Effect of different surface irrigation systems and organic fertilization on water productivity of maize yield.

Hassan Hadi Alkarawi [1*] Ghassan Jassim Obaid [1], andAbdulsattar Hashim A Ghani [1]

[1]Al-Mussaib Technical College ,Al-Furat Al-Awast Technical University, Babylon, Iraq

*Corresponding author's e-mail address: : hassan.alkarawi@atu.edu.iq

Abstract

This study aimed to assess the performance and the impacts of different surface irrigation systems, growth, and yield of maize crops in the irrigation district of Babil Iraq.Field experiments were conducted in the autumn of 2020 to manage five surfaces irrigation systems Besides, two irrigation intervals (5 and 8 days) and two levels of organic fertilizers (humic acid) (0 OM0 and 20 OM1 kg ha^{-1}). The experiment was a Split Split Block Design with three replications. The results indicated that the actual water consumption use (ETa) varied with irrigation systems. ETa reached 688, 673 mm season^{-1} for BSI treatment and decreased to 293, 275 mm season^{-1} for APFIRB under irrigation intervals 5 days and OM0, OM1 treatments respectively .Organic fertilizer reduced the amount of ETa by 4 and 2.5% compared to control in 5 and 8 days irrigation intervals, respectively.The mean grain yield reached 7149.9 kg ha^{-1} for OM1, while organic humic acid application improved the grain yield by 7.95% compared to OM0**.** Meanwhile that the no significant differences in corn grain yield with irrigation systems.

Key words: *basin & furrow irrigation, corn* **,** *Organic fertilization*

introduction

The location of Iraq within the arid and semi-arid region is one of the most important determinants that stand in the expansion's way of irrigated agriculture, As well as climatic fluctuations and drought with the increasing problems of desertification and the consequent loss of large areas of arable land. Therefore, the increase in the productivity of the water unit used in the production of crops achieved by the application of different field technologies through irrigation scheduling and fertilizer additions, It is of great importance, especially in areas where water is a determining factor for the growth and productivity of crops [1].Surface irrigation systems are easy to apply systems with low operating, implementation, and maintenance costs, besides the fact that farmers have accumulated practical experience, which made most of them practice this type of irrigation system, especially the Furrow irrigation system. High irrigation efficiency characterized furrow irrigation system, and the wet area in the agricultural unit is less than the wet area of other surface irrigation systems (Border Strip Irrigation). Partial Root-Zone Irrigation is an innovative irrigation method to reduce the amount of added water in order to save water from wastage and loss, and then increase the efficiency of its use, assuming that the decrease in production has a little effect on the lack of water. This method of irrigation is very suitable for areas that suffer from a shortage of water resources and high evaporation rates. Partial irrigation is an ingenious method of irrigation management. The goal is to improve and increase the productivity of irrigation water by improving the production for each unit of water added to the field and works to provide Approximately 55% of the amount of irrigation water needed to be added using the traditional irrigation system [2].Cultivation by using elevated terraces with Furrow irrigation one of the advanced agricultural techniques that would raise the efficiency of the use of productive resources and water resources in particular, through its great role in reducing the quantities of irrigation water at a high rate and increasing productivity while reducing production costs [3]. The addition of humic acid to the soil improves the chemical, physical and biological properties and increases the respiratory activity of the roots, which increases the growth and development of the root and vegetative group and increases the production of plants[4]. Corn is one of the important grain crops and an important source of energy. We used ground corn flour in the production of bread after mixing it with wheat flour. Starch is used in making pastries and various foods, and Corn is high in dietary fiber, contains the antioxidant and oil extracted from seeds, as well as the possibility of using its stems and leaves in the manufacture of paper. The corn crop contributes to the processing of about 25% of the nutritional requirements of humans and approximately 60-70% of the feed needs in feeding poultry and large animals, and the remaining 5% is used as raw materials for industrial products [5]. Given the importance of this corn in terms of food and fodder, it is necessary to search for all possible means to increase productivity by using modern agricultural methods such as irrigation, fertilization, service operations and scientific methods, Therefore, the present study is came to achieve:-Evaluation of irrigation systems and water consumption of the maize by management of different surface irrigation systems and Estimation of water productivity, growth, and yield of maize with organic fertilization.

Material and methods

Experiment site and soil properties

A field experiment was carried out for cultivating corn. During the fall of 2020, in the Al-Musayyab Al-Kabeer project district, near the general estuary of the Babil Governorate, about 50 km south of Baghdad 32° 79' 69.3N 44° 40' 16.1" E) and about 28 meters above sea level.

Experimental parameters and statistical design

Surface Irrigation systems:
1)Basin Surfaces Irrigation (BSI)
2) Continuous Furrow Irrigation (CFI)

3)Alternate Partial Furrow Irrigation (APFI)
4)Continuous Furrow Irrigated Raised Bed (CFIRB)
5) Alternate Partial Furrow Irrigated Raised Bed (APFIRB)
Irrigation period: includes five and eight days

Table 1. The physical and chemical properties of the soil before planting

Properties	Value	Unit
Ec	1.20	**dsm^{-1}**
pH	7.31	
Organic matter	0.87	%
Carbonate minerals	38.21	%
Ca	5.10	$mmol.L^{-1}$
Available N	28.22	$mg.kg^{-1}$
Available P	123	$mg.kg^{-1}$
Available K	8.33	$mg.kg^{-1}$
Sand	464	$g.kg^{-1}$
Silt	336	$g.kg^{-1}$
Clay	200	$g.kg^{-1}$
Texture	Loam	
Porosity	56.6	%
volumetric moisture content(saturated)	0.505	$cm^3.cm^{-3}$
Plant Available Water330 PAW	0.303	$cm^3.cm^{-3}$
Plant Available Water 15000 PAW	0.140	$cm^3.cm^{-3}$
Available water	0.163	
Bulk density	1.15	$Mg\ m^{-3}$

Organic fertilization transactions: using Humic acid absence (Om 0) or presence of compost (Om 1)Humic acid 20 kg/ha^{-1}. The Humic acid was added to the soil and mixed with the soil at a depth of 0.3 m.The experimental design was a Split Split Block Design with three replications. The main plot treatment was the irrigation system using five field irrigation , the two irrigation periods , and the split was the subplot with the presence or absence of compost (compost or no compost). thus the number of experimental units (5 irrigation systems x 2 irrigation period x 2 levels of organic fertilizers x 3 replications = 60 experimental units).

Farming: The corn was planted on 25/7/2020 and the crop was serviced by weeding and was removed manually throughout the experiment period. The plants were harvested on 11/13/20.

Calculation of water requirements :A calculation of the depth of water to be added to replace the exhausted humidity by [6].

$$d = (\theta_{fc} - \theta_w) \times D \ldots\ldots\ldots\ldots..(1)$$

The time for irrigation is calculated to deliver the moisture of the soil to the limits of the field capacity using the equation [7].

$$Q \times t = A \times d \ldots\ldots(2)$$

Water balance equation and calculation of actual water consumption ETa

The actual water consumption of corn was estimated using the water balance equation [6].

Statistical analysis: The data of the experiment were statistically analyzed using SAS (Statistical Analysis Systems Institute Inc.,)SAS (2012), and the significant difference among treatment means were analyzed at (P ≤ 0.05 level).

Results and discussion

Total actual water consumption ETa(mm/season^{-1})

Results of Tables 2 indicate the water balance equation factors for the treatments of various irrigation systems corn at irrigation intervals a 5-day and when no organic fertilization and organic fertilization (humic acid) were added, respectively.The results showed that there were differences in the values of the actual water consumption (ETa) of maize under the treatments of different irrigation systems, as the highest water consumption of maize when treated with (BSI) irrigation was 688 and 673 mm season^{-1} at the irrigation interval of 5 days without addition and with the addition of organic fertilization, on order, followed by the (CFI) irrigation which amounted to 589 and 567 mm season^{-1} at the interval of 5 days and without addition and with the addition of organic fertilization, respectively, then the (APFI) irrigation

which amounted to 336 and 315 mm season^{-1} at the irrigation interval of 5 days and without addition and with the addition of organic fertilization, respectively and then the (CFIRB) irrigation, which amounted to 571 and 544 mm season^{-1} at the irrigation interval of 5 days and without the addition and addition of organic fertilization, respectively, and then the (APFIRB) treatment and with the lowest water consumption amounted to 293 and 275 mm season^{-1} at the irrigation interval of 5 days and without the addition and addition of organic fertilization, Respectively.

However, for the 8-day irrigation interval, the highest water consumption in (BSI) reached 741 and 726 mm season^{-1} through treating without and adding organic fertilization, respectively, followed by irrigation (CFI) 621 And 603 mm season^{-1} and irrigation treatment (APFI) and it amounted to 352 and 335 mm season^{-1}, then (CFIRB) treatment and it reached

593 and 585 mm season^{-1} and then (APFIRB) irrigation with the lowest water consumption reached 309 and 301 mm season-1 when treated without addition and addition of organic fertilization, respectively (Tables 3).

2. Treatment of irrigation systems for corn crop with irrigation interval of 5 days and when no addition and addition of organic fertilization using the water balance equation.

Treatments No addition (Om 0)	**Number of irrigations**	**Added water depth(mm)**	**Rain depth (mm)**	**Moisture storage depth (mm)**	**Actual water consumption (mm)**
BSI	21	713	0.0	-25	688
CFI	21	610	0.0	-21	589
APFI	21	355	0.0	-19	336
CFIRB	21	590	0.0	-19	571
APFIRB	21	310	0.0	-17	293
Treatments Addition (Om 1)	**Number of irrigations**	**Added water depth(mm)**	**Rain depth (mm)**	**Moisture storage depth (mm)**	**Actual water consumption (mm)**
BSI	15	750	0.0	-24	726
CFI	15	620	0.0	-17	603
APFI	15	350	0.0	-15	335
CFIRB	15	600	0.0	-15	585
APFIRB	15	315	0.0	-14	301

3. Treatment of irrigation systems for corn crop with irrigation interval of 8 days and when no addition and addition of organic fertilization using the water balance equation.

Treatments No addition (Om 0)	**Number of irrigations**	**Added water depth(mm)**	**Rain depth (mm)**	**Moisture storage depth (mm)**	**Actual water consumption (mm)**
BSI	**21**	**700**	0.0	**-27**	**673**
CFI	**21**	**590**	0.0	**-23**	**567**
APFI	**21**	**340**	0.0	**-25**	**315**
CFIRB	**21**	**570**	0.0	**-26**	**544**
APFIRB	**21**	**300**	0.0	**-25**	**275**
Treatments Addition (Om 1)	**Number of irrigations**	**Added water depth(mm)**	**Rain depth (mm)**	**Moisture storage depth (mm)**	**Actual water consumption (mm)**
BSI	**15**	**762**	**0.0**	**-21**	**741**
CFI	**15**	**640**	**0.0**	**-19**	**621**
APFI	**15**	**370**	**0.0**	**-18**	**352**
CFIRB	**15**	**610**	**0.0**	**-17**	**593**
APFIRB	**15**	**325**	**0.0**	**-16**	**309**

The reason for the difference in the actual water consumption values ETa is because of the depth of irrigation water used during the season for the different irrigation systems treatments, as the irrigation water depth was 713, 610, 355, 590, and 310 mm season-1 for the different irrigation treatments (BSI, CFI, APFI, CFIRB, and APFIRB), respectively, at the irrigation interval at 5 days without the addition of organic fertilization, the depth of the irrigation water added at the same interval and with the addition of organic fertilization was 700, 590, 340, 570 and 300 mm season-1 for different irrigation treatments (BSI, CFI, APFI, CFIRB, and APFIRB), respectively. While the depth of irrigation water added at the irrigation interval of 8 days and without the addition of organic fertilization was 762, 640, 370, 610, and 325 mm season-1 for different irrigation treatments (BSI, CFI, APFI, CFIRB, and APFIRB), respectively. When adding organic fertilization and for the same irrigation parameters, the values of the added irrigation water depths were 750, 620, 350, 300, and 315 mm season-1, respectively. This resulted in a difference in the number of irrigations during the growing season, as it reached 3, 8, 4, and 6 irrigations at the 5-day irrigation interval, and 3, 5, 3, and 4 irrigations at the 8-day irrigation interval.

The reason is that the actual water consumption of the BSI at the irrigation interval of 5 days reached its highest value because the moisture content is available to the plant at the depth that provides its water needs, which led to an increase in the water consumption of the plant whose stomata are open allowing the loss of water by transpiration [8] , as the rate of plant water consumption increases with the increase in moisture content, in which soil moisture is close to the field capacity. As for the reasons for the decrease in the values of ETa in the mutual partial irrigation coefficients (APFI and APFIRB) because of the decrease in the wetting area of the soil surface during the mutual partial irrigation, which led to a decrease in evaporation and a decrease in deep infiltration [9 ,10]. Also, following the alternating partial irrigation method during the growth stages led to a reduction in the depth of the added water (Tables 2, and 3), which was reflected in reducing both evaporations from the soil surface because of reducing the surface exposed to wetting and transpiration by the plant because part of the root system exposed for drought. Or it may be the effect of water stress resulting from the low moisture content in the root area in the dry part from which it cut the water off. The other part of the root system with the watering fully plants absorbs water continuously to meet the water requirements of the plant to get vegetative growth and in quantities to compensate for the lack of moisture resulting from the use of the exchange method in irrigation and a dry area in one part and a wet area in another part of the root system [11] ,and the application of partial irrigation led to a decrease in the amount of irrigation and the wetting area, and thus reduced evaporation from the soil and transpiration from the plant. It is also clear that the irrigation of traditional terraces CFI and CFIRB consumed more added water than the irrigation treatments of partial terraces and APFI and APFIRB. This increase in the amount of water used for the irrigation of traditional terraces and terraces may be attributed to the increase in wetting, as the used water filters into the soil body from During the wet circumference of the cross-section of the meridian, the water movement is bidirectional, as the water filters in a horizontal direction under the influence of capillary tensile forces, and a vertical direction under the influence of earth attraction and capillary tension, and with the increase in the amount of water used, The wet environment of the furrow increases and the evaporation from the soil surface increases, which is reflected in the amount of irrigation water used to provide the water needs of the plant.It is clear from the results of the water budget schedules 2, and 3 varied ETa values on the different irrigation methods, but they took a similar behavior to interval irrigation. As for the low ETa values of (CFI) and terracing irrigation comparison with the Basin Surfaces Irrigation (BSI), it is because of the low wet area of the soil surface when furrow irrigated. This is first, and second, to a decrease in the irrigation's depth of water added, besides reducing the total quantities of added irrigation water. This was reflected in reducing the evaporation of the soil surface because of reducing the surface exposed to wetting and reducing deep leaching because the quantities of added water are calculated because of the depth of water needed by the plant according to each irrigation interval (5 and 8 days). When comparing the values of water consumption of corn .From the results got, the depths of irrigation water added to the crop vary according to the growth stages, the number of days of the growth stage, the number of irrigations in it, and the increase in plant size, height, and leaf area.

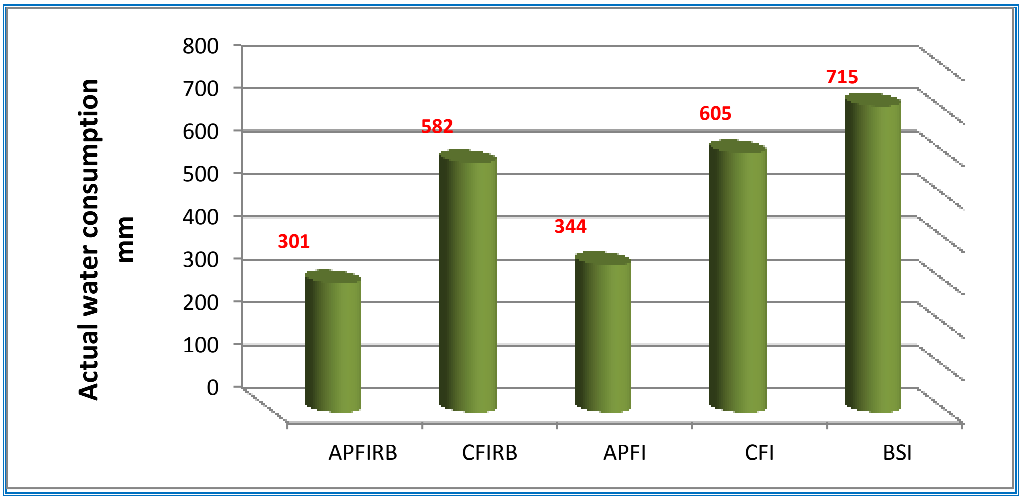

Figure 1. Average actual water consumption of irrigation system treatments when no organic fertilization with humic acid.

The reason for that of the increase in the plant's height, the increase in the leaf area, and the almost completion of the vegetative growth phase with the progression of the growth stages of the crop, which caused an increase in plant transpiration. Then the values increased again for all the different irrigation treatments:(BSI, CFI, APFI, CFIRB, and APFIRB) in the stage of yield formation. Plant by transpiration. Figure 1 shows the actual average water consumption for irrigation systems' treatments. The actual water consumption was 715 mm season^{-1} for

BSI treatment without organic fertilization with humic acid, and this treatment increased by 15.38, 51.89, 18.60, and 57.90% over CFI and APFI irrigation treatments. and CFIRB and APFIRB, respectively. Figure 2 shows the actual average water consumption for irrigation systems treatments, as the actual water consumption was 700 mm season^{-1} for BSI treatment when organic fertilizing with humic acid, and this treatment increased by 16.43, 35.57, 19.29, and 58.86% for CFI and APFI irrigation treatments and CFIRB and APFIRB, respectively.

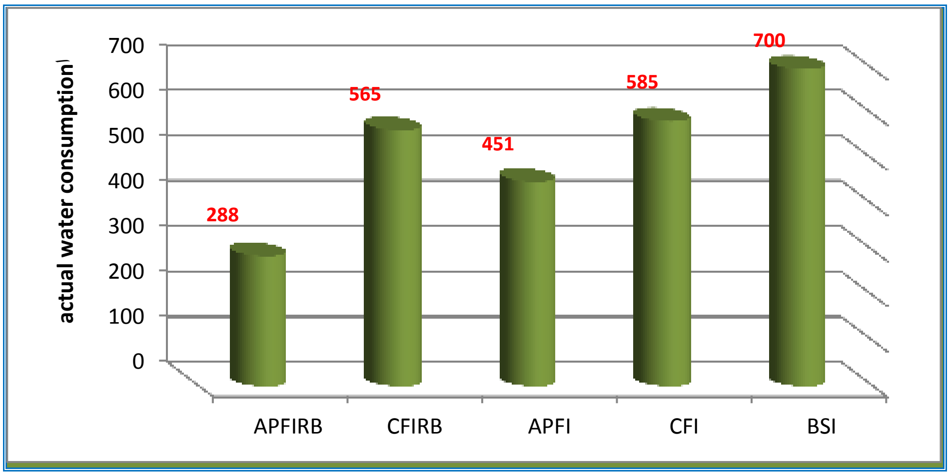

Figure 2. Average actual water consumption of irrigation systems treatments with humic acid organic fertilization.

The reason for the decrease in ETa may be attributed to the adoption of the partial mutual irrigation method during the growth stages, which led to a reduction in the depth of the added water, which was reflected in reducing both evaporations from the soil surface because of reducing the surface exposed to wetting and transpiration by the plant because part of the root system is subject to drying out. From Figure 3 shows the effect of organic fertilization with humic acid on the average total actual water consumption of corn. It is noted that the average water consumption reached 495 and 523 mm season^{-1} in the treatment that did not add organic matter (OM0) at the 5 and 8 day interval, respectively. While the average water consumption of organic matter treatments (OM1) decreased to 475 and 510 mm season^{-1} at the interval of 5 and 8 days, respectively. The addition of organic matter to the soil reduced the plant's water consumption by 4% compared to the treatment of not adding organic matter at the 5 day irrigation interval and by 2.5% compared to the treatment of not adding the organic matter at the 8 day irrigation interval. Tables 2 and 3 showed a decrease in ETa Total when adding organic fertilizer compared to not adding it. The reasons for the decline may be due to the effect of organic matter in increasing the soil's ability to hold water and at different water efforts, or the reasons may be attributed to the effect of organic matter in increasing the soil's ability to deliver water because of the improvement in soil construction, which results in a redistribution of soil pore volumes. Increasing the area of the water-carrying section increases the water permeability and increases its movement to the adjacent meridians and within the effective depth of root propagation. Besides increasing the specific surface area of the organic matter, which increases the ability of these surfaces to hold water as thin films, which increases the difficulty of losing water and consequently a decrease in the actual water consumption. This mechanism may explain the increase in the efficiency of water use by the crop, and, the organic matter is an important source of nutrients, as it led to an increase in the size and height of the plant which caused an increase in the soil's shading surface, so evaporation decreased and water consumption decreased .

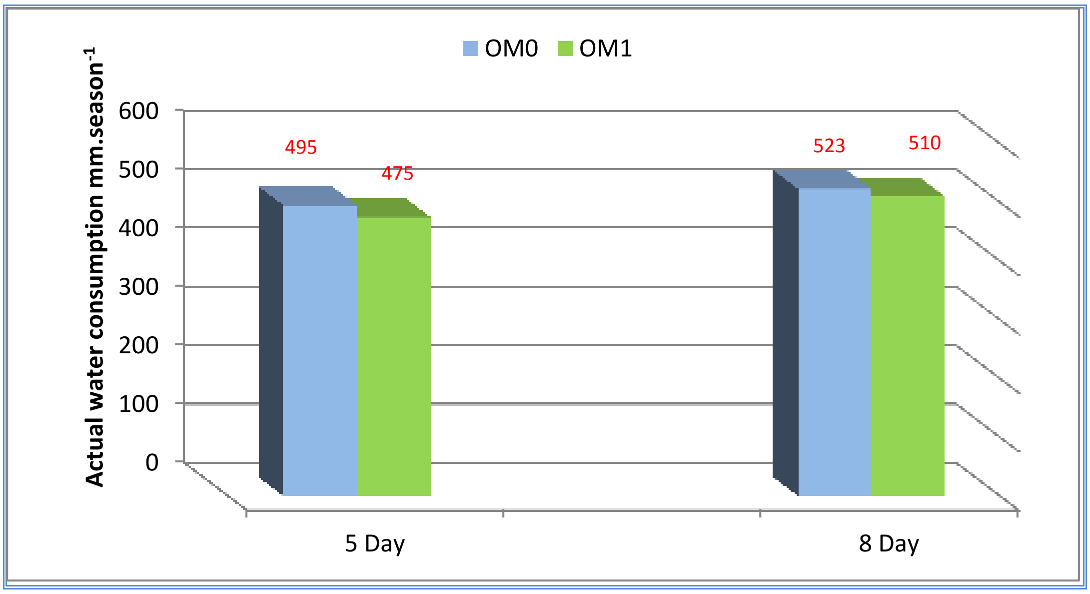

Figure 3. Average actual water consumption without adding and adding organic fertilization

Total grain yield

Table 7 shows the effect of different irrigation treatments, irrigation intervals, and humic acid fertilization on the dry grain weight of maize. The average grain yield was 6720.7, 6911.3, 6764.3, 7043.8, and 6992.8 kg ha^{-1} for the different irrigation treatments BSI, CFI, APFI, CFIRB, and APFIRB, respectively. The statistical analysis showed that there were no significant differences in the average grain yield for the different irrigation treatments. This means that the mutually partial irrigation did not cause water stress on the plant due to its ability to absorb water from the neighboring meadows. Using water management methods under different irrigation systems, as in the current study, has improved the production conditions compared to continuous irrigation for traditional shingle irrigation, despite the moderate amounts of irrigation water added in other irrigation systems. The results of the statistical analysis also showed that there were no significant differences in the interaction between the irrigation interval and the different irrigation systems, as well as the absence of significant differences in the triple interaction between the irrigation interval and the different irrigation systems and the organic matter despite the significant increase in the yield in the mutual partial irrigation treatments when adding the organic matter. The application of corn cultivation technology on the terracing on the lands of furrow reduces the pressure generated in the field by reconstructing the degraded soil because of surface irrigation, and reducing the risk of groundwater rise, besides the moisture distribution for plant growth, the soil keeps moisture for a longer period because the soil not compacted at the root area, and the physical properties of the soil improved, which is positively reflected on the growth and distribution of roots in the soil bed, thus increasing the absorption of water and nutrients [12],Also, the advantage of applying terracing cultivation is the distribution of fertilizers, maximizing their benefit of them, especially nitrogen fertilizers, and reducing waste through the use of less irrigation water in this method. As well as a decrease in fungi and other diseases because of the good interception of the sun's rays and light and heat suitable for plant growth to avoid crowding between plants. As for the traditional cultivation method, in this method, as is well known, the entire surface of the cultivated area covered, which results in the demolition of soil construction, weakening of its gatherings, and the washing of fertilizers largely, and it does not get symmetry in the distribution of plants grown in the experimental unit, as well as the rate of plant density planted in The unit area of the plates that determines the growth and spread of the roots.

Irrigation water productivity (crop water use efficiency)

Figure 4 shows the average crop water use efficiency for corn irrigation treatments at 5 and 8 day irrigation intervals. The efficiency of crop water use varied according to different irrigation systems treatments, and the highest efficiency of crop water use was in the treatment of mutual irrigation for terracing APFIRB, which was 2.33 and 2.42 kg m^{-3} at the irrigation interval of 5 and 8 days, respectively. Whereas, the lowest value for the efficiency of crop water use in the treatment of conventional irrigation was the irrigation of BSI plates, which amounted to 0.94 and 0.96 kg m^{-3} at the irrigation interval of 5 and 8 days, respectively. The results of the statistical analysis showed that there were significant differences in the efficiency of crop water use for all partial reciprocal irrigation treatments when compared with the traditional BSI irrigation treatment. It turns out that (CFI) and (APFIRB), (CFIRB)It caused an increase in the efficiency of crop water use, and the percentage of increase was 18, 52, 23, and 60% for the treatments of CFI, APFI, CFIRB, and APFIRB, respectively, when compared with BSI without organic fertilization with humic acid. While the increase in crop water use efficiency was 19, 36, 23, and 60%, respectively, for CFI, APFI, CFIRB, and APFIRB, respectively, when compared with BSI when organic fertilization with humic acid. The reasons for the increase in the efficiency of crop water use for the constant and alternating irrigation treatments of the turf irrigation system and the terracing system of arable landscaping are attributed to the adoption of the irrigation method, which led to a reduction in evaporation from the soil surface because of a decrease in the surface exposed to wetting and transpiration from the plant and thus reducing water consumption (Tables 2, and 3), besides the fact that grain production was not affected by these treatments, which was reflected in an increase in the efficiency of crop water use. The mutual partial irrigation method led to a reduction in irrigation water, which made the plants can absorb higher compensating water, a decrease in moisture storage, and this led to an increase in the efficiency of water use.

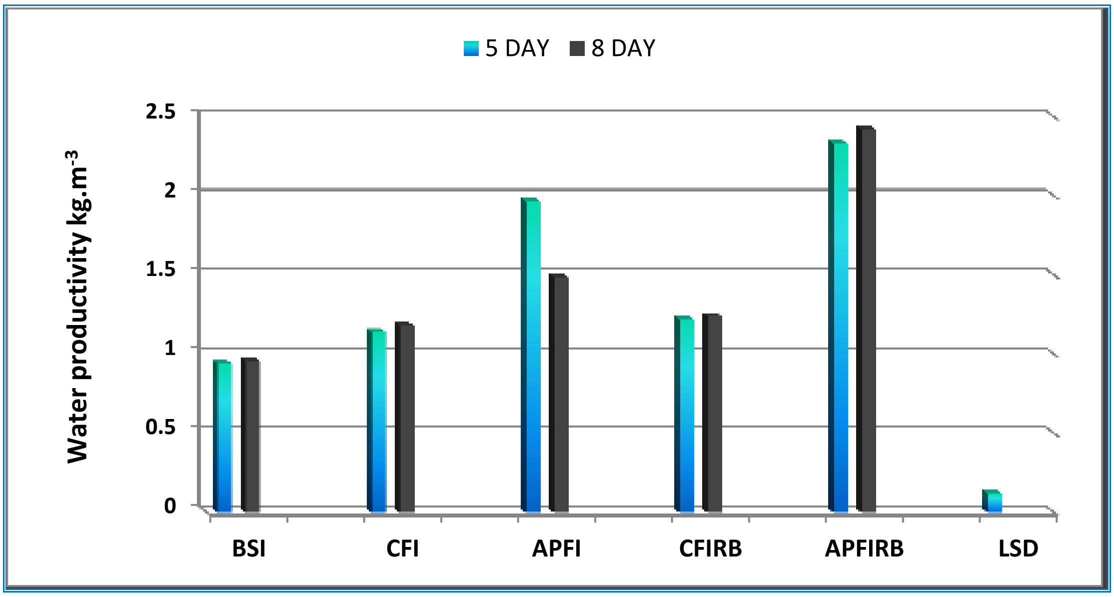

Figure 4. Average water productivity (efficiency of crop water use) for the different irrigation systems treatments.

Figure 5 shows the average efficiency of crop water use for the organic matter treatments of corn. The addition of organic matter OM1 led to a significant increase in the efficiency of crop water use, which amounted to 1.51 kg m^{-3}, with an increase of 12.67%, compared with not adding organic matter OM0, in which the efficiency of crop water use reached 1.34 kg m^{-3} at the 5 day irrigation interval.

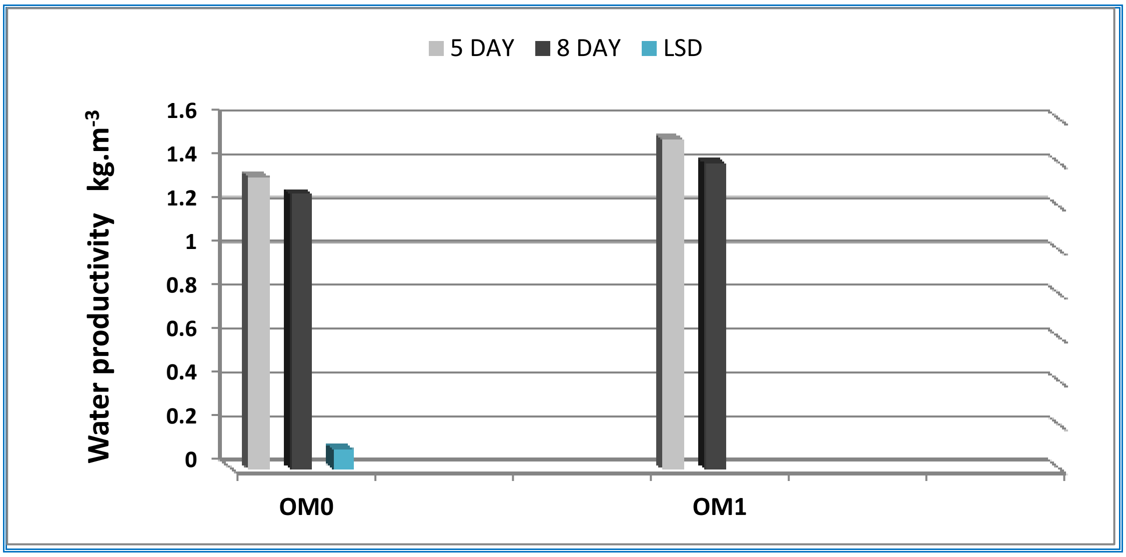

Figure 5. Average water productivity (crop water use efficiency) for organic fertilization treatments.

While the efficiency of crop water use was 1.40 kg m^{-3} when treating OM1 with an increase of 11.11% compared to not adding organic matter OM0, in which the efficiency of using crop water reached 1.26 kg m^{-3} at the 8-day irrigation interval. This is due to the effect of adding organic matter in raising the efficiency of water used because of increasing moisture storage in the soil and reducing the actual water consumption (Tables 2, and 3),Besides the organic matter content of nutrients, which contributed to increasing the yield and using less water because of the high efficiency of the soil well fertilized with organic manure, which led to water retention and an increase in its content of ready water and an improvement in the movement of water in the soil and its distribution and then in the efficiency of its use.

References

[1] Hameedi, I.H., Ati, A.S. and Jasim, H.M.K.H., 2015. Effect of irrigation period and organic fertilization (TOP10) on growth, production and water use by maize crop. *Journal of Agriculture and Veterinary Science*, *8*(5), pp.01-04.

[2] Cheng, M., H. Wang, J. Fan, F. Zhang, and X. Wang. 2021. Effects of Soil Water Deficit at Different Growth Stages on Maize Growth, Yield, and Water Use Efficiency under Alternate Partial Root-Zone Irrigation. *Water*, *13*(2), p.148.

[3] **Miao, Q., Gonçalves, J.M., Li, R., Gonçalves, D., Levita, T. and Shi, H., 2021.** Assessment of Precise Land Levelling on Surface Irrigation Development. Impacts on Maize Water Productivity and Economics. *Sustainability*, *13*(3), p.1191.

[4] Purwanto, B., P., Wulandari, E., Sulistyaningsih S. Utami, and S. Handayani. 2021. Improved Corn Yields When Humic Acid Extracted from Composted Manure Is Applied to Acid Soils with Phosphorus Fertilizer. *Applied and Environmental Soil Science*.

[5] Saritha, A., A.V. Ramanjaneyulu, N.Sainath, and E.Umarani. 2020. Nutritional importance and value addition in maize. *Biotica Research Today*, *2*(9), pp.974-977.

[6] **Allen, R.; L. Pereira; D. Raes and M. Smith. 1998.** Crop Evapotranspiration. FAO Irrigation and Drainage. Rome. Paper 65.

[7] Israelsen, O.W. and Hansen, V.E., 1962. Irrigation Principles and Practices, John Wiley and Sons. *Inc New York, London*.

[8] Kang, S. and Zhang, J., 2004. Controlled alternate partial root-zone irrigation: its physiological consequences and impact on water use efficiency. *Journal of experimental botany*, *55*(407), pp.2437-2446.

[9] Wang, S., Sun, J., Gao, C. and Fei, L.,.2010. Research on the effect of controlled alternate furrow irrigation on soil evaporation.*The 2nd Conference on Environmental Science and Information Application Technology*.

[10] Xie, K., Wang, X.X., Zhang, R., Gong, X., Zhang, S., Mares, V., Gavilán, C., Posadas, A. and Quiroz, R., 2012. Partial root-zone drying irrigation and water utilization efficiency by the potato crop in semi-arid regions in China. *Scientia Horticulturae*, *134*, pp.20-25.

[11] Hu , T., S. Kang, F. Li and J. Zhang. 2011. Effects of partial root-zone irrigation on hydraulic conductivity in the soil-root system of maize plants. *J. Eap. Bot*. 62 (12): 4163 – 4172.

[12] Wang, R.,Y. Kang, S. Wan, W. Hu, S. Liu, and s. Liu, .2011 . Salt distribution and the growth of cotton under different drip irrigation regimes in a saline area. *Agric. Water Manag*. 100: 58- 69.