Bionatura
Latin American Journal of Biotechnology and Life Sciences

Bionatura Issue 3 Vol 8 No 1 2023

Article

Effect of Partial Drip Irrigation Methods on Soil Moisture and Water Potential Distribution, Growth Characteristics and Yield of Maize

Saja M. Ahmed[1], and Tareq K. Masood[2*]
[1]Department of Agricultural Research, Ministry of Agriculture, Iraq.
[2]Department of Soil and Water Resources, College of Agriculture Engineering Science, University of Baghdad, Iraq. *Correspondence: tareqmasood@coagri.uobaghdad.edu.iq

Abstract
A field experiment was conducted during the autumn of 2021 at the Agricultural Research Department station / Abu Ghraib to evaluate the soil moisture, water potential distribution, and growth factors of maize crops under alternating and constant partial drip irrigation methods. In the experiment, two irrigation systems were used, surface drip irrigation (DI) and subsurface irrigation (SD); under each irrigation system, five irrigation methods were: conventional irrigation (CI), and 75 and 50% of the amount of water of CI of each of the alternating partial irrigation APRI75 and APRI50 and the constant partial irrigation FPRI75 and FPRI50 respectively. The results showed that the water depth for conventional irrigation (C1) was 658.3 and 579.4 mm for the DI and SD irrigation systems, respectively, and the irrigation depth was reduced to 18% when applied APRI75 and FPRI75 and 37% when applied APRI50 and FPRI50 respectively. The moisture distribution differed according to the irrigation method, and the SD provided a higher moisture content and lower water potential due to the lower evaporation rate from the soil surface. Also, the growth traits of maize varied according to the irrigation system and its methods. The SD system was significantly superior in the grain yield of maize with an increase of 5.4% compared with DI, and the alternating partial irrigation treatments were significantly superior to the constant partial irrigation.

Keywords: Matric suction, Zea mays L., irrigation system, irrigation depth.

Introduction

Climate change is one of the most essential reasons threatening global food security, especially in arid and semi-arid areas. One of the adverse effects of climate change is the scarcity of rain, as it does not meet water needs, especially in the agricultural sector, which is the largest consumer of water[1]; which prompted those interested in irrigation to pay attention to the provision of water and the optimal use of this resource by knowing and determining the water needs of crops, determining the amount of water to be added and reducing the losses[2,3] In addition to the use of irrigation methods and strategies to reduce water wastage in the agricultural sector as well as maintaining production. Thus, partial root-zone irrigation was introduced[4,5], a type of incomplete irrigation aimed at water conservation, improving the efficiency of its use and reducing water consumption, especially evaporation from the soil surface[6,7,8] without causing a large amount of production[9].

This method is based on alternating or constantly wetting half of the root system and keeping the other half exposed to drought, conserving 50% of irrigation water[10].To raise the water use efficiency, it was necessary to use efficient irrigation systems that reduce water wastage, and these systems include modern irrigation technologies such as drip irrigation systems, as it is one of the latest irrigation methods that have been used and spread in many regions of the world, predominantly arid and semi-arid areas that suffer from water scarcity and salinity problems, as loss rates by evaporation, deep permeation and runoff are reduced to the lowest possible. Hence, drip irrigation efficiency is higher than other irrigation methods[11]. In recent years, surface drip irrigation systems (DI) and subsurface drip irrigation (SSDI) have been used in some dry areas. Subsurface drip irrigation has been defined as a system for adding water and nutrients below the soil's surface near the plants' roots. It is direct irrigation in the root zone for better water conservation and reduced water consumption, especially the evaporation rate of the surface layer[12,6].

This system is affected by the soil texture, the type of plant, the unsaturated water conductivity, and the extent of groundwater's contribution to the root zone's wetting, as these factors determine the position of the drips under the soil surface. The study aims to know the moisture distribution as a function of irrigation time, the water potential distribution during the soil profile, and its effect on the growth traits of maize.

Materials and Methods

A field experiment was conducted during the autumn of 2021 at the Agricultural Research Department station / Abu Ghraib in sedimentary soil to evaluate the moisture distribution, water potential, and growth factors of maize crops under alternating and constant partial drip irrigation methods. Selected soil physical and chemical properties are shown in Table 1.

Soil Property	Value
Sand($g\ kg^{-1}$)	349
Silt($g\ kg^{-1}$)	474
Clay ($g\ kg^{-1}$)	177
Soil texture	Loam
Bulk density ($Mg\ m^{-3}$)	1.37
Field capacity($cm^3 cm^{-3}$)	0.36
Permanent wilting point($cm^3 cm^{-3}$)	0.12
Available water ($cm^3 cm^{-3}$)	0.24
$EC_{1:1}$	3.3
Soil pH	7.5

Table 1: Some physical properties of soil.

The experiment included the use of two irrigation systems and five irrigation methods:

1. Irrigation Systems: Surface drip irrigation system (DI) and subsurface drip irrigation system (SD).

2. Irrigation methods, including CI = conventional irrigation, APRI75 =alternating partial irrigation of the root zone by adding 75% of the amount of water of CI and alternately on both sides of the plant, APRI50 =alternating partial irrigation of the root zone by adding 50% of the amount of water of CI and alternately on both sides of the plant, FPRI75 = constant partial irrigation of the root zone by adding 75%

of the amount of water of CI and steadily to one side of the root system and FPRI50 = constant partial irrigation of the root zone by adding 50% of the amount of water of CI and steadily to one side of the root system.

Chemical fertilizers were added before planting according to fertilizer recommendation[13] (250 Kg N ha^{-1}, 88 Kg P $ha^{-1,}$ and 125 Kg K ha^{-1}). Maize seeds were planted in experimental units. The area of the experimental unit was 40 m^2 (5 m × 8 m) on 03 Aug. 2021. The experiment was conducted according to the design of the split-plot. The main plots included two irrigation systems, while the subplots included five irrigation methods at three replications. The soil water content was measured using the gravimetric method before and after irrigation throughout the growing season according to the depth of the added water (d mm) from the following equation[14]:

$$d = (\theta_{FC} - \theta_i)D \quad \textbf{(1)}$$

As:

fcθ= Field capacity (cm^3 cm^{-3})

iθ= moisture content before irrigation (cm^3 cm^{-3})

D = depth of the root system (mm)

The moisture content was estimated at each of the stress used, and the Van Genuchten (1980) equation was used to describe the volumetric moisture content relationship (θ) as a function of the potential stress (ψ):

$$\theta = \theta_r + \frac{(\theta_s - \theta_r)}{\left[1 + (\alpha h)^n\right]^m} \quad \textbf{(2)}$$

Water potential was estimated in the different experimental treatments after irrigation and before the subsequent irrigation by estimating the moisture content and the corresponding water potential according to Van Genuchten's (1980) equation to describe the relationship between water potential (h) and water content (θ) to correspondent the data of the moisture description curve and obtaining correspondent functional factors.

$$h(\theta) = \frac{\left[\left(\frac{\theta - \theta_r}{\theta_s - \theta_r}\right)^{-1/m} - 1\right]^{1/n}}{\alpha} \quad (3)$$

Leaf area (cm^2) was estimated according to Solaimalai et al., (2020) equation:

$$LA = (L \times W) \times 0.75 \quad (4)$$

As:

LA = Leaf area

L = leaf length

W = leaf width

0.75 = Constant

Crop growth rate (g m^{-2} day^{-1}) was calculated using following equation[15]:

$$CGR = \left[\frac{1}{GA}\right] \times \left[\frac{(W_2 - W_1)}{(T_2 - T_1)}\right] \quad (5)$$

As:

CGR = Crop growth rate

GA = area occupied by the plant (m^2)
W_1 and W_2 = Dry weight (g) in the first and second stages, respectively
T_1 and T_2 = Measurement date of the first and second stages, respectively.

Results

Depth irrigation

The results in Table (2) show that the amount of added water to the maize in the DI irrigation system treatment was CI685.28 mm season^{-1}, while the amounts of added water in the APRI and FPRI irrigation treatments which received 75% and 50% of the total added water were CI559.5 and 433.6 mm season^{-1}respectively. The amount of water for these treatments at the 75% and 50% irrigation levels decreased compared with CI irrigation treatment at 18.4 and 36.7%, respectively. Regarding the SD irrigation system, the amount of added water was 579.3 mm season-1 and 475.9 and 372.5 mm season^{-1} for APRI and FPRI, respectively, which decreased at 17.9 and 35.7%, compared with CI treatment.

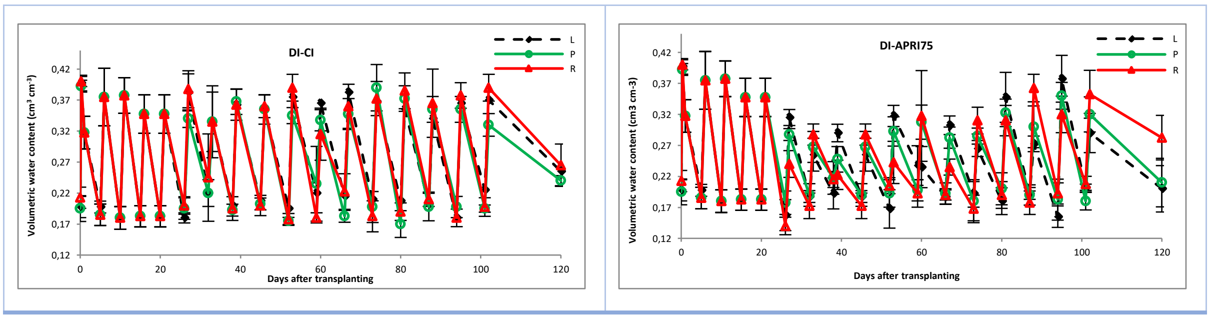
Tr.	SD		DI	
	V (m^3ha^{-1})	I (mm)	V(m^3ha^{-1})	I(mm)
CI	5794	579.4	6853	685.3
$APRI_{75}$	4759	475.9	5595	559.5
$APRI_{50}$	3725	372.5	4336	433.6
$FPRI_{75}$	4759	475.9	5595	559.5
$FPRI_{50}$	3725	372.5	4336	433.6

Table 2. Depth of water added for irrigation treatments.

Moisture distribution during the growth stages of maize

Figures 1 and 2 show the volumetric moisture distribution of the surface and sub-surface drip irrigation system, as irrigation was on both sides of the plant during the growing season (CI treatment) at a depth of 0-40 cm for three sites (plant line, right side and left side). All treatments in the emergence stage took the same amount of irrigation water to ensure germination for all experimental units. The average volumetric moisture content for the three sites at 0-40 cm depth before irrigation ranged from 0.21-0.18 cm^3 cm^{-3}, while the volumetric moisture content after irrigation ranged between 0.38-0.32 cm^3 cm^{-3}. Also, the figures show the standard deviation, which could be due to the moisture content difference between the soil's upper and lower depths.

.



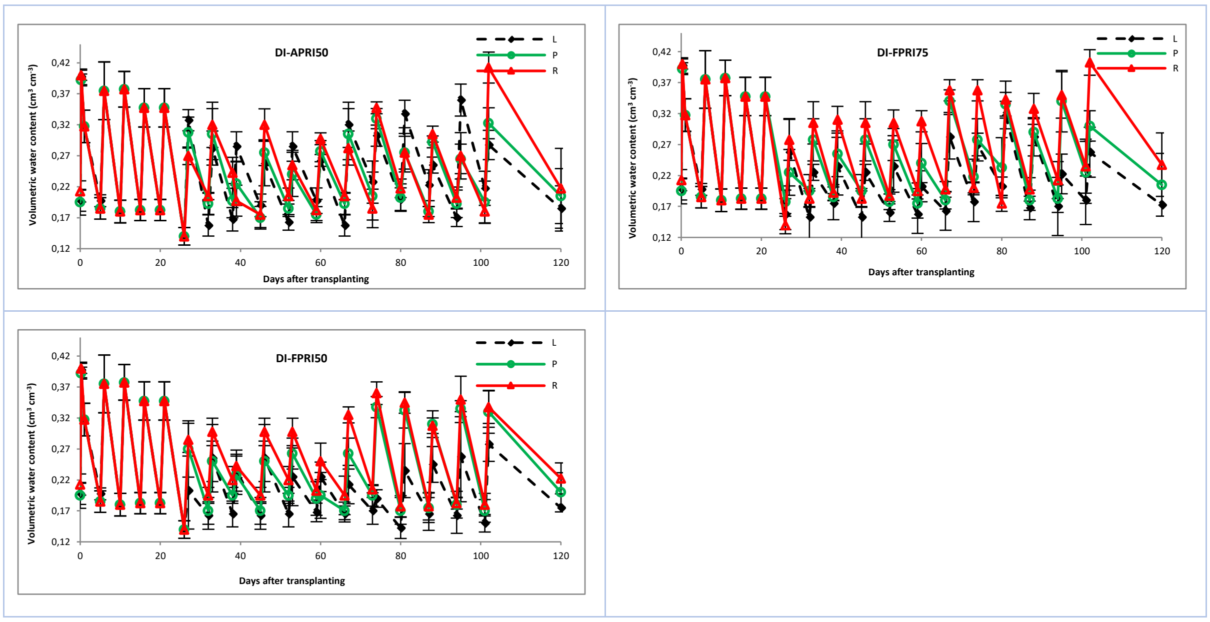


Figure 1. The moisture distribution rate of soil depth, right R, and left Land plant line P as a function of time and experiment parameters under the surface drip system.

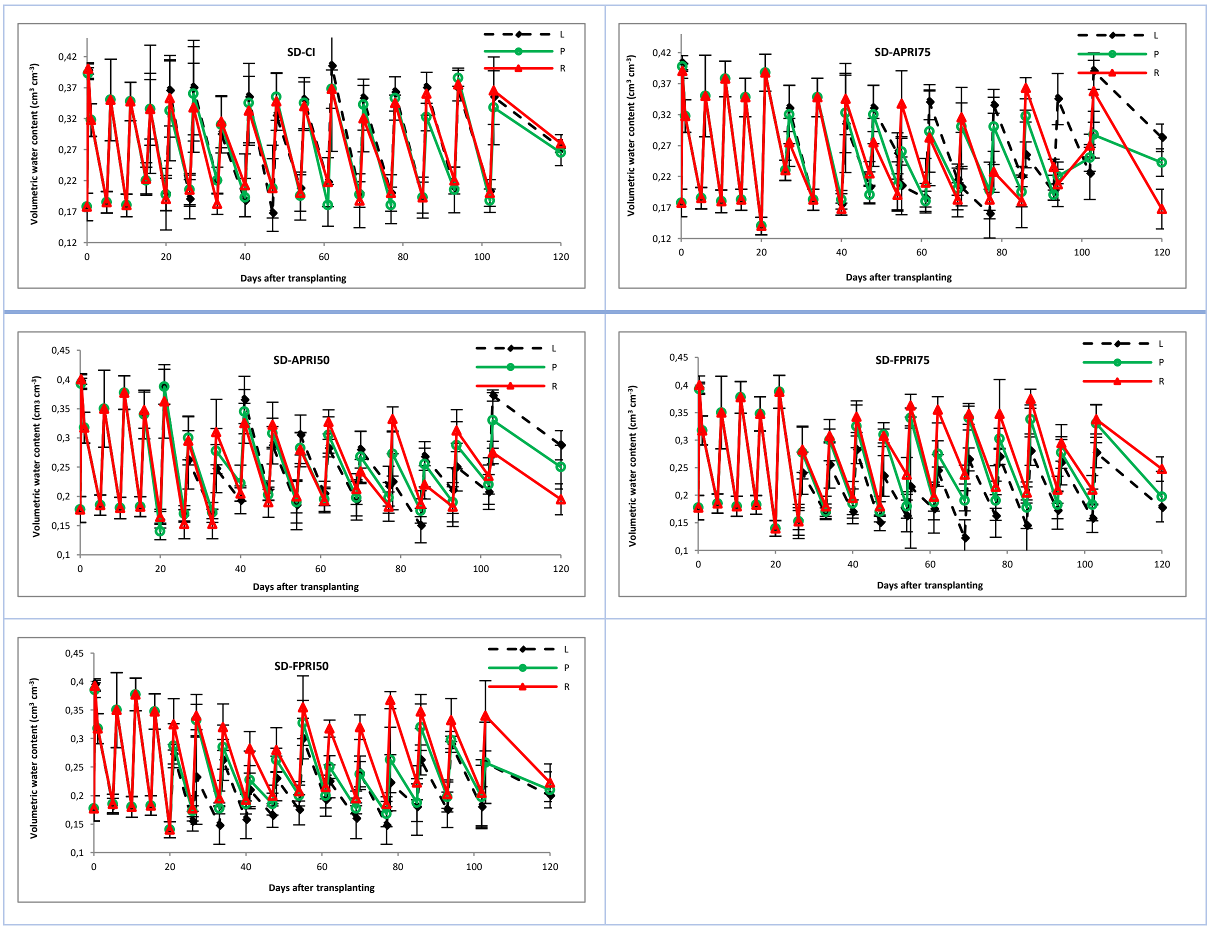


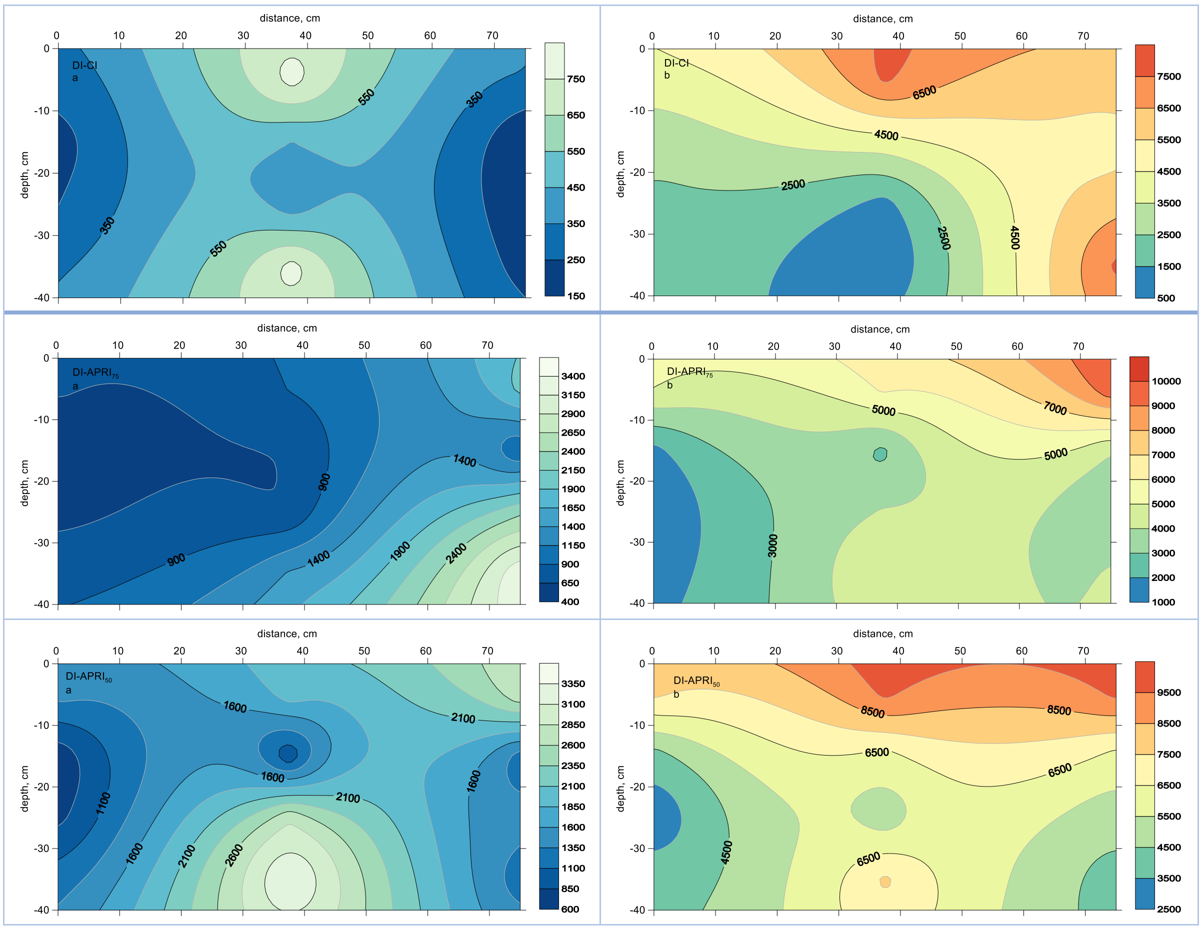
Figure 2. The moisture distribution rate of soil depth, right R and left Land plant line P as a function of time and experiment parameters under the sub-surface drip system.

Also, the SD system provided the appropriate moisture between irrigations, which made the plant less affected by water potential than the DI system due to the low evaporation rate from the soil surface. Thus, the soil retains moisture for the plant to meet its complete needs and on both sides of the plant in an optimal method. The moisture in the SD system was better than the DI system and more intense. There were differences in the SD system regarding lateral and vertical movement and up and down drips. This is consistent[22].

Potential distribution in the soil profile

The water potential (Fig. 3 and 4) shows the availability of moisture content in the soil profile, as the water potential decreases with an increase in the soil moisture content as a result of adding irrigation water[23], and with the progression of the plant growth stages, the depth of the added water increases depending on the growth of the roots and increase the adequate depth of the root. However, it was found that the potential decreases under the drips, while the potential increases horizontally and vertically when moving away from the water source.

In the surface drip irrigation system (DI) of the CI treatment, Figure 3 shows the potential was decreased in the upper layers after the irrigation, as the lowest potential was 151.3 cm of water under the water source. In contrast, the highest potential held by the water was 786.9 cm water in the middle of the distance (between the drip lines). This may be due to the absorption of water by the plant and evaporation from the soil surface. Water spreads in the soil trough on both sides towards the plant line at a potential rate of 364.5 cm water, which is almost the limits of the field capacity, while before the subsequent irrigation, the potential increased at a surface layer (10-0 cm) as It reached 7682.6 cm of water. In contrast, the average potential between the drip lines was 4191.6 cm of water, approximately 55% of the available water.



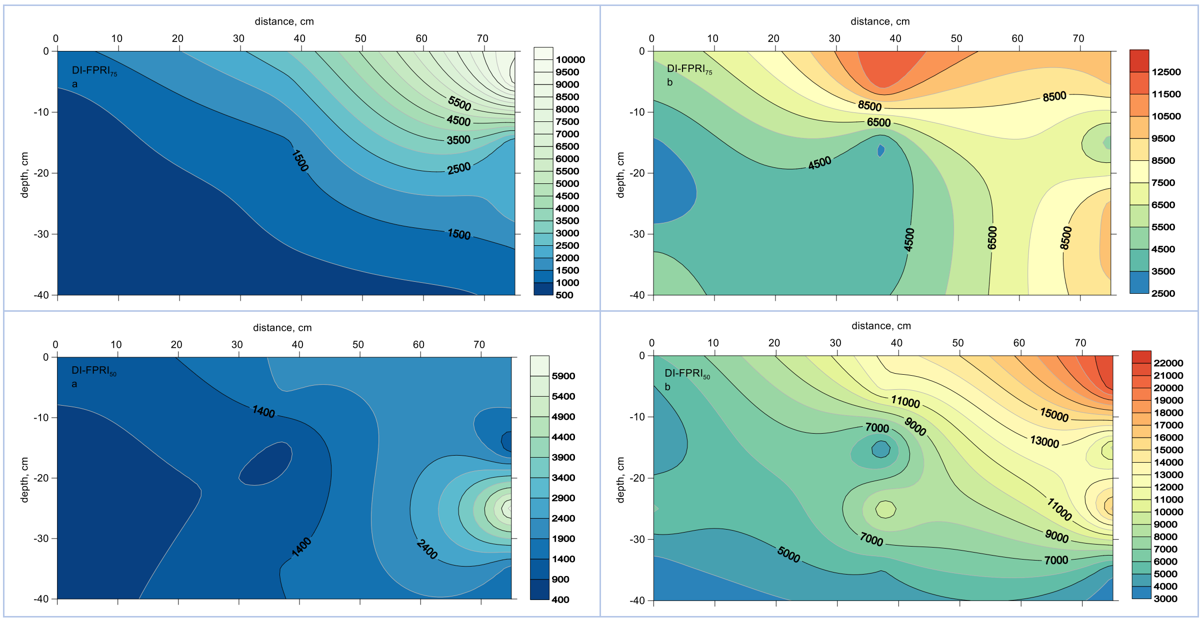
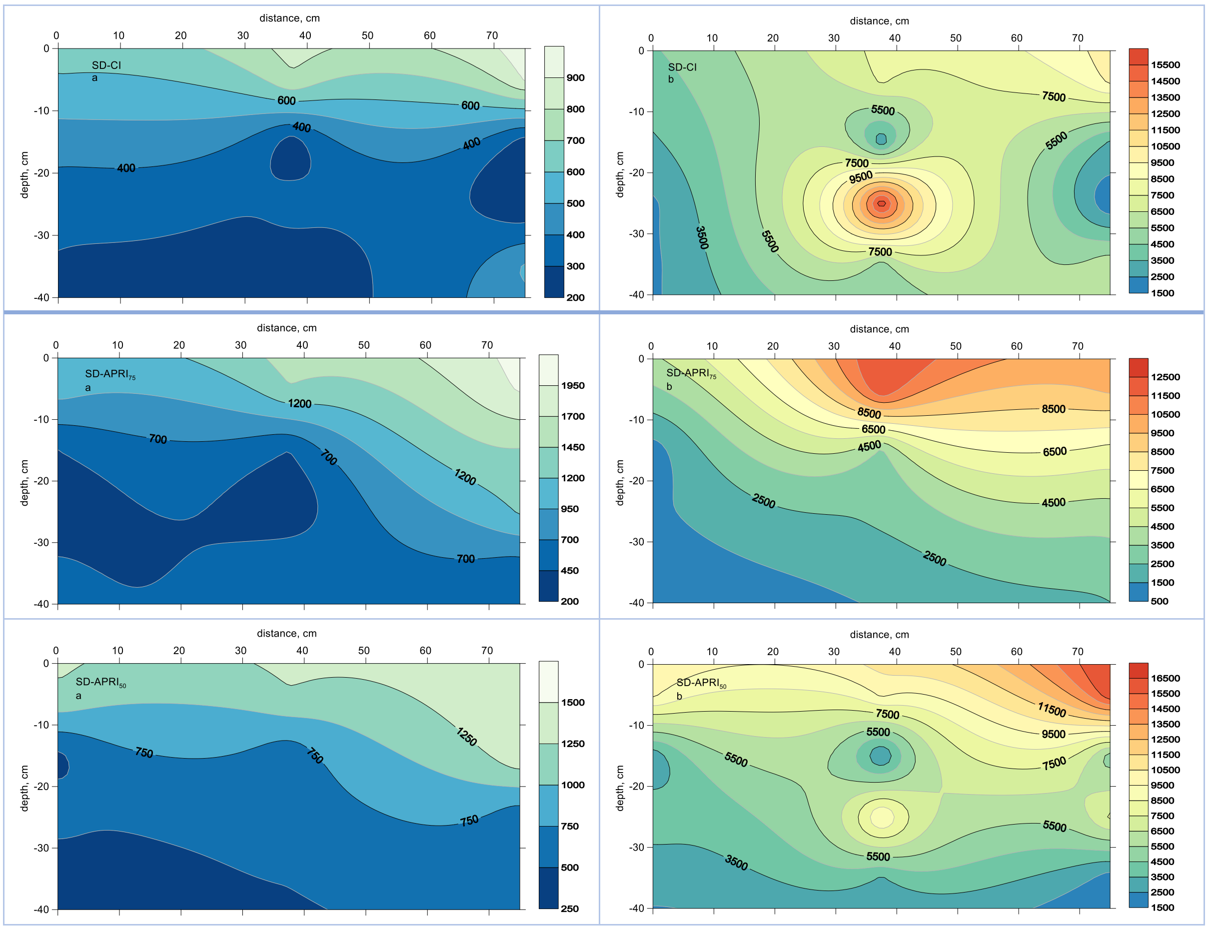


Figure 3. The distribution of water potential in the soil after irrigation (a) and before (b) subsequent irrigation of the surface drip irrigation system (DI).



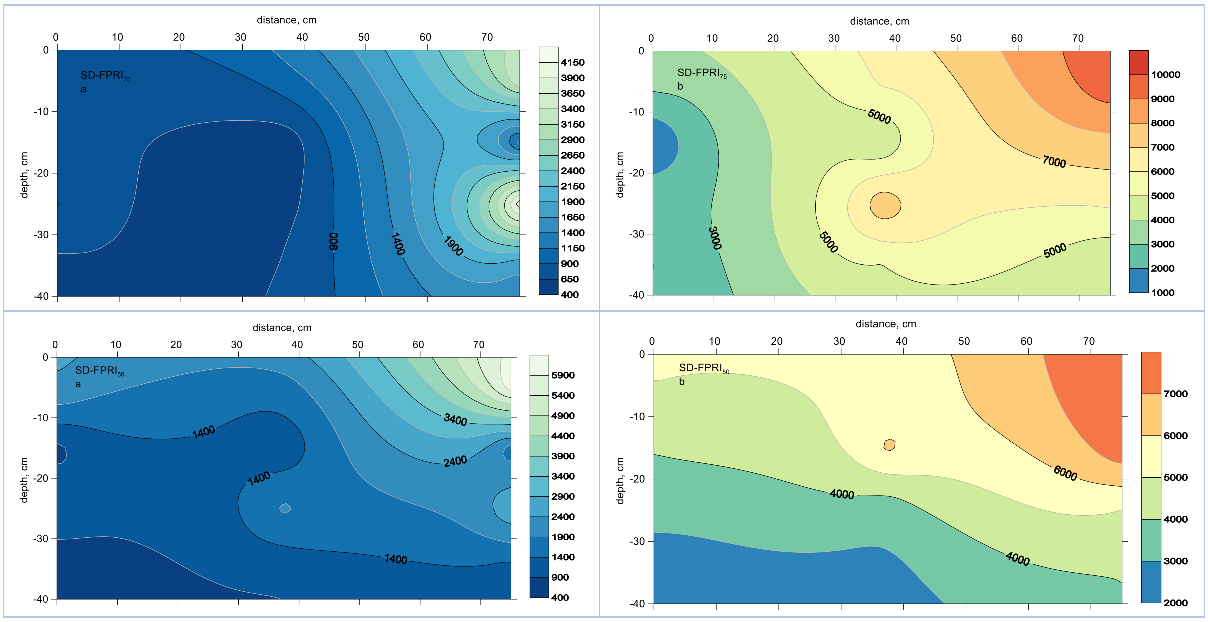


Figure 4. The distribution of water potential in the soil after irrigation (a) and before (b) subsequent irrigation of the subsurface drip irrigation (SD).

The effect of partial irrigation of the root zone on growth traits

The results in Figure (5) show the effect of drip irrigation systems on the leaf area during the growth stages of maize. The results showed non-significant differences in the leaf area at the emergence stage. This could be due to traditional irrigation for all treatments at this stage. As for vegetative, flowering, and reproductive stages, the subsurface drip irrigation system was significantly superior, with an increase of 13.3, 9.4, and 3.9%, respectively, compared with the surface drip irrigation system.

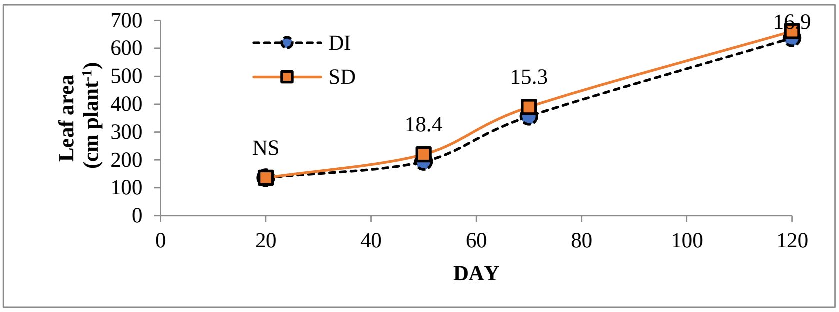


Figure 5. The effect of irrigation system on the leaf area (cm plant^{-1})of maize crop.

Figure 6 shows the effect of partial irrigation methods of the root zone on the leaf area. The results showed that there were non-significant differences during the emergence stage. The CI treatment at the vegetative growth stage was significantly superior, with an increase of 11.1, 23.8, and 39.7% compared with $APRD_{50}$, $FPRD_{75}$ and $FPRD_{50}$, respectively.

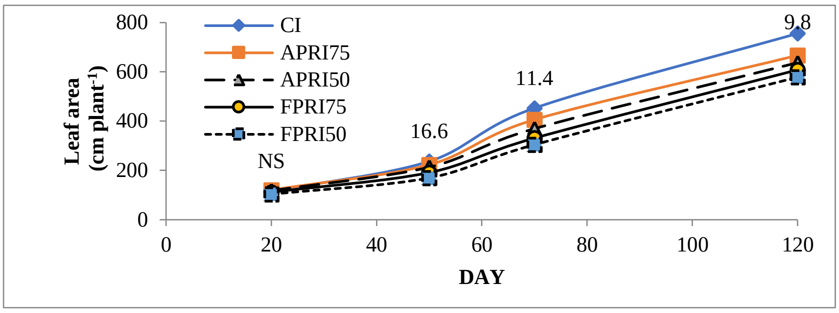


Figure 6. The effect of irrigation treatments on the leaf area (cm plant^{-1}) of maize crop.

Figure 7 reveals the effect of drip irrigation systems on the crop growth rate during the growth stages. The results showed non-significant differences between the treatments in this trait.

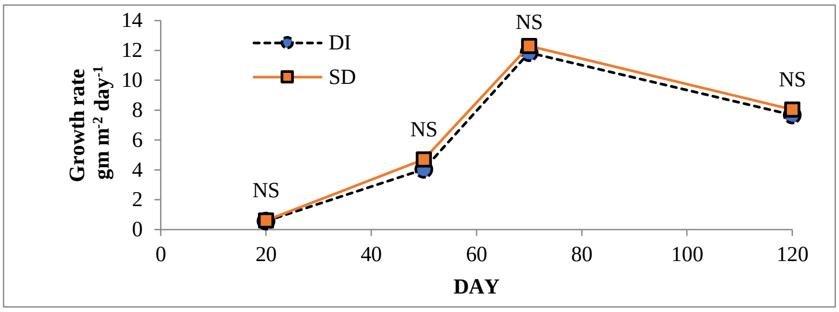


Figure 7. The effect of irrigation system on growth rate (gm m^{-2} day^{-1})of maize crop.

Figure 8 shows the effect of alternating partial irrigation of the root zone on the crop growth rate. The results showed non-significant differences between CI and other treatments in this trait during the emergence stage. The CI treatment at the vegetative growth stage was significantly superior, with an increase of 24.3, 72.8, 171.3 and 284.4% compared with $APRD_{75}$, $APRD_{50}$, $FPRD_{75}$ and $FPRD_{50}$, respectively. Regarding the flowering stage, CI treatment was significantly superior, with an increase of 25.6, 24.3 and 45.4% compared with $APRD_{50}$, $FPRD_{75}$ and $FPRD_{50}$, respectively. However, there are non-significant differences between CI and $APRD_{75}$ treatments in this trait at the flowering stage. As for the reproductive stage, CI treatment was significantly superior in this trait area, with an increase of 33.7 and 30.1% compared with $FPRD_{75}$ and $FPRD_{50}$ treatments, respectively. However, there are non-significant differences between CI $APRD_{75}$ and $APRD_{50}$ treatments in this trait at the reproductive stage.

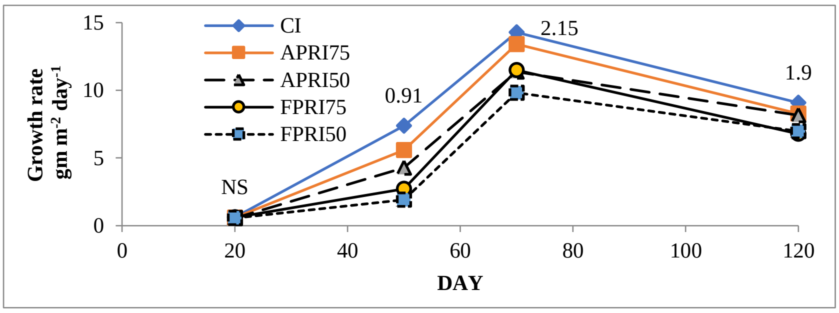


Figure 8. The effect of irrigation treatments on the growth rate (gm m^{-2}day^{-1})of maize crops.

Table 3 shows the effect of partial irrigation of the root zone on the grain yield of maize. The results showed significant differences between irrigation systems in grain yield; the SD irrigation system was significantly superior, with an increase of 5.4%, compared with DI irrigation system. Also, the results showed that the CI treatment was significantly superior to other treatments in this trait. Also, alternating partial irrigation was significantly superior to constant partial irrigation in this trait. In addition, the CI treatment under the SD irrigation system was significantly superior in the grain yield, with an increase of 11.4%, compared with $APRI_{75}$. CI.

Treatment	CI	$APRI_{75}$	$APRI_{50}$	$FPRI_{75}$	$FPRI_{50}$	Mean
DI	11322	9686	9554	8607	6603	9154
SD	11916	10698	9718	9090	6839	9652
$LSD_{0.05}$	252.6					121
Mean	11619	10192	9638	8849	6721	
$LSD_{0.05}$		195.5				

Table 3. The effect of partial root-zone irrigation on maize crop's grain yield (kg h^{-1}).

Table 4 shows the effect of partial irrigation of the root zone on the biological yield of maize. The results indicated non-significant differences between irrigation systems in this trait. Also, the results showed that the values of CI treatment decreased at 8.7, 16.1, 22.2 and 38.7%, respectively, compared with $APRD_{75}$, $APRD_{50}$, $FPRD_{75}$ and $FPRD_{50}$ in the interaction between irrigation treatments and irrigation systems, and the values of $APRD_{50}$, $FPRD_{50}$ and $FPRD_{75}$ decreased at 16.0, 24.0 and 40.3% respectively when using DIirrigation systems compared with CI treatment.

Treatment	CI	$APRI_{75}$	$APRI_{50}$	$FPRI_{75}$	$FPRI_{50}$	Mean
DI	20035	18001	16838	15233	11967	16415
SD	21626	20049	18115	17172	13585	18109
$LSD_{0.05}$	2549.6					2755.5
Mean	20831	19025	17476	16203	12776	
$LSD_{0.05}$		1802.8				

Table 4. The effect of partial root-zone irrigation on the maize crop's biological yield(kg h^{-1}).

Discussion

The variation in the added water values depends on the irrigation volume, wetting area of the soil surface during irrigation, and percentage of the active root system, in addition to the climatic factors during the study, the traits of the studying soil, and the percentage of depletion of available water. The basis of the difference is the irrigation system used in the field[5,16]. The reason for the decrease in the amount of added water when applying constant and alternating partial irrigation compared with CI may be due to the decrease in the amount of water added in the partial irrigation treatments, i.e., due to the difference the addition between the right and left of the plant line, which affected the evaporation rate[17] because the evaporation - transpiration rate is reduced by the plant with a decrease the level of available water in the soil, which affects the stomata and leads to its partial closure.

The pattern of irrigation differs when applying APRI. The moisture content changes due to alternating between drying and wetting cycles on both sides of the plant. However, when applying FPRI, the water received was less than conventional irrigation. It retained a higher water content in the side that was constantly irrigated. In contrast, the other side had a low moisture content throughout the experiment, as the plant faced a water deficit at half of the root system due to the stability of irrigation on one side only and the dependence of the plant line and the other side non-irrigated on the lateral movement of water and redistribution of moisture in the root zone in addition to the presence of evaporation from the soil surface, so the plant suffers during the stages of crop growth. As a result of acute stress in this treatment, the aging stage is reached early due to matric suction. The volumetric moisture distribution of irrigation treatments varies according to the irrigation pattern, environmental factors, growth conditions, stress rate, water potential level, and the length of time using these methods [18,19] . Generally, partial irrigation, with its two types, alternating and constant, and with different irrigation methods, reduces the values of evaporation -transpiration of the crop compared with traditional irrigation[20]. When using the surface drip irrigation system, evaporation is significant compared to subsurface drip irrigation due to evaporation from the soil surface or water depletion by plant roots[21], in addition to the growth stages of maize, as each stage has a specific water need that depends on stage length and stage sensitivity.

Figure 4 reveals that the lowest potential of 212.9 cm of water in the subsurface drip irrigation SD of the CI treatment was found in the 40-30 cm soil layers because the drip tubes are placed at a depth of 20 cm. In comparison, the highest water potential (910 cm water) was found near the surface layer

due to a decrease in the moisture content when approaching the upper layers as well as the location of the subsurface drip tubes[24] as the water is distributed almost evenly and efficiently for the plant, as the potential reaches 430.8 cm water near the root zone. The reason could be due to a decrease in water loss by evaporation and transpiration, and the soil's water stock increases with the progression of growth stages due to an increase in the depth of practical roots, thus increasing the depth of irrigation. When drought and before the subsequent irrigation of the same treatment of the SD irrigation system, the potential applied to the water increases, and its retention is 16317.9 cm of water. This area is located near the surface layer and at a depth of 20-30 cm and the middle of the distance between the drip lines (plant line). The spread of practical plant roots characterizes this area and the potential increases due to water consumption by the plant and deep permeation. The SD irrigation system will retain more moisture content than the surface drip by 22.41% at the depths before the subsequent irrigation, and the continuing stress on plants can affect growth and productivity. When applying the partial irrigation treatments in the field, it was found that the water potential of the treatments changed compared with CI. This may be due to the different irrigation patterns and the difference in the amount of irrigation.

Figure 3 shows the distribution of the water potential after irrigation of the alternating partial irrigation treatment $APRI_{75}$ and $APRI_{50}$ for the DI irrigation system after 24 hours. The potential decreased on the irrigated side of the plant to a depth of 0-40 cm, and the transfer of moisture to the other side of the plant as a result of lateral permeation of the soil layers, while the non-irrigated side at a depth of 40 cm suffered from a high potential because this depth is far from the source of the drip, while the water was spreading in the soil profile from the irrigated side, passing through the plant line to the non-irrigated side. Regarding the alternating partial irrigation treatment $APRI_{75}$ and $APRI_{50}$ for the SD irrigation system, Figure 4 shows that the potential on the irrigated side decreased after 24 hours of irrigation. The reason may be attributed to the depth of the drip tubes (20 cm). It was found that the irrigated side of the surface layer contains a low water potential due to the rise of water by the capillary property.

In contrast, the plant line's surface layer and the previously irrigated dry side suffered from high matric suction. As for the horizontal spread of moisture, it is increased after the depth of 20 cm. This may be due to the lateral permeation of water into the soil profile. The potential increase in the three locations (right, left and plant line) of the upper layer of the soil profile (0-20 cm) before the subsequent irrigation of the SD irrigation system due to water retention at a high potential (12489.9 cm water) in the soil, especially in the previously un-irrigated side. This may be due to the irrigation method and the depth of irrigation. When applying the alternating partial irrigation treatment of the root zone, the advantage of alternating is to reduce the water potential conditions due to the roots continuing to grow and obtaining water from the depths so that production is not significantly affected and maintaining the fresh water[25] .In addition, partial irrigation is considered one of the promising strategies for providing fresh water despite its limitations[5]. When applying the constant partial irrigation method of the root zone throughout the growing season, the plant suffers from stress due to the limited irrigation water, as the surface layer and the un-irrigated side retain the water at a high potential (12489.8 cm water) as a result of drought to a depth of 0-40 cm, which is a point close to a permanent wilting point, which exposes the plant to severe stress in this side, which makes the roots extend and grow on the irrigated side only in order to compensate and absorb water and nutrients due to providing moisture to half of the root system. However, there are non-significant differences between CI and $APRD_{75}$ treatments. This may be due to the increase in the amount of added water by more than half, as well as the role of alternating partial irrigation in the secretion of abscisic acid by root cells (when exposed to drought), as it works to reduce water loss from the plant through partial closure of the stomata and to maintain the water content of the cells, so the growth and expansion of the leaves continues[26]. Also, CI treatment at the flowering stage was significantly superior, with an increase of 11.5, 22.6, 36.8 and 48.7% compared with $APRD_{75}$, $APRD_{50}$, $FPRD_{75}$ and $FPRD_{50}$, respectively. Regarding the reproductive stage, CI treatment was significantly superior in leaf area with an increase of 13.3, 18.6, 24.3 and 30.7% compared to the above treatment, respectively. It is clear that applying partial irrigation of the root area, especially the constant, led to a decrease in the leaf area. The reason for this may be due to a decrease in the amount of added water, which led to weak cell division and lack of normal expansion, as it caused a decrease in turgor pressure as a result of the effect of water potential on the plant, which led to decrease the level of growth regulators (gibberellins and auxins), which stimulates cell elongation, as well as decrease cytokines that stimulate cell division. Accordingly, in underwater potential conditions, the leaf expansion rate decreases, reducing the leaf area[27].

The increase of water potential causes a decrease in the biochemical processes, as the water potential reduces the amount of dry matter and grain filling and decreases the weight and size of the grain when applying constant partial irrigation[28] . These results agreed with 25 regarding that the productivity, which does not exceed 12%, for APRI75 treatment was not significantly affected by water potential compared with [29].

Conclusion

The SD system was distinguished from the DI system by maintaining a higher moisture content for all treatments due to reducing evaporation from the soil surface. This result led to the retention of less water effort, especially in the subsurface layers. In contrast, the water effort was higher in the surface layers for subsurface irrigation. Decreased leaf area compared to reciprocal irrigation. No significant differences existed between the alternating and conventional partial irrigation in the crop growth rate. However, there was a significant decrease in the grain yield with reciprocal and constant irrigation.

Author Contributions

T.K.Masood; methodology, software, validation, formal analysis, review and editing, supervision

S.M. Ahmed; writing—review and editing, resources, data curation.

Acknowledgments

The authors thank the Department of Agricultural Research- Ministry of Agriculture, Iraq, for the facilities to conduct this experiment.

Conflict of interest

The authors declare that they have no conflict of interest.

References

1. Mousa pour Syahjel, S.; Hosseini, M., Ahmad pour Brazjani, M.; Nurouziyan, M. The effect of irrigation water subsidy reduction policy on farmers' water demand and area under cultivation of agricultural products. *Water Management in Agriculture*, **2021**, *8(1)*, 103-114.
2. Masood, T.K.; and Shahadha S. S. Simulating the effect of climate change on winter wheat production and water/nitrogen use efficiency in Iraq: A case study. *Iraqi Journal of Agricultural Sciences* **2021**, *52(4)*, 999-1007
3. Nandan, R.; Woo, D. K.; Kumar, P.; Adinarayana, J. Impact of irrigation scheduling methods on corn yield under climate change. *Agricultural Water Management*, **2021**, 255, 106990.
4. Rashid M. A.; Zhang X, Andersen M.N.; Olesen J.E. Can mulching of maize straw complement deficit irrigation to improve water use efficiency and productivity of winter wheat in north China Plain *Agric .water Manag*., **2019,** *213*:1-11.
5. Masood, T.K. Effect of Partial Alternate Furrow Irrigation Management on Water and Potato Yield Productivity. *Indian Journal of Ecology* **2022**. 49 Special Issue *(18)*: 101-104.
6. Hashem MS. Zin El-Abedin TK, Al-Ghobari HM Assessing effects of deficit irrigation techniques on water productivity of tomato for subsurface drip irrigation system. *Int J Agric.Biol.Eng.* **2018** , *11(4)*:156–167.
7. Suwaid, A. H. .; Rashid, M. A. .; Taha, M. M. . Genetic Analysis For Combining Ability And Estimation Of Some Genetic Parameters Of Yield And Its Components In Maize Using Half Diallel Cross. Journal of Life Science and Applied Research. **2020**, 1, 60-64..
8. Masood, T.K. Effect of irrigation methods on water content distribution, water and corn productivity. *Iraqi Journal of Agricultural Sciences*, **2017**, *48(1*): 178-184.
9. Fu, B., Li, Z., Gao, X., Wu, L., Lan, J., and peng, W. Effects of subsurface drip irrigation on alfalfa (Medicago sativa L.) growth and soil microbial community structures in arid semi-arid areas of northern China. *Applied Soil Ecology*, **2021**. *159*,103859.
10. Kumar, S.; Bhamini, K.; Kumari.P.and Raj. R. Effect of Partial Root-Zone Drying (PRD) Irrigation in Fruit Crops: A Review. *Int. J. Curr. Microbiol. App. Sci.* **2019**, *8(11)*, 807-813.
11. Wang, Y., Li, S., Cui, Y., Qin, S., Guo, H., Yang, D.; Wang, C. Effect of Drip Irrigation on Soil Water Balance and Water Use Efficiency of Maize in Northwest China. *Water*, **2021**, *13(2)*, 217.
12. Mattar, M. A.; El-Abedin, T.K. Z.; Al-Ghobari, H. M., Alazba, A. A.; Elansary, H. O. Effects of different surface and subsurface drip irrigation levels on growth traits, tuber yield, and irrigation water use efficiency of potato crop. *Irrigation Science,* **2021, 1-17.**
13. Ali, N.S. *Fertilizer Technology and Uses*. University house for printing, publishing, and translating. MOHE. Iraq, 2012.
14. Waller, P.; and Yitayew, M. Irrigation and drainage engineering. Springer. 2016.

15. Younis, Muayyad Ahmed Plant growth curves. Translator by Roderick Hunt. Higher Education Press-Baghdad. 1990.
16. FAO, Crop yield response to water. Irrigation and Drainage paper 66. Food and Agriculture Organization of United Nations., Rome, Italy,2012.
17. Nobel, P.S. Physicochemical and Environmental Plant Physiology.5th addition. Academic Press, 2019.
18. Beis, A.; Patakas, A.; Differential physiological and biochemical responses to drought in grapevines subjected to partial root drying and deficit irrigation. *Eur. J. Agron*. **2015**, *62*, 90–97**.**
19. Mehrabi, F.; and Sepaskhah, A. R.; Partial root zone drying irrigation, planting methods and nitrogen fertilization influence on physiologic and agronomic parameters of winter wheat. *Agricultural Water Management*, **2019.**223**.**
20. Du, S., Kang, S.; Li, F.; & Du, T.Water use efficiency is improved by alternate partial root-zone irrigation of apple in arid northwest China. *Agricultural Water Management*, **2017**, 179, 184-192.
21. Shareef, T.M.E.; Ma, Z.; and Zhao, B.; Essentials of Drip Irrigation System for Saving Water and Nutrients to Plant Roots: As a Guide for Growers. *Journal of Water Resource and Protection*, **2019**,11(9), 1129-1145.
22. AL-Ghobari, H.M.and Mohamed Said EL-Marazky. .Surface and subsurface irrigation system wetting patterns as affected by irrigation scheduling techniques in an arid region.https://www.researchgate.net/publication/290149666. 2012.
23. Sun, F.; Xiao, B.; Li.; S.; and Kidron, G. J. Towards moss biocrust effects on surface soil water holding capacity: Soil water retention curve analysis and modeling. *Geoderma*, **2021,** 399, 115120.
24. Huang, X.; Wang.; H.; Zhang, M., Horn, R.; and Ren, T.; Soil water retention dynamics in a Mollisol during a maize growing season under contrasting tillage systems. *Soil and Tillage Research*, **2021**, 209, 104953.
25. Dodd, I.C.; Puértolas, J.; Huber, K.; Pérez-Pérez, J.G.; Wright, H.R., Blackwell, M.S., The importance of soil drying and re-wetting in crop phytohormonal and nutritionalresponses to deficit irrigation. *J. Exp. Bot*., **2015**, 66, 2239–2252.
26. Hussien, S. .; Doosh, K. S. . Production And Characterization Of B-Galactosidase Enzyme In The Plant Extract From (Ziziphus Spina-Christi) And Its Application In Milk.). Journal of Life Science and Applied Research. 2021, 2, 1-8
27. Sepaskhah, A. R.; and S. H.; Ahmadi. A review on partial root zone drying irrigation . *Int. J. plant prod*, **2010**, 4(4):241-258.
28. Gholami, R.; &Zahedi, S. M.; Identifying superior drought–tolerant olive genotypes and their biochemical and some physiological responses to various irrigation levels. *Journal of Plant Nutrition*, **2019**, 42(17), 2057-2069.
29. Abdulateef, S.M. ,O.K. Atalla, MQ. Al-Ani, TH. T. Mohammed, F.M. Abdulateef, O.M. Abdualmajeed , K. Mahmod. The effect of the electric shock on embryonic development and neurophysiological traits in the chick's embryo . *IOP Conference Series: Earth and Environmental Science*.**2021**, 761(1), 012090.

Received: May 15, 2023/ Accepted: June 10, 2023 / Published: June 15, 2023
Citation: Ahmed, S.M. and Masood, T.K. Effect of Partial Drip Irrigation Methods on Soil Moisture and Water Potential Distribution, Growth Characteristics and Yield of Maize. Revis Bionatura 2023;8 (3) 2. http://dx.doi.org/10.21931/RB/CSS/2023.08.03.2