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Effect of Partial Root-Zone Drying Irrigation and Potassium Fertilizer on Water use Efficiency, Growth and Yield of Cowpea (*Vigna Unguiculata* L.) in Gypsiferous Soil

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ABSTRACT: A field experiment was carried out to study the effect of partial root-zone drying Irrigation and Potassium on water use efficiency, growth, and yield of Cowpea (Vigna unguiculata L.) in gypsiferous Soil, at the experimental station of the College of Agriculture, Tikrit University, located at 34°40 49 and 43° 38 40 longitude and 129m above sea level. The experiment was conducted with a randomized complete block design (RCBD) with two factorial combinations, irrigation and potassium fertilizer. the first treatment, irrigation with 100% water requirement, was added to two sides of the root zone along the growth season. Second irrigation treatment with 50% water requirement alternately for each side during the growth season. Third irrigation treatment requires 50% of the water requirement for one side of the growth season. The second factor was potassium fertilizer which added the doses 0, 100, 200, and 300 kg k ha^{-1} for each treatment. the best results were. The highest water consumption was1163.50 mm $season^{-1}$ with full irrigation treatment, the lowest water consumption was566.45 mm with alternative partial zone irrigation, and the treatment of full irrigation with 300 kg k ha^{-1} give the highest results in $seeds.pod^{-1}$, number of $pods.plant^{-1}$, Pods Wight, plant (vegetative part), root weight, and Seed yield. highest water use efficacy was 1.69 % with alternative partial zone irrigation and 300 kg k ha^{-1}.

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KEYWORDS: PRD Irrigation, Potassium Fertilizer, water consumption use, Cow bea, gypsiferous soil.

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INTROUCTION

Water scarcity and drought are the main factors hindering increased agricultural crop production in the arid and semi-arid regions of the world. In recent years, irrigation has been the main consumer of fresh water on earth. Therefore, by improving irrigation water management, it is possible to conserve water, and soil and meet the community's needs for food and industrial crops. Thus, agriculture has an important role in solving the problem of water scarcity (Katohar *et al.,* 2023; Rathore *et al.*,2024), Various techniques have been used in water management in this area, including deficit irrigation "DI" Which is a method used in Agriculture production in regions that suffered of water scarcity without causing a significant decline in agriculture productivity (Kirda *et al.*, 2007)

Partial root-zone drying (PRD) is another method that has been also developed based on this method, which is commonly applied as part of a deficient irrigation program because it does not require adding more than 50-70% of the water requirement used in the full irrigation program as well as achieving the goal of increasing water productivity Marsal *et al.*, (2008) also mentioned that exposing plant roots to water stress stimulates them to send signals through the formation of the hormone abscisic acid (ABA) to the vegetative part to control the closure of stomata as a response to the drought state of the soil. As partial closure of the stomata occurs, the plant tissues are protected from losing their water content by regulating the transpiration process. This later leads to water conservation, and when the other part of the roots are given sufficient water needs, plant growth and production are not affected. Abscisic acid has an important role in the physiological processes of the plant, via two directions. It acts as a chemical signal when it is secreted by the roots, and it is considered a hydraulic signal when it is transported with water in the xylem to the vegetative part, and through the two chemical indicators. The hydrological processes of plants are regulated under drought conditions (Kang *et al.*, 2002), Therefore, alternating drying helps to false the sense, as one part of the root zone is exposed to drought while the other area is irrigated. Thus, the same results from drought are obtained from the release of ABA, this process of reducing the expansion of leaves and regulating the opening and closing of stomata, and this leads to an increase in water use efficiency (Liu *et al.*, 2013).

Fertilization is one of the factors that has a major impact on increasing the productivity of various crops and improving their quality, especially in low fertility. Adding nutrients is also important to increase the economic output of the crop per unit of the cultivated area itself (Iqbal *et al.*,2021; Yildirim *et al.*,2022), Potassium has a vital role in the process of photosynthesis, the transfer of the products of photosynthesis, protein synthesis, controlling ionic balance, regulating the opening and closing of plant stomata, water use, and the effectiveness of plant enzymes, in addition to many other processes (Reddy *et al.*, 2004). Potassium is also an essential element in maintaining osmotic balance, so plants that grow in drought conditions accumulate potassium ions in their tissues, which plays a role in absorbing water despite the plant being water-stressed. Increasing levels of abscisic acid in drought conditions stimulates the release of Potassium, which leads to the closer of stomata (Sangakkara *et al.*,2001).

Cowpea are one of the leguminous crops that gain great nutritional importance due to their high protein content. They are used in both human and animal food and are grown in a wide range of soils, and climatic and environmental conditions. Cowpea cultivation has great economic importance, due to its ability to adapt to different climatic, environmental, and soil conditions, in addition to the low production cost and high nutritional value. It is an excellent source of proteins and carbohydrates. (Saravanan *et al.*, 2023).

From an agricultural perspective, gypsiferous soils are soils that contain an amount of gypsum ($CaSO_4.2H_2O$) which influences plant growth (Ismaeal *et al.*, 2024). From anther land, 5.42 million hatares are located in Iraq (study area) and constitute about 12% of the total area of Iraq and 38% of the total arable land (Al-Kayssi and Mustafa, 2016). It is characterized by poor soil structure and deterioration of its physical properties and ability to retain water (Al-Kayssi,2022 ., Al-Juboori *et al.*, 2023). It is also characterized by its weakness in terms of chemistry and fertility (Al-Jumaily *et al.,* 2022 ; Ismaeal,2022).

Therefore, this study aims to determine the effect of partial drying of the root zone and potassium fertilization on the growth, yield, and water consumption of cowpea (Vigna unguiculata L.) under gypsiferous soil conditions.

MATERIAL AND METHODS

Study area and samples collection

A field experiment was carried out on gypsiferous soil (90 gm kg^{-1}) to study the effect of partial root-zone drying irrigation and Potassium Fertilizer on water use efficiency , growth and yield of cowpea (*Vigna unguiculata* L.) cultivar Bayader Almokhtar Production Golden land company during the 2022 summer season in the research station of Agriculture College, Tikrit University, which is located on Latitude 49° 40′ 34″ North and Longitude 40° 38′ 43″ East At an altitude of 129 m above sea level. Soil samples at a depth of 0-0.3 m were taken from five sites of the field designated for the study before planting to estimate some physical and chemical properties of the soil according to Bremner (1965) and Black (1965) fot soil had 3.4 mm cm^{-1} field moisture capacity (FMC) at 33 kPa, 1.2 mm/cm permanent wilting point moisture at 1500 kPa, 2.2 mm/cm available water capacity,1.38 g cm^{-3} bulk density, 1.7 dS m^{-1} electrical conductivity (EC), 7.18 pH, 5.6 g kg^{-1} organic carbon (SOC), 0.6 g kg^{-1} total N, 122 g kg^{-1} carbonate minerals, 47 mg kg^{-1} available N, 4.8 mg kg^{-1} available P, 14 mg kg^{-1} extractable K, 7 cmolc kg^{-1} cation-exchange capacity, and 4.7, 4.2, 1.62, 3.5, 6.2, 5.6, 0.6, and 1.8 mmol/kg water-soluble Mg, Na, K, Ca, Cl, SO_4, CO_3 and HCO_3, respectively.

The field was leveled and divided into three main sectors. The experiment's field was plowed and divided into three main blocks, and divided into planks with dimensions of 3 × 3 m. Seeds were planted at distance 0.25 m between plants and 0.50 m between two rows. Planting date was the 16^{th} of October 2021 by using three seeds in each hole. The two plants were thin two weeks after emergence. The experiment included three irrigation coefficients, as shown in table 1, NP fertilizer was added as urea (46% N), Super Phosphate (21% P), 50,100 and 60 kg K ha^{-1} respectively for all treatments when planting, potassium fertilizer added as potassium sulfate (43% K), it was added according to the treatments listed in a table 1, Randomized Complete Block Design was used with three repetitions. The data were statistically analyzed and the means were compared to the least significant difference (L.S.D) test at the 5% level.

The experiment was established in completely randomized design with two factorial combinations of irrigation and potassium fertilizer. While treatment I_1 of irrigated when 100% of the of the water requirement, Irrigation water is added to two side of the root zone along of the growing season, I_2 of irrigated when 50% of the of the water requirement, Irrigation water is added to two side of the root zone alternately for each side along of the growing season, I_3 of irrigated with 50% of the of the water requirement, Irrigation water is added to one side of the root zone along of the growing season . and potassium were applied at 0, 100 , 200 and 300 kg k ha^{-1} of soil .

Calculation of irrigation water

T-tape drip irrigation method has been used by two irrigation lines on either one or two side of the planting line at a distance of 10 cm from the planting line The irrigation water depths were defined based on reference evapotranspiration

values (ET_o) obtained by the pan Class A method and the crop coefficients (K_c) , The field water use efficiency (WUE_C) was calculated using the following equation (Hansen et al., 1980):

WUEc = Y/ ETa

Where,WUE_c represents crop water use efficiency (kg m^{-3}), Y: total seed yield (kg),

ET : was evapotranspiration (Calculated based on evaporation from the evaporation pan class A) (M^3 season $^{-1}$).

Multivariate statistical analyses were performed using SAS® for the growth and yield parameters, nutrient uptake, N and water-use efficiency attributed to the compost, biochar and irrigation, and their interactive effects. irrigation and potassium fertilizer. 2-factorial analysis of variance (ANOVA). The data were statistically analyzed and the means were compared to the least significant difference (L.S.D) test at the 5% level.

RESULTS AND DISSCUSION

water consumption (mm season^{-1}) of cowpea

The water consumption of the bean crop varied with the amount of added irrigation water (Table 1) and arrangement of irrigation treatment: $I_2 < I_3 < I_1$.

Water consumption amount with reduce as the level of potassium fertilizer increase water consumption reached its highest value of 1268.2 mm for the treatment I_1 K_0 (traditional irrigation treatment with full water requirements), and the constant partial drying treatment with a 50% (I_2 K_3) lack of irrigation gave the lowest value for water consumption of 501.6 mm . Applying the partial drying method to the root zone gave the lowest values for the depth of added water as well as reducing the number of irrigations during the growing season, which led to a reduction in the total depth of added water compared to other irrigation treatments (Alrajhi et al,2015., Iqbal et al,2021) , Also, increasing the level of added potassium fertilization reduced the plant's water consumption. This is due to the role of potassium in creating a balance in the opening and closing of the stomata in the leaf, which subsequently reduces water consumption (Mrunalini et al,2024)

Table 1: Effect of partial root-zone drying Irrigation and Potassium Fertilizer on water consumption (mm season^{-1}) of cowpea

Variables	K_0	K_1	K_2	K_3	Mean
I_1	1268.2	1205.6	1137.4	1042.8	1163.50 a
I_2	622.5	589.5	552.2	501.6	566.45 c
I_3	634.0	604.2	570.5	522.4	582.77 b
Mean	841.56	799.76	753.36	688.93	
LSD 0.05		I = 4.25	K = 5.72	I * K = 7.15	

plant height (cm) of cowpea

Fig. 1 shows the Effect of partial root-zone drying Irrigation and Potassium Fertilizer on plant height (cm) of cowpea , The full irrigation treatment chives a significant highest compered the alternative partial treatment and fixed partial irrigation treatments with an increase of 5.63 and 25.09 % respectively The increase in the mean length of the plant when alternating partial drying was applied compared to constant drying in which it was not applied can be attributed to the role of alternating partial drying in increasing the secretion of abscisic acid in the roots, which subsequently works to reduce water loss from the plant by partially closing the stomata and thus reducing the negative effect of water stress on plant growth compared to constant stress (Kang and Zhang, 2004) K_3 also gave highest mean of plant height 48.95 cm It was better than all other potassium fertilization treatments by an increase of 28.78 , 16.27 and 7.81 for K_0 , K_1 and K_2 .

As for the interference treatments, the I_1 K_3 treatment gave the highest rate of plant height 55.16 cm. Among the good results of the interaction treatments, there was no significant difference between I_1 K_2 and I_2 K_3 This shows the role of added potassium in regulating water loss from the plant and the role of partial drying in reducing the water requirements of crops these reasons affected the length of the plant

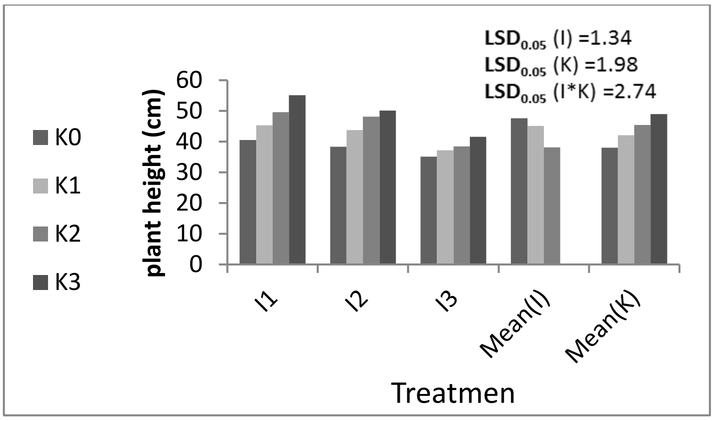

Fig. 1. the Effect of partial root-zone drying Irrigation and Potassium Fertilizer on plant height (cm) of cowpea

- **Number of seeds.pod^{-1} number of pods.plant^{-1}, Pods length and Pods Wight**

Fig. 2 (a,b,c and d) shows the Effect of partial root-zone drying Irrigation and Potassium Fertilizer on seeds.pod^{-1}, number of pods.plant^{-1}, Pods length and Pods Wight of cowpea , The full irrigation treatment outperformed the partial, and fixed root zone irrigation A decrease in the amount of irrigation water beyond water needs leads to weak plant growth and a decrease in the process of photosynthesis, which affects the reduction of plant biomass (Blum, 2009).

The effect values of potassium fertilizer levels were arranged as follows: $K_3 > K_2 > K_1 > K_0$. Potassium is necessary for plant growth, as increasing the level of potassium fertilization increases the process of photosynthesis and respiration, which increases the accumulation of carbohydrates, and thus increases various plant characteristics (Costa et al , 2023).

As far as concerned the interference treatments, the I_1 K_3 treatments gave the highest rate of all plant characteristics in the fig. 1 , Among the good results of the interaction treatments fig. 1 (a,c and d) , there was no significant difference between I_1 K_2 and I_2 K_3 As I_2 K_2 and I_1 K_3 in fig. 1(d) This shows the role of added potassium in regulating water loss from the plant and the role of partial drying in reducing the water requirements of crops

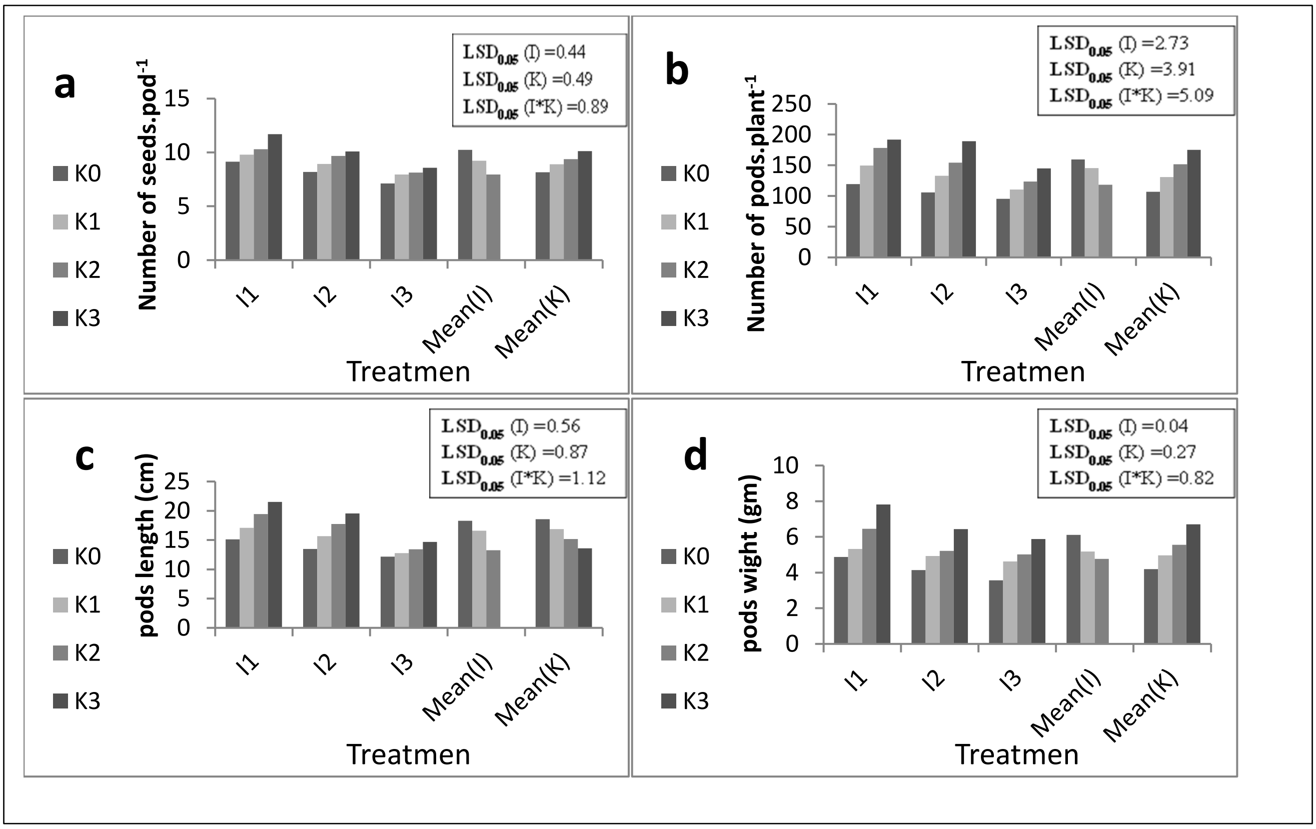

Fig. 2. the Effect of partial root-zone drying Irrigation and Potassium Fertilizer on (a) seeds.pod^{-1} ,

(b) number of pods.plant^{-1} ,(c) Pods length and (d) Pods Wight of cowpea.

Table 3: Effect of partial root-zone drying Irrigation and Potassium Fertilizer on Number of seeds.pod^{-1} of cowpea

Variables	K_0	K_1	K_2	K_3	Mean
I_1	9.13	9.81	10.31	11.71	10.24
I_2	8.20	8.94	9.67	10.09	9.22
I_3	7.12	7.95	8.13	8.57	7.94
Mean	8.15	8.90	9.37	10.12	
LSD 0.05		I = 0.44	K = 0.49	I * K = 0.89	

Shoot dry wight (g)

Fig. 3. (a) Shows the Effect of partial root-zone drying Irrigation and potassium fertilizer on many shoot dry weight of cowpie. The traditional full-quantity irrigation treatment outperformed the partial, alternative, and fixed irrigation with an increase of 21.34 and 9.91 % respectively Increasing the level of irrigation affects the growth of the plant naturally, increases its physiological activity, and increases the process of photosynthesis, which affects the increase in the accumulation of dry matter of the shoot and its increase in weight (Khairo, 2024)

K3 also gave 44.38 gm mean of shoot dry weight It was better than all other potassium fertilization treatments by an increase of 33.23, 17.90, and 7.92 for K_0, K_1, and K_2 respectively Potassium is one of the necessary elements for plant growth, as increasing the level of potassium fertilization increases the process of photosynthesis, increases the accumulation of carbohydrates, and increases the weight of the shoot. (Costa et al, 2023) .

As far as concerned to the interference treatments, the I1 K3 treatment gave the highest rate of plant weight at 48.59 gm, We can also mention another good result, the difference was not significant between I1 K2 and I2 K3 this is due to the role of added potassium in regulating water loss from the plant and increasing enzymatic activity as well as the role of partial drying in reducing irrigation water and providing water needs for crops at the same time these reasons affected the length of the plant.

Root dry weight (gm)

Fig.3.(b) Shows the Effect of partial root-zone drying Irrigation and potassium fertilizer on the root dry weight of cowpies. The difference was not significant either between full irrigation and partial alternating drying, and or between alternating and constant partial drying. The full-quantity irrigation treatment outperformed the partial fixed irrigation, with an increase of 27.28 % The increase in root spread in the full irrigation treatment and its decrease in growth in other treatments can be attributed to the fact that keeping part of the soil continuously moist during the growing season can limit and reduce the growth of the root system in a way that leads to the spread of roots in the moist surface layer only (Mcmichael and Quisenberry, 1993).

K3 also gave a 9.39 gm mean of root weight. it was better than all other potassium fertilization treatments except K_2, by an increase of 52.68 and 27.75 for K_0 and K_1 respectively Increasing the level of potassium fertilization stimulates the formation of strong and widespread roots in the soil by stimulating the formation of sclerenchyma cells and increasing the thickness of the roots, and this has an effect on the weight of the roots (Adepetu and Akapa , 1977).

As far as the interference treatments were, the I1 K3 treatment gave the highest rate of pods with 10.17 gm Another important result was that the difference was not significant between I1 K2 and I2 K3 this is due to the effect of potassium fertilizer in controlling the work of the stomata in the leaves and water loss from the plant and increasing the enzyme activity as well as the role of partial drying in reducing irrigation water and providing the water needs of crops at the same time these reasons affected the dry weight of the roots.

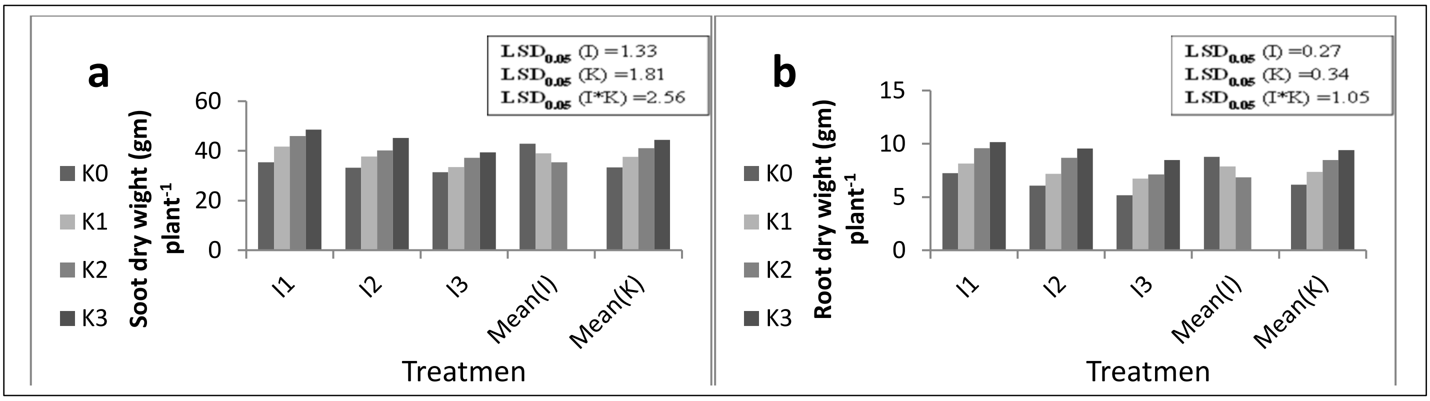

Fig. 3. Effect of partial root-zone drying Irrigation and potassium fertilizer on (a) shoot dry wight ,(b) root dry wight of cowpea

Seed yield (ton. ha^{-1}) of cowpea

Table 2. shows the Effect of partial root-zone drying Irrigation and Potassium Fertilizer on Seed yield of cowpea , The difference was not significant between full alternating partial root zone drying,. The treatment of full irrigation and alternating partial drying was significantly superior compared to fixed partial drying with an increase of 68.12 and 67.99 % respectively Good management of alternating partial drying can achieve the best results while saving at least 50% of irrigation water (Al-Kayssi, 2023., Khairo, 2024). Increasing irrigation water also leads to increased plant growth and increased dry matter accumulation. Rotating irrigation can also be one of the means of increasing production when there is a scarcity of water resources (Igbadun et at, 2008)

K_3 also gave 7.591 ton. ha^{-1} mean of seeds yield, it was better than all other potassium fertilization treatments, by an increase of 23.57, 15.55 and 13.07% respectively Increasing the yield components with potassium fertilizer increase in resulting from an increase in the process of photosynthesis, respiration, and enzymatic activity which led to an increase in yield (Sangakkara et al, 2001., Costa et al, 2023). As far as concerned to the interference treatments, the I_1 K_3 treatment gave the highest rate seeds yield was 8.6591 ton.ha^{-1} but difference was not significant between this treatment with I_1 K_2 and I_2 K_3 this is perhaps one of the most important results that can be obtained when applying the partial drying method with potassium fertilization in the appropriate amount for the plant.

Table 2. Effect of partial root-zone drying Irrigation and potassium fertilizer on seed yield (ton. ha^{1}) of cowpea

Variables	K_0	K_1	K_2	K_3	Mean
I_1	6.924	7.691	8.266	8.659	7.885 a
I_2	7.637	7.543	7.854	8.484	7.879 a
I_3	3.868	4.475	4.786	5.632	4.690 b
Mean	6.143 d	6.569 c	6.968 b	7.591 a	
LSD 0.05		I = 0.23	K = 0.54	I * K = 0.88	

water use efficiency (%) of cowpea

Table 3. shows the Effect of partial root-zone drying Irrigation and Potassium Fertilizer on the Seed yield of cowpeas, The alternating partial root-zone drying Irrigation treatment gave the highest water use efficiency was 1.40 % compared to partially fixed root-zone drying Irrigation and full irrigation treatment, is known that the water use efficiency for the crop is the result of dividing the seeds yield on the amount of water irrigation because alternating partial root-zone drying Irrigation treatment received half the total amount of water of the full irrigation treatment and gave a same result to full irrigation, it gave best result (Blum, 2009.,Khairo, 2024).

K3 also gave a 1.19 % mean of water use efficiency It was better than all other potassium fertilization treatments, This result can be attributed to the role of potassium fertilizer in increasing yields, and role in reducing the amount of irrigation water due to the impact of potassium in controlling the opening and closing of stomata (Sangakkara et al, 2001)

As for the interference treatments, the I1 K3 treatment gave the highest rate seed yield 8.6591 ton. ha^{-1} this is attributed to the role of irrigation and potassium in increasing plant growth.

Table 3. Effect of partial root-zone drying Irrigation and Potassium Fertilizer on water use efficiency (%) of cowpea

Variables	**K_0**	**K_1**	**K_2**	**K_3**	**Mean**
I_1	0.54 k	0.63 i	0.60 j	0.83 g	**0.65 c**
I_2	1.22 d	1.27 c	1.42 b	1.69 a	**1.40 a**
I_3	0.61 j	0.74 h	0.83 g	1.07 e	**0.81 b**
Mean	0.79 d	0.88 c	0.95 b	1.19 a	
LSD 0.05		I = 0.03	K = 0.07	I * K = 0.15	

Concentration N , P , K and protein % in seeds of cowpea

Fig. 4. shows the effect of partial root-zone drying Irrigation and potassium fertilizer on concentration N , P , K and protein % in seeds of cowpea the full irrigation treatment outperformed the partial, and fixed root zone the reason for the increase in the content of nitrogen, phosphorus and potassium in the plant with increasing irrigation levels may be the increase in moisture supply in the root zone. It may also be the result of increased spread of the root system due to the availability of moisture, which increases better absorption of nutrients from the soil. (Campbell et al., 1977). The effect values of potassium fertilizer levels were arranged as follows: $K_3 > K_2 > K_1 > K_0$

Regarding nitrogen and protein, potassium fertilizers greatly help in absorbing nitrogen, and the enzymatic activity of potassium is important in converting nitrate into ammonia to form amino acids, which are the basis for the formation of protein, Potassium fertilization also increases the efficiency of using nitrogen fertilizer (Geetha and Varughese ,2001 .,Symanowicz et al, 2018) . In general, the presence of potassium fertilizer with nitrogen and phosphorus leads to the formation of a strong and widespread root system that helps increase its efficiency in absorbing nutrients from the soil, in addition to the role of potassium in increasing root thickness because it stimulates the formation of sclerenchyma cells that increase its resistance to diseases and unsuitable soil conditions. Potassium and phosphorus together help transport the products of photosynthesis to storage places in the plant (Adepetu and Akapa , 1977).

As for the interference treatments, the I_1 K_3 treatment gave the highest rate of For all plant characteristics in the Fig. 4 (a,b,c and d) maybe because providing the plant with full water requirements along with the highest potassium fertilization played a role in increasing the plant’s content of nutrients and protein.

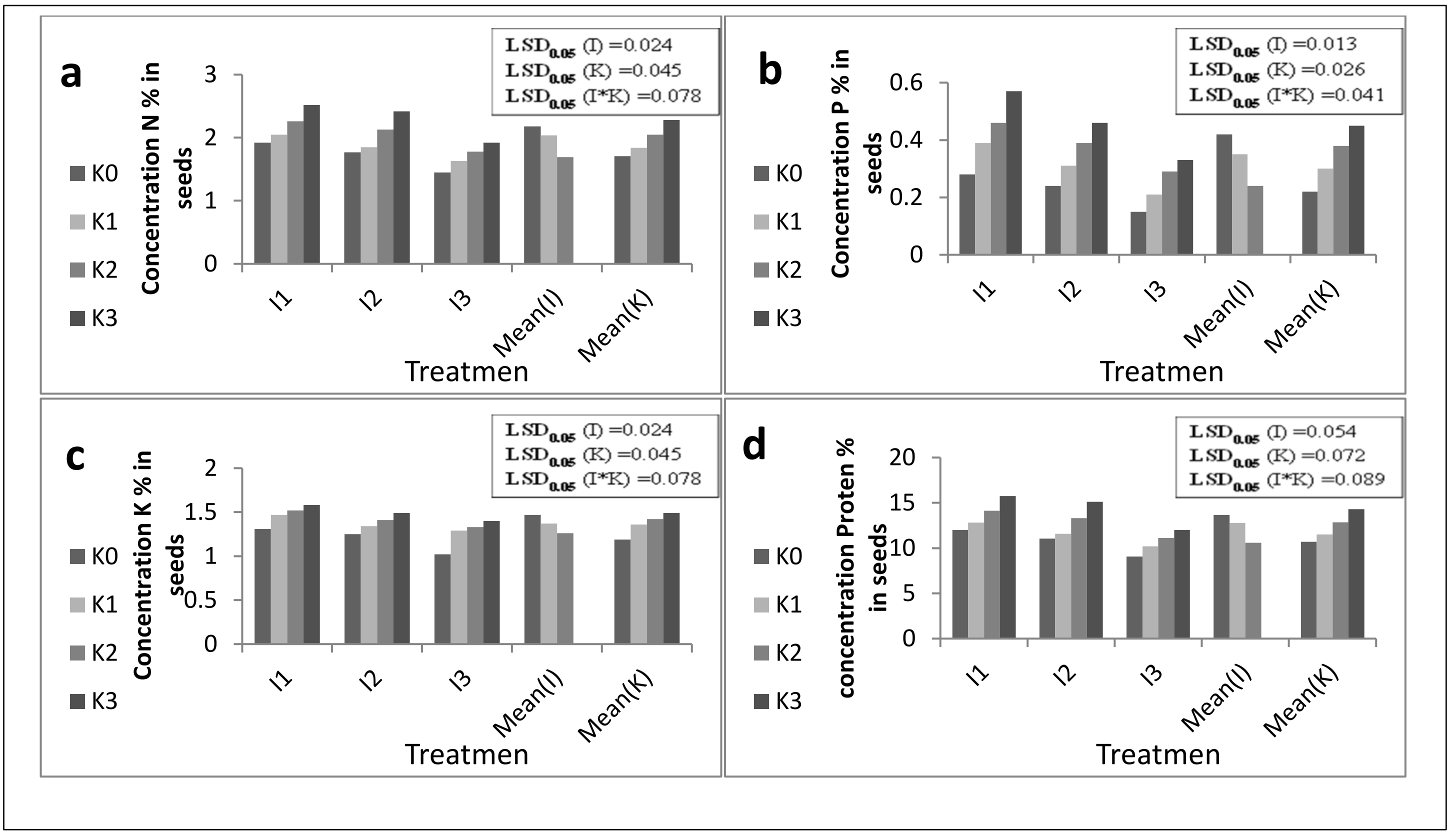

Fig. 4. the Effect of partial root-zone drying Irrigation and potassium fertilizer on concentration (a) N% (b) P % (c) K% and (de) protein % in seeds of cowpea

CONCLUSION

Partial and alternating drying irrigation could save half the amount of irrigation water used without having a major impact on the cowpea yield. The positive effect of alternating drying is greater in the conditions of gypsum soils, which suffer from a weak ability to retain water.This positive water saving can be better with potassium fertilization, which improves growth characteristics and yield.

CONFLICT OF INTEREST

The author declare no conflicts of interest associated with this manuscript.

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