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Research Article

Drip Irrigation System Design for one of the Olive Farm Species (Olea europea) Growing in Mosul

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Keywords
olive tree, head loss, irrigation system, main pipelines, lateral pipelines.

Abstract
The research was conducted in the city of Mosul in the southern Sinjar region, with more than 30,000 hectares of agricultural land, the largest area of which depends on rainwater, and the amount of rain falling was little its seasonal distribution did not meet the needs of crop growth in a good way. The solution that can be provided to the problem of the water shortage was the serious thinking about increasing the efficiency of water use by adopting other types of irrigation such as drip irrigation. In this study, we designed a drip irrigation system for olive lands in Mosul, especially as Mosul is appropriate for olive cultivation. The olive farms of (*Olea europea*) species are very economic and profitable. The drip irrigation system was used, the design results were that the density of trees was 400 trees/ha, each tree needed four droppers with a drainage of 4 liters/hour and an operating pressure of one bar, the water requirement was 195 liters/tree/day. The olive farms of (*Olea europea*) species were very economic and profitable. The drip irrigation system was used, the design results were, that the density of trees was 400 trees/ha, each tree needed four droppers with drainage of 4 liters/hour and operating pressure of one bar, the water requirement was 195 liters/tree/day. The olive farm (stand) was divided into 3 units, the number of operating hours was 10 hours/day, and the period between two successive irrigations was 3 days, but the irrigation duration per day (Ta) was 10 hr, the total feeding pips for all farm units were 30 pipes. Water drainages were 0.23m^3/hr for each feeding pipe. Water losses of 10-20% from the operating pressure of the emitter. Otherwise, the first, second, and third main pipe drainages were (10, 9.6, 6.4 m^3/hr) respectively. Three lateral pipe drainages (9.6, 6.4, 3.2 m^3/hr) respectively helping small farmers grow olives and providing them with loans and agricultural facilities particularly the agricultural college graduates, will reduce unemployment among young people and restore balance to the agricultural sector.

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1. Introduction

Olive trees have a great economic importance, such as food industries, soap industries, and their various usages in animal feed, soil fertilizer with its fruits and seed residues, as well as wood productions [1]. The olive trees are belong to

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the plant family called (*Oleaceae*) which, include the olive Genus (*Olea*), which had many species, like European species which is found in Iraq in several varieties such as Ashrassi, Bashaki, etc[2].

As a result of awareness programs to drought and desertification, The united nations division for sustainable development, in cooperation with the international cooperation agency, which organized many international workshops about the utilization of a small-scale low-pressure drip irrigation system at agriculture and forestry lands where the annual crops and trees were cultivated [3]. The "operating system" allowed farmers to utilize science-based irrigation and increased their vegetables and fruit crops throughout a year with a highly efficient resource usage. Developed countries used an intensive olive cultivation since the 1990s, led to the thinking of using an irrigation system at low cost with large production , high profitability, led to the thinking of using an irrigation system at low cost with large production, with high profitability and water efficiency in the medium and long term [4]. The original habitat of olive trees is the Mediterranean basin, which grown throughout a year in all regions as the northern and central Iraq, in addition to their success cultivations in other countries such as Australia, Japan, United States, Mexico, and many South American countries as Peru, Brazil, Chile, and Argentina.

The resistance of olive trees to different conditions as drought, salinity and the soil nutrient lakes, encourage us to achieve the target of our researches to investigate a new drip irrigation system design for one of olive farms in Mosul province and help small farmers for utilizing it in their olive farms [5]. Several equations were used in the irrigation design.

2. Material and Methods

2.1. Research Area Locations

We searched for an olive farm that has enough trees next to a water source in a rural area of Nineveh Province in Al-Jazeera region between talafar and singar because the availability of olive plantations.

2.2. Physiographic of Research Area

The physical and topographical characteristics of the research area in the olive farm were studied, which included determining the type, depth and specific weight of the soil, in addition to its texture and moisture content.

2.3. The Olive Farm Selected Data

The (*Olea europea*) species was studied carefully about its physical and growth properties, then all data was collected.

2.4. The Irrigation System

The drip irrigation system was preferred according to [6], which was very adaptable with the farm land slopes.

2.5. Farm Land (Stand) Areas

The total of the olive (stand) farm areas was estimated, after that, the total number of trees was calculated.

2.6. The Olive Trees Water Requirements

Climate data of Talafar District and the olive farm regions for 12 month at several years was collected and the average range of temperature, relative humidity, speed winds were at a height of 2m height, at ever sunrise, then, many mathematical equations were used to determine the olive water requirements such as the potential evapotranspiration, the reference evapotranspiration range, the ground cover reduction factor, irrigation at peak demand, the field application efficiency, ratio of leaching requirement, net irrigation requirement, and the gross irrigation requirement.

3. The Potential Evapotranspiration Eto

Benman Monteth's equation was used to calculate the potential evapotranspiration and the reference evapotranspiration range [7], as shown in equation (1), Then the effective rainfall was calculated [8] and the crop evapotranspiration, and Reference crop evapotranspiration, and ground cover reduction factor from equations (1, 2, 3) was obtained [9].

3.1. The Reference Evapotranspiration Range (Eto)

$$ETo=\frac{0.408\Delta(Rn-G)+Y\frac{900}{T+273}U_2(es-ea)}{\Delta+Y(1+0.34U_2)} \tag{1}$$

ETo: Reference crop evapotranspiration (mm day^{-1}).

$ETcrop$: Crop evapotranspiration.

Rn: Net radiation (MJ $m^{-2}day^{-1}$).

Δ: Slope at vapor pressure curve (kPa /°C^{-1}).

G: Heat flux of soil (MJ/$m^{-2}day^{-1}$).

Y: Constant (kPa /°C^{-1}).

T: Air temperature (°C).

U_2 : Wind velocity (ms^{-1}).

$(es - ea)$: deficiency at the saturation vapor pressure (kPa).

3.2. The Ground Cover Reduction Factor (Kr)

First of all the evapotranspiration of crop from equation (2) was obtained, then we were calculated the ground cover reduction factor from equation (3).

$$ETc=Eto*kc \tag{2}$$

ETc: Evapotranspiration of crop (mm d^{-1}).

Kc: Crop coefficient.

Kr: Ground cover reduction factor.

$$ETcrop = ETc * Kr \tag{3}$$

3.3. Irrigation At Peak Demand (Td)

From equation (4), the localized estimated irrigation at peak demand (Td) was calculated.

$$Td = Ud * [0.1(pd)^{0.5}] \quad (4)$$

Td : Estimated (ETcrop) at peak demand .

Ud : Conventionally estimated peak (ETcrop).

Pd : Percentage of ground cover (%).

Then, we were finding the density of trees per hectare in olive stand trees.

3.4. The Field Application Efficiency (Ea)

The field application efficiency was estimated from the equation (5).

$$Ea = Ks * Eu \quad (5)$$

Ea: The efficiency of field application.

Ks: Water stored in root average / Average of water applied.

Eu: Coefficient of water application.

3.5. Ratio of Leaching Requirement, Net Irrigation Requirement, and The Gross Irrigation Requirement (Irg)

Equations (6), (7), and (8) were used to calculate the ratio of leaching requirement, net irrigation requirement, and gross irrigation requirement (IRg) respectively.

$$LRt = \frac{Ec_w}{2 * [max\, ECe]} \quad (6)$$

LRt: Ratio of leaching requirement.

EC_w: Electrical conductivity of water.

EC_e: Electrical conductivity of the soil saturation.

$$LRt = LRt * \frac{IRn}{Ea} \quad (7)$$

IR_n: Net irrigation requirement.

LRt: Leaching requirement.

$$IRg = \frac{IRn}{Ea} - R + LR \quad (8)$$

IRg: Gross irrigation requirement.

R: Rain.

3.6. The Emitter Per Tree (Np)

From equation (9), the emitter per tree (Np) was determined.

$$Emitter\ \ Per\ \ Tree(Np) = \frac{Se * Sr * Pw}{Aw} \tag{9}$$

p : Number of emitter per plant.

Se :Distance between emitters(emitter spacing).

Sr : Distance between plant row (Row spacing).

Pw : percentage wetted area.

Aw : Area witted per one emitter.

3.7. The Net Irrigation Per Tree

By (10) and (11) equations, we found the net irrigation per tree.

$$IRg = \frac{Sp}{Np} \tag{10}$$

Se : Emitter spacing.

Sp : Distance between plants in row.

$$Net\ \ irrigation\ \ per\ \ tree = \frac{IRg * Se * Sr}{1000} \tag{11}$$

3.8. The Readily Available Water(RAW)

Equation (12)was used to calculate the readily available water (RAW).

$$RAW = (\theta_{FC} - \theta_{WP})* Rd * Dp\% * Pw \tag{12}$$

RAW: Readily available water of soil at the root zone.

θ_{FC} : The water content at field capacity.

θ_{WP} : The water content at welting point.

Rd : Root depth.

$Dp\%$: Deep percolation%.

Pw : Percentage wetted area.

3.9. Irrigation Frequency at Peak Demand and The Duration of Irrigation per Day

From (13) and (14) equations, the irrigation frequency at peak demand and the Continuance of irrigation per day estimated.

$$Irrigation\ \ frequency\ \ at\ \ peak\ \ demand = \frac{Readily\ \ Available\ Water\ \ of\ \ soil\ \ at\ \ the\ root\ \ zone}{Net\ \ irrigation\ \ per\ \ tree} \tag{13}$$

$$Ta = \frac{NIR}{Np \times q} \tag{14}$$

Ta : Duration of irrigation per day.

NIR : Net irrigation requirement.

Np : Number or emitter per plant.

q : Emitter discharge (1/hr).

4. The Drip Irrigation System

The well had one of a submerged water pumps to pull the water from it, and the irrigation pipes system network design attached to it.

The field pipes system network contained two types, the first one called lateral lines made of a polyethylene, but the other contained of a main pipe lines and manifold pipelines made of a PVC materials , in addition to a connection parts, such as drippers or emitters, pressure & flow regulators, and fitting &valves made of a polyethylene.

5. The Lateral Lines Design

The number of lateral pipe lines per unit and the total number of lateral lines were calculated, then the drain through lateral pipe was estimated which equal to the number of emitters on one lateral pipe multiplied by drainage of a single emitter, and drain of one lateral pipe units was m^3/hr.

The friction head loss for each meter length segment pipe for all pipes was calculated from equations of fraction losses in meters per meter of a tube [10].

$$hf = 1.21 \times 10^{10} \times (\frac{QL}{C})^{1.852} \times \frac{1}{D^{4.87}} \times L \times F \tag{15}$$

h_f: Fraction losses in meters per meter of tube.

H : Emitter operating pressure.

L : Length of pipe.

F : Correction factor (Christiansen's coefficient) = 0.359.

Q : Drain of pipe.

C : Coefficient of retardation depending on pipe material =140 for plastic.

D : Inside diameter of pipe (mm).

Manifold Pipe Design

The drain of the first manifold pipe, drain the second manifold pipe and drain the third manifold were calculated of (m^3/hr) units, and then, 1.1 was added as positional wastes, which were equal to 10% as longitudinal wastes.

The Drain of the Main Tube Design

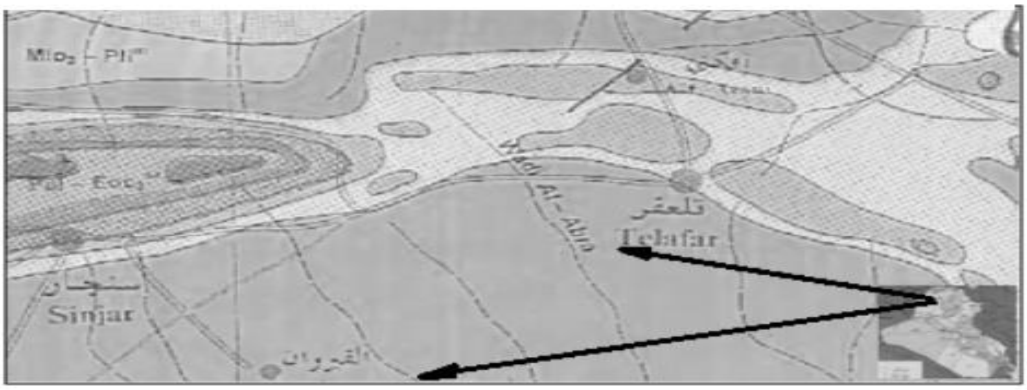
The drain of the first main pipe, drain the second main pipe, and the drain of the third main pipe were estimated whereas, the main pipes were made of PVC material at 75mm diameters.

6. Results and Discussion

6.1. Research Area Locations

As Fig.1 shown, the olive stand area of (*Olea europea*) species was located in the north-west of Iraq in Aljazeera in the south of Sinjar Mountains and was about 70 kilometers southwest from Mosul between Longitude (42) and (43) east, and in the latitude (50° 36°) and (20° 37°) north, whose land topographies was flat with a slight slope from the northwest toward the southeast.

Figure 1. The olive stand research Areas



7. Physiographic of Research Area

The research area was characterized by good fertility with flat agricultural lands w ith little slope, and it consists of sediments resulted from the process of transforma tion and sedimentation. It also consisted of layers of sand and alluvial clay rocks wi th gradient grains from medium to coarse size and there are some layers of gypsu m. Soil color in general was light brown because it contains large amounts of gypsum. The field capacity was estimated to be around 35-46% permanent, while the permanent wilting point was 17-22% [11]. The color of the soil in general was light brown because it contains large amounts of gypsum, as the percentage of gypsum in the soil at (0-100 cm) depth was about (30-40%). The apparent density of farm soil was changed as it reached (1.25-1.34gm/cm^3) at the surface above 100 cm. The acidity of the farm soil was weak (pH 7.8-8.0) whereas, the organic matter of soil was decreased when depth increased. Table 1, shows the obtained values of moisture content, apparent specific weight, soil texture, and soil depth.

Table 1. Physical properties of the research area soils

moisture content %	Apparent specific weight	texture	Clay%	Separators Silt%	Sand%	Depth (cm)
26.2	1.25	Silt loam	20.8	65.8	13.4	0-15
12.2	1.30	Silt clay	43.3	49.9	6.7	15-75
22.5	1.34	Silt loam	17.3	50.2	32.5	75-150

8. The Olive Farm Selected Data

The (*Olea europea*) species was an olive trees of long-life evergreen types with short and sharp leaves able to withstand abnormal conditions, and it was capable of survival in dry soils [12]. All of the selected trees in the farm3

+ were at about 3-4 years of age.

The selected olive trees in the stand roots were extended laterally to 12 meters inside the soil with 120-170 cm deep at their root depth and were approximate rates of one meter[13, 14, 15].

9. The Irrigation System

The irrigation system was selected according to the results obtained. It was good option in terms of the low cost and water availability, as well as sustainability considerations [16].

10. Farm Land (Stand) Areas

The total area of the olive farm was 1.5 hectares, and its topographic land was flat. It was very easy to use farm machines [17]. The distances between the olive trees were of (2-3 m) and the distance between one line and another was about (3-5m). The olive farm was square in shape, it didn't need any adjustment, and the drip irrigation overcomes the simple variation in elevations and lows in the farm earth. There was an equal space between trees inside and among rows, this type was an easy-to-plan stand, and therefore the distance of 5*5 m was selected.

11. The Olive Trees Water Requirements

11.1. The Potential Evapotranspiration (Eto)

After using Benman Monteth's reference evapotranspiration range was calculated [7] according to the equation (1). The effective rainfall [9], the crop evapotranspiration, and reference crop evapotranspiration *ETcrop* was estimated by equations (1), (2), and (3).

As shown in table 2, all results for the rainfall values among months and seasons, *ETo*, *ETc*, and *ETcrop* were observed. The highest rate value of the effective rainfall (Re) was about (32.7mm) in March, and the lowest value was (2.1mm) in October. Whereas the highest value of (*ETo*) was in August with an average (8.82). But, the (*ETcrop*) had a higher value in July with an average of (6.25).

The rainfall amounts in the search area fluctuated according to the quantity and the time of precipitation, which led us to use supplementary irrigation especially when the rain was insufficient to meet the tree needs to maintain production-proven.

Table 2. Result range values(average) for Re, ETo, ETc, and ETcrop for twelve months.

	Jan.	Fab.	Mar.	Apr.	May	Jun	Jul.	Aug.	Sep.	Oct.	Nov	Dec.
Re	32.9	37.2	38.0	32.7	8.4	0	0	0	0	2.1	21.6	31.5
ETo	1.62	2.83	4.11	5.70	7.40	9.03	9.8	8.82	6.81	3.75	2.76	1.68
Etc	1.13	1.98	2.67	3.71	4.8	6.78	7.35	6.62	4.77	2.63	1.93	1.18
Etcrop	0.96	1.68	2.27	3.15	4.08	5.76	6.25	5.62	4.05	2.23	1.6	1.01

Irrigation at Peak Demand (Td)

From equations (3), (4), (5) the localized estimated irrigation at peak demand (Td) was in about (6.15mm).

11.2. The Density of Trees per Hectare

The density of trees in hectare was estimated and it was of about 400 trees per one hectare.

11.3. The Field Application Efficiency (Ea)

From equation (5) we found the field application efficiency (Ea), which was at 0.86 range, therefore, we designed one of a low-pressure drip irrigation system based on the earthly attraction and without any need to use pumps for the irrigation of the olive trees.

We also found in this study, that the necessary amount of irrigation water was (65.5 m^3 per 3 hectares) per day, which was at the minimum water supply for tree irrigation during peak periods from June to September, at a attrition rate of 50%.

From table 3, this was suggested by Keller and Karmeli [18]. We found the ground cover reduction factor (kr) between 0.12 and 1.00 ranges.

Table 3. Values reduction factor (kr)suggested Keller and Karmeli

Ground Cover (%)	10	20	30	40	50	60	70	80	90	100
values of (kr)	0.12	0.24	0.35	0.47	0.59	0.70	0.82	0.94	1.00	1.00

Ratio of Leaching Requirement, Net Irrigation Requirement, and Gross Irrigation Requirement (Irg)

Equations (6), (7) and (8) gave us the percentage of filtration requirements, which was about 0.0714, while the net irrigation requirements was about 6.25, and the efficiency of the field application was about 0.86.

The leaching requirement ratio under drip irrigation was 0.071, and the leaching requirement was 5.2mm/day, whereas the gross irrigation requirement (*IRg*) was $7.79mm/day$.

11.3. The Emitter per Tree (Np)

From equation (9), the emitter per tree (*Np*) value was about 4 emitter/ tree.

11.4. The Net Irrigation per Tree

From the equations (10), (11), and (12) we found the emitter drained (Se), which was about 1.25 L /hr

(0.00125m3/ hr), the net irrigation per tree was about 194.75 L /day/tree, and the readily available water (RAW) was about 600 L/tree.

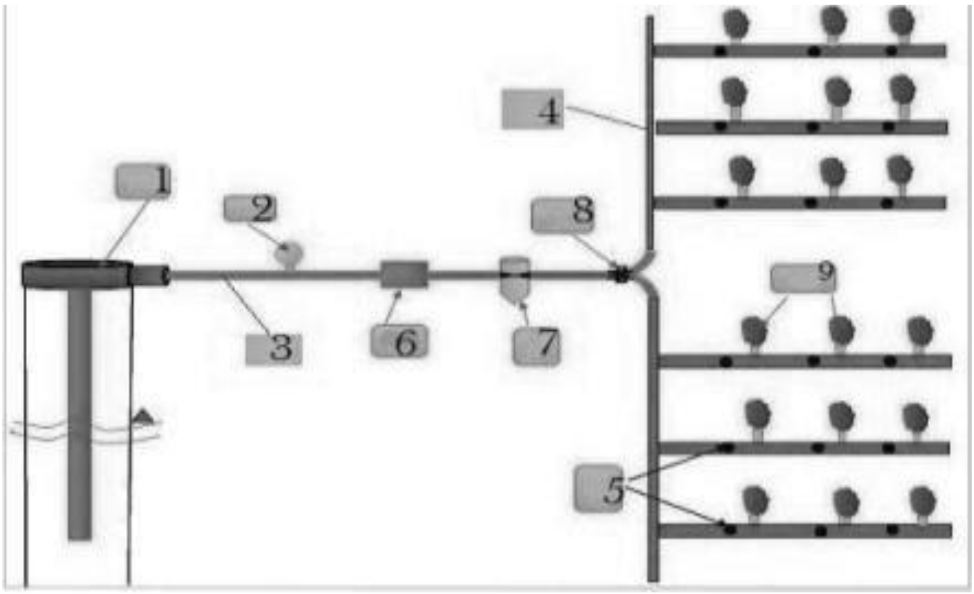
11.5. Irrigation Frequency at Peak Demand and the Continuance of Irrigation per Day

From equation (13) and (14) we found the irrigation frequency at peak demand which was about 3 days, but the duration of irrigation per day was about 9.75. As the results obtained, the stand divided into three irrigated units with 50x 100 m dimensions of the irrigated unit. The number of trees was 600, the density of trees was was 400 trees per hectare, and the olive farm areas divided into 3 irrigation units [19].

12. The Drip Irrigation System.

The field pipe system components made of PVC materials, and the pipeline network as the flow chart in Fig 2.

Figure 1. Irrigation system component.



1. Pump
2. Meter
3. Main pipe lines
4. Lateral Pipe Lines
5. Emitters
6. Drainage regulator
7. pressure gage
8. Main Trap
9. olive trees

12.1. The Lateral Lines Design

Table 4, shows the water discharge, length, and diameter results for the pipe lines such as the main line, manifold line, and lateral line.

The lateral line lengths was about 100m, the water discharge of the lateral pipe was 0.32m^3/hr, while its diameter was 25 mm. It should be noted that the loss in water along feeding pipes must not exceed 10-20% from operating pressure of the dripper for diameter of 16 mm, and 100 meter long of the uPVC lateral line pipe [20].

Table 4. Water discharge, Diameter, and length of the pipe lines.

	Main Line			**Manifolds Line**			**Lateral Line**
	1	**2**	**3**	**1**	**2**	**3**	
Water discharge (M^3/hr)	10	9.6	6.4	9.6	6.4	3.2	0.32
Length (M)	30	55	50	55	55	50	100
Diameter(mm)	75	75	75	50	50	50	25

12.2. Manifold pipe designs

The first manifold pipe water discharges was 9.6 m^3/hr, the second manifold pipe water discharges was 6.4 m^3 /hr, and the third manifold pipe water discharges was 3.2 m^3/hr, whereas its diameter was 50 mm for all manifold pipe lines and the total length of all three manifold pipes line was 160 meters as shown in table 4, (Then 1.1 had been added as positional wastes, which were equal to 10% of longitudinal wastes).

12.3. The drain of the main tube design

The drain of the first main tube was about 10m^3/ hr, the drain of the second main tube was about 9.6m^3/hr, and the drain of third main tube was about 6.4 m^3/ hr while its diameter was 75 mm for all mainline pipes, and the total length of all three feeding pipes was 135 meters as seen in table 4. Therefore it was better for us to prefer the drip irrigation system in our study to get a good start for the young olive trees planted in the stand, without any suffering of water stresses. Trees need frequent irrigation and once a day irrigation during summer period [21].

13. Conclusion

In our project drip system, the gross irrigation requirement (7.79 mm /day) was compatible with the tree density (400/ hectare) of (10*50 meter) dimensions and with 4 emitters per tree at a 3-day period, in irrigation frequency at peak demand, and 10 hours of a duration of irrigation per a day (Ta). The pipeline network was 30 pipes with water drained capacity for main pipes (6.4, 9.6, 10m^3/hr) and water drain capacity of manifold pipeline value (3.2, 6.4, 9.6 m^3/hr). The system was based on the geography and climate of the irrigated areas, as well as on the trees or plants species cultivation.

Drip irrigation will encourage olive growers to cultivate it and improve green spaces while increasing its productivity at low cost, thus improving farm soil properties, reducing soil degradation inside olive nurseries by increasing irrigation water quality to maintain high productivity.

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