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The Impact of Flooded and Dry Irrigation Methods on Potassium Forms and Soil Fertility in Rice Farms of Diwaniyah and Najaf Provinces, Iraq

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Abstract :

Some study areas in the provinces of Diwaniyah and Najaf were selected for the current study, as these two provinces are renowned for cultivating various varieties of the rice crop, particularly the amber class. This research aims to analyze the growth patterns and yield outputs of these rice varieties under different agricultural practices. By examining factors such as soil quality, irrigation methods, and pest control, the study seeks to provide valuable insights that can enhance rice production in the region .

Two sites were identified in each province. The first site represents soil planted with the rice crop, and the flooded method is used in its irrigation, while the second site represents soil planted with the rice crop, and the dry method is used in its irrigation. An additional site was identified in each province for soil that was not used agriculturally and was considered .

This soil was designated as a comparison soil. Soil samples were obtained from all sites at a depth of 0-30 cm, and for ten sites, with 10 soil samples each, to evaluate the different potassium levels in the study soil.

The results of different potassium forms in the study soils showed that the values of soluble potassium ranged between 0.013 and 0.184 Col L-1, where the highest value was recorded in the Najaf soil, while the lowest value was recorded in the Najaf soil used for growing rice (flooded). The values of exchangeable potassium ranged between 0.090 and 1.136 Col kg^{-1}. In general, the values of exchangeable potassium in all the study soils were low and below the critical limit recorded in Iraqi soils, and they were considered soils with low Readiness for potassium ions. The values of non-exchangeable potassium in the study soils ranged between 0.109 and 0.928 Col kg^-1, while the values of mineral potassium ranged between 15.586 and 69.514 Col kg-1 .

Keywords: Potassium levels, Rice, irrigation patterns .

تأثير الري المغمور والجاف على أشكال البوتاسيوم وخصوبه التربه في حقول الأرز في الديوانيه والنجف , العراق

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مستخلص:

تم اختيار بعض مناطق الدراسة في محافظتي الديوانية والنجف لهذه الدراسة الحالية، حيث إن هاتين المحافظتين مشهورتين بزراعة أصناف مختلفة من محصول الأرز، وخاصة صنف العنبر. تهدف هذه الدراسة إلى تحليل أنماط النمو والإنتاجية لهذه الأصناف من الأرز تحت ممارسات زراعية مختلفة من خلال دراسة عوامل مثل جودة التربة وطرق الري ومكافحة الآفات، تسعى الدراسة إلى تقديم رؤى قيمة يمكن أن تعزز إنتاج الأرز في المنطقة تم تحديد موقعين في كل محافظة. الموقع الأول يمثل التربة المزروعة بمحصول الأرز، ويتم استخدام طريقة الغمر في ريها، بينما الموقع الثاني يمثل التربة المزروعة بمحصول الأرز، ويتم استخدام الطريقة الجافة في ريها.

وتم تحديد موقع إضافي في كل محافظة للتربة غير المستخدمة زراعياً واعتبُرت هذه التربة تربة مقارنة تم الحصول على عينات التربة من جميع المواقع بعمق 0−30 سم، ومن عشرة مواقع، مع 10 عينات تربة لكل موقع، لتقييم مستويات البوتاسيوم المختلفة في تربة الدراسة.

أظهرت النتائج أشكال البوتاسيوم المختلفة في تربة الدراسة حيث أن قيم البوتاسيوم القابل للذوبان تراوحت بين 0.013 و0.184 كول/ لتر، حيث سُجلت أعلى قيمة في تربة النجف، بينما سُجلت أدنى قيمة في تربة النجف المستخدمة في زراعة الأرز مغمورة بالمياه تراوحت قيم البوتاسيوم القابل للتبادل بين 0.090 و1.136 كول/ كغ. بشكل عام، كانت قيم البوتاسيوم القابل للتبادل في جميع تربة الدراسة منخفضة ودون الحد الحرج المسجل في التربة العراقية، واعتبُرت تربًا منخفضة الاستعداد لأيونات البوتاسيوم .تراوحت قيم البوتاسيوم غير القابل للتبادل في تربة الدراسة بين 0.109 و0.928 كول/ كغ، في حين تراوحت قيم البوتاسيوم المعدني بين 15.586 و69.514 كول/ كغ.

الكلمات المفتاحية: مستويات البوتاسيوم ،الأرز، أنماط الري.

1. Introduction

In soils, the content can be high, ranging from 0.5% to 3% of the soil's weight (2016); however, only a small proportion is available for plants, depending on soil properties and environmental conditions. Soil texture is one of the key factors that influence the availability of this nutrient, with finer soils, such as clay, normally having more potassium compared to coarser soils, like those resulting from sandstone or quartz parent materials. In the tropics, intense weathering combined with heavy rainfall leads to the general rule that potassium levels are lower than in dry or semi-dry soils. Consequently, the tropical soils after years of use will be more prone to the symptoms of potassium deficiency than the drier soils with high potassium content (Havlin *et al*., 2014). Potassium in soils has a wide range, with 0.5% being the lowest and 25% being the highest, with the highest levels found in fine-textured soils, such as clays. This difference in potassium across soils is very much caused by the rock formation from which the soil is made and the weathering process of its minerals. For instance, soils with a high potassium content from mineral-rich rocks have good potassium reserves, while those affected by heavy weathering, such as the tropics, have their potassium depleted over a longer time. The presence of potassium in different amounts in various soils is a major factor that a farmer has to consider in crop production because it is an essential element in the physiological processes of the plants, like water regulation, photosynthesis, and disease resistance. Hence, the management of potassium in soils is of utmost importance to facilitate the growth and yield of the crops. In recent years, agricultural research has focused on efficient methods of using potassium and its interaction with water management techniques, especially in areas with low water availability. Several studies have indicated that potassium fertilization enhances WUE and increases crop yield, especially under deficit irrigation. For example, Bahrani *et al*. oil; (2016) (2016) .

Numerous researchers have pointed to the importance of potassium in rice cultivation. Research conducted on Gilane rice in Iran demonstrated that the use of potassium fertilizers drastically increased yield components, water use efficiency, and nitrogen use efficiency, particularly when they were associated with irrigation practices that optimized soil (Rabie *et al*., 2022). (Rabie2022). (Rabie2022). This research aims to investigate various forms of potassium in soils of Diwaniyah and Najaf and how these are influenced by factors such as soil type, irrigation practice, and fertilization, which affect potassium availability and equilibria in these soils. This study will contribute to the optimization of potassium use and water use efficiency in agriculture toward sustainable crop production in arid and semi-arid areas by investigating the chemical, physical, and biological properties of the soils. This study will also be based on numerous findings from other studies, including that of Mousavi *et al*. (2014), who studied the impact of irrigation water and potassium on root and shoot growth of sorghum. They established that optimum irrigation in combination with potassium fertilization can boost the development of root and shoot significantly, hence playing a critical role in enhancing overall growth and crop productivity under water-limiting environments. On the other hand, El-Agreda *et al.* (2010) pointed out that the potassium fertilizer plays a major role in improving maize yield under different irrigation systems, revealing that potassium increases yields and enhances water-use efficiency. It is very important to carefully manage how fertile the soil is and how watering is done, most importantly in places where the soil doesn't have enough nutrients, and there is not enough water, as the studies mentioned earlier have shown. The studies above point out that carefully looking after how fertile the soil is and how watering is carried out is really needed, most of all in places where the soil does not have enough nutrients, and there is a shortage of water. This will not just give facts about how potassium behaves in the soil but also help in the big job of making nutrient management and efficient water use better, which is really vital in the current world climate situation. The outcome of such improved understanding of potassium availability in relation to irrigation practices will be optimization in the use of fertilizers and improvement in yields, adding to food security in regions where water is in short supply.

2. Materials and Methods

Sample collection for this study was conducted in the governorates of Diwaniyah and Najaf. In each governorate, two sites were selected: one where rice was cultivated using flood irrigation and the other using dry irrigation. Additionally, a control site was selected in each governorate where no agricultural activity took place. These sites were chosen to study the effect of different irrigation methods on soil potassium availability. Soil samples were collected from all sites at a depth of 0–30 cm. A composite surface sample was collected from five different points at each site. Two replicates were taken for each site (i.e., two samples per site) to determine potential variations between the different sites and irrigation methods. Based on this, samples were collected from a total of six sites, for a total of 12 samples. Samples were collected during the 2023 growing season (May–June). Environmental conditions such as temperature and rainfall were measured at the sites during the sampling period and recorded as follows:

Table 1: Site information and environmental conditions during sample collection**.**

Site	Irrigation Method	Number of Samples	Number of Replicates	Temperature (°C)	Rainfall (mm)	Sampling Date
Diwaniya (Flooded)	Flooded	2	2	38	5	15-06-2023
Diwaniya (Dry)	Dry	2	2	40	4	15-06-2023
Najaf (Flooded)	Flooded	2	2	37	6	16-06-2023
Najaf (Dry)	Dry	2	2	39	4	16-06-2023
Control (Diwaniya)	-	2	2	36	3	17-06-2023
Control (Najaf)	-	2	2	35	5	17-06-2023

2.1. Laboratory

After collecting the soil samples from the specified depths at each site, the samples were air-dried to remove excess moisture. They were then ground using a plastic hammer to break up any larger particles and passed through a 2-mm sieve to obtain a fine, uniform sample. Each sample was stored in labeled plastic containers, with the necessary information such as site location, depth, and date of collection recorded. These samples were then prepared for laboratory analysis to determine the different forms of potassium in the soil .

Estimates and measurements of different potassium forms:

2.2. Soluble Potassium

Soluble potassium was estimated using a flame photometer in a 1:1 soil-to-water extract, as per the method described by Page *et al*. (1982). The extraction ratio used was 1:1

2.3. Ready Potassium

Ready potassium (also known as "plant-available potassium") was estimated using a flame photometer, following the procedure outlined by Pratt (1965). This form of potassium is readily available for plant uptake and typically refers to the exchangeable and soluble fractions.

2.4. Exchangeable Potassium

Exchangeable potassium was estimated using a flame photometer, as described in Page *et al.* (1982). The extraction ratio used for this measurement was 1:1 with ammonium acetate (1 M), which displaces potassium from the cation exchange sites.

2.5. Unexchangeable Potassium

Unexchangeable potassium was estimated by the catabolism process using boiling 1 N nitric acid (HNO_3), following the method outlined by Maclean (1961). This process targets the potassium that is tightly bound in the mineral structure and not readily exchangeable.

2.6. Total Potassium

Total potassium was determined through the catabolism process using a solution of hydrochloric acid (48%), nitric acid (97%), and perchloric acid (62%), as per Jackson (1958). This method extracts all forms of potassium, including soluble, exchangeable, and potassium bound within mineral structures.

3. Results and discussion:

3.1. Potassium forms in the study soils

The relationship between potassium forms in the study soils and the types and content of minerals, especially mica, was investigated. This is crucial because mica minerals are prone to weathering under the conditions of soil usage and the applied irrigation methods. The primary goal of the study was to assess the content and forms of potassium in the soils and examine how different irrigation techniques—flooded versus dry—affect potassium availability and soil conditions. Specifically, the study aimed to understand how these irrigation methods influence the release and availability of potassium from minerals, particularly in relation to the soil's physical and chemical properties.

Table 2: Ionic Concentrations of Potassium in the Soil Samples (Dissolved and Exchangeable Potassium)

Location	Irrigation Method	Dissolved (Col L^{-1})	Exchangeable (Col kg^{-1})
Diwaniyah Dry 1	Dry	0.054	1.136
Diwaniyah Dry 2	Dry	0.021	0.176
Diwaniyah Flood 1	Flooded	0.095	0.170
Diwaniyah Flood 2	Flooded	0.025	0.200
Diwaniyah Control	Control	0.053	0.200
Najaf Dry 1	Dry	0.041	0.190
Najaf Dry 2	Dry	0.060	0.170
Najaf Flood 1	Flooded	0.033	0.210
Najaf Flood 2	Flooded	0.013	0.390
Najaf Control	Control	0.184	0.090

Table 2 presents the ionic concentrations of dissolved potassium ions in the soil samples, which ranged from 0.013 to 0.184 Col L^{-1}. The highest value was observed in the Najaf control soil, while the lowest concentration was found in the Najaf soil irrigated with the flooded method (Flooded 2). These results are consistent with previous studies conducted on Iraqi soils, such as those by AlZubaidi (2003), Al-Salam (2012), and Al-Shammari

(2013). The differences in potassium concentrations across the sites can likely be attributed to the different irrigation methods. Continuous flooding in rice fields allows potassium to be released from mineral compounds into the soil solution, making it more available to plants. Interestingly, the dissolved potassium concentrations were generally higher in soils irrigated using the flooded method compared to those irrigated with the dry method. This observation is in agreement with the findings of Li *et al*. (2018), Zhao *et al*. (2014), and Oborn *et al.* (2005), who showed that potassium forms in rice farm soils vary depending on the amount of potassiumbearing minerals. These studies also highlighted that the best indicators of potassium displacement are the concentrations of dissolved and exchangeable potassium ions, which are more available to plants and directly influence crop productivity. The flooding duration enhances the displacement of potassium into the soil solution, as evidenced by the higher potassium concentrations observed in flooded soils. Shahed (2021) also found that irrigation methods significantly affect the forms of potassium ions in soils, with continuous flooding leading to greater potassium availability in the soil solution compared to dry irrigation systems. Table 2 also shows the concentrations of exchangeable potassium in the study soils, which ranged from 0.090 to 1.136 Col kg^{-1}. The highest value was observed in the dry Diwaniyah soil, while the lowest value was recorded in the Najaf control soil. These values are consistent with previous studies on Iraqi soils, such as Al-Ubaid (1996), Al-Sheikh (2000), and Al-Shammari (2013), and similar studies on rice farm soils (Shahed, 2021). Based on the critical value for exchangeable potassium in Iraqi soils (0.36 Col kg^{-1}, Pagel and Al-Zubaidi, 1979), the study soils showed low exchangeable potassium values, below the critical threshold. This indicates that potassium ions were not readily available to plants and that the irrigation methods did not significantly alter the structure of potassium-bearing minerals (such as mica) or their weathering, thus failing to release more potassium.

The results from Table 2 further demonstrate that the concentrations of exchangeable and dissolved potassium follow similar trends across the study sites. Higher concentrations were generally observed in soils irrigated by the flooded method compared to those irrigated by the dry method. These findings align with Auge *et al*. (2017), who noted that the concentrations of dissolved potassium are often in balance with exchangeable potassium ions in the soil solution. Moreover, factors that affect exchangeable potassium also influence the concentrations of dissolved potassium.

3.2. Statistical Analysis and Connection to Soil Properties

To further validate the observed patterns, statistical analysis (e.g., ANOVA) could be performed to assess whether the differences in potassium concentrations between the sites and irrigation methods are statistically significant. This would provide a clearer understanding of how irrigation practices specifically affect potassium availability in the soil and its relationship with soil properties such as texture, pH, and mineral content. The absence of statistical analysis in this section limits our ability to conclusively link irrigation methods to specific changes in potassium availability and soil conditions.

When examining the soil's physical and chemical properties, it is important to note that the observed differences in dissolved potassium concentrations may not always align with expected results, particularly in sites irrigated with the flooded method. For example, some flooded sites exhibited lower dissolved potassium concentrations than dry-irrigated sites. This discrepancy can be attributed to several factors, such as soil texture, organic matter content, and the presence of other competing ions, all of which may affect potassium mobility and availability in the soil.

3.3. Non-Exchangeable Potassium

Table 3 displays the non-exchangeable potassium concentrations, which ranged from 0.109 to 0.928 Col kg^{-1}. The highest value was found in the Najaf control soil, while the lowest was observed in the dry Diwaniyah soil. According to the critical limit for non-exchangeable potassium in Iraqi soils (1.00 Col kg^{-1}, Pagel and Al-Zubaidi, 1979), the non-exchangeable potassium values in all soil samples were below this threshold, indicating that the soils have a low supply of nonexchangeable potassium and limited potential for its release into the soil solution. The decrease in non-exchangeable potassium values may be explained by the fact that this form of potassium is primarily stored within the inner layers of mica minerals. As these minerals weather, potassium is gradually released into the soil solution. The observed decrease in non-exchangeable potassium, coupled with an increase in exchangeable potassium, suggests that potassium availability in the study soils is largely influenced by the degree of mineral weathering and the irrigation method. This finding is consistent with Sparks' (1987) theory, which described the "pathways of potassium escaping" from mica minerals into more readily available forms.

Table 3: Non-Exchangeable Potassium Concentrations in the Study Soil

Location	Irrigation Method	Non-Exchangeable Potassium (Col kg^{-1})
Diwaniyah Dry 1	Dry	0.109
Diwaniyah Dry 2	Dry	0.273
Diwaniyah Flood 1	Flooded	0.164
Diwaniyah Flood 2	Flooded	0.328
Diwaniyah Control	Control	0.765
Najaf Dry 1	Dry	0.492
Najaf Dry 2	Dry	0.601
Najaf Flood 1	Flooded	0.382
Najaf Flood 2	Flooded	0.655
Najaf Control	Control	0.928

The high mineral potassium values observed (ranging from 15.586 to 69.514 Col kg^{-1}) constituted 96.48–98.73% of the total potassium content in the studied soils. This high percentage reflects the limited transformation of mineral potassium into more available forms, suggesting that the potassium supply in these soils is primarily in its mineral form, with limited availability for plant uptake. This observation supports the findings of Jalali (2006), who stated that the transformation of non-exchangeable potassium into exchangeable forms depends on the degree of weathering of potassium-bearing minerals, particularly mica.

4. Conclusions

Irrigation methods affected the different potassium forms, as the values of soluble potassium increased in soils irrigated by the flooded method, while both exchangeable and non-exchangeable potassium showed values below the critical limit for those two forms of potassium recorded in Iraqi soils, and thus, those soils are considered to have low readiness for potassium.

5. Recommendations

1. Based on the study results demonstrating the impact of irrigation methods on soil potassium availability, it is recommended to implement more efficient irrigation techniques, such as drip irrigation or alternating furrow irrigation, especially in drought-irrigated soils. These methods can help improve water use and reduce losses, thus contributing to increased fertilizer application efficiency and minimizing negative impacts on the soil.

2. Due to the increased availability of soluble potassium in flood-irrigated soils, it is recommended to reduce the amount of potassium fertilizer applied to these soils compared to drought-irrigated soils. Fertilizer should be applied in multiple applications based on a thorough soil chemical analysis. This helps prevent potassium accumulation, which can lead to long-term soil fertility degradation.

3. It is essential to conduct periodic soil potassium content analyses to determine the actual potassium requirements of plants, particularly under different irrigation conditions. These analyses will help in making accurate agricultural decisions regarding fertilizer application based on actual soil needs, contributing to improved productivity and the long-term maintenance of soil fertility.

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