Egyptian J. Desert Res., 56, No.1, 47-64 (2006)

EFFECT OF MULCHING AND IRRIGATION INTERVALS ON WATER CONSUMPTIVE USE AND YIELD OF OLIVE GROWN IN MIDDLE SINAI, EGYPT

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An experiment has been conducted in El-Maghara Research Station of Desert Research Center at Middle Sinai, Egypt, to test the effect of soil mulching under olive trees with gravel and black plastic sheets engaged with some irrigation intervals (2 , 4 and 6 days) on soil water regime as well as the productivity of olive crop. The collected data can be summarized in the following:

1- A significant increase of fruit yield, water consumptive use (ETa), beneficiary factor (Bf), crop coefficient (Kc), environmental stress coefficient (Ks), water use efficiency and water economy was found by using black plastic mulch under olive trees followed by gravel mulch, but the influence of irrigation intervals, was not significant.
2- Mulching treatments show considerable effect on the water regime of soil especially with wider irrigation interval of 6 days. However, 2 days treatment shows some water losses.
3- Mulching with plastic sheets under wide irrigation intervals, i.e. 6 days gave the highest beneficial water use and productivity of olive trees.
4- The highest economic applications coordinate with plastic mulching under 6 days irrigation interval.

Keywords: irrigation intervals, mulching, olive, water consumptive use, water use efficiency, environmental stress coefficient.

Desert soils suffer mainly from the shortage in water. So several soil management practices are adopted to restrict water losses and to maximize the output of limited water resources. One of the most important and effective measure for controlling soil water and improving thermal regime is soil mulching. Among the muching technique are the black plastic sheets, gravels and plant residues which generally used to conserve soil water and to reduce heat losses in winter, reduce the risk of frost on soil and plant surfaces (Monteith, 1973). Moreover, mulching materials can consist of paper, plastic sheets, and gravel; and the use of black or white powders to rise or lower the temperature of the surface by changing its reflectivity.

Rosenberg *et al.* (1983) mentioned some examples of manufactured mulching materials used for moisture conservation and / or soil temperature modification including paper of various texture and colors, aluminum foil, gravel, coal, cinders, petroleum by products, black, transparent, and white opaque plastics of various origin, i.e.: i) synthetic non-organic mulches such as plastic sheets, black or white opaque, or transparent, polyethylene, powders, gravel, black granular, aluminum foil and petroleum refining products. ii) synthetic organic materials such as: paper, coal, granular, black or white powders and cinders. Natural materials: such as natural plant residues or various other materials i.e.: a) non-organic materials such as dust, trash and gravel. b) organic materials such as plant residues, weed, stubble, straw, hay, farmyard manure, biomass and town refuse.

Allen *et al.* (1998) stated that plastic mulches substantially reduce the evaporation of water from the soil surface, especially under trickle irrigation system. Crop coefficient (Kc) values decrease by an average of 10 – 30 % due to the 50 – 80 % reduction in soil evaporation. Polyethylene and perhaps asphalt mulches are effective in reducing ET of crop, when they cover more than 80 percent of the soil surface and crop cover is less than 50 percent of the total cultivated area. Weed control adds to the successful use of plastic. Generally, crop growth rates and yield are increased by the use of plastic mulches.

Metochis (1998) found that irrigation with 400 – 450 mm of water which is corresponding to 0.35 of pan evaporation was sufficient for olive trees. When olive irrigation requirement was fully met, daily evapotranspiration ranged from 1.0 to 1.5 mm at the beginning and to 2.5 – 3.0 mm at the end of the irrigation season during the summer. Doorenbos and Kassam (1986) reported that water utilization efficiency for harvested yield of fresh olives containing about 30 percent moisture is 1.5 to 2.0 kg/m^3. The economical evaluation of the experimental findings in any research is of a great importance depending on the net return of such treatments which could encourage the farmer to use, or not especially when it increased the input costs by any untraditional treatments. In this accord, the investment ratio is expressed as Investment Ratio (IR) = Output LE/Input LE. (Rana *et al.*, 1996).

This work is an attempt to clarify the effect of mulching with gravel and black plastic sheets engaged with some irrigation treatments on improving water use efficiency, water economy and productivity of olive grown on sandy soils.

MATERIALS AND METHODS

Experimental Site

The current work was carried out in the Agricultural Experimental Station of the Desert Research Center at EL–Maghara region, about 90 Km south El-Arish city, North Sinai Governorate during the growth season 2003 - 2004.

Meteorological data for five years (1999-2003) were collected from the meteorological station located inside the experimental field with altitude of about 200 meter above sea level, latitude is 30"35' N. and longitude is 33"20' E to compute ETo according to Penman–Monteith equation as recommended by the FAO using CROPWAT, software version 5.7 (Smith, 1992). These data are presented in table (1).

TABLE (1). Measured climatic variables of EL–Maghara region during the period from 1999-2003.

Elements	Max.	Min.	Avg. air	Relative	Wind speed	Sunshine	Total	ETo
Month	temp. °C	temp. °C	temp. °C	humidity (%)	(m/sec)	hours (n)	rain (mm)	(mm/day)
Jan.	21.85	7.28	14.56	83.29	2.32	7.70	6.57	2.23
Feb.	22.25	7.42	14.83	81.50	2.16	8.20	6.97	2.61
Mar.	25.78	8.59	17.19	79.55	2.27	8.30	3.62	3.65
Apr.	30.32	10.11	20.21	72.69	2.50	9.60	0.81	5.29
May	33.70	11.23	22.47	75.33	2.34	10.90	0.52	6.24
June	37.82	12.61	25.22	77.99	2.10	12.60	0.00	7.16
July	40.80	13.60	27.20	77.80	1.74	12.40	0.00	7.23
Aug.	42.39	14.13	28.26	77.84	1.75	11.40	0.00	6.97
Sep.	40.02	13.34	26.68	78.02	1.60	10.60	0.00	5.78
Oct.	35.50	11.83	23.67	78.53	1.96	9.30	4.09	4.55
Nov.	33.13	11.04	22.09	76.39	2.00	7.80	8.43	3.50
Dec.	29.03	9.68	19.35	77.02	1.85	7.00	13.53	2.64
Annual mean	32.72	10.91	21.81	78.00	2.05	9.65	44.55	4.82

The relevant physical and chemical properties of the soil of the experimental site were determined according to Richards (1954). Particle size distribution was carried out by using the pipette method. The obtained results given in table (2a and b) indicate that the soils are non saline, non-alkali, sandy in texture and the available moisture for plant growth reaches 5.64 % (w/w).

Experimental Design

The study was conducted in split plot design in which three replicates for each treatment were used. The experiment includes 36 olive trees having 8 years age and cultivated at 6 x 6 m distances, (i.e. 116 tree / feddan). The applied treatments included:

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Jan.	21.85	7.28	14.56	83.29	2.32	7.70	6.57	2.23
Feb.	22.25	7.42	14.83	81.50	2.16	8.20	6.97	2.61
Mar.	25.78	8.59	17.19	79.55	2.27	8.30	3.62	3.65
Apr.	30.32	10.11	20.21	72.69	2.50	9.60	0.81	5.29
May	33.70	11.23	22.47	75.33	2.34	10.90	0.52	6.24
June	37.82	12.61	25.22	77.99	2.10	12.60	0.00	7.16
July	40.80	13.60	27.20	77.80	1.74	12.40	0.00	7.23
Aug.	42.39	14.13	28.26	77.84	1.75	11.40	0.00	6.97
Sep.	40.02	13.34	26.68	78.02	1.60	10.60	0.00	5.78
Oct.	35.50	11.83	23.67	78.53	1.96	9.30	4.09	4.55
Nov.	33.13	11.04	22.09	76.39	2.00	7.80	8.43	3.50
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Experimental Design

The study was conducted in split plot design in which three replicates for each treatment were used. The experiment includes 36 olive trees having 8 years age and cultivated at 6 x 6 m distances, (i.e. 116 tree / feddan). The applied treatments included:

i) Three irrigation intervals (the interval between two successive irrigations) as 2, 4 and 6 days. However the total amount of irrigation, calculated using Penman-Monteith equation, was constant for all interval treatments.

ii) Three mulching treatments viz: control, gravel and black plastic.

TABLE (2a). Some physical properties of the experimental soil site.

Soil depth (cm)	Particle size distribution (%)				Texture class	Particle density (g/cm^3)	Bulk density (g/cm^3)	Total porosity (%)	Organic matter (%)	Moisture content (%)		Available soil water		Infiltration rate	
	Coarse sand	Fine sand	Silt	Clay						Field capacity	Wilting point	%	mm	cm/hr	Class
0-30	0.00	98.50	0.70	0.80	Sand	2.65	1.55	41.51	0.24	10.23	4.45	5.78	90	34.15	Very rapid
30-60	0.00	98.00	1.00	1.00	Sand	2.63	1.58	39.92	0.23	9.98	4.51	5.47	86		
60-90	0.00	98.00	1.00	1.00	Sand	2.64	1.60	39.39	0.19	10.35	4.64	5.71	91		
90-120	0.00	99.50	0.20	0.30	Sand	2.65	1.57	40.75	0.28	9.87	4.41	5.46	86		
120-150	0.00	98.00	1.00	1.00	Sand	2.63	1.56	40.68	0.22	10.18	4.39	5.79	90		

TABLE (2b). Some chemical properties of the experimental soil site.

Soil depth (cm)	$CaCO_3$ (%)	pH soil paste	ECe (dSm^{-1})	Soluble cations (me/l)				Soluble anions (me/l)			
				Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	$SO_4^{=}$	Cl^{-}
0-30	1.96	7.00	1.37	8.00	4.00	1.40	0.32	—	7.20	2.52	4.00
30-60	1.71	6.90	1.92	6.00	10.00	2.76	0.40	—	9.60	4.36	5.20
60-90	1.15	7.00	2.00	8.00	8.00	3.84	0.12	—	9.60	7.16	3.20
90-120	1.58	7.00	2.12	10.00	6.00	5.04	0.12	—	4.80	12.36	4.00
120-150	2.56	7.30	1.78	8.00	4.00	5.72	0.04	—	7.20	6.56	4.00

All trees received the recommended doses of organic manure, (25 Kg / tree) and mineral fertilization of (NPK): 70, 30 and 70 kg/fed as ammonium sulphate (20.6 % N_2), calcium superphosphate (15.5 % P_2O_5) and potassium sulphate (48 % K_2O), respectively.

Soil moisture was measured with both tensiometer and gravimetric method at depths of 0 -30, 30 - 60 and 60 - 90 cm.

Saline ground water (about 3000 ppm) was used for irrigation viz drip system. The analysis of irrigation water given in table (3) revealed that this water belongs to high salinity, medium sodium, i.e., C_4S_2 water class. It is also evident that water quality of such source shows a prononunced variation throughout the year being of higher salinity in summer than in winter (Table 3).

TABLE (3). Chemical analysis of the irrigation water.

Season	pH	E C		S A R	R S C (me/l)	T D S (ppm)	Units	Soluble cations				Total	Soluble anions				Total	Class
		ppm	dSm⁻¹					Ca^{++}	Mg^{++}	Na^{+}	K^{+}		$CO_3^{=}$	HCO_3^{-}	$SO_4^{=}$	Cl^{-}		
Winter	7.6	2557	4.00	4.80	-9.8	2209	ppm	210.6	130.7	359.7	64.91	765.9	0	696.7	511.5	582.9	1442	C, S
							epm	10.51	10.75	15.64	1.66	38.56	0	11.42	10.65	16.44	38.51	
							%	27.26	27.88	40.56	4.30	100.0	0	29.65	27.66	42.69	100.0	
Summer	7.3	3190	4.98	5.63	-13.2	2798	ppm	267.1	155.34	467.5	84.06	974.1	0	785.2	633.5	797.5	1824	C, S
							epm	13.33	12.78	20.33	2.15	48.59	0	12.87	13.19	22.49	48.55	
							%	27.43	26.30	41.84	4.42	100.0	0	26.51	27.2	46.3	100.0	

S.A.R = Sodium adsorption ratio R.S.C. = Residual sodium carbon T.D.S. = Total dissolved solids epm. = equivalent per million

The amount of irrigation water was calculated using the equation of Doorenbos and Pruitt (1984):

$$D_{iw} = ((ETo \times Kc \times D \times Cr \times No.\ T.) / Ea) + R.$$

Where:

- D_{iw} = Applied irrigation water (liter/tree/day)
- ETo = Potential evapotranspiration (mm / day)
- Kc = Crop coefficient .
- Cr = Canopy cover represented by the shadow area under trees at mid-day which in average = 4.71 m^2.
- No. T. = No. of trees/fed = 116 tree.
- Ea = Irrigation system efficiency (%) = 85 % for drip irrigation.
- D = Root depth = (1.5 m).
- R = rainfall (mm).

The amounts of applied irrigation water are shown in table (4).

TABLE (4). Irrigation water applied to olive trees grown in El-Maghara area.

Elements	ETo	olive	ETc	Rainfall	Amounts of applied irrigation water			
Months	mm/d	Kc FAO	mm/d	mm/month	m^3/fed/day	m^3/fed/month	mm/month	l/tree/day
Jan	2.23	0.65	1.45	6.57	1.52	46.98	11.19	13.07
Feb	2.61	0.65	1.70	6.97	1.77	51.27	12.21	15.24
Mar	3.65	0.65	2.37	3.62	2.35	72.90	17.36	20.27
Apr	5.29	0.65	3.44	0.81	3.33	99.85	23.77	28.69
May	6.24	0.65	4.06	0.52	3.92	121.56	28.94	33.80
Jun	7.16	0.65	4.65	0.00	4.49	134.60	32.05	38.68
Jul	7.23	0.65	4.70	0.00	4.53	140.53	33.46	39.08
Aug	6.97	0.70	4.88	0.00	4.70	145.82	34.72	40.55
Sep	5.78	0.70	4.05	0.00	3.90	117.05	27.87	33.64
Oct	4.55	0.70	3.18	4.09	3.14	97.38	23.19	27.08
Nov	3.50	0.70	2.45	8.43	2.51	75.44	17.96	21.68
Dec	2.64	0.70	1.85	13.53	2.02	62.71	14.93	17.44
Avg	4.82	0.67	3.23	3.71	3.19	97.17	23.14	27.43
Year	1765			44.5		1166.10	277.64	10041

ETo = Potential evapotranspiration (mm / day) Kc = Crop coefficient
ETc: Crop evapotranspiration (mm / day) = ETo x Kc

The values of soil moisture content which gravimetrically determined were employed for calculating the crop water consumptive use using Doorenbos and Pruitt (1984) equation as follows:

$ETa = (M_{.2} \% - M_{.1} \%) \times d_b \times D \times 1000$ mm

Where:

- ETa = actual evapotranspiration (mm).
- $M_{.2}$ = Moisture content after irrigation (%).
- $M_{.1}$ = Moisture content before irrigation (%).
- d_b = Bulk density of soil (g / cm^3)
- D = Active root depth (m).

Water use efficiency was calculated by dividing the crop yield by the amount of seasonal evapotranspiration according to Giriappa, (1983). Water economy was calculated by dividing the crop yield by the amount of water added as kg/m^3 according to Talha *et al.* (1980). Crop coefficient was calculated by dividing the actual evapotranspiration (ETa) by potential evapotranspiration (ETo) according to Yaron *et al.* (1973). Environmental stress coefficient (Ks) was calculated by dividing the actual evapotranspiration (ETa) by maximum crop evapotranspiration (ETc) according to Allen *et al.* (1998). Beneficiary factor (Bf) was calculated by dividing the actual evapotranspiration (ETa) by the applied irrigation water (Diw) as reported by Allen et al., (1998). At the end of the experiment, olive yield was recorded. Data were statistically analyzed using Snedecor and Cochran (1989). Investment Ratio (IR) = Output LE / Input LE according to Rana *et al.* (1996).

RESULTS AND DISCUSSION

Actual Evapotranspiration (ETa)

Data presented in table (5a) show non significant increase in water consumptive use with increasing irrigation intervals, but exhibit highly significant increase in water consumptive use under black plastic mulch for olive trees. The data also show significant interaction between the applied 6 days irrigation interval and plastic mulch treatment.

Table (5a) gives the monthly actual evapotranspiration values (liter/tree/day) as detected by field measurements throughout the growth season and show that the effect of irrigation intervals on olive water consumptive use was not significant, however the impact of black plastic mulches on water consumptive use was highly significant.

TABLE (5a). Monthly actual evapotranspiration of olive crop grown in El-Maghara region.

Intervals (days)	Mulch	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Avg	mm/day	m^3/fed/season	Increase due to irrigation interval 2 days (%)	Increase due to irrigation interval 4 days (%)	Increase due to mulch (%)
		Liter/tree/day																	
2	Control	5.8	7.0	10.0	14.7	17.9	20.6	21.1	20.4	16.3	12.4	9.4	6.8	13.5	2.87 c	575.4			0.0
	Gravel	6.1	7.4	10.7	15.4	18.5	21.2	21.8	21.3	18.0	13.7	10.1	7.3	14.3	3.04 b	599.1			4.1
	Plastic	6.3	7.4	10.5	15.7	18.8	21.6	21.8	21.7	18.0	13.7	10.2	7.5	14.4	3.06 a	613.2			6.6
Average		6.1	7.3	10.4	15.3	18.4	21.1	21.6	21.1	17.4	13.3	9.9	7.2	14.1	2.99	595.9			
4	Control	6.0	7.1	10.3	14.9	18.2	20.9	21.5	20.7	16.6	12.9	9.7	7.1	13.8	2.94 c	587.9	2.2		0.0
	Gravel	6.1	7.3	10.5	15.4	18.2	21.2	21.8	21.0	17.2	13.3	9.9	7.2	14.1	2.99 b	607.7	1.4		3.4
	Plastic	6.4	7.6	10.8	15.9	18.8	21.9	22.8	22.3	19.1	14.4	10.5	7.8	14.9	3.16 a	632.3	3.1		7.6
Average		6.2	7.3	10.5	15.4	18.4	21.4	22.0	21.3	17.6	13.5	10.1	7.4	14.3	3.03	609.3			
6	Control	6.0	7.3	10.3	15.2	18.2	20.9	21.5	21.0	16.9	13.1	9.7	7.2	13.9	2.96 c	592.5	3.0	0.8	0.0
	Gravel	6.3	7.5	10.7	15.9	18.8	21.9	22.1	22.0	18.5	14.1	10.4	7.7	14.7	3.11 b	623.6	4.1	2.6	5.2
	Plastic	6.4	7.7	11.0	15.9	19.1	21.9	22.8	22.3	19.1	15.0	10.7	7.8	15.0	3.18 a	637.3	3.9	0.8	7.6
Average		6.2	7.5	10.7	15.7	18.7	21.6	22.1	21.8	18.2	14.1	10.3	7.6	14.5	3.08	617.8			
L.S.D. 0.05 Intervals															0.11	ns			
L.S.D. 0.05 Mulch															0.07	***			
L.S.D. 0.05 Interaction between intervals and mulch															0.04	*			

The data given in table (5b) was used to calculate the actual amounts of irrigation water after adding irrigation efficiency and substraction of rainfall amount (liter/tree/day) on ETa values for each treatment.

TABLE (5b). The calculated monthly amounts of irrigation water (liter/tree/day) required for olive trees grown in El-Maghara area.

Intervals (days)	Mulch	Jan	Feb	Mar.	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Average
2	Control	12.05	14.50	18.64	26.17	31.80	36.30	37.28	35.92	28.83	23.06	18.98	15.76	24.94
	Gravel	12.66	15.20	19.89	27.49	32.84	37.49	38.48	37.65	31.71	25.38	20.22	16.75	26.31
	Plastic	13.06	15.20	19.58	27.94	33.36	38.08	38.48	38.23	31.71	25.38	20.53	17.00	26.55
Average		12.59	14.97	19.37	27.20	32.67	37.29	38.08	37.27	30.75	24.61	19.91	16.50	25.93
4	Control	12.46	14.73	19.26	26.61	32.32	36.89	37.88	36.50	29.31	23.83	19.60	16.25	25.47
	Gravel	12.66	14.97	19.58	27.49	32.32	37.49	38.48	37.07	30.27	24.61	19.91	16.50	25.95
	Plastic	13.26	15.67	20.20	28.38	33.36	38.68	40.28	39.39	33.64	26.54	21.14	17.75	27.36
Average		12.79	15.12	19.68	27.49	32.67	37.69	38.88	37.65	31.07	24.99	20.22	16.84	26.26
6	Control	12.46	14.97	19.26	27.05	32.32	36.89	37.88	37.07	29.79	24.22	19.60	16.50	25.67
	Gravel	13.06	15.44	19.89	28.38	33.36	38.68	39.08	38.81	32.67	26.15	20.83	17.50	26.99
	Plastic	13.26	15.91	20.51	28.38	33.88	38.68	40.28	39.39	33.64	27.70	21.45	17.75	27.57
Average		12.92	15.44	19.89	27.94	33.19	38.08	39.08	38.43	32.03	26.03	20.63	17.25	26.74
Annual mean		12.77	15.18	19.64	27.54	32.84	37.69	38.68	37.78	31.29	25.21	20.25	16.86	26.31

Table (5c) gives the values of water loss (-) or water saving as a difference from applied amounts of irrigation water (Table, 4).

TABLE (5c). Monthly water loss or water saving as a difference from applied amounts of irrigation water (liter/tree/day) for olive trees grown in El-Maghara area.

Irrigation intervals (days)	Mulch	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Average
2	Control	1.01	0.74	1.63	2.52	2.00	2.38	1.80	4.63	4.81	4.02	2.70	1.68	2.49
	Gravel	0.41	0.04	0.39	1.20	0.96	1.19	0.60	2.90	1.92	1.70	1.46	0.68	1.12
	Plastic	0.01	0.04	0.70	0.76	0.44	0.60	0.60	2.32	1.92	1.70	1.15	0.44	0.89
Average		0.48	0.27	0.90	1.49	1.13	1.39	1.00	3.28	2.88	2.47	1.77	0.93	1.50
4	Control	0.61	0.51	1.01	2.08	1.48	1.79	1.20	4.06	4.32	3.25	2.08	1.18	1.96
	Gravel	0.41	0.27	0.70	1.20	1.48	1.19	0.60	3.48	3.36	2.47	1.77	0.93	1.49
	Plastic	-0.19	-0.43	0.07	0.31	0.44	0.00	-1.20	1.16	0.00	0.54	0.53	-0.31	0.08
Average		0.28	0.12	0.59	1.20	1.13	0.99	0.20	2.90	2.56	2.09	1.46	0.60	1.18
6	Control	0.61	0.27	1.01	1.64	1.48	1.79	1.20	3.48	3.84	2.86	2.08	0.93	1.77
	Gravel	0.01	-0.19	0.39	0.31	0.44	0.00	0.00	1.74	0.96	0.93	0.84	-0.06	0.45
	Plastic	-0.19	-0.66	-0.24	0.31	-0.08	0.00	-1.20	1.16	0.00	-0.62	0.22	-0.31	-0.13
Average		0.14	-0.19	0.39	0.76	0.61	0.60	0.00	2.12	1.60	1.05	1.05	0.19	0.69
Annual		0.30	0.07	0.63	1.15	0.96	0.99	0.40	2.77	2.35	1.87	1.43	0.57	1.12

From table (5c) it is clear that:

a- The values of water loss or water saved ranged between – 1.2 to 4.81 being at maximum level under the control indicating that mulching treatments seems the ideal case for water use, most probably due to the improvement occurred on water use values in the mode of water under these conditions. It is worthmentioning that the negative values means over use of water than planned regime.

b- The minimum values of control indicate that water loss is high due to deep percolation than the calculated applied water (27.43 liter/tree/day) in table (4). Worthy to note that if this fraction lost by evaporation it might be appeared in the ETa values.

c- This criterion vanished in spring and summer months (March to September) which is coordinated with maximum growth period, while appeared strictly in autumn and winter months which is coordinated with minimum growth period.

d- Comparing the values of water consumption under plastic sheets and gravel treatments shows the following:

   i- Dark color of plastic sheet enhance heat reservation under trees canopy, so providing sufficient energy to processes and conditions related to plant growth. These include movement and uptake of soil water and nutrients, chemical and biological reactions, microbial activities, root growth .....etc. It is important to note that such effects are with gravel soil.

ii- Evaporation has been highly retarded under plastic sheets than that under gravel layer partially blocking occurred.

iii- It is also noticed that the control plots suffered from weed growth which consume some of the added water, so the residual for trees decreased than planned amount, thereby plant growth appreciably decreased.

Similar results were obtained by Doorenbos and Kassam (1986), Metochis (1998) and Allen *et al.* (1998).

Beneficiary Factor (Bf)

Beneficiary factor of olive trees increased by increasing intervals between successive irrigation and mulching (Table, 6). Amounts of applied water will be decreased to rise the beneficiary factor of olive experiment as show in table (6).

TABLE (6). Beneficiary factor (Bf) of olive crop grown in El-Maghara region.

Irrigation intervals (days)	Mulch	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Average Bf	Increase due to irrigation interval 2 days (%)	Increase due to irrigation interval 4 days (%)	Increase due to mulch (%)
2	Control	0.44	0.46	0.49	0.51	0.53	0.53	0.54	0.50	0.49	0.46	0.43	0.39	0.49			0.0
	Gravel	0.47	0.48	0.53	0.54	0.55	0.55	0.56	0.53	0.53	0.51	0.46	0.42	0.51			4.1
	Plastic	0.48	0.48	0.52	0.55	0.56	0.56	0.56	0.53	0.53	0.51	0.47	0.43	0.53			6.6
Average		0.46	0.48	0.51	0.53	0.55	0.55	0.55	0.52	0.52	0.49	0.46	0.41	0.51			3.6
4	Control	0.46	0.47	0.51	0.52	0.54	0.54	0.55	0.51	0.49	0.47	0.45	0.41	0.50	2.2		0.0
	Gravel	0.47	0.48	0.52	0.54	0.54	0.55	0.56	0.52	0.51	0.49	0.46	0.41	0.52	1.4		3.4
	Plastic	0.49	0.50	0.53	0.56	0.56	0.57	0.58	0.55	0.57	0.53	0.49	0.45	0.54	3.1		7.6
Average		0.47	0.48	0.52	0.54	0.55	0.55	0.56	0.53	0.52	0.50	0.46	0.42	0.52	2.2		3.6
6	Control	0.46	0.48	0.51	0.53	0.54	0.54	0.55	0.52	0.50	0.48	0.45	0.41	0.51	3.0	0.8	0.0
	Gravel	0.48	0.49	0.53	0.56	0.56	0.57	0.57	0.54	0.55	0.52	0.48	0.44	0.53	4.1	2.6	5.2
	Plastic	0.49	0.51	0.54	0.56	0.57	0.57	0.58	0.55	0.57	0.55	0.49	0.45	0.55	3.9	0.8	7.6
Average		0.48	0.49	0.53	0.55	0.55	0.56	0.57	0.54	0.54	0.52	0.47	0.44	0.53	3.7	1.40	4.3
Annual mean		0.47	0.48	0.52	0.54	0.55	0.55	0.56	0.53	0.53	0.50	0.46	0.42	0.52	2.75	1.39	3.82

Regarding the beneficiary factor, table (6) shows that the obtained values ranged between 0.49 and 0.55 with an average of 0.52. This finding confirm the success of 6 days interval of irrigation than other two treatments due to low irrigation efficiency. It is worthy to note that the efficiency of drip irrigation was assumed to have 85 % (Doorenbos and Pruitt, 1984), so adopting expanded irrigation intervals with some mulching surface application is advised to these conditions. Similar findings were stated by Doorenbos and Kassam (1986), Metochis (1998) and Allen *et al.* (1998).

Olive Crop Coefficient (Kc)

Data presented in table (7) reveal that the influence of irrigation intervals on crop coefficient of olive plant progressively increasing was not significant. However, significant increase resulted by using mulch of gravel and black plastic compared to the control (irrigation interval at 2 days without mulch).

TABLE (7). Olive crop coefficient (Kc) under El-Maghara conditions.

Irrigation interval, days	Mulch	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Average Kc	Increase due to irrigation interval 2 days (%)	Increase due to irrigation interval 4 days (%)	Increase due to mulch (%)
	Kc FAO	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.70	0.70	0.70	0.70	0.70	0.67			
2	Control	0.55	0.57	0.58	0.59	0.61	0.61	0.62	0.62	0.60	0.58	0.57	0.55	0.59			0.0
	Gravel	0.58	0.60	0.62	0.62	0.63	0.63	0.64	0.65	0.66	0.64	0.61	0.59	0.62			6.0
	Plastic	0.60	0.60	0.61	0.63	0.64	0.64	0.64	0.66	0.66	0.64	0.62	0.60	0.63			7.0
Average		0.58	0.59	0.60	0.61	0.63	0.63	0.63	0.64	0.64	0.62	0.60	0.58	0.61			4.3
4	Control	0.57	0.58	0.60	0.60	0.62	0.62	0.63	0.63	0.61	0.60	0.59	0.57	0.60	2.4		0.0
	Gravel	0.58	0.59	0.61	0.62	0.62	0.63	0.64	0.64	0.63	0.62	0.60	0.58	0.61	-1.5		1.9
	Plastic	0.61	0.62	0.63	0.64	0.64	0.65	0.67	0.68	0.70	0.67	0.64	0.63	0.65	3.2		7.8
Average		0.59	0.60	0.61	0.62	0.63	0.63	0.65	0.65	0.65	0.63	0.61	0.59	0.62	1.4		3.2
6	Control	0.57	0.59	0.60	0.61	0.62	0.62	0.63	0.64	0.62	0.61	0.59	0.58	0.61	3.3	0.8	0.0
	Gravel	0.60	0.61	0.62	0.64	0.64	0.65	0.65	0.67	0.68	0.66	0.63	0.62	0.64	2.7	4.2	5.4
	Plastic	0.61	0.63	0.64	0.64	0.65	0.65	0.67	0.68	0.70	0.70	0.65	0.63	0.65	4.1	0.9	7.8
Average		0.59	0.61	0.62	0.63	0.64	0.64	0.65	0.66	0.67	0.66	0.62	0.61	0.63	3.4	2.0	4.4
Annual mean		0.59	0.60	0.61	0.62	0.63	0.63	0.64	0.65	0.65	0.64	0.61	0.59	0.62	2.4	2.0	3.8
L.S.D. 0.05 Intervals														0.02 ns			
L.S.D. 0.05 Mulch														0.02 **			
L.S.D. 0.05 Interaction between intervals and mulch														0.02 *			

Adjusting crop coefficient in suitable environmental conditions which could be considered as water saving parameter. These findings may be the increase actual evapotranspiration due to increasing soil moisture content under mulch and thus increase crop coefficient.

Environmental Stress Coefficient (Ks)

When cultivating crops in fields , the real crop evapotranspiration may deviate from ETc due to non – optimal conditions such as the presence of pests and diseases , soil salinity , low soil fertility, water shortage or water logging. This may result in reducing the evapotranspiration rate below ETc. Therefore, under soil water limiting conditions, Ks < 1, and where there is no soil water stress, Ks = 1.

Likewise, the same trend of crop coefficient of olive were observed for environmental stress coefficient which, progressively increased by increasing irrigation intervals with non significant differences and significant increase with using mulch of gravel and black plastic compared to the control (irrigation interval at 2 days without mulch), table (8).

To increase water saving and decrease water loss we must modified the calculated irrigation water amounts formula by multiplying with stress coefficient Ks and Kc or by adjusting Kc for all kinds of other stresses and environmental constraints on crop evapotranspiration, then become as;

$$D_{iw} = ((ETo \times Kc \times Ks \times D \times Cr \times No.\ T.) / Ea) + R.$$

TABLE (8). Environmental stress coefficient (Ks) of olive crop grown in El-Maghara region.

Irrigation intervals (days)	Mulch	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Average Ks	Increase due to irrigation interval 2 days (%)	Increase due to irrigation interval 4 days (%)	Increase due to mulch (%)
2	Control	0.85	0.88	0.89	0.91	0.94	0.94	0.95	0.89	0.86	0.83	0.81	0.79	0.88			0.0
	Gravel	0.89	0.92	0.95	0.95	0.97	0.97	0.98	0.93	0.94	0.91	0.87	0.84	0.93			5.9
	Plastic	0.92	0.92	0.94	0.97	0.98	0.98	0.98	0.94	0.94	0.91	0.89	0.86	0.94			6.9
Average		0.89	0.91	0.93	0.94	0.96	0.96	0.97	0.92	0.91	0.89	0.86	0.83	0.91			4.3
4	Control	0.88	0.89	0.92	0.92	0.95	0.95	0.97	0.90	0.87	0.86	0.84	0.81	0.90	2.4		0.0
	Gravel	0.89	0.91	0.94	0.95	0.95	0.97	0.98	0.91	0.90	0.89	0.86	0.83	0.92	-1.4		1.9
	Plastic	0.94	0.95	0.97	0.98	0.98	1.00	1.03	0.97	1.00	0.96	0.91	0.90	0.97	3.1		7.7
Average		0.90	0.92	0.94	0.95	0.96	0.97	0.99	0.93	0.92	0.90	0.87	0.85	0.93	1.4		3.2
6	Control	0.88	0.91	0.92	0.94	0.95	0.95	0.97	0.91	0.89	0.87	0.84	0.83	0.91	3.2	0.8	0.0
	Gravel	0.92	0.94	0.95	0.98	0.98	1.00	1.00	0.96	0.97	0.94	0.90	0.89	0.95	2.7	4.2	5.3
	Plastic	0.94	0.97	0.98	0.98	1.00	1.00	1.03	0.97	1.00	1.00	0.93	0.90	0.98	4.1	0.9	7.7
Average		0.91	0.94	0.95	0.97	0.98	0.98	1.00	0.95	0.95	0.94	0.89	0.87	0.94	3.3	2.0	4.3
Annual mean		0.90	0.92	0.94	0.96	0.97	0.97	0.99	0.93	0.93	0.91	0.87	0.85	0.93	2.3	2.0	3.8

This may be interpreted that due to increasing actual evapotranspiration, increased crop coefficient (Kc) and thus increased (Ks), which could be considered as water saving parameters and suitable environmental conditions. Similar findings were reported by Allen *et al.* (1998).

Fruit Olive Yield

Data in table (9) show that non significant increase in olive yield with increasing irrigation intervals, but highly significant increase by using black plastic mulch for olive trial. The magnitude of order for irrigation intervals were: 6 > 4 > 2 days with non significant differences. In brief, the influence of mulch on olive crop yield was highly significant with maximum effect of plastic sheet treatment. On the other hand, irrigation intervals has no significant effect on yield.

TABLE (9). Fruit yield of olive crop grown in El-Maghara region.

Irrigation intervals (days)	Mulch	Yield (ton/fed)	Yield (kg/tree)	Increase due to interval 2 days (%)	Increase due to interval 4 days (%)	Increase due to mulch (%)
2	Control	0.899 c	7.75			0.00
	Gravel	1.682 b	14.50			87.10
	Plastic	1.769 a	15.25			96.80
Average		1.450	12.50a			
4	Control	1.146 c	9.88	27.40		0.00
	Gravel	1.653 b	14.25	-1.70		44.30
	Plastic	1.987 a	17.13	12.30		73.40
Average		1.595	13.75a			
6	Control	1.233 c	10.63	37.10	7.60	0.00
	Gravel	1.856 b	16.00	10.30	12.30	50.60
	Plastic	2.161 a	18.63	22.10	8.80	75.30
Average		1.750	15.08a			
L.S.D. 0.05 Intervals		ns	2.99			
L.S.D. 0.05 Mulch		**	3.67			
L.S.D. 0.05 Interaction between intervals and mulch		*	2.12			

a, b, c, letters indicated to significant differences between treatments.

From table (9) it is clearly noticed the following:

a- Irrespective to mulching treatments it is clear that yield increases upon increasing irrigation intervals. These findings may be explained by the effect of expanding irrigation period on enhancing root elongation, while mulching accelerate this result which in turn reflected on yield of trees.

b- High response of olive grown under control treatment to increasing irrigation period by expanding interval especially with 4 days compared with 2 days treatments. However, mulching treatment show smaller increase in yield due to expanding irrigation interval.

c- Comparing mulching methods both gave the highest response under 6 days irrigation interval treatment, while smaller differences under other two irrigation intervals.

These findings are mainly due to stimulation of concurrent flow of water and heat and partial aeration, which increase the yield. On the other hand, data show that variation in yield due to alternate bearing and yield improved .These results are in agreement with findings of Doorenbos and Kassam (1986), Metochis (1998) and Allen *et al.* (1998).

Water Use Efficiency of Olive Crop (W.U.E.)

Data presented in table (10) reveal that the influence of increasing irrigation intervals on WUE is not significant differences. Whereas mulch treatments significantly increases upon applying mulching treatments compared to the control (irrigation interval at 2 days without mulch). The highest value of WUE is associated with irrigation interval at 6 days by using black plastic mulch was reached 3.39 (kg/m^3) followed by using gravel mulch was reached 2.98 (kg/m^3).

TABLE (10). Water use efficiency and water economy of olive crop grown in El-Maghara region.

Irrigation Intervals (days)	Mulch	Water use efficiency (kg/m^3)	Increase due to irrigation interval 2 days (%)	Increase due to irrigation interval 4 days (%)	Increase due to mulch (%)	Water economy (kg/m^3)	Increase due to irrigation interval 2 days (%)	Increase due to irrigation interval 4 days (%)	Increase due to mulch (%)
2	Control	1.56			0.0	0.77			0.0
	Gravel	2.81			79.7	1.44			87.1
	Plastic	2.88			84.7	1.52			96.8
Average		2.42			54.8	1.24			61.3
4	Control	1.95	24.7		0.0	0.98	27.4		0.0
	Gravel	2.72	-3.1		39.6	1.42	-1.7		44.3
	Plastic	3.14	8.9		61.2	1.70	12.3		73.4
Average		2.60	10.2		33.6	1.37	12.7		39.2
6	Control	2.08	33.1	6.8	0.0	1.06	37.1	7.6	0.0
	Gravel	2.98	6.0	9.4	43.1	1.59	10.3	12.3	50.6
	Plastic	3.39	17.5	7.9	63.0	1.85	22.1	8.8	75.3
Average		2.82	18.9	8.0	35.4	1.50	23.2	9.5	42.0

However, plastic sheets mulches may be associated with pronounced increases in soil temperature. So, it is suggested that this result activate both water and nutrient consumptions by root of trees which affect the crop yield. Also, may due to stimulation of concurrent flow of water and heat and partial aeration, which increase the yield. Similar results were obtained by Doorenbos and Kassam (1986) and Metochis (1998).

Water Economy of Olive Crop (W.E.)

Data in table (10) reveal that the same trend of water use efficiency is observed in water economy of olive which increased by increasing irrigation intervals. However, for mulch treatments significant increase compared to the control (irrigation interval at 2 days without mulch). The highest value of W.E. is associated with irrigation interval at 6 days by using black plastic mulch reached 1.85 (kg/m^3) followed by gravel mulch which reached 1.59 (kg/m^3). These findings may be due to saving the stored soil moisture and also to high yields, thereby high water economy values. Similar results were obtained by Doorenbos and Kassam (1986) and Metochis (1998).

Economical Assessment

The values of investment ratio (IR) are illustrated in tables (11a and b). Table (11a) calculate the investment rate for the applied treatments in the experiment as a rate for investing one pound as it is calculated as following: IR = Total outputs / Total inputs, LE. However, the modified IR values calculated depends on the modified irrigation water referring to actual evapotranspiration data.

TABLE (11a). Initial and modified inputs, outputs items and investment ratio (IR) of olive yield grown in El-Maghara region.

Economical item	Soil management	2 days			4 days			6 days		
		Control	Gravel	Plastic mulch	Control	Gravel	Plastic mulch	Control	Gravel	Plastic mulch
List of inputs, LE/fed	Land preparation, LE/fed	30.0	40.0	40.0	30.0	40.0	40.0	30.0	40.0	40.0
	Organic fertilization, LE/fed	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
	Cultivation, LE/fed	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
	Irrigation, LE/fed	291.5	291.5	291.5	291.5	291.5	291.5	291.5	291.5	291.5
	Modified irrigation, LE/fed	274.2	274.2	274.2	274.2	274.2	274.2	274.2	274.2	274.2
	Mineral fertilizer, LE/fed	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Fertilizer labors costs, LE/fed	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
	Mulch, LE/fed	0.0	174.0	174.0	0.0	174.0	174.0	0.0	174.0	174.0
	Weed control, LE/fed	30.0	10.0	10.0	30.0	10.0	10.0	30.0	10.0	10.0
	Pest control, LE/fed	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
	Labors costs, LE/fed	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
	Machines, LE/fed	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
	Fuel, LE/fed	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
	Harvesting, LE/fed	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
	Crop transportation, LE/fed	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
	Rent, LE/fed	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0
	Total input, LE/fed	1271.5	1435.5	1435.5	1271.5	1435.5	1435.5	1271.5	1435.5	1435.5
	Modified total input, LE/fed	1254.2	1418.2	1418.2	1254.2	1418.2	1418.2	1254.2	1418.2	1418.2
List of outputs	Yield, kg/fed	899.00	1682.00	1769.00	1145.5	1653.0	1986.5	1232.5	1856.0	2160.5
	Price, LE/kg	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
	Total price, LE/fed	674.3	1261.5	1326.8	859.1	1239.8	1489.9	924.4	1392.0	1620.4
	Net income, LE/fed	-597.3	-174.0	-108.8	-412.4	-195.8	54.3	-347.2	-43.5	184.9
	Modified net income, LE/fed	-579.9	-156.7	-91.4	-395.0	-178.4	71.7	-329.8	-26.2	202.2
Investment ratio, LE/ILE		0.53	0.88	0.92	0.68	0.86	1.04	0.73	0.97	1.13
Modified investment ratio, LE/ILE		0.54	0.89	0.94	0.69	0.87	1.05	0.74	0.98	1.14

Table (11b) arranges the resulted IR values for all treatments in ascending order with guidance of the national IR value which is about 1.10 for this area.

From table (11b) it can be concluded the following:

1- Mulching with plastic sheets gives the high values especially under 6 days irrigation interval (1.14) with modified irrigation value.
2- Gravel mulching under 6 days irrigation interval give higher IR values than the plastic mulch under 2 days irrigation interval.
3- All plots without mulching (control) give lower IR values than the national one with increasing trend by increasing irrigation interval

being 6 > 4 > 2 days and modified irrigation value give always higher values than ordinary ones.

These findings give a group of options which could be adapted with different conditions in the site.

TABLE (11b). Rank of investment ratio (IR) of olive yield grown in El-Maghara region.

Treatments Rank	IR value	Cost value	Irrigation interval	Mulching treatments
1	0.53	Initial	2	Control
2	0.54	Modified	2	Control
3	0.68	Initial	4	Control
4	0.69	Modified	4	Control
5	0.73	Initial	6	Control
6	0.74	Modified	6	Control
7	0.86	Initial	4	Gravel
8	0.87	Modified	4	Gravel
9	0.88	Initial	2	Gravel
10	0.89	Modified	2	Gravel
11	0.93	Initial	2	Plastic
12	0.94	Modified	2	Plastic
13	0.97	Initial	6	Gravel
14	0.98	Modified	6	Gravel
15	1.04	Initial	4	Plastic
16	1.05	Modified	4	Plastic
17	1.13	Initial	6	Plastic
18	1.14	Modified	6	Plastic

CONCLUSION

From the above mentioned discussion it can be concluded the following:

1- Adopting different irrigation intervals (6 > 4 > 2 days) show the need to adjust and modify some coefficients used in ETc calculations like Kc and Ks upon the detected ETa values with moisture sampling process.

2- Mulching with different materials resulted in considerable improvement values by different ways:

   a- By water saving values with some treatments especially under 2 and 4 days treatments which assume some modifications to make for irrigation cost values.

   b- By high productivity of trees through benefiting from the existed soil moisture, while the reserved soil heat by these treatments facilitate the beneficial use of both moisture and nutrients as well. Meanwhile, elongation of root could be increased under these conditions.

3- Plastic sheet mulching give the highest investments under 6 days irrigation interval (1.13) with superiority with increasing irrigation interval, i.e. increasing moisture deficit level.
4- Olive trees under the site conditions without mulching seems to be unbeneficial as the net gains will not exceed input costs or IR value < 1.

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Received: 29/06/2005
Accepted: 22/01/2006

تأثير التغطية وفترات الرى على الاستهلاك المائي ومحصول الزيتون النامى بوسط سيناء- مصر

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يهدف هذا البحث إلى دراسة تأثير فترات الرى ومعاملات خدمة التربة المختلفة (التغطية) على ترشيد استهلاك مياه الرى لأشجار الزيتون تحت ظروف الري بالتنقيط في الأراضي الرملية الصحراوية بمحافظة شمال سيناء وعلى كفاءة استخدام المحصول للمياه واقتصاديات المياه. أقيمت تجربة حقلية بمزرعة محطة بحوث المغارة بوسط سيناء بمصر من خلال تصميم قطع منشقة مرة واحدة خلال موسم ٢٠٠٣ / ٢٠٠٤ لدراسة تأثير كلا من فترات الرى المختلفة ومعاملات خدمة التربة (التغطية) والتفاعل بينهما على أشجار الزيتون وكفاءة استخدامها للمياه تحت ظروف الرى بالتنقيط.

تضمنت التجارب ثلاث فترات رى (٢ ، ٤ ، ٦ أيام) وثلاث معاملات تغطية (كنترول بدون إضافة، تغطية بحصى زلط ، تغطية ببلاستيك اسود) وأربعة مكررات ، ورويت التجربة بكمية مياه ري محسوبة طبقا لمعادلة بنمان- مونتيث. وقد تم النتائج إحصائيا وكانت النتائج التالية:

١- زيادة غير معنوية لقيم كل من محصول الزيتون والاستهلاك المائي وكفاءة استخدام المحصول للمياه واقتصاديات المياه ومعامل المحصول ومعامل الإجهاد البيئي وعامل الإفادة من الرى بزيادة فترة الري الى ٦ أيام وكانت معاملة ٦ > ٤ > ٢ يوم، وزيادة معنوية لكل القيم باستخدام التغطية ببلاستيك أسود تحت الأشجار على سطح التربة يليها التغطية بحصى زلط ولكن بدون فروق معنوية بينهما بالنسبة للمحصول، بينما كانت هناك فروق معنوية بالمقارنة مع معاملة الكنترول.

٢- معاملات التغطية لها تأثير كبير مع فترة رى ٦ أيام والتى لها قيم فقد مياه عن معاملة ٢ يوم.

٣- التغطية ببلاستيك أسود مع فترة رى ٦ أيام أعطت أعلى إفادة لإستخدام المياه وإنتاجية أشجار الزيتون.

٤- أعلى تطبيق أقتصادى بالنسبة للتغطية ببلاستيك مع فترة رى ٦ أيام. كذلك التغطية بالحصى أعطت عائد إقتصادى كاف مع الرى كل ٦ أيام فقط.

وتوصى الدراسة باستخدام الرى بالتنقيط ومعادلة بنمان- مونتيث في حساب كميات مياه الري المضافة مع الأخذ فى الأعتبار كل من معاملى الإجهاد البيئى والمحصول المعدل فى الحسابات كل ٦ أيام، واستخدام التغطية ببلاستيك اسود تحت الأشجار والتى أعطت أعلى عائد إستثمار للجنيه حوالى ١,١٣ جنيه، بينما كان ٠,٩٧ جنيه لمعاملة حصى الزلط وذلك تحت الظروف المشابهة لمنطقة الدراسة.