INFLUENCE OF IRRIGATION SYSTEMS AND COVER CROP ON WATER PRODUCTIVITY, AND MAIZE GROWTH

A. H. A. AL-ARIDHEE[1*] N. T. MAHDI[2]
Researcher Prof.
[1] Directorate of Agriculture in Babylon Governorate, Iraq
[2]Department of Desertification Combat, College of Agriculture Engineering Sciences. University of Baghdad, Iraq.
alialardi86@gmail.com

ABSTRACT

A field experiment was carried out to assess the effect of different irrigation systems, which included surface drip irrigation, sub-surface drip irrigation, surface irrigation in basins and cover crop on water productivity, growth and yield of maize in a silty clay loam soil in the Nile sub-district of Babil Governorate, in the fall season 2020. The experiment was designed using the split plot arrangement according to a complete randomized block design (RCBD) with three replications. The experiment treatments included two factors: cover crop (C) includes cover crop (C_1) and without the cover crop (C_0), and irrigation systems (I): includes surface drip irrigation (I_1) subsurface drip irrigation (I_2) and surface irrigation in basins (I_3). Scheduling Irrigation was applied after 50% depletion of the plant available water. The water balance equation was used to determine the water consumption of maize. The results showed that C_1I_3 treatment was highest mean of plant height 235 cm, grain yield 11236 kg ha^{-1}, leaf area 6076 cm^2 $plant^{-1}$, and leaf area index 4.05. Whereas, C_0I_1 was the lowest values for the previous traits, 183 cm, 5200 kg ha^{-1}, 3997 cm^2 $plants^{-1}$, and 2.67 respectively. Treatment C_1I_2 was superior in the value of field water use efficiency and crop water use efficiency, which reached 3.49 kg m^{-3} and 3.05 kg m^{-3}, respectively. Whereas, treatment C_0I_1 gave the lowest value for field and crop water use efficiency, which was 1.11 kg m^{-3} and 1.05 kg m^{-3}, respectively. The highest water consumption of maize was 709 mm $season^{-1}$ was for treatment C_0I_3, and the lowest water consumption was 362 mm $season^{-1}$ for the treatment C_1I_2. It is clear that surface drip irrigation in the presence of cover crop contributed to saving irrigation water by reducing water consumption of maize.

Key words: surface drip irrigation, subsurface drip irrigation, surface irrigation in basins, water use efficiency, growth characteristics.

*** Part of Ph.D. dissertation of the 1st author.**

تأثير نظم الري و محصول الغطاء في إنتاجية المياه ونمو وحاصل الذرة الصفراء

علي حامد عبد الحسن العارضي[1*] نمير طه مهدي[2]
باحث استاذ
(مديرية الزراعة في محافظة بابل, العراق)[1]
(قسم مكافحة التصحر– كلية علوم الهندسة الزراعية – جامعة بغداد, العراق)[2]

المستخلص:

نفذت تجربة حقلية لمعرفة تأثير نظم ري مختلفة هي ري التنقيط السطحي وري التنقيط تحت السطحي وري سطحي بالأحواض ومحصول الغطاء في إنتاجية المياه ونمو وحاصل الذرة الصفراء في تربة مزيجة طينية غرينية في ناحية النيل التابعة الى محافظة بابل. في الموسم الخريفي 2020. صممت التجربة بحسب توزيع الألواح المنشقة بنظام القطاعات التامة التعشية (RCBD) وبثلاث مكررات. تضمنت التجربة على عاملين, الأول هو محصول الغطاء (C) ويشتمل على مستويين هما: وجود محصول الغطاء (C_1) وبدون محصول الغطاء (C_0) أما العامل الثاني فهو نظم الري (I): ري التنقيط السطحي (I_1) وري التنقيط تحت السطحي (I_2) والري السطحي بالأحواض (I_3). اجري الري بعد إستنزاف 50 % من الماء الجاهز للنبات. استعملت معادلة التوازن المائي لتحديد الاستهلاك المائي للذرة الصفراء. أظهرت النتائج تفوق معاملة C_1I_3 في الحصول على أعلى متوسط كل من إرتفاع النبات 235 سم، وحاصل الحبوب 11236 كغم هكتار$^{-1}$، و المساحة الورقية 6076 سم^2 نبات$^{-1}$، ودليل المساحة الورقية 4.05 . في حين أعطت المعاملة C_0I_1 أقل القيم للصفات السابقة وبلغت حسب الترتيب 183 سم، و5200 كغم هكتار$^{-1}$ ، و3997 سم^2 نبات$^{-1}$، و2.67. تفوقت المعاملة C_1I_2 في قيمة كفاءة استعمال الماء الحقلي وكفاءة استعمال الماء المحصولي اذ بلغت 2.92 كغم م$^{-3}$ و3.05 كغم م$^{-3}$ على الترتيب . في حين اعطت المعاملة C_0I_1 أقل قيمة لكفاءة استعمال الماء الحقلي والمحصولي فبلغت 1.05كغم م$^{-3}$ و1.05كغم م$^{-3}$ على الترتيب. أعلى استهلاك مائي للذرة الصفراء بلغ 709مم موسم$^{-1}$ عند المعاملة C_0I_3 وأقل استهلاك مائي 362 مم موسم$^{-1}$ عند المعاملة C_1I_2. يتضح ان ري التنقيط السطحي بوجود محصول الغطاء قد أسهم بتوفير مياه الري من خلال خفض الاستهلاك المائي للذرة الصفراء.

الكلمات المفتاحية: ري التنقيط السطحي، ري التنقيط تحت السطحي, ري سطحي بالأحواض ، كفاءة استعمال الماء، صفات النمو.

*** بحث مستل من أطروحة دكتوراه للباحث الأول**

Received:12/4/2021, Accepted:25/7/2021

INTRODUCTION

Water shortage has become a critical challenge for agricultural producers to secure a sustainable food source in arid, semi-arid and semi-humid regions of the world (9). Water shortage is one of the determinants affecting agricultural operations in the world in general and in Iraq in particular, despite the availability of fertile lands and the addition of reclaimed lands to it, in return there is relatively limited irrigation water and even decreases annually. The surface irrigation method is the traditional method used to irrigate the fields of maize in Iraq. However, although this method is easy and quick and provides large amounts of water for plants, it is characterized by a large amount of waste that may reach 50% of the field need (1). Therefore, in recent decades, those interested in agriculture and irrigation have resorted to unconventional irrigation methods that rationalize water, such as micro irrigation systems or called low flow irrigation water systems such as surface drip irrigation (DI) and subsurface drip irrigation (SDI), it is considered one of the efficient irrigation systems in the use of water, as the water requirements of plants are few with few water additions and high frequency, and the initial costs of preparing the land and plowing are almost non-existent, and a clear reduction in the use of fertilizers. Micro irrigation systems meet the demand for water easily and on time, with low discharge rates and high uniformity of distribution, and water losses such as runoff and deep leaching are few or non-existent. Both DI and SDI are two irrigation methods that are effective in meeting the water requirements of plants and at the same time they work to save water and reduce water wastage and waste. Precision irrigation systems require good management and accumulated experiences to control more than one common factor affecting the homogeneity of irrigation water distribution, such as the drip lines, the distance between them, the depth of the drip line location, the distance between the drippers, the operating pressure, the drip discharge rate, the frequency of irrigation and the irrigation time (24). Previous studies showed that drip irrigation has improved water use efficiency and reduced soil loss (33). Its role in significantly increasing plant growth characteristics in terms of leaf number, leaf area, plant height and grain production (8). Ayers, *et al.* (5) demonstrated the importance of drip irrigation in increasing crop yield, improving crop quality, reducing irrigation water use, and reducing the costs of tillage, fertilization and weed control. Cover crops are a key tool that can contribute to increasing yields, maintaining surface and groundwater quality, reducing erosion potential, and improving soil quality in arid and semi-arid areas (17). Cover crops have a very high potential to reduce corrosion and soil erosion and reduce airborne dust (7). Cover crops appear to be a good climate change adaptation and mitigation practice (11). Reducing evaporation from the soil surface is a means of water management, and this can be accomplished through the use of the cover crop, as the previous plant residues lead by 30% to change the thermal and moisture regime of the soil, as well as maintaining a water stock and reducing the amount of irrigation water used due to reducing evaporation rates of soil surface (16). Sandhu, *et al.* (25) evaluated the effect of a previous cover crop during an agricultural cycle in which maize and wheat crops were alternated using surface drip irrigation and flood irrigation, the researchers obtained an increase in grain yield, saving in irrigation water, and an increase in water productivity under drip irrigation with the presence of cover crop compared with flood irrigation without cover crop. Maize (*Zea mays* L.) is one of the most productive cereal crops in Iraq, it is the fourth important crop after wheat, barley and rice. The cultivated areas amounted to 515,160 and 405,427 hectares, with a productivity of 473,064 and 419,345 tons for the years 2019 and 2020, respectively. Babylon Governorate ranks first in terms of cultivated area with crop at the level of Iraq, at a rate of 29.1% (20). Maize ranks first in Latin America and Africa, but ranks third after rice and wheat in Asia. Maize is the fastest grown. cereal crop in 70 countries, including 53 developing countries. Maize is grown on more than 100,000 hectares. The long-range distribution of maize production is indicative of its excellent ability to adapt to many environments (12). and due to lack of studies in Iraq that dealt with the use of cover crop and its importance in reducing evaporation and increasing soil water retention and its effective role in reducing the costs of cultivating, fuel and fertilization, as well as improving the physical properties of the soil. Therefore, this experiment was carried out with the aim of evaluating the yield of maize under different irrigation systems and the cover crop and comparing the results with a traditional irrigation treatment followed by farmers (surface irrigation), as well as evaluating the productivity of the unit of water used in the production of maize yield under different irrigation systems and cover crop.

MATERIALS AND METHODS

A field experiment was carried out in one of the fields of the Nile sub-district of Babil Governorate, 86 km south of Baghdad, during the fall season of 2020. The experiment site is located at latitude 35' 32º 31' north, longitude 21" 36' 44º east, at an altitude of 31 m above sea level. The studied area is characterized by a flat to semi-flat topography with a slope of less than 2%. The field soil was classified as sedimentary with a mixture of silty clay loam texture and classified under the Typic torrifluvent group according to the classification of Soil Survey Staff (26). The field was planted with wheat, Plant residues were left after harvesting to cover the soil surface by 30%. Soil samples were taken randomly from the site of the experiment before planting from the 0-0.30 m and 0.30-0.60 m layer to estimate some soil physical and chemical properties. Table 1 shows the results of some of the soil physical and chemical properties.

Table 1. Some soil physical and chemical properties of studied area

Property	Soil layer (m)	
	0-0.30	0.30–0.60
Sand (gm Kg^{-1})	181	230
Silt (gm Kg^{-1})	471	453
Clay (gm Kg^{-1})	348	317
Soil Texture	SiCL	SiC
Bulk density (Mg m^{-3})	1.32	1.38
Particle density (Mg m^{-3})	2.65	2.65
Volumetric water content at 33 kpa (cm^3 cm^{-3})	0.32	——
Volumetric water content at 1500 kpa (cm^3 cm^{-3})	0.13	——
Available water (cm^3 cm^{-3})	0.19	——
Saturated Soil hydraulic conductivity (cm hr^{-1})	3.20	2.91
EC_e (dS m^{-1})	1.70	1.75
pH	7.6	7.6
Organic matter (gm Kg^{-1})	18	17
CEC (Cmolc kg^{-1} soil)	16.83	16.05

*** Properties were estimated according to methods described in Klute, (15).**

The irrigation water applied in the experiment was chemically analyzed (Table 2). The water class was defined as C_1S_3, according to the Irrigation Water Use Manual (6).

Table 2. Chemical analysis of irrigation water

Property	Value
Ec (dS m^{-1})	0.79
pH	7.55
Ca^{+2} (mmol L^{-1})	3.55
Mg^{+2} (mmol L^{-1})	3.19
Na^{+} (mmol L^{-1})	2.76
K^{+} (mmol L^{-1})	0.11
Cl^{-} (mmol L^{-1})	2.08
SO_4^{-2} (mmol L^{-1})	4.55
Co_3^{-2}	Nill
HCO_3^{-1} (mmol L^{-1})	2.17
NO_3^{-1} (mmol L^{-1})	0.08
SAR (mmol L^{-1} $)^{2/1}$	1.508
Classify the water according to (USDA)	C_1S_3

Experimental design and Statistical Analysis: The experiment was designed according to the Randomized complete block design (RCBD) with in split plot arrangement using three replications. The experiment involved two factors: 1) main plots is the cover crop (C), which two levels: cover crop (C_1), no cover crop (C_0). 2) the sub-plots, includes irrigation systems (I) with three systems: Surface Drip Irrigation (I_1), Subsurface drip irrigation (I_2), and Surface irrigation in plots (I_3) (Table 3.).

Table 3. Experimental treatments symbols

Symbol	Treatment
C_0I_1	Without cover crop + surface drip irrigation
C_0I_2	Without cover crop + Subsurface drip irrigation
C_0I_3	Without cover crop + Surface irrigation
C_1I_1	Cover crop + surface drip irrigation
C_1I_2	Cover Crop + Subsurface drip irrigation
C_1I_3	Cover Crop + Surface irrigation

Maize planting: The land was plowed at a minimum tillage by chisel plow at a depth of 0.10 m, after which the land was divided into plots of dimensions 5 x 6 m. A separation distance was left between the experimental units from all directions of about 2 m for the purpose of controlling the irrigation systems. As well as leaving a gap of 3 m between the replications. Maize seeds (*Zea mays* L.) Hybrid Al-Furat were sown from the Dutch company Monarch on 07/23/2020. The planting was carried out in the form of rows inside the plots with a direction from south to north, and each plot included 7 rows, the distance between rows was 0.75 m, and between hills 0.20 m, at a rate of 25 hill for each row, with a total of 175 hill for each plot (the experimental unit). Three seeds were placed in each hill at a depth of 0.04-0.05 m, thinned to one plant after two weeks of germination to obtain a plant density (6.6 plants m^{-2}, 66666 plants ha^{-1}). Corn stem borer *Sesamia criteca* was controlled using the granular diazinon pesticide 10% (6 kg ha^{-1}) in the heart of the plant on two dates, the first 24 days after germination and the second 15 days after the first date (4). The crop management continued from weeding and removing the weeds manually throughout the trial period. The plants were harvested on 20/11/2020 (growing season 120 days). The fertilizers were added according to the fertilizer recommendation for maize, which is 200 kg N, 78.5 kg P and 120 kg K ha^{-1} (2). The fertilizer DAP (18%N and 23.3%P) and potassium sulfate (41.5% K) were also used. At planting, DAP fertilizer and potassium sulfate were added, and after 25 days of planting, the first batch of urea fertilizer (46% N) was added, while the second batch was added after 60 days at the beginning of flowering.

Drip irrigation system: A drip irrigation system was used with pipes dedicated to surface and subsurface irrigation with a diameter of 0.016 m. The discharge of these drippers is very low, about 4.00 liters $hour^{-1}$ for the dripper. The experimental units for surface and subsurface drip irrigation were equipped with seven drip pipes for each experimental unit. The length of the drip pipe is 5 m and the distance between pipes is 0.75 m. The number of dripper in one drip pipe reached 25 drippers, as the distance between drippers is 0.20 m. The drip pipes were connected to the secondary pipe with a diameter of 0.038 m. The surface and subsurface drip irrigation system in each experimental unit were arranged according to the open system in order to facilitate the cleaning process as well as control the irrigation process with high efficiency. Subsurface drip pipes are installed at a depth of 0.20 m. Whereas, the surface irrigation treatment, irrigation water was added for each treatment through field pipes branching from the secondary pipe at the middle of the plot to be watered.

Irrigation: The irrigation was carried out after depleting 50% of the available soil water based on the measurements of soil moisture content before and after irrigation. The depth of the roots was adopted to determine the depth of the added irrigation water according to the following equation as mentioned in (31):

$$\mathbf{d = (\theta_{fc} - \theta_I) \times D} \qquad [1]$$

Where d is the depth of water added (mm), θ_{fc} the volumetric moisture content at field capacity (cm^3cm^{-3}), θ_I the volumetric moisture content before the irrigation procedure and after depletion of 50% of the available water (cm^3 cm^{-3}), D the depth of the soil layer (mm).

Soil moisture measurement: The soil moisture content was measured by the Gravimetric method to determine the irrigation period and the amount of water to be added. Soil samples were dried using a micro-wave oven according to the method mentioned in (14) and to standardize the use of a micro-wave oven, an electric oven was used for this purpose.

Irrigation scheduling: The depth of the added water (mm) was measured in each irrigation for the drip irrigation system by applying the following equations, The wet area (%) was calculated from the following equation:

$$Pw = \frac{SW}{SR} \times 100 \qquad [2]$$

Where P_w is the wet area percentage (%), Sw the diameter of the wetted area (m), which was

0.30 m for surface dripping and 0.27 m for subsurface drip, SR the distance between drip lines (m), which was 0.75 m.

The depth of water added in each irrigation was calculated for the drip irrigation system

dn = AW × Ds × Pw × dep **[3]**

Where dn is the maximum net irrigation depth per irrigation (mm), AW the capacity of the soil to store water {(%) = ($\theta_{fc} - \theta_{wpw}$)}, Ds the depth of the root zone (m), Pw the wet area percentage (%), dep the depletion rate of available water (%).

The time required for irrigation T (minutes) was calculated from the following equation:

$$\mathbf{T} = \frac{\mathbf{Ae} \times \mathbf{d}}{\mathbf{Q}} \quad [4]$$

Where Ae is The area of wetness for the single dripper was calculated from the following equation:

$$\mathbf{Ae = 0.8\ (Sw)^2} \quad [5]$$

d the depth of water added (cm), which represents the net depth of irrigation (NDI). Q the given discharge, which was 4 liters hr^{-1} per drip.

The actual water consumption of maize was estimated using the following water balance equation (35)

$$\mathbf{(I+P+C) - (ETa + D_p + R) = \pm \Delta S} \quad [6]$$

$$\mathbf{ETa = I + P \pm \Delta S} \quad [7]$$

Where ETa is the actual evapo-transpiration (mm), I the depth of irrigation water added (mm), P the rain water depth (mm), C=0 capillary height of water (mm) because the groundwater is deep, ΔS the change in soil moisture storage during a specified period of time (mm), R= 0 runoff. D = 0 leaching if the losses of deep leaching are zero. At the completion of the flowering stage, ten plants were randomly taken from the guarded plants from each line, five plants where their heights were measured, according to the average of plant height from soil surface to the lower node of the male inflorescence (13). The average total leaf area of a plant (cm^2) was also calculated and measured by multiplying the square of the leaf length under the main ear-bone by 0.75 as well as measuring the leaf area index for each plant by applying the following equation (27).

$$LAI = \frac{LA}{A} \quad [8]$$

LAI is the leaf area index. A the area occupied by the plant in the ground (0.20 x 0.75 m), LA the average total leaf area of a plant (cm^2).

The grain yield (Mg ha^{-1}) it was calculated from the average weight of the grains of all the ears harvested from the ten plants after being threshed and then dried in an electric oven at 65 degrees Celsius for 48 hours until reaching the standard humidity (15%), then the average yield of one plant was extracted and multiplied by plant density used to obtain grain yield, Mg ha^{-1} (21).

$$WUE_f = \frac{Yield}{Water\ applied} \quad [9]$$

Where WUE_f is the field water use efficiency (kg m^{-3}), Yield the total yield (kg ha^{-1}), water applied the amount of irrigation water added ($m^3\ ha^{-1}$).

$$WUE_C = \frac{Yield}{ET_a} \quad [10]$$

Where WUE_C is the crop water use efficiency (kg m^{-3}), ET_a the Actual seasonal evapo-transpiration per unit area ($m^3\ ha^{-1}$).

RESULTS AND DISCUSSION

1. Added water and actual water consumption of maize during the growing season

The results presented in Table 4 show the amount of irrigation water added, the number of irrigations for each treatment, and the actual water consumption during the maize growing season. The results showed that the highest depth of water added was for the treatment C_0I_3 reached 751.90 mm, with an increase of 137.83% compared to treatment C_1I_2, which gave the lowest depth of water added which was 316.15 mm. Whereas, the C_0I_3 treatment, it was the highest in terms of actual water consumption (709 mm $season^{-1}$), with an increase of 95.85% compared to treatment C_1I_2, which gave the lowest actual water consumption (362 mm $season^{-1}$).

Table 4. Effect of irrigation systems and cover crop on water depth applied and actual water consumption of maize (ET_a)

Treat.	Irri. no.	Applied irrigation water (mm)	Rain depth (mm)	ΔS (mm)	ET_a (mm)
C_0I_1	44	467.15	15.1	-12.75	495
C_0I_2	36	358.25	15.1	-11.65	385
C_0I_3	12	651.9	15.1	-42	709
C_1I_1	40	427.45	15.1	-26.45	469
C_1I_2	32	316.15	15.1	-30.75	362
C_1I_3	11	618.65	15.1	-40.25	674

The reason for the increases in the amount of water added in the C_0I_3 treatment than the rest of the treatments is due to a wide wetting area under surface irrigation and the exposure of the soil surface to direct sunlight, which increases evaporation. This requires adding more water quantities to provide the plant's water requirements of irrigation water. The results are consistent with what was found by Umair, *et al.* (29). Whereas, the value of water consumption in this treatment was close to the value of the amount of added water, which was relied on the elements of the water balance in calculating the actual water consumption, and that the quantities of rain water were not large during the growth period of the crop, and the contribution of the ground water was also neglected as it is deep (more than 3 m), and the value of ΔS was low and did not add large amounts to the water consumption values, as there was no significant difference in the moisture content at the beginning and end of the season. The increase in the value of water consumption While, the minimum depth of water added for the treatment C_1I_2, is attributed to the method of adding irrigation water at the effective root zone, as the wetting area is determined by the size of the soil surrounding the drip pipe under the soil surface, and the wetting volume and wetting diameter in subsurface drip irrigation were inside the soil body without wetting the soil surface so less evaporation from the soil surface, and this led to increase period between irrigations, which was reflected in the water consumption of the plant. At the same time, the lateral leaching and deep percolation are very few and the surface runoff is non-existent, and this was in agreement with what was reached (30).

2. Effect of irrigation systems and cover crop on growth characteristics.

2-1. Plant height (cm): The effect of irrigation systems and cover yield on the average height of maize plant presented in Table 5, the average height was 183, 208, 216, 191, 226 and 235 cm for the treatments C_0I_1, C_0I_2, C_0I_3, C_1I_1, C_1I_2, and C_1I_3, respectively. Statistical analysis showed that there were no significant differences in the average height of maize plant for different irrigation treatments, which means that the subsurface drip irrigation system has a similar effect with traditional basin irrigation, although the amount of water added in the drip irrigation treatments was less. The treatment C_1I_3 achieved the highest average plant height with an increase of 28% compared to treatment C_0I_1 which gave the lowest average plant height and reached 183 cm. The reason for the decrease in plant height is due to the difference in the water balance between the soil and the plant, which affected the expansion and division of cells, and these processes are affected by the variation in soil moisture due to the different treatments of the experiment, in addition to the role of the cover crop, which led to an increase in soil moisture retention by reducing evaporation from the soil surface**.**

Table 5. Effect of irrigation systems and cover crop on plant height, (cm)

Cover crop	Irrigation Systems			Average
	I_1	I_2	I_3	
C_0	183	208	216	202.33
C_1	191	226	235	217.33
Average	187	217	225.5	
LSD $_{0.05}$		N. S.		0.414

2-2. Leaf area and Leaf area index: Table 6 shows the effect of irrigation systems and cover yield on the leaf area values for maize, which were 3997, 4922, 5422, 4334, 4809 and 6076 cm^2 $plant^{-1}$ for the treatments C_0I_1, C_0I_2, C_0I_3, C_1I_1, C_1I_2, and C_1I_3, respectively. The results of the statistical analysis showed that there were significant differences in the average leaf area for irrigation treatments and cover yield. Irrigation treatments affected the average leaf area, as the traditional surface irrigation treatment in basins gave the highest average leaf area (5749 cm^2 $plant^{-1}$), and the surface drip irrigation treatment gave the lowest average leaf area (4165.5 cm^2 $plant^{-1}$), while the subsurface drip irrigation treatment did not differ significantly from the treatment of traditional surface irrigation and it differed significantly from the treatment of surface drip irrigation in the average leaf area, the reason for this is due to the role of the irrigation methods, it is one of the environmental factors that have priority in influencing the stages of emergence and formation of plant organs and their growth, as water plays a major role in increasing the availability to absorb nutrients NPK, and in cell growth and division, and the constancy of photosynthesis. In addition to being a solvent and a carrier medium for these substances to the different parts of the plant, including the leaves, as well as power supply for energy needed for photosynthesis processes in which organic food is manufactured. The results are in agreement with Dehghanisanij, *et al.* (10) and Al-Maeini and Kadim (3). The average leaf area decreased by 38.01 and 7.15% in the treatment of surface drip irrigation (I_1) and subsurface drip irrigation (I_2) compared to the treatments of conventional irrigation (I_3), respectively. The data of the same table showed that the treatments of cover crop also had a significant effect on the average leaf area of maize, as it was the largest mean leaf area at C1 treatment (5406 cm^2 $plant^{-1}$), and treatment C_0 gave the lowest average leaf area by 4780 cm^2 $plant^{-1}$. The reason for this is due to the role of the cover crop in maintaining soil moisture in a good condition, which increased the efficiency of absorption of nutrients and water by the plant, which was positively reflected in the leaf area of the maize plant. It is also attributed to the fact that the cover crop improved the physical properties of the soil represented by soil construction, bulk density, porosity and water conductivity, as well as the accumulation of organic matter in the surface layers of the soil and increasing the biological efficiency of microorganisms. The same table also showed the effect of the two-way interaction between irrigation systems and cover crop, so the highest value of leaf area was 6076 cm^2 $plant^{-1}$ for C_1I_3 and the lowest value was 3997 cm^2 $plant^{-1}$ for C_0I_1. The leaf area values varied within the interactions of the treatments, as it decreased in treatments C_0I_1 and C_0I_2 than that of C_0I_3 by 35.65 and 10.15%, respectively, and the leaf area decreased in treatments C_1I_1 and C_1I_2 by 40.19 and 26.34%, respectively.

Table 6. Effect of irrigation systems and cover crop on leaf area cm^2 $plant^{-1}$

Cover crop	Irrigation Systems			Average
	I_1	I_2	I_3	
C_0	3997	4922	5422	4780
C_1	4334	4809	6076	5406
Average	4165.5	5365	5749	
LSD 0.05		407		299

Table 7 shows the effect of irrigation systems and cover crop on the leaf area index values for maize, which were 2.67, 3.28, 3.62, 2.89, 3.87, and 4.05 for the treatments C_0I_1, C_0I_2, C_0I_3, C_1I_1, C_1I_2, and C_1I_3 respectively. The results of the statistical analysis showed that there were significant differences in the mean leaf area index for irrigation treatments and cover crop. Irrigation treatments affected the average leaf area index, as the traditional irrigation treatment in basins gave the highest average leaf area index, which amounted to 3.83, and the surface drip irrigation treatment gave the lowest average leaf area index, (2.82), while the subsurface drip irrigation treatment did not differ significantly from the traditional irrigation treatment and differed significantly from the treatment of surface drip irrigation in the mean leaf area index. This can be explained that the reasons for the increase in the leaf area index values are due to the high leaf area values for I_3 and I_2, due to the presence of a direct relationship between leaf area and leaf area index on the one hand and the result of the availability of sufficient moisture content in the root area as well as an increase in water availability and increase in the availability of nutrients, this results in an increase in growth of the plant and its vegetative parts, and then an increase in the leaf area index of the plant. These results were in agreement with the results of Zhang *et al.* (34). The mean leaf area index decreased by 35.81 and 7.28% in the treatment of surface drip irrigation (I_1) and subsurface drip irrigation (I_2) compared to the treatment of conventional irrigation (I_3), respectively. The data of the same table showed that the treatments of cover crop also had a significant effect on the mean leaf area index of maize, as the largest mean leaf area index for C_1 treatment was 3.60, and C_0 treatment gave the lowest mean leaf area index 3.22. The reason for this is that the cover crop increases the soil's ability to retain water by reducing evaporation from the soil surface, as well as changing the soil thermal system, in addition to improving the health of the soil, as well as its impact on the physical properties of the soil, improving its construction and increasing its ventilation, and this is reflected positively in the plant through the increase of the physiological processes of the plant, the growth of the plant increases, thus increasing the leaf area of the plant and increasing its index, and this is consistent with the findings of Papanikolaou, *et al.* (23). The table also showed the effect of the two-way interaction between irrigation systems and cover crop, so the highest value of the leaf area index was 4.05 for C_1I_3 and the lowest value was 2.67 for C_0I_1. The leaf area index values varied within the interactions of the treatments, as it decreased in treatments C_0I_1 and C_0I_2 than that of C_0I_3 by 35.58 and 10.36%, respectively, and the leaf area index decreased in treatments C_1I_1 and C_1I_2 than in C_1I_3 by 40.13 and 4.65%, respectively.

Table 7. The effect of irrigation systems and cover crop on the leaf area index

Cover crop	Irrigation Systems			Average
	I_1	I_2	I_3	
C_0	2.67	3.28	3.62	3.22
C_1	2.89	3.87	4.05	3.60
Average	2.82	3.57	3.83	
LSD $_{0.05}$		0.42		0.33

2-3. Grain yield (Mg ha^{-1}): Table 8 shows the effect of irrigation systems and cover crop on the values of dry grain yield of maize, as the values were 5.200, 10.050, 10.150, 6.974, 10.236 and 11.050 Mg ha^{-1} for treatments C_0I_1, C_0I_2, C_0I_3, C_1I_1, C_1I_2, and C_1I_3 respectively. The results of the statistical analysis showed that there were significant differences in the average grain yield of maize for irrigation treatments and cover crop, as well as the interaction between them. Irrigation treatments affected the average dry grain yield, as the traditional irrigation treatment in basins gave the highest average grain yield, which amounted to 10.60 Mg ha^{-1}, and the surface drip irrigation treatment gave the lowest average grain yield of 6.09 Mg ha^{-1}, while the subsurface drip irrigation treatment did not differ significantly from the traditional irrigation treatment and significantly different from the surface drip irrigation treatment in grain yield, the reason for this is due to the role of the irrigation methods, it is one of the environmental factors that have priority in influencing the stages of emergence and formation of plant organs and their growth, as water plays a major role in increasing the availability to absorb nutrients NPK, in the growth and division of cells, and the regularity of the photosynthesis process. In addition to being a solvent and a carrier medium for these substances to the different parts of the plant, including the leaves, as well as power supply for energy needed for photosynthesis processes in which organic food is manufactured. and this is consistent with Liu, *et al.* (18). The average grain yield decreased by 74.14 and 4.50% in the surface drip irrigation treatment (I_1). and subsurface drip irrigation (I_2) compared to conventional irrigation (I_3), respectively. The results showed that cover yield treatments significantly affected the dry grain yield of maize (Table 8). The treatment C_1 gave the highest average dry grain yield of 9.420 Mg ha^{-1} and C_0 gave the lowest average dry grain yield of 8.47 Mg ha^{-1}. The reason for the increase in the average yield of grain when cover crop treatments is attributed to its positive role in improving the physical and chemical properties of the soil, in addition to decomposition by microorganisms in the soil and providing plants with the necessary nutrients, especially nitrogen and potassium, They are credited with increasing the vigor and activity of vegetative growth, in addition to the increase in the number of grains in the ear, which is positively reflected in the increase in the total yield, and these results agreed with what was mentioned by Mingotte, *et al.* (18). The reason for the increase in the grain yield may be attributed to the role of the cover crop in improving the physical properties, maintaining water storage, reducing evaporation and the abundance of nutrients for the plant, thus improving plant growth and increasing the yield. Cover crop plays an effective role in increasing the total yield compared to the treatment without the cover crop, by getting rid of the weeds and not competing with the economic crop for water and nutrients, and this in turn increases the effectiveness of carbon metabolism in addition to providing the necessary nutrients for the plant, especially organic nitrogen, which in turn increases the leaf area of the plant, which reflected positively on the yield (30). The results also show the effect of the two-way interaction between irrigation and cover crop, the highest value of grain yield was 11.050 Mg ha^{-1} for C_1I_3 treatment and the lowest value was 5.200 Mg ha^{-1} for C_0I_1 treatment. The values of the dry grain yield of maize plant varied within the interactions of other treatments, as it decreased in treatments C_0I_1 and C_0I_2 from that of C_0I_3 by 95.19 and 0.99%, respectively, and the grain yield in treatments C_1I_1 and C_1I_2 decreased by 58.44 and 7.95% from the treatments C_1I_3 respectively.

Table 8. The effect of irrigation systems and cover crop on grain yield, (Mg ha^{-1})

Cover crop	Irrigation Systems			Average
	I_1	I_2	I_3	
C_0	5.200	10.050	10.150	8.467
C_1	6.974	10.236	11.050	9.420
Average	6.087	10.143	10.600	
$LSD_{0.05}$		0.464		0.307

3- Water productivity

3-1. Field water use efficiency (kg m^{-3})

Table 9 shows the efficiency of field water use (Eq. 9) for maize. The efficiency of field water use varied according to the different experimental treatments, and as shown in the table, the treatment C_1I_2 gave the highest field water use efficiency, which amounted to 3.49 kg m^{-3}, with an increase of 214.14% compared to the lowest value of field water use efficiency achieved by treatment C_0I_1 (1.11 kg m^{-3}). The crop water use efficiency of other treatments, was 2.80, 1.81, 1.63 and 1.55 kg m^{-3} for treatments C_0I_2, C_1I_3, C_1I_1 and C_0I_3, respectively. The reason why C_1I_2 treatment achieved the highest field water use efficiency is attributed to the method of adding water to this system, which maintains moisture levels close to the field capacity in the root zone of the plant and at the same time consumed less water and gave a high grain yield compared to other treatments. These results are consistent with what was stated by Thamer, *et al.* (28).

Table 9. The effect of irrigation systems and cover crop on the field water use efficiency (kg m^{-3})

Cover crop	Irrigation Systems			Average
	I_1	I_2	I_3	
C_0	1.11	2.80	1.55	1.82
C_1	1.63	3.49	1.81	2.31
Average	1.37	2.64	1.68	
$LSD_{0.05}$		0.028		0.017

3-2. Crop water use efficiency (kg m^{-3})

Table 10 shows the crop water use efficiency (Eq. 10) for maize. The efficiency of crop water use differed according to the different treatments of the experiment. The C_1I_2 treatment gave the highest crop water use efficiency of 2.82 kg m^{-3} with an increase of 168% compared to the lowest efficiency of crop water use efficiency 1.05 kg m^{-3} for C_0I_1 treatment. while the other treatments the crop water use efficiency was 2.61, 1.63, 1.48 and 1.43 kg m^{-3} for treatments C_0I_2, C_1I_3, C_0I_3, and C_0I_3, respectively. The reason for the increase in the crop water use efficiency for the treatment C_1I_2 is that it consumed the least amount of water due to the effect of the cover crop by reducing water evaporation and retaining more moisture from the soil and reduce the losses of deep infiltration, as well as this treatment gave a grain yield close to the treatment of traditional irrigation in plots and these results came in agreement with the results of Wang *et al.* (32).

Table 10. The effect of irrigation systems and cover crop on the crop water use efficiency (kg m^{-3})

Cover crop	Irrigation Systems			Average
	I_1	I_2	I_3	
C_0	1.05	2.61	1.43	1.69
C_1	1.48	3.05	1.66	2.06
Average	1.26	2.83	1.54	
$LSD_{0.05}$		0.026		0.015

CONCLUSION

It is clear that drip irrigation in the presence of the residues of the previous crop improved the efficiency of irrigation water use by increasing the yield of maize and reducing the added water. Treatment C_1I_2 gave the highest efficiency of water use with a yield similar to that of conventional surface irrigation. When comparing drip irrigation with surface irrigation, a significant difference is observed in the production of grain yield, growth factors and water use efficiency. The drip irrigation systems have saved about 33% and 45% of the water used for the subsurface drip irrigation and surface drip irrigation systems compared to the traditional surface irrigation system respectively. And the difference in the amount of water used represents an excess amount of water, which is a very important amount of water for the possibility of using it in another location or to irrigate another crop or preferably use it at a later time.

REFERENCES

1- Al-Ansari, N., S, Jawad. N., Adamo. and V., Sissakian,. 2019. Water quality and its environmental implications within tigris and euphrates rivers. Journal of Earth Sciences and Geotechnical Engineering, 9(4): 57-108.

2- Al-Hilfy, I. H. H., and A., H., Al-Temimi. 2017. Response of three synthetic maize (*Zea mays* L.) cultivars to different fertilizers for growth traits and biological yield. Iraqi Journal of Science and Technology, 8(3).

3- Al-Maeini, A. H. A. and H. A. M. Kadim. 2017. Growth and yield of maize under irrigation methods and some physical treatments. Al-Furat Journal of Agricultural Sciences – 9(4): 72-85.

4- Al-Roumi, A. H., H. Abdul Jalil and A. A. Kubba. 2018. The effect different levels of diazenon on sesamia criteca in different time for farieties of *Zea mays* L. J. of kerbala Uni. 16(4): 213-223.

5- Ayers, J.; A., Fulton, and B., Taylor. 2015. Subsurface drip irrigation in California—Here to stay? Agric. Water Manag. 157, 39–47.

6- Ayers, R.S. and D.W. Westcot. .1985. Water quality for agriculture. FAO. Irrigation and drainage. Paper 29, Rev. 1, U.N. Rome.

7- Bergtold, J. S., S., Ramsey. L., Maddy. and J. R., Williams. 2019. A review of economic considerations for cover crops as a conservation practice. Renewable Agriculture and Food Systems. 34(1): 62-76.

8- Chitra, R.; R. M. Havaraddi. S. Subramanian. and J., Suresh .2017. Effect of scheduling of drip irrigation on growth, yield and water use efficiency of turmeric (*Curcuma longa* L.) var. CO2. J. Spices Aromat. Crop. 26, doi:10.25081/josac.2017.v26.i1.801.

9- Comas, L.H., T. J. Trout, K. C., DeJonge, H., Zhang and S. M., Gleason. .2019. Water productivity under strategic growth stage-based deficit irrigation in maize. Agric. Water Manag. 212: 433-440.

10- Dehghanisanij, H., E., Kanani, and S. Akhavan. 2018. Evaluation of corn evapotranspiration and its components and relationship between leaf area index and components in surface and subsurface drip irrigation systems. J. of Water and Soil. 31(6). 1549 – 1560.

11- Delgado, J. A., V. H. B. Mosquera, J. R. Alwang, A. Villacis-Aveiga, A. Ayala, Y. E. C. Neer, and L. O. E. López. 2021. Potential use of cover crops for soil and water conservation, nutrient management, and climate change adaptation across the tropics. 176 – 237.

12- Dowswell, C. .2019. Maize in The Third World. CRC Press.

13- El-Sahookie, M. M. 1990. Maize Production and Improvement. Ministry of Higher Education and Scientific Research. Baghdad University. Pp 400.

14- Jastrzebska, M. 2019. Practical application of the microwave oven in the geotechnical laboratory. Architecture Civil Eng. Env. 2(2019): 91-104.

15- Klute, A. (eds.). 1986. Methods of Soil Analysis: part 1-physical and mineralogical methods (ASA and SSSA. SSSA Book Series No. 5. Madison, WI: Soil Sci. Soc Am, USA.

16- Kaye, J. P., and M. Quemada. 2017. Using cover crops to mitigate and adapt to climate change. A review. Agron. for Sustainable development, 37(1): 1 – 17.

17- Kumar, V., A., Obour, P., Jha, R., Liu, M. R., Manuchehri, J. A., Dille, and P. W. Stahlman. 2020. Integrating cover crops for weed management in the semiarid US Great Plains: opportunities and challenges. Weed Science. 68(4): 311-323.

18- Liu, Y., J. Zhang and Y. Qin. 2020. How global warming alter future maize yield and water use efficiency in China. Tech. Fore. and Soc. Change, 160, 120229.

19- Mingotte, F. L. C., C. A. Jardim, M. M. Yada, C. B. Amaral, T. P. L. C. Chiamolera, A. P. Coelho, and D. F. Filho. 2020. Impact of crop management and no-tillage system on

grain and straw yield of maize crop. Cereal Res. Comm. 48: 399-407.
20- Ministry of Planning - Central Bureau of Statistics. .2021. Agricultural Statistics Department, Republic of Iraq. 1– 20.
21- Mulvaney, M. J. and P. Devkota. 2020. Adjusting Crop Yield to Standard Moisture Content. The Institute of Food and Agricultural Sciences (IFAS), University of Florida, United States, 4.
22- Omran, E. S. E. and A. M. Negm (Eds.). 2020. Technological and Modern Irrigation Environment in Egypt: Best Management Practices and Evaluation. Springer Nature.
23- Papanikolaou, C. D. and M. A. Sakellariou-Makrantonaki .2020. Estimation of corn leaf area index and ground cover with vegetation indices as a result of irrigation dose. J. of Agric. Sci. 12(12). 234 – 244.
24- Robi Borena, F, and T. Seyoum. 2021. Effect of drip and furrow irrigation at different irrigation levels on water use efficiency and economics of maize (*Zea mays* L.) at Werer, middle awash, Ethiopia. Irriga. Drainage Sys. Eng. 10(5): 1-5.
25- Sandhu, O. S., R. K. Gupta, H. S. Thind, M. L. Jat, and H. S. Sidhu. 2019. Drip irrigation and nitrogen management for improving crop yields, nitrogen use efficiency and water productivity of maize-wheat system on permanent beds in north-west India. Agric. Water Mana. 219: 19-26.
26- Soil Survey Staff .2019. Soil Survey Manual (U.S. Department of Agriculture Handbook No. 18). Pp 587.
27- Solaimalai, A., P. Anantharaju, S. Irulandi and M. Theradimani. 2020. Maize Crop: Improvement, Production, Protection and Post Harvest Technology. CRC Press.
28- Thamer, T. Y., N. Nassif and A. H. Almaeini. 2021. The productivity of maize (*Zea mays* L.) water using efficacy and consumptive use under different irrigation systems. Peri. of Eng. and Natu. Sci. (PEN), 9(1): 90-103.
29- Umair, M., T. Hussain, H. Jiang, A. Ahmad, J. Yao, Y. Qi and Y. M. Shen. 2019. Water-saving potential of subsurface drip irrigation for winter wheat. Sustainability, 11(10): 2978.
30- Vincent-Caboud, L., M. Casagrande, C. David, M. R. Ryan, E. M. Silva, and J. Peigne. 2019. Using mulch from cover crops to facilitate organic no-till soybean and maize production. A review. Agron. for Sustainable Development. 39(5): 1-15.
31- Waller, P., and M. Yitayew. 2016. Irrigation and Drainage Engineering. Springer. Pp 747.
32- Wang, D., G. Li, Y. Mo, D. Zhang, X. Xu, C. J. Wilkerson, and G. Hoogenboom. 2021. Evaluation of subsurface, mulched and non-mulched surface drip irrigation for maize production and economic benefits in northeast China. Irri. Sci. 39(2):159-171.
33- Wang, D., G. Li, Y. Mo, M. Cai, and X. Bian. 2018. Evaluation of optimal nitrogen rate for corn production under mulched drip fertigation and economic benefits. Field Crops Research. 216 : 225-233.
34- Zhang, T., Y. Zou, I. Kisekka, A. Biswas, and H. Cai. 2021.Comparison of different irrigation methods to synergistically improve maize’s yield, water productivity and economic benefits in an arid irrigation area. Agric. Water Mana. 243 : 106497.
35- Zhang, Y., J. Wang, S. Gong, D. Xu, and J. Sui. 2017. Nitrogen fertigation effect on photosynthesis, grain yield and water use efficiency of winter wheat. Agric. Water Mana. 179 : 277-287.