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ON-FARM ENERGY REQUIREMENTS FOR LOCALIZED IRRIGATION SYSTEMS OF CITRUS IN OLD LANDS

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ABSTRACT

The energy required to operate pump irrigation water for crop production can be measured in terms of fuel consumption or electric power usage. Energy usage depends on the amount of irrigation water, irrigation time and consequentley on the fuel consumption or electric power required for each pumping unit of water. Field experiments were conducted at Shalakan Experimental Farm, Faculty of Agriculture, Ain Shams University, Kaliobiya Governorate, Egypt. Orchard (Citrus trees) is irrigated by four localized irrigation systems, namely: surface drip, mini-sprinkler, standard bubbler and low-head bubbler. The performance of these systems from the point of view of the consumed energy was compared with gated pipes irrigation system as a modified surface system of irrigation. The objectives of this study were to discuss the factors that affect energy requirements for irrigation pumps, to emphasize ways that localized irrigation systems can be designed and managed to minimize energy requirements for localized irrigation, to estimate the energy requirements for localized irrigation and to compare between the tested irrigation systems based on energy requirements. The results indicated that, the amount of water applied depends on crop, climate, irrigation system and management factors that are independent of the irrigation system such as irrigation duration. The energy required per cubic unit of water delivered depends on the irrigation system design, field site characteristics and irrigation time. Irrigation time affects strongly the fuel consumption, and consequently energy required. The surface drip irrigation system recorded the highest values of fuel consumption which were (615.49, 492.39 and 295.44 lit/fed) at 100%, 80% and 60% of potential evapotranspiration (ETP) respectively. As for gated pipes irrigation system, the yearly fuel consumption was the lowest compared with the other tested

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systems, was due to the high discharge of gates and consequently the low irrigation time. Therefore, localized irrigation systems requested particularly higher annual total irrigation costs to be applied in old lands.
***Keywords*:** Localized irrigation systems, energy requirements, water application depth of citrus in old lands, irrigation cost.

1. INTRODUCTION

The need to obtain a better understanding of the energy inputs available to agriculture has become more pressing in recent years as a result of the world energy crisis. This is particularly true with regard to irrigation systems, especially when considering the energy terms of the conversion of traditional plants into ones of higher technological content. The availability of low-cost energy in the past was a particular incentive to the introduction of high-technology irrigation schemes. These in fact, thanks to mechanization and the use of automatic and semi-automatic control systems, offer a reduction in manpower requirements and hence lower running costs, given the fast-rising cost of labor. It goes without saying that the high energy consumption now represents an obvious limitation to the introduction of plants having high levels of technology than traditional plants. In fact, at least in an unrestricted economy, any such rise in energy demand can be expected to result in increased running cost. This confirms the need to obtain further knowledge of the energy balance of irrigation systems. The energy required to pump irrigation water for crop production is measured in terms of fuel consumption or electric power usage. Energy usage depends on the amount of water applied and on the fuel or electric power required to apply each cubic unit of water. The amount of water applied depends on several irrigation system factors and on crop, climate, and management factors that are independent of the irrigation system [Smajstrla et al, 1998]. Irrigation system factors include specific system design factors, such as the potential irrigation system efficiency, the system design uniformity, and the relative area of coverage. Crop factors include type of crop, size of plants, plant density, and other production system factors such as the use of plastic mulch. Climate factors include solar radiation, temperature, humidity and wind speed. Management factors include irrigation scheduling decisions, which affect irrigation frequencies and durations. The energy required per cubic unit of water delivered depends on the irrigation system design and on field site characteristics. These factors can be summarized as the total dynamic head that the pump is operating against and the efficiency of the pumping system. Total dynamic head depends on the vertical distance that the water is lifted, the pressure required to operate the drip emitters, and the friction losses that must be overcome as water is pumped from its source until it is delivered from the emitters. Efficiency of the pumping system depends on the efficiencies of the pump, and connecting drive units. Recommendations were made for selecting, installing, and maintaining components to minimize energy loss and maximize pumping efficiency.

The objectives of this research were to study the factors that affect energy requirements for irrigation pumps, to emphasize ways that localized irrigation systems can be designed and managed to minimize energy requirements for localized irrigation, to estimate the energy requirements for localized irrigation and to compare between some different irrigation systems, which are surface drip, mini-sprinkler, standard bubbler and low-head bubbler compared to the modified surface irrigation system by gated pipes based on energy requirements.

2. MATERIALS AND METHODS

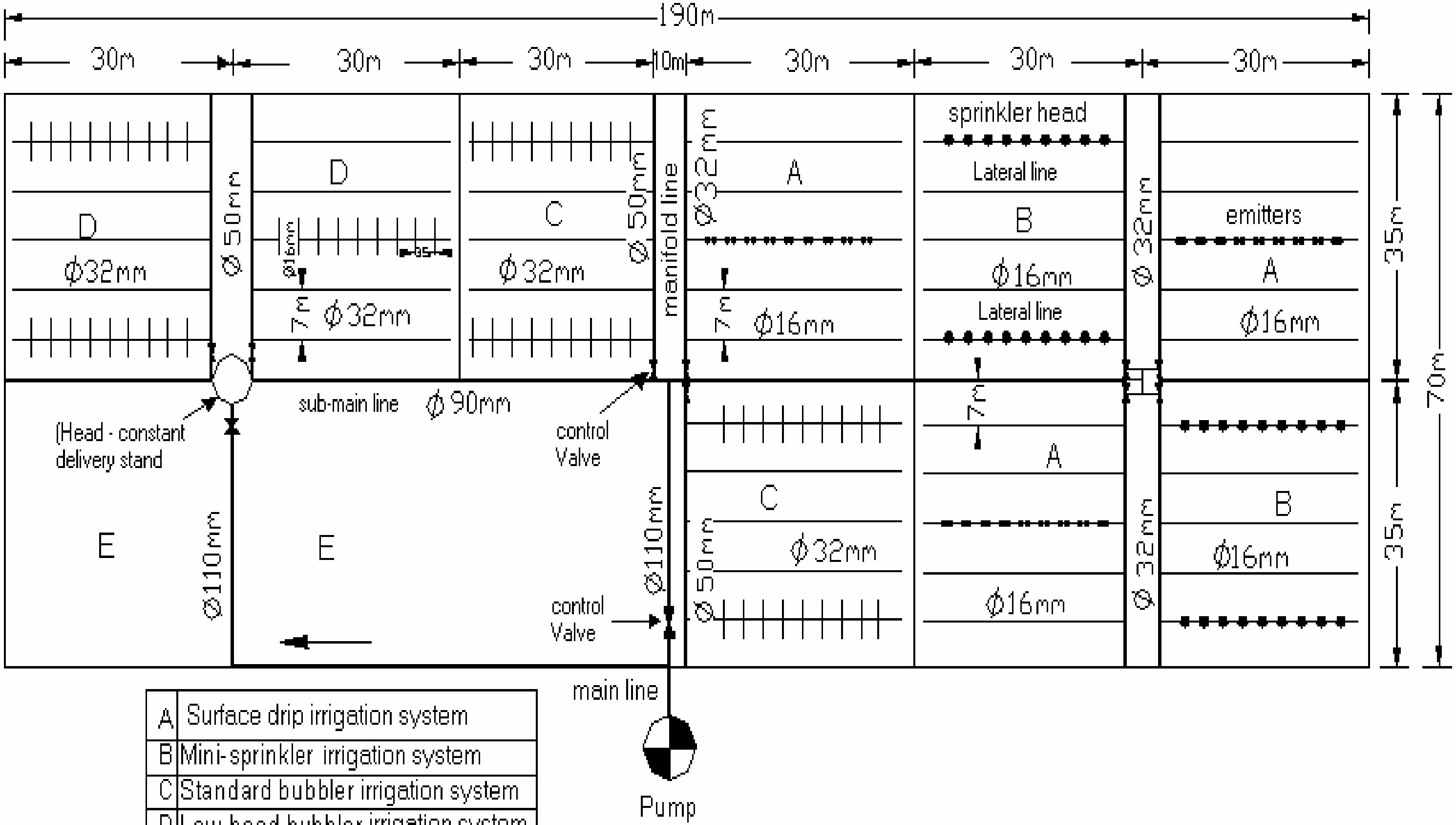
2.1. EXPERIMENTAL SITE

Field experimental work was conducted at Shalakan Experimental Farm, Faculty of Agriculture, Ain Shams University, Kaliobiya Governorate, Egypt. Ground water was used as a source of irrigation water. Citrus trees were irrigated by four localized irrigation systems (Surface drip, mini-sprinkler, standard bubbler and low head bubbler irrigation systems). The experimental site has the following characteristics: (longitude 31.25 E°, latitude 30.13 N° and altitude 14.90 m). The soil texture of the experimental site is clay loam with water field capacity of 36.23%, wilting point 18.40% and soil bulk density of 1.44 gm/cm^3. The total experimental area was three feddans cultivated with citrus (summer orange, Valencia).

2.2. EXPERIMENTAL SET UP

Figure (1) illustrates the experimental layout of the used localized irrigation systems for irrigation of citrus, which are surface drip, mini-sprinkler, standard bubbler, low-head bubbler, besides the furrow irrigation with gated pipes systems. These five systems occupied an area of three feddan (180 x 70 m). Diesel centrifugal pump (4/3 inch, 80 m^3/hr discharge and 50 m head) which operated by a diesel engine of 50 HP (36.8kW) was used for lifting ground water to the tested systems of irrigation. The delivery pipe was connected with a relief valve to control the operated pressure. A sand media filter of 48" consists of two tanks with discharge 70 m^3/hr were fitted on the pump delivery pipe to provide the adequate filtration required for processing all the amount of water entering the systems. A fertilizer injection pump was used to inject fertilizers into irrigation water follows the pumping unit. Non-return valve, pressure regulator, pressure gauges, flow meters and control valves were fitted with delivery pipe to control the flow of water to the irrigation systems.

Polly Vinyl Chloride (PVC) pipe was used as a main line for all systems with an outer diameter of 110 mm and connected to the sub-main line of 90 mm outer diameter.



A	Surface drip irrigation system
B	Mini-sprinkler irrigation system
C	Standard bubbler irrigation system
D	Low-head bubbler irrigation system
E	Gated pipes irrigation system

Fig. (1) : Plan view and layout of the used irrigation systems in irrigation citrus crop (Shalakan Experimental Farm).

The water flow was controlled at the sub-main line through a control unit sited at its inlet. The control unit contains a control valve of 3", screen filter of 3", pressure gauge and fertilizer outlets. A manifold of 32 mm outer diameter was used with drip and mini-sprinkler systems. For standard and low-head bubbler systems a manifold of 50 mm outer diameters was used respectively. Each manifold was fitted with a control valve and a flow meter of 1.5 and 1 inch respectively. Surface drip irrigation system represented by the symbol (A) in Figure (1), in which each citrus tree was irrigated by two turbo-key emitters operated at100 kPa with a discharge 16 liter/hr/tree. They are connected with Poly Ethylene, (PE) lateral line of 16mm outer diameter. For mini-sprinkler irrigation system represented by the symbol (B) in Figure (1), the operating pressure was 100 kPa and the discharge of each sprinkler was 45 liter/hr. The sprinklers were connected to Poly Ethylene, (PE) lateral line of 16mm outer diameter and each sprinkler head irrigates one citrus tree. The standard bubbler irrigation system represented by the symbol (C) was connected with bubblers having a discharge ranged from 150 to 250 liter/hr/tree at 60 kPa. Each bubbler was connected with lateral line of 32 mm outer diameter. The low-head bubbler irrigation system represented by the symbol (D) connected with lateral line of 50mm outer diameter. The sub-main line was connected with a standpipe of 2m height and 0.5 m outer diameter to adjust both water head and discharge. Low-head bubbler was connected with 16 mm diameter of lateral line diameter having a discharge 100 liter/hr/tree at 10 kPa. A plastic gate, (4 m^3/hr discharge & 40 cm head) was connected to a modified (aluminum pipe) of 160mm outer diameter and used to irrigate one furrow as represented in Figure (1) by the symbol (E).

2.3. EXPERIMENTAL PROCEDURE

Citrus trees (summer orange, Valencia) were cultivated in January 12, 1999. The spacing between rows and between trees was 7 m and 3.5 m respectively. The total experimental area was three feddans (180x70 m) divided into 12 experimental plots. The area of each experimental plot was 1050 m^2 (35x30 m). Each experimental plot contains five rows with nine trees in each row. Both drip irrigation and gated pipes irrigation systems occupied an area of 3150 m^2 (3 experimental plots). The other three irrigation systems (mini-sprinkler, standard bubbler and low-head bubbler) occupied an area of 2 experimental plots (2100 m^2). For all systems, the experiments were conducted at three levels of water application rates, which were, 100%, 80% and 60% of ETp (ETp means potential evapotranspiration). For surface drip irrigation and gated pipes irrigation systems, each plot considered as individual treatment. For both mini-sprinkler, standard bubbler and low-head bubbler, the first plot considered as an experimental treatment of 100% of ETp, while the second plot is divided into two sub-plots, one for 80% of ETp which contains three citrus rows and the other for 60% of ETp which contains two citrus rows. Water requirements are estimated by using Doorenbos and Pruitt model, [1977]. The evaporation pans provide a measurement of the integrated effect or radiation, wind, temperature and humidity on evaporation from a specific open water surface. In a similar fashion the plant responds to the same climatic variables but several major factors may produce significant differences in loss of water. Reference crop evapotranspiration (ETp) can be obtained from the following equation:

$$ETp = K_p . E_{pan} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where:

E_{pan} = pan evaporation in mm/day and represents the mean daily value of the period considered.

K_p = average pan coefficient (0.7).

ETp is calculated from equation (1) and the average has been used in calculating the gross irrigation requirements (IRg), [FAO, 1980] as follows.

$$IRg = \frac{A \quad ETp \quad Kc. \quad Kr}{(1 - Lr)Ea} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where:

IRg = gross irrigation requirements, (liter / tree / day).

A = total area allocated to each plant, (m^2 / plant).

ETp = average potential evapotranspiration, (mm / day) which can be calculated by equation,(1) related to the Pan Evaporation data.

Kc = crop factor according to the months within the growing season.

Kr = reduction factor of minimum of Gc / 0.85 where, Gc is the area shaded by the crop as percentage of the total area, (Kr taken 0.3 for citrus).

Ea = irrigation efficiency in %.

Lr = extra amount of water needed for leaching, [FAO, 1985] which can be calculated as follows:

$$Lr = Ecw / \text{maximum } Ece \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where:

Ecw = salinity of the applied irrigation water, (dS / m).

Ece = average soil salinity tolerated by the crop as measured on a soil saturated extract.

For all irrigation systems, field experimental procedure has been carried out for evaluation of both Christiansen's coefficient of uniformity, (*CU*) and distribution uniformity, (*DU*) at different levels of operating pressure. The following equations are used for estimating Christiansen's coefficient of uniformity (*CU*) and distribution uniformity, (*DU*) (Christiansen, 1942).

$$CU = \left(1 - \frac{\sum x}{nm}\right)100 \quad \text{...}(4)$$

Where:

x = absolute deviations of application depths observations from the mean, (mm).

m = mean of observed depths, (mm).

n = number of observations.

The distribution uniformity, *DU* (%), defined by the following relation (Keller and Bliesner, 2000):

$$Du = 100\frac{Zlq}{Zav} \quad \text{...}(5)$$

Where:

Zlq = average infiltrated depth in the low quarter of the field, (mm).

Zav = average infiltrated depth in the entire field, (mm).

The infiltrated depths are replaced by the observed applied depths in sprinkler irrigation, and by the observed emitter discharges in surface drip irrigation system.

The application efficiency *Ea* [%], was calculated by the following equation, mentioned by Pereira, (2000):

$$Ea = 100\frac{Zr}{D} \quad \text{...}(6)$$

Where:

Zr = average depth of water added to the root zone storage, (mm).

D = average depth of water applied to the field, (mm).

Several Parameters are used as indicators for the system uniformity of water application. Uniformity indicators relate also to crop uniformity implications on the yield of irrigated crops as well as on the respective economic benefits. Most commonly used indicators are the coefficient of Christiansen's Uniformity;(CU(%)) introduced by Christiansen, [1942] and the emission uniformity (EU). CU is more often utilized in sprinkler irrigation, when it comes to surface irrigation; the application depths are replaced by infiltrated depths and, in drip irrigation, by the observed emitter discharges. Emission Uniformity is widely used in drip irrigation [Pereira, 2000]. For each irrigation system, both uniformity coefficient of water distribution, (DU), Christiansen's coefficient of uniformity,(CU) and water application efficiency, (Ea) were measured and listed in Table (1). The data presented in this table showed that, the surface drip irrigation system operated satisfactory because of its high values of all parameters except (DU) where it was slightly higher in mini-sprinkler. Both low-head bubbler and gated pipes systems recorded the minimum values of the measured indicators of uniformity. The maximum value of Christiansen's Coefficient of Uniformity,(CU) for surface drip, mini-sprinkler and standard bubbler reflect the uniformity distribution of water applied by these systems. Therefore, a remarkable uniformity of water applied besides a higher efficiency of water application can be expected when such systems being in operation.

Energy defined as work per unit time. Work is required to lift water out of a well and the amount of water delivered in a unit of time can be related to the required power by the following formula [Arnaout, 1995]:

$$Bp = \frac{Q * Hd * Yw}{Ei * Ep * 1000} \quad \text{......................................(7)}$$

Where:

Bp = Brake power, (kW).

Q = Discharge, (m^3/sec).

Hd = Total head, (m).

Ep = Pump efficiency, (%).

Yw = Water specific weight, (9810 N/m^3).

Ei = irrigation efficiency, (%).

Energy consumed = (*Bp* x operating hours of irrigation)…..........……(8)

3. RESULTS AND DISCUSSION

3.1. SEASONAL WATER APPLIED AND SEASONAL FUEL CONSUMPTION

Figure (2) and Table (2) represent the required seasonal water application depth, and volume of fuel consumption which was applied with the tested localized irrigation systems under the three levels of water application. Results showed that, mini-sprinkler

Table. (1): Uniformity Coefficient of water distribution, Christiansen's Coefficient of Uniformity, and Water Application Efficiency for irrigation systems under study.

Indicators	Irrigation systems				
	Surface drip	Mini-Sprinkler	Standard bubbler	Low-head bubbler	Gated pipes
Uniformity Coefficient of Water Distribution (DU) (%)	92.30	93.2	84.2	82.00	81.40
Christiansen's Coefficient of Uniformity (CU) (%)	99.72	95.0	93.0	81.75	81.75
Application Water Efficiency (Ea) (%)	92.00	88.0	84.0	82.00	80.00

at all levels of water applied and surface drip irrigation systems recorded the lowest values of seasonal depth of application; where they were 726.5 mm and 733.9 mm for mini sprinkler and surface drip irrigation respectively at 100%ETp.

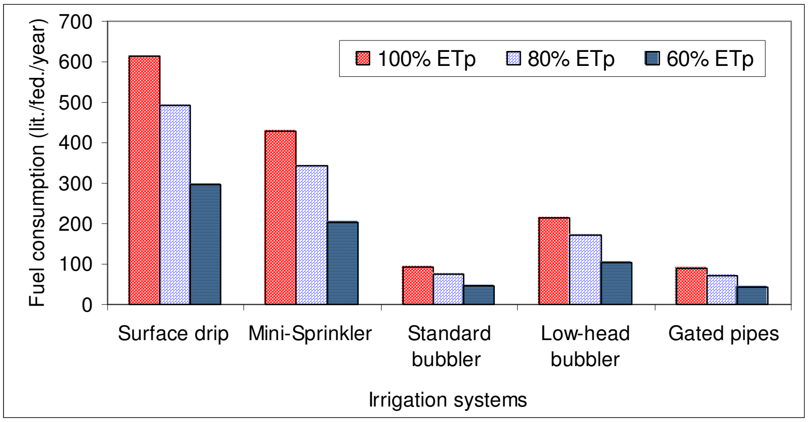


Fig. (2): Fuel consumption for irrigating of citrus trees by the different tested irrigation systems.

Table(2): Relationship between seasonal water applied and fuel consumption for the tested localized systems of irrigation.

Irrigation system	Applied water (mm/season)			Fuel consumption (lit./fed.)		
	100% of ETp	80% of ETp	60% of ETp	100% of ETp	80% of ETp	60% of ETp
Surface drip	733.9	587.4	442.1	615.49	492.39	295.44
Mini-sprinkler	726.5	583.7	435.9	426.79	341.43	204.86
Standard bubbler	804.0	642.7	481.4	94.57	75.66	45.39
Low-head bubbler	823.4	661.5	491.5	215.66	172.53	103.52
Modified surface (gated pipes)	831.6	665.5	494.0	88.15	70.52	42.31

Meanwhile, the higher value (831.6 mm) was absorved by gated pipes. Also, both low-head bubbler and standard bubbler applied a higher seasonal depth at 100% ETp of water applied compared with mini-sprinkler and surface drip, which were 823.4 mm and 804.0 mm respectively. Consequently, using mini-sprinkler leads to save about 12.64% more than gated pipes system, while using surface drip save about 11.75%. In the other hand using standard and low-head bubbler saved only 0.033% and 0.01% respectively compared with gated pipes. Finally, it can be concluded that mini-sprinkler and surface drip irrigation systems can be recommended as a localized irrigation systems for citrus in old land conditions. Table (2) also showed that, although the water applied by both standard bubbler and low head bubbler was the greatest comparing with the other localized systems, they consumed the lowest value of fuel needed. The seasonal fuel consumption was 94.57 lit/fed and 215.66 lit/fed for standard and low head bubbler systems respectively at 100% ETp of water application rate.

3.2. FUEL CONSUMPTION RELATED TO WATER APPLIED

Table (3) represented monthly water application depth and the corresponded monthly average fuel consumption. The presented data in Table (3) show that for citrus trees monthly water application depth increased gradually and reached to its maximum value at the end of June, and then decreased to the end of the growing season at December. Generally, the monthly fuel consumption increased from improvement stage to the mid season (January to June) and tended to decrease at the end of the year for all treatments. For all tested systems of irrigation, the monthly fuel consumption decreased as the water application rate decreased. The maximum fuel consumption per month was observed with drip irrigation system compared with the other treatments at all levels of water application. It was due to the low discharge and consequently high irrigation time. Fuel consumption by the five irrigation systems took the same trend as in water application depth. The results also showed that although both of standard bubbler and low head bubbler systems delivered high amounts of water comparing with surface drip and mini-sprinkler systems, so they consumed a low volume of fuel. This may be due to the low pressure at these two systems operating, high discharge and low irrigation time compared with other tested irrigation systems. Table (3) summarized the final relationship between seasonal water applied and fuel consumption for the tested systems of irrigation.

Results showed that, the peak of each monthly depth of water application at three tested levels achieved in June for all treatments of irrigation water regimes. However, the value of the depth at mid season differed from one system to another. Where the maximum required depth (115.5 mm), observed with gated pipes at 100% of ETp, while the minimum application depth (61.4 mm),was observed with surface drip irrigation system at 60%of ETp.

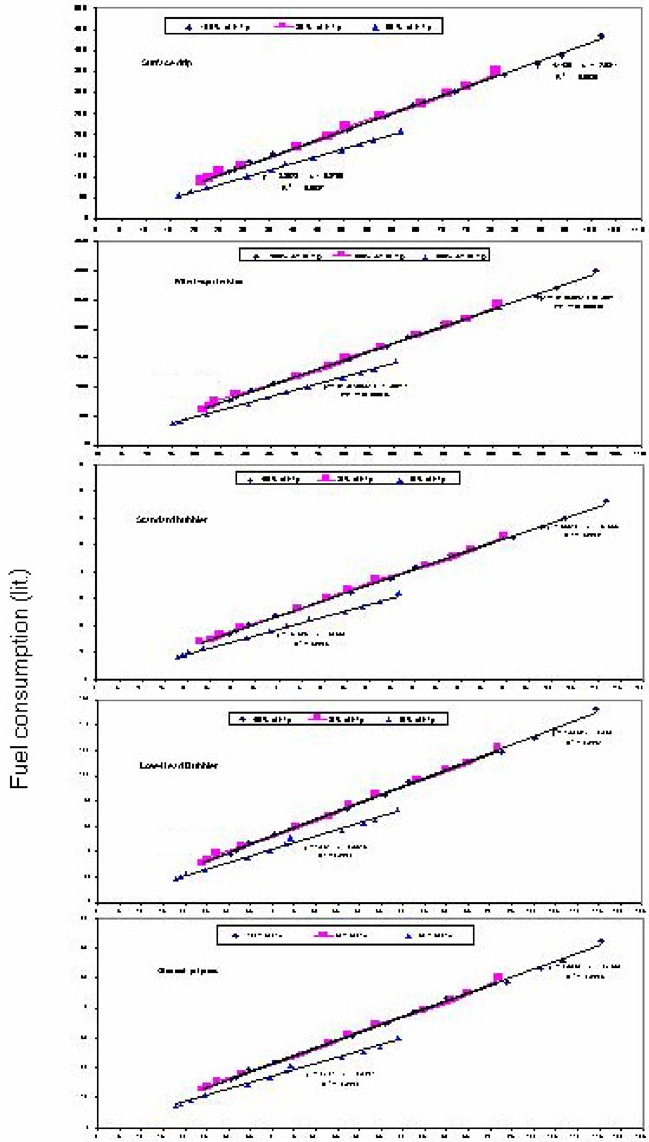
Figure (3) represents the difference between treatments, where the surface drip irrigation system recorded maximum values of fuel consumption followed by mini-sprinkler. As for gated pipes, the yearly fuel consumption is minimum compared with other tested systems, due to the high discharge of gates and consequently the low irrigation time.

3.3. RATE OF FUEL CONSUMPTION

Calculation of the consumed energy is considered as an important element in evaluating a particular irrigation system under different crop patterns. Measuring of fuel consumption reflects the required energy for irrigation operation. Table (4) illustrates seasonal fuel consumption and the rate of fuel consumption per cubic meter of water applied. The total fuel consumption in lit./feddan per year took the same trend of the monthly fuel consumption. Where, the maximum yearly fuel consumption (615.49 lit./feddan) was observed with surface drip irrigation system at 100% of ETp, while the minimum value (42.31 lit./feddan) is observed with gated pipes at 60% of ETp. The results also show that, low-head bubbler irrigation system consumed the largest amount of fuel (either per month or year) compared with standard head bubbler.The fuel consumption observed with low-head bubbler is almost double that observed with standard bubbler. The distributor discharge of standard bubbler is 220 lit/hr while, the distributor discharge is 100 lit./hr for low-head bubbler irrigation system.

Table (3): Average monthly water application depth (mm) and monthly foul consumption (lit) under each tested system with different levels of water application rates

Irrigation system	Water application level, (% of ETp)	Monthly water application depth, (mm) and fuel consumption (lit.) recorded each month throughout growing season																								Total seasonal water, mm
		Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sep.		Oct.		Nov.		Dec.		
		mm water	lit. fuel	mm water	lit. fuel	mm water	lit. fuel	mm water	lit. fuel	mm water	lit. fuel	mm water	lit. fuel	mm water	lit. fuel	mm water	lit. fuel	mm water	lit. fuel	mm water	lit. fuel	mm water	lit. fuel	mm water	lit. fuel	
Surface drip	100 %	26.7	21.99	30.9	27.20	50.8	42.24	63.9	54.28	88.9	73.91	102.0	86.85	93.9	77.83	82.5	68.01	72.5	60.42	58.4	48.37	35.6	30.95	27.9	23.45	733.9
	80 %	21.6	17.59	24.9	21.76	40.6	33.79	50.4	43.43	71.1	59.13	81.1	69.48	74.9	62.26	66.0	54.41	57.5	48.33	47.0	38.70	29.5	24.76	22.9	18.76	587.4
	60 %	16.5	10.55	19.0	13.06	30.5	20.27	38.1	26.06	53.3	35.48	61.4	41.69	55.9	37.36	49.5	32.64	43.7	29.00	35.5	23.22	22.1	14.85	16.5	11.26	442.1
Min-sprinkler	100 %	26.7	15.25	30.9	18.78	50.8	29.30	62.7	37.65	88.9	51.26	100.7	60.24	92.7	53.98	81.2	47.17	70.0	41.89	58.4	33.55	35.6	21.47	27.9	16.27	726.5
	80 %	21.6	12.20	23.8	15.03	40.6	23.44	50.4	30.12	71.1	41.01	81.1	48.19	74.9	43.18	64.7	37.74	57.5	33.51	47.0	26.84	28.3	17.17	22.9	13.01	583.7
	60 %	15.2	7.32	17.8	9.02	30.5	14.06	38.1	18.07	53.3	24.61	60.2	28.91	55.9	25.91	49.5	22.64	42.5	20.11	34.3	16.11	22.1	10.30	16.5	7.81	435.9
Standard bubbler	100 %	29.2	3.38	33.3	4.16	55.9	6.49	70.0	8.34	97.8	11.35	111.8	13.34	102.8	11.95	91.4	10.52	77.4	9.27	64.7	7.43	39.3	4.75	30.5	3.60	804.0
	80 %	22.9	2.70	27.3	3.33	44.4	5.19	55.3	6.67	78.7	9.08	89.7	10.67	82.5	9.56	72.4	8.41	61.4	7.42	50.8	5.94	31.9	3.80	25.4	2.88	642.7
	60 %	17.8	1.62	20.2	2.00	33.0	3.11	41.8	4.00	58.4	5.45	66.3	6.40	62.2	5.74	54.6	5.05	46.7	4.45	38.1	3.57	23.3	2.28	19.0	1.73	481.4
Low-head bubbler	100 %	30.5	7.70	34.4	9.48	57.1	14.80	71.3	19.02	100.3	25.90	114.3	30.44	104.7	27.28	92.7	23.84	79.9	21.17	66.0	16.95	40.5	10.85	31.7	8.22	823.4
	80 %	24.1	6.16	27.3	7.59	45.7	11.84	57.7	15.22	80.0	20.72	92.1	24.35	85.1	21.82	73.6	19.07	63.9	16.93	53.3	13.56	33.2	8.68	25.4	6.58	661.5
	60 %	17.8	3.70	20.2	4.55	34.3	7.10	43.0	9.13	60.9	12.43	68.8	14.61	63.5	13.09	55.9	11.44	44.2	10.16	39.4	8.14	24.6	5.21	19.0	3.95	491.5
Modified surface (Gated pipes)	100 %	30.5	3.15	34.4	3.88	58.4	6.05	72.5	7.78	101.6	10.59	115.5	12.44	106.7	11.15	93.9	9.74	79.9	8.65	66.0	6.93	40.5	4.43	31.7	3.36	831.6
	80 %	24.1	2.52	27.5	3.10	47.0	4.84	57.7	6.22	81.2	8.47	92.1	9.95	85.1	8.92	74.9	7.79	63.9	6.92	53.3	5.54	33.2	3.55	25.4	2.69	665.5
	60 %	17.8	1.51	21.4	1.86	34.3	2.90	43.0	3.73	60.9	5.08	68.8	5.97	64.7	5.35	55.9	4.68	44.2	4.15	39.4	3.33	24.6	2.13	19.0	1.61	494.0



water application depth (mm)

Fig. (3). Relationship between water application depth (mm) and fuel consumption (lit.) for all the tested systems of irrigation

It can be concluded that, the required irrigation time affects strongly the fuel consumption and operating cost for irrigation system. It also noticed from table (4) that, the rate of fuel consumption per cubic meter of water applied, was constant for each system at all levels of water application rate except for mini sprinkler and low head bubbler at 60% of ETp. The highest rate was 0.25 lit fuel/m^3 observed with surface drip, while the lowest rate 0.03 lit fuel/m^3 was observed with gated pipes irrigation system.

Table (4): Total water applied, irrigation time and total fuel consumption for the different tested systems of irrigation for citrus.

Irrigation system	Water application level (% of ETp)	Total water applied (m^3/fed.year)	Irrigation time (hr/fed. year)	Total fuel consumption (lit./fed. year)	Rate of fuel consumption per m^3 of water applied (lit. fuel/ m^3)
Surface drip	100%	2470.17	512.91	615.49	0.25
	80%	1976.14	410.33	492.39	0.25
	60%	1482.10	246.20	295.44	0.25
Mini-sprinkler	100%	2446.94	355.66	426.79	0.17
	80%	1957.55	284.53	341.43	0.17
	60%	1468.16	170.72	204.86	0.14
Standard bubbler	100%	2711.04	78.81	94.57	0.03
	80%	2168.83	63.05	75.66	0.03
	60%	1626.62	37.83	45.39	0.03
Low-head bubbler	100%	2782.03	179.72	215.66	0.08
	80%	2225.62	143.77	172.53	0.08
	60%	1669.22	86.26	103.52	0.06
Modified surface (gated pipes)	100%	2804.87	73.46	88.15	0.03
	80%	2243.90	58.77	70.52	0.03
	60%	1346.34	35.26	42.31	0.03

*Percent of wetted area to total cultivated area was take 0.8 for all tested systems.

3.4. COST OF LOCALIZED IRRIGATION SYSTEMS

Table (5) represents the total irrigation cost in LE/Feddan/year for all the tested systems at (100% ETp) of water application rate. The presented data in Table (5) showed that, although the total fixed cost of surface drip irrigation was lower than mini-sprinkler, standard bubbler the low head bubbler, the total irrigation cost was higher due to the highest value of operating cost required with surface drip irrigation system. It also showed that, constructing the standard bubbler irrigation system required a higher fixed cost (720.41 LE/Feddan/year) followed by mini-sprinkler (602.76 LE/Feddan/year). It was also showed that, fuel consumption of each system is effected strongly on the total irrigation cost. The highest consumption of fuel was observed with surface drip irrigation system, which in turn affects the required cost of fuel. Gated pipes recorded the lowest total irrigation cost (653.18 LE/Feddan/year) while standard bubbler system recorded the highest value (951.93 LE/Feddan/year). Therefore, from the cost analysis point of view, the gated pipes irrigation system takes the priority. However, comparing between the localized irrigation systems, the low head bubbler irrigation system can be recommended due to it's lowest value of the total annual irrigation cost. Analysis of both fixed and operating costs for all systems showed that, the localized irrigation systems need higher and considerable costs to be applied in old land.

Table (5): Total irrigation cost in (LE/fed/year) for citrus trees under the tested irrigation systems (at 100% ETp of water application rate.

Cost items	Localized irrigation systems				Modified surface by gated pipes
	Surface drip	Mini-sprinkler	Standard bubbler	Low-head bubbler	
Capital coat (LE/fed)	**3541.74**	**4169.74**	**4891.14**	**3993.64**	**3493.34**
Fixed cost (LE/fed/year)					
1- Depreciation	227.23	290.03	353.57	263.82	232.59
2- Interest	212.50	250.18	293.47	239.62	209.60
3- Taxes and insurance	53.13	62.55	73.37	59.90	52.40
Sub-total	**492.86**	**602.76**	**720.41**	**563.34**	**494.59**
Operating costs (LE/fed/year)					
1- Fuel	246.19	170.72	34.39	86.27	33.66
2- Maintenance and Repair	106.25	125.09	146.73	119.81	34.93
3- labor	50.4	50.4	50.4	50.4	90
Sub total	402.84	346.21	231.52	256.47	158.59
Total annual irrigation cost (LE/fed/year)	**895.70**	**948.97**	**951.93**	**819.82**	**653.18**

- Interest rate, 12% of capital cost.
- Taxes and insurance, 15% of capital cost.
- Fuel consumption of the pump, 6 liter fuel/hr and irrigated area 5 feddans per one value.
- Annual maintenance and repair costs are expressed as a percentage, (3% and 1%) of initial cost for localized and modified surface irrigation systems respectively.
- Irrigation labor required was estimated to be (0.28 and 1 hr/fed/event) for localized and modified surface irrigation systems respectively.

4. CONCLUSION

The amount of water applied depends on several irrigation system factors and depends on crop, climate, and management factors that are independent of the irrigation system. Both of mini sprinkler and drip irrigation systems are recommended localized irrigation systems for irrigation citrus under old land.

Surface drip irrigation system operated satisfactory because of its high values of all performance parameters except (DU). In mini-sprinkler DU is high. Both low-head bubbler and gated pipes recorded the low values of the measured parameters. The required irrigation time affects strongly fuel consumption and operating cost. The surface drip irrigation system recorded the high values of fuel consumption followed by mini-sprinkler. As for gated pipes, the yearly fuel consumption is low compared with other tested systems, due to the high discharge of gates and consequently the low irrigation time.

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الملخص العربي

متطلبات الطاقة لنظم الري الموضعي اللازمة لرى أشجار البرتقال في الأراضي القديمة

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أجريت الدراسة بمزرعة شلقان التابعة لكلية الزراعة – جامعة عين شمس بمحافظة القليوبية واستهدفت قياس الطاقة المستهلكة فى تشغيل نظم الرى الموضعى وهى (التنقيط السطحى، الرشاشات الصغيرة، الرى النافورى القياسى، الرى النافورى منخفض الضغط) مقارنة بالطاقة المستهلكة بالرى السطحى المطور بالمواسير المبوبة وذلك لرى أشجار البرتقال. وأجريت الدراسة تحت ثلاث مستويات للمياه المضافة خلال كل نظام فى كل رية وهى ١٠٠% و ٨٠% و ٦٠% من البخر نتح المرجعى وقسمت مساحة التجربة الكلية وقيمتها ١٢٦٠٠ م٢ (٣ فدان) الى ١٢ قطعة تجريبية مساحة كل منها ١٠٥٠ متر مربع حيث كانت المساحة المخصصة لكل من نظام الرى بالتنقيط السطحى والرى السطحى المطور ذو البوابات هى ٣١٥٠ متر مربع (ثلاث قطع تجريبية) بينما كانت المساحة المخصصة للري بالرشاشات الصغيرة ولأنظمة الرى النافورى هى ٢١٠٠ متر مربع (قطعتان تجريبيتان لكل نظام) وأعتبر استهلاك الوقود (لتر/فدان) لمضخة الرى المتصلة بشبكة الرى عند كل مستوى من مستويات المياه المضافة يمثل الطاقة المستهلكة لكل نظام عند كل مستوى من مستويات اضافة المياه وقد تم قياس كل من معامل الانتظامية (DU) ومعامل كريستيانسن لانتظامية توزيع مياه الرى (CU) وكفاءة إضافة مياه الرى (Ea) لكل نظام من نظم الرى تحت الدراسة. وللمفاضلة بين معاملات الدراسة تم حساب عمق مياه الرى الشهرى وعمق مياه الرى الموسمي المضاف لأشجار البرتقال تحت كل نظام من نظم الرى تحت الدراسة.

وتوصلت الدراسة الى النتائج الأتية:

١. تحقق أقل عمق لمياه الرى الموسمى وقيمته ٧٢٦,٥ مم تحت نظام الرى بالرشاشات الصغيرة وأكبر عمق موسمى لمياه الرى ومقداره ٨٣١,٩مم تحقق تحت نظام الرى السطحى المطور ذو البوابات.

٢. كان العمق الكلى لمياه الرى المضافة تحت نظام الرى بالتنقيط ٧٣٣م بينما وصل الى ٨٢٣,٤ و ٨٠٤ مم تحت نظام الرى النافورى منخفض الضغط و الرى النافورى القياسى على الترتيب.

٣. تحقق أعلى استهلاك موسمى للوقود ومقداره ٦١٥,٤٩ لتر/فدان/سنه تحت نظام الرى السطحى بالتنقيط وعند معدل مقداره ١٠٠% من البخر نتح بينما أقل استهلاك موسمى للوقود ومقداره ٤٢,٣١ لتر/فدان/ سنة تحقق تحت نظام الرى السطحى المطور ذو البوابات وبمعدل رى مقداره ٦٠% من البخر نتح.

٤. تحقق أقل معدل لاستهلاك الوقود ومقداره ٠,٠٣ لتر/متر مكعب من مياه الرى عند استخدام نظام الرى النافورى القياسى ونظام الرى السطحى المطور ذو البوابات بينما أعلى معدل ومقداره ٠,٢٥ لتر/متر مكعب من مياه الرى تحقق عند استخدام الرى بالتنقيط السطحى وذلك عند معدلات رى ١٠٠%، ٨٠% ، ٦٠% من البخر نتح.

٥. تحقق أقل استهلاك شهرى للوقود عند استخدام كل من نظام الرى النافورى القياسى ونظام الرى النافورى منخفض الضغط وذلك على مدار العام على الرغم من زيادة عمق مياه الرى المضاف شهرياً بهذين النظامين مقارنة بكل من نظام الرى بالتنقيط السطحى والرى بالرش الصغيرة.

٦. أقل تكاليف ري كلية سنوية ومقدارها ٦٥٣,١٨ جنية/فدان تحققت عند استخدام نظام الري السطحي المطور بينما أعلي تكاليف كلية سنوية ومقدارها ٩٥١,٩٣ جنية/فدان تحققت عند استخدام نظام الري الفقاعي القياسي.

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