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IMPACT OF LASER LAND LEVELING ON WATER PRODUCTIVITY OF WHEAT UNDER DEFICIT IRRIGATION CONDATIONS

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ABSTRACT

*Nowadays determining the optimum crop water requirements is considered one of the most important factors affecting plant productions, especially, with scarce water resources. This may be due to the interrelation between the amount of water added and the ability of plant. Two field experiments were carried out during the two growing seasons 2010/2011–2011/2012, at the Research Farm of the National Research Centre in Nubarya region, Egypt, to study the effect of both deficit irrigation and laser land leveling on saving water and increasing yield of wheat crop under Egyptian growing conditions. Studied factors were deficit irrigation (100% Irrigation Requirements "IR", 80%IR, 60%IR and 40%IR) and land leveling techniques (conventional "C" and laser "L"). The following parameters were studied to evaluate the effect of deficit irrigation and laser land leveling; (1) Soil moisture distribution, (2) Growth of wheat plant, (3) Yield of wheat , (4) Irrigation water use efficiency of wheat and (5) Economical parameters of wheat production process. Statistical analysis of the effect of the interaction between land leveling and irrigation on IWUE of wheat indicated that the maximum values were detected at adding 100%IR*L. However, no significant difference was observed between 100%IR*L >80%IR*L >and 60% IR*L, this means that we can save 40% of irrigation water by adding 60% IR with laser land leveling technique to irrigate wheat under sandy soil conditions.*

Keywords: Laser leveling, Water productivity, Deficit irrigation, Wheat, Water requirements, Soil moisture distribution

Contribution/ Originality

This study contributes in the existing literature to improve water use efficiency of wheat under deficit irrigation conditions and rotational irrigation system by using laser land leveling techniques.

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is the world's most important crop. A crop of wheat is harvestedsomewhere in the world during every month of the year [1]. Greater importance of bread wheat can be expected as a main source of food for solving the increasing population's

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emergency of the world. In arid and semiarid regions with Mediterranean climate, wheat crops usually encounter drought during the grain filling period. Wheat quality was controlled not only by genetic factors, but also by environmental conditions, especially the supply of water and fertility in soil that can change wheat quality under normal cropping condition [2].

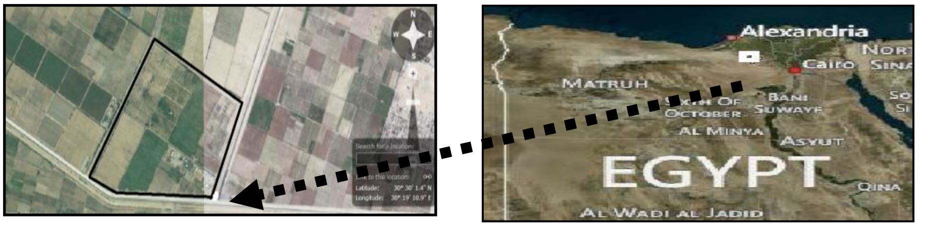
Traditional methods of land leveling are cumbersome, time consuming, and expensive, so more and more farmers are turning to modern methods to level the land. Laser leveling is a process of smoothing the land surface (± 2 cm) from its average elevation using laser-equipped drag buckets. This technique is well known for achieving higher levels of accuracy in land leveling and offers great potential for water savings and higher grain yields. [3]. Effective land leveling reduces the work involved with crop establishment and crop management. It increases yield, improves uniformity of crop maturity and reduces weeds and the amount of water needed for land preparation. Laser land leveling when applied under various crops and cropping patterns has resulted in water savings up to 15-30 % [4]. Deficit irrigation is a way for maximizing water use efficiency, it means obtaining higher yields per unit of irrigation water applied. The crops are exposed to a certain level of water stress either during a particular period or throughout the whole growing season. The expectation is that any yield reduction will be insignificant compared with the benefits gained through diverting the saved water to irrigate other crops. [5].The aim of the present work is to study the effect of Laser land leveling and deficit irrigation levels for saving water and increasing yield of wheat under Egyptian growing conditions.

2. MATERIALS AND METHODS

2.1. Location and Climate of Experimental Site

Field experiments were conducted during two winter seasons 2010/2011–2011/2012 at the experimental farm of National Research Center, El-Nubaria, Egypt (latitude 30.8667 N, and longitude 30.1667 E, and mean altitude 21 m above sea level) as shown in fig. (1). The experimental area has an arid climate with cool winters and hot dry summers prevailing in the experimental area. The data of maximum and minimum temperature, relative humidity, and wind speed were obtained from "Local Weather Station inside El-Nubaria Farm". There was not rainfall that could be taken into consideration through the two seasons, because the amount was very little and the duration didn't exceed few minutes.

Fig-1. Location of the Experimental Farm in EL-NUBARIA Region, Egypt



2.2. Irrigation System

Irrigation system components consisted of control head, pumping and filtration unit. It consists of centrifugal pump with 45 m^3/h discharge and it was driven by electrical engine and screen filter and back flow prevention device, pressure regulator, pressure gauges, flow-meter, control valves. Main line was of PVC pipes with 110 mm in diameter (OD) to convey the water from the source to the main control points in the field. Sub-main lines were of PVC pipes with 75 mm diameter (OD) was connected to the main line. Manifold lines: PE pipes were of 63 mm in diameter (OD) were connected to the sub main line through control valve 2`` and discharge gauge. Sprinklers were 3/4" diameter and discharge was 1.2 m^3/ h at 2.5 bar operating pressure and 12 m service radius.

2.3. Some Physical and Chemical Properties of Soil and Irrigation Water

Some Properties of soil and irrigation water for experimental site are presented in (Tables 1,2 and 3).

Table-1. Some chemical and mechanical analyses of soil study site.

Depth	Chemical analysis				Chemical analysis			Texture
	OM (%)	pH (1:2.5)	EC (dSm^{-1})	$CaCO_3$ %	Course sand	Fine sand	Silt + clay	
0-20	0.65	8.7	0.35	7.02	47.76	49.75	2.49	Sandy
20-40	0.40	8.8	0.32	2.34	56.72	39.56	3.72	
40-60	0.25	9.3	0.44	4.68	36.76	59.40	3.84	

OM= organic matter. pH= power of hydrogen EC= Electrical Conductivity

Table-2. Soil water characteristics.

Depth	SP (%)	F.C (%)	W.P (%)	A.W (%)	Hydraulic conductivity(cm/hr)
0-20	21.0	10.1	4.7	5.4	22.5
20-40	19.0	13.5	5.6	7.9	19.0
40-60	22.0	12.5	4.6	7.9	21.0

S.P. = saturation point, F.C. = field capacity, W.P. = wilting point and A.W. = available water.

Table-3. Some chemical characteristics of used irrigation water in the open channel at farm study site.

pH	EC (dSm^{-1})	Cations and anions (meq/L)								SAR %
		Cations				Anions				
		Ca^{++}	Mg^{++}	Na^+	K^+	--CO3	HCO3-	Cl-	SO4--	
7.35	0.41	1	0.5	2.4	0.2	--	0.1	2.7	1.3	2.8

pH= power of hydrogen EC= Electrical Conductivity SAR= Sodium Adsorption Ratio

2.4. Irrigation Requirements

Seasonal irrigation requirements for wheat crop were estimated. The seasonal irrigation water applied was found to be 2304 m^3/fed./season for sprinkler irrigation system by following equation and as tabulated in table (4):

$$IRg = (ET_O \times Kc) / Ei - R + LR$$

Where: IRg = Gross irrigation requirements, mm/day

ET_O = Reference evapotranspiration, mm/day (estimated by the meteorological data of Central Laboratory for Agricultural Climate (CLAC) according to Penman-Monteith equation)

Kc = Crop factor (FAO reference)

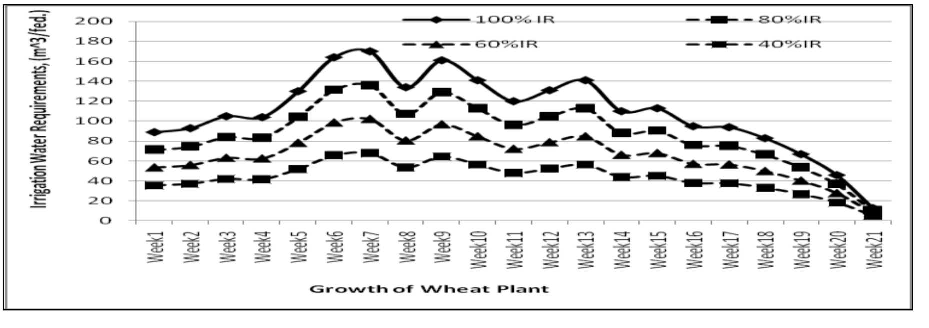
Ei = Irrigation efficiency = Ea x EU where Ea = (Ds/Da) x 100 where Ds = Average water stored in root volume; Da = Average water applied; EU = Coefficient reflecting the uniformity of application

R = Water received by plant from sources other than irrigation, mm (for example rainfall)

LR = Amount of water required for the leaching of salts, mm = LRt x (IRn/Ei) where: LRt = leaching requirement ratio under drip irrigation = ECw /(2 x max ECe) where ECw = electrical conductivity of irrigation water (ds/m); max ECe = electrical conductivity of saturated soil extract that will reduce the crop yield to zero (dS/m); IRn (net irrigation requirement) = ETo x Kc

The seasonal irrigation water applied for wheat crop was 2304, 1843, 1382 and 922 m^3/ fed. for 100 %, 80 %, 60 % 40 % IR, respectively as shown in fig. (2).

Fig-2. Relation between growth of wheat plant and irrigation requirements.



2.5. Components of Laser Leveling Equipment

Laser leveling unit was 4 m width and agriculture tractor was 65 hp were used.

2.6. Experimental Design

Experimental design was made as split plot with three replications. Land leveling and deficit irrigation were put in the main plots and sub main plots, respectively and the treatments were irrigation requirements (100%, 80%, 60% and 40% IR) and land leveling (conventional and laser).

2.7. Soil Moisture Distribution

Soil moisture distribution was determined according to Liven and Van Rooyen [6]. The soil moisture content was measured by profile probe device, 2 hours directly after irrigation at equal 100 cm intervals along 1200 cm, the distance between each two sprinklers line. All the measures were taken at 15 cm intervals to a 90 cm depth at each point. Using "contouring program Surfer version 8", contouring map for different moisture levels, distances and depths were obtained.

2.8. Irrigation Water Use Efficiency "IWUE"

IWUE of wheat crop was calculated according to James [7] as follows: WUE (kg/m^3) =Total yield (kg/fed.) / Total applied irrigation water (m^3/fed./season).

2.9. Leaf Area

Leaf area= leaf length x maximum leaf width x 0.75 according to Stickler, et al. [8].

2.10. Statistical Analyses

Statistical analyses were done using the method described by Snedecor and Cochran [9], whereas treatments means were compared according to Duncan [10].

3. RESULTS AND DISCUSSION

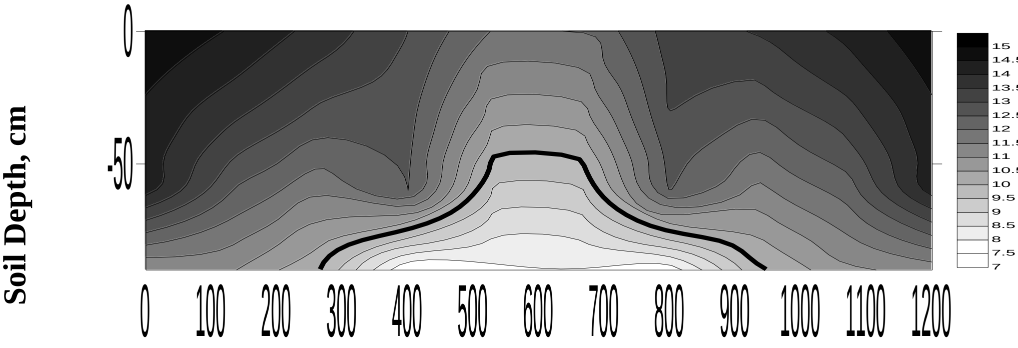
The water resource for irrigation coming from an irrigation channel under rotational irrigation where the water exist in the channel just for three days every week and the residual four days the channel is empty, the idea was using laser land leveling and deficit irrigation techniques under rotational irrigation conditions may decrease from run-off and to evaluate its effect on growth, yield and irrigation water use efficiency of wheat (IWUE).

3.1. Soil Moisture Distribution

Soil moisture distribution in the root zone and wetted soil volume (more than or equal 100% of field capacity) was measured at the growth period of maximum irrigation requirement. Both SMD and WSV improved under laser land leveling technology than conventional land leveling at 100%IR, 80% IR, 60%IR, and 40%IR, respectively. This by the effect of laser land leveling on the land surface which creates more uniform moisture distribution in the root zone. This uniformity results is more suitable condition for growing roots and lowest drought stress. (Bold line in contouring maps = field capacity) as shown as from Fig. (3) to Fig. (6).

Fig-3. Soil Moisture Distribution at 100% Irrigation requirements.

(a) Laser land leveling



(b) Conventional leveling

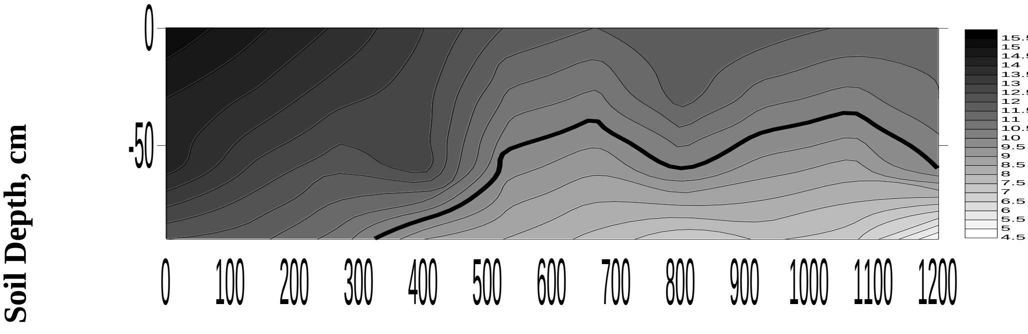
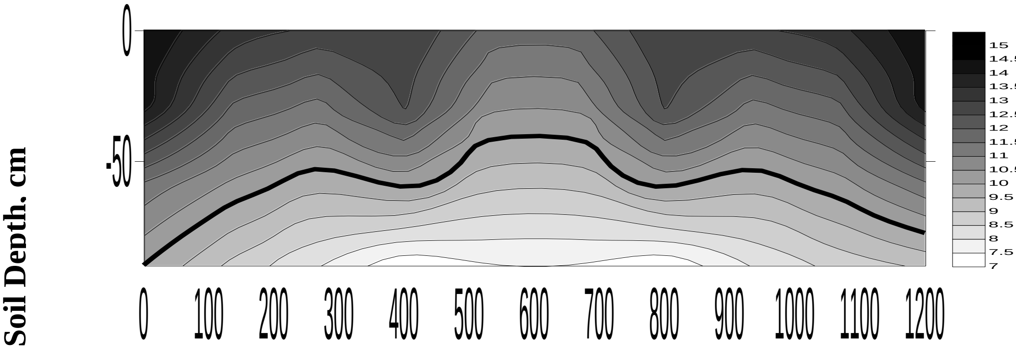


Fig-4. Soil Moisture Distribution at 80% Irrigation requirements.

(a) Laser land leveling



(b) Conventional leveling

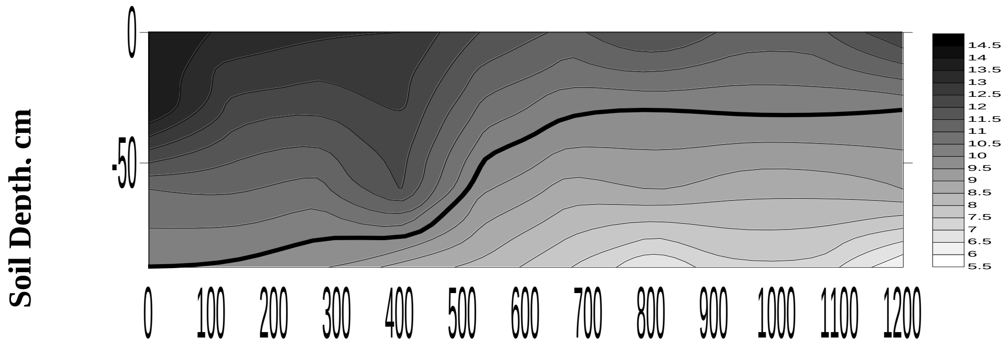
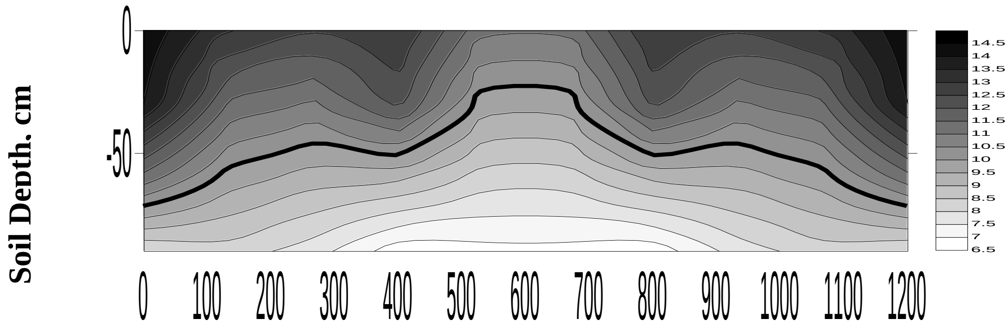


Fig-5. Soil Moisture Distribution at 60% Irrigation requirements.

(a) Laser land leveling



(b) Conventional leveling

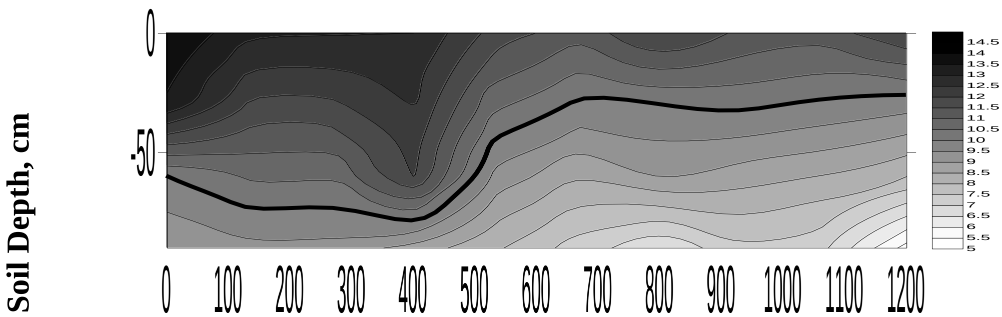
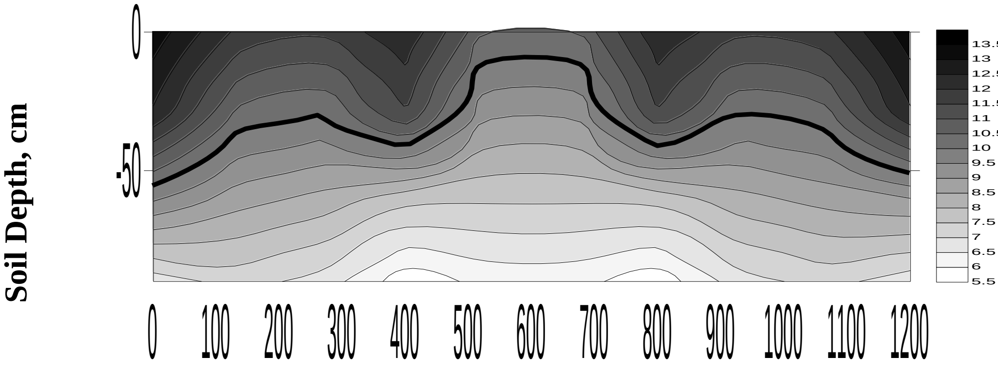
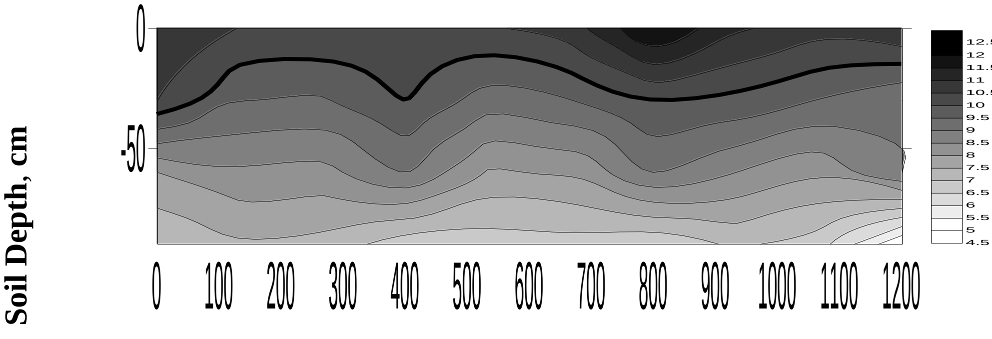


Fig-6. Soil Moisture Distribution at 40% Irrigation requirements.

(a) Laser land leveling



(b) Conventional leveling



Growth Characters of Wheat Plant

Data presented in Table (4) show the effect of land leveling techniques on the growth parameters of wheat plants. It could be observed that the highest values were obtained by using laser land leveling technology this is may be due to improvement in the soil moisture distribution in root zone. Table (4) shows clearly that irrigation affected significantly all studied wheat growth parameters. It could be safely concluded that irrigating wheat plants with 2304 m^3/ fed./ season (100 % IR) led to the highest values of most growth parameters, then the values decreased by decreasing the deficit irrigation this may be due to increasing soil moisture content in root zone and also increasing in leaching process and removing the salts. Effect of interaction between irrigation and land leveling techniques is shown in table (4) as an average of the two growing seasons. The highest values of growth parameters were detected under laser land leveling technology and adding 2304 m^3/ fed. / season (100 % IR). Subjecting wheat plants to water stress conditions from 100 % to 40 % IR led to reductions of plant height, total dry weight of whole plant, number of leaves per mean stem, and flag area by 9.14 %, 24.63 %, 22.17 %, and 31.53 %, respectively, under laser land leveling technique. The same trend was observed under the conventional land leveling condition.

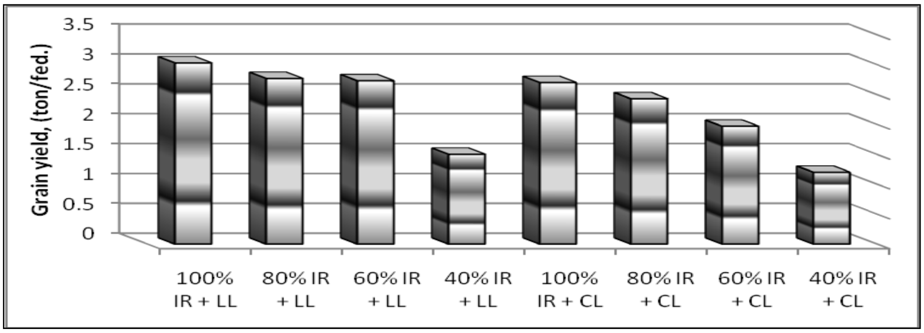
Table-4. Effect of irrigation, land leveling and their interaction on vegetative growth parameters of wheat in Nubarya (average of two seasons)

		Plant height, cm	No. of spikes/m²	Dry weight / plant, g	No. of leaves /mean stem	Flag leaf area, cm²
Land leveling techniques						
Laser leveling		119.17 a	489.50	4.81	5.17	25.92
Conventional leveling		116.17 b	477.67	4.54	4.67	24.00
Irrigation amounts, m³/ fed. / season						
2304		121.50 a	470.33 b	5.23 a	5.50 a	30.50 a
1843		119.33 ab	483.50 ab	4.93 ab	4.83 ab	26.67 b
1382		117.83 b	495.33 a	4.63 b	4.50 b	21.33 c
922		112.00 c	485.17 ab	3.90 c	4.83 ab	21.33 c
Interaction between land leveling techniques and irrigation						
Laser leveling	2304	124.00 a	480.33 ab	5.40 a	6.00 a	30.67 a
	1843	121.33 ab	495.33 a	5.10 a	5.33 ab	29.33 a
	1382	118.67 b	497.00 a	4.67 ab	4.67 b	22.67 b
	922	112.67 cd	485.33 ab	4.07 bc	4.67 b	21.00 b
Conventional leveling	2304	119.00 b	460.33 ab	5.07 a	5.00 ab	30.33 a
	1843	117.33 bc	471.67 ab	4.77 ab	4.33 b	24.00 b
	1382	117.00 bc	493.67 a	4.60 ab	4.33 b	20.00 b
	922	111.33 d	485.00 ab	3.73 c	5.00 ab	21.67 b
L.S.D. at 5% level		4.57		0.79	1.09	4.13

3.3. Wheat Yield Parameters

The main goal of any development in agriculture is increasing the yields of the crops. Table (5) shows that the highest significant values of wheat yield and its attributes were achieved by preparing the soil surface by laser technique more than preparing the land by the conventional method. This may be due to improvement in the soil moisture distribution in root zone which creates good conditions for growth of roots. Data in table (5) show the relation between wheat yield and irrigation**.** Generally, wheat yield was decreased by decreasing amount of irrigation water. This may be due to increasing in soil moisture content in root zone and also increasing in leaching process and removing the salts. The important attribute (grain yield, ton/fed.) was lessened when the used irrigation water was dropped from 2304 m³/ fed./ season to 922 m³/ fed./ season by 52.79 %.Data shown in Fig. (7) and Table (5) indicated the effect of the interaction between land leveling techniques and deficit irrigation on the yield of wheat crop. Although, the highest value of grain yield was achieved by using laser land leveling technique under 100% IR (2304 m³/ fed./ season) but the statistical analysis indicated that no significant deference was achieved between 100% and 60% IR, in the grain yield, this means saving 40% from irrigation water.

Fig-7. Effect of land leveling techniques and deficit irrigation on the yield of wheat.



3.4. Irrigation Water Use Efficiency of Wheat Crop

Response of wheat IWUE to the interaction between studied water regimes and the two land leveling technique was recorded in Table (5). The highest IWUE (1.98 kg/ m^3) was obtained by using 1382 m^3/ fed./ season (60 % IR) water regime under laser soil leveling technique. From the viewpoint of water conservation, it is observed that using of 2304 m^3/ fed./ season (100 % IR) is not efficient to irrigate wheat crop. Therefore, the efficient water regime is 60 % IR under laser soil leveling technique, because there was no significant differences of grain yield of wheat crop between using of 60 %, 8.0 % and 100 % IR. Consequently, 40 % of the irrigation water could be saved for irrigating other crops.

Table-5. Effect of irrigation, land leveling and their interaction on yield parameters and Nubarya (average of two seasons)

		Biological yield, (ton/fed.)	Straw yield, (ton/fed.)	Grain yield, (ton/fed.)	IWUE, (kg/ m^3)
Land leveling techniques					
Laser leveling		8.74 a	6.23 a	2.51 a	1.61 a
Conventional leveling		7.34 b	5.27 b	2.08 b	1.31 b
Deficit irrigation , m^3/fed./season					
2304		8.23	5.37 b	2.87 a	1.25 c
1843		8.28	5.68 ab	2.60 b	1.41 b
1382		8.03	5.68 ab	2.35 c	1.70 a
922		7.62	6.27 a	1.35 d	1.47 b
Interaction between land leveling techniques and deficit irrigation					
Laser leveling	2304	8.83 ab	5.80 abc	3.03 a	1.32 cd
	1843	8.97 ab	6.20 ab	2.77 ab	1.50 bc
	1382	9.17 a	6.43 a	2.73 ab	1.98 a
	922	8.00 bc	6.50 a	1.50 d	1.63 b
Conventional leveling	2304	7.63 cd	4.93 c	2.70 ab	1.17 d
	1843	7.60 cd	5.17 bc	2.43 b	1.32 cd
	1382	6.90 d	4.93 c	1.97 c	1.42 bcd
	922	7.23 cd	6.03 ab	1.20 d	1.3 cd
L.S.D. at 5% level		1.00	0.98	0.35	0.23

3.5. Economical Analysis

Method for calculation net income as shown in table (6) and values of total costs of inputs, total income of outputs and net income were presented according to Rizk [11].

Table-6. Method of calculating the net income for the studied experimental factors in wheat plant

Items	Land Leveling Techniques Deficit Irrigation	All treatments			
List of inputs	Cost of Irrigation, E/fed.	100%IR	80%IR	60% IR	40%IR
		600	480	360	240
	Cost of land preparation, LE/fed.	150 and 300 with laser Leveling			
	Cost of seeds, LE/fed.	230			
	Cost of mineral fertilizers, LE/fed.	1100			
	Cost of compost, LE/fed	1500			
	Cost of bio-fertilizers LE/fed	50			
	Cost of weed control, LE/fed.	200			
	Cost of pest control, LE/fed.	150			
	Cost of harvesting, LE/fed.	150			
	Cost of labor, LE/fed.	600			
	Rent (on season), LE/fed.	2000			
	Total costs, LE/fed.				
Output	Yield, ton/fed.(Grain yield + Straw yield)	Y_n= (Yg +Ys)			
	Price, LE/ ton.	Yg = 350 * 6.66 ardb = 2331 ,Ys = 600			
	Total income, LE/fed.	Y_n*(2331 + 600)			
Net income = list of outputs – list of inputs		Y_n*2931 – T.C.I.			

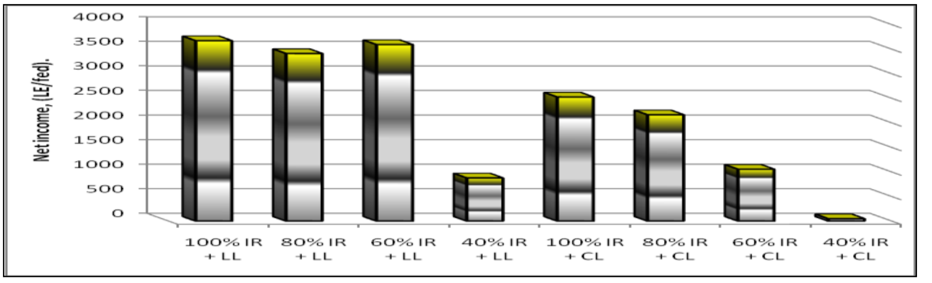
Y_n = Y is yield and n= number of treatment (from 1 to 8 treatment), T.C.I.= Total Costs for InputsThe prices according to 2011/2012where 1$ = 5.85L.E

The data plotted in Fig. (8) and Table (7) show the effect of land leveling techniques and irrigation treatments on the total costs and the total income as well as the net income (LE/ fed.). The economical analysis of the production of wheat crop under the experiment conditions explained that the total costs of wheat production inputs increased by increasing of irrigation water from 40 % to 100 % IR under the two experimental land leveling techniques. Otherwise, the highest values of the net income were acquired by using of 100 %, 80 %, and 60 % IR under laser land leveling technique and there were no significant differences between the three values, because these three treatments produced the highest values of grain yield. Generally, the more efficient and the economical treatment was 60 % IR (1382 m^3 / fed./ season) under laser land leveling.

Table-7. Effect of experimental treatments on the total costs for Inputs, total income for outputs and net income

		Total costs for Inputs, LE/fed	Total income for outputs, LE/fed	Net income, LE/fed.
Laser leveling	2304	6880 a	10550.6 a	3670.67 a
	1843	6760 b	10169.3 ab	3409.33 ab
	1382	6640 d	10231.3 ab	3591.33 a
	922	6520 f	7396.6 d	876.67 dc
Conventional leveling	2304	6730 c	9254.0 bc	2524.00 bc
	1843	6610 e	8772.3 c	2162.33 c
	1382	6490 g	7544.3 d	1054.33 d
	922	6370 h	6417.0 e	47.00 e

Fig-8. Effect of land leveling techniques and deficit irrigation on the net income.



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