   | 26   | 32   |

analysis of soluble salts in water to measurement the different phase concentrations of potassium, carry out in chemical laboratories of Geosurve shown in table 3, 4.

Table 3. Analysis of soluble salts in water of soil samples

| Test          | sandy soils | Gypsiferous soil |
|---------------|-------------|------------------|
| PH            | 7.7         | 6.8              |
| TDS           | 1.01%       | 37%              |
| CaO           | 0.04%       | 13.7%            |
| MgO           | 0.02%       | 0.14%            |
| K₂O           | 0.01%       | 0.066%           |
| Na₂O          | 0.02%       | 0.39%            |
| SO₃           | 0.04%       | 19.7%            |
| CO₃           | n.a.        | 0.02%            |
| Cl            | 0.08%       | 0.60%            |

Table 4. Distribution of potassium in its different phases of soil samples

| samples        | total potassium | potassium soluble in water | exchange potassium | fixed potassium |
|----------------|-----------------|----------------------------|-------------------|-----------------|
| sandy soil     | 16200           | 200                        | 175               | 15825           |
| Gypsiferous soil| 6800           | 550                        | 150               | 6100            |

3.3. Practical experiments

Improving the ionic exchange of potassium includes two stages that are explained in detail as follows:

3.3.1. Samples treatment with NPK fertilizer

In this stage, the NPK fertilizer was added directly to the sandy and gypsiferous soil samples with concentrations (0.020% ,0.040% ,0.040%), the ion exchange ratio of potassium in the soil were measured, the results show in table 5.

Table 5. Ion exchange ratio of potassium of soil samples (ppm)

| Sample          | Before adding fertilizer | 0.020 % | 0.040 % | 0.070 % |
|-----------------|--------------------------|---------|---------|---------|
| sandy soil      | 124                      | 130     | 136     | 140     |
| Gypsiferous soil| 156                      | 165     | 173     | 180     |

3.3.2. Treatment with Bentonite Clay

In this stage, bentonite ore will be added to sandy and gypsiferous soil samples before NPK fertilizer is added, then the ion exchange ratio of potassium was measured for both soils, the results shown in table 6.
Table 6. Ion exchange ratio of potassium for two samples after addition of bentonite (ppm) and NPK fertilizer.

| Sample   | Bentonite | the ion exchange ratio of potassium after adding NPK fertilizer |
|----------|-----------|---------------------------------------------------------------|
|          |           | 0.020%  | 0.040%  | 0.070%  |
|          | Sandy Soil|          |          |          |
| 10%      | 167       | 190     | 210     |
| 20%      | 231       | 240     | 255     |
| 30%      | 245       | 269     | 340     |
|          | Gypsum Soil|         |          |          |
| 10%      | 180       | 200     | 240     |
| 20%      | 220       | 270     | 360     |
| 30%      | 275       | 335     | 450     |

4. Results and Discussion
Based on the previous results, it is possible to improve the specifications of sandy and gypsiferous soil by increasing the exchange ion of potassium can be improved through treatment with NPK fertilizer by adding grinded bentonite.

4.1. Effect of adding NPK fertilizer directly to poor soils in increasing ion exchange
When addition (0.020% & 0.040%) concentration of NPK fertilizer to the samples that were not treated with bentonite ore notice a slight increase in the ion exchange capacity of sandy and gypsiferous soils, also even when adding (0.070 %) concentration of NPK fertilizer to the sandy and gypsiferous soil, the ion exchange increased only from (124 ppm) to (140 ppm) K₂O and from (156 ppm) to (180 ppm) K₂O respectively shown in table 5.

4.2. Effect of adding bentonite to improving ion exchange process
Bentonite is a fine grain clay consisting of the montmorillonite mineral which consists of two structural units, the alumina octahedron, and the silica tetrahedron which interconnected and extend to form layers that are arranged one above the other, to form a crystal particle [21]. When water enters between the crystal particle it will separate the sheets and causes the swelling of bentonite, the swelling mechanism results from its net negative charge and microstructure [22]. Most types of bentonite contain sodium or calcium ions in ion exchange sites, table 7 shows the chemical analysis of bentonite used.

Table 7. Chemical analysis of the bentonite

|   | SiO₂% | Al₂O₃% | Fe₂O₃% | CaO% | MgO% | Na-O% | K₂O% | L.O.I % |
|---|-------|--------|--------|------|------|-------|------|--------|
|   | 51.67 | 14.52  | 5.70   | 6.91 | 5.11 | 1.20  | 0.63 | 12.87  |

Therefore, When addition bentonite ore with different concentrations to the sandy and gypsum soils notices that in gypsum soil will obtain ion exchange higher than sandy soil (156 ppm) to (450 ppm) K₂O comparing with (124 ppm) to (340 ppm) K₂O of sandy soil respectively due to the presence of the palygorskite clay mineral in the first which works to achieve a relative increase in the ability of the soil
to ion exchange, adding bentonite to sandy and gypsum soils improves the texture components of these soils, which lack the clay part (sandy soil) or need to increase the clay part in them (gypsum soil) in order to achieve a better balance in the components of the soil texture shown in table 6.

5. Conclusions
Based on the results of experiments on the development ionic exchange process of potassium, so conclude the following:
1- The results indicate the possibility of improving the properties of poor sandy and gysiferous soils by increasing their ability to ion exchange of potassium by adding bentonite ore (30 %) with (0.070 %) concentration of NPK fertilizer and the process of addition bentonite ore is the essential stage to obtain high efficiency of ion exchange.
2- The availability of bentonite ore in Iraq in large quantities and the possibility of using it without prior treatments to improve the poor soil leads to reclaiming large areas of land covered by sand or those rich in gypsum and without using any chemical material so it is considered a good economic method.

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