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WATER REQUIREMENTS FOR THE NILE MAIZE CROP USING A LASER BEAM

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ABSTRACT

The aim of this research is to study the optimal time for irrigation, estimate water requirements of maize using visible laser and calculate water use efficiency to irrigate Nile maize crop. The experimental and field setups were carried out at the Institute of Laser Enhanced Science (NILES) and Farm of the Faculty of Agriculture, Cairo University, Giza, Egypt. Maize crop (11 hybrid variety) was used in the planting during autumn season of 2012, under the furrow and drip irrigation systems. Also two water regimes used soil moisture depletion (S.M.D) and evapotranspiration of crop (ETc) with three levels of water (10,25 and 50% for S.M.D and 1.25, 1 and 0.75 for Etc). In the meantime the ETc was calculated using CROPWAT program. The experimental setup of laser beam transmission (LBT) measures transmission light through maize leaves considering the moisture content in the canopy leaf for different plants. The obtained results were as follows: 1) The values of laser beam transmission increased by decreasing of the SMD to the best time to irrigate according to use of LBT within range between 30 to 35 mV at water regimes 10% of SMD and 1.25 ETc, 2) The crop water use efficiency (CWUE) was 1.40 and 1.66 kg/m^3 under furrow and drip irrigation systems with fully irrigation regimes, while, the traditional methods of furrow irrigation gave low CWUE (1.0 kg/m^3), and 3) The crop yield increased 856.70 and 531.57 kg/fed, with water saving of 167 and 40 m^3/fed for drip and furrow irrigation systems at 10% SMD respectively, compared with traditional furrow method.

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INTRODUCTION

Waskom (1994) reported that to maximize water productivity and avoid waste or water quality impacts, producers should determine; 1) When irrigation water should be applied; 2) How much water is needed to satisfy crop requirements?; 3) Application rate, set time, stream size, or set size required to apply the correct amount of water; and 4) Potential for agricultural chemicals to move from the target site due to irrigation practices.

George et al. (2002) reported that irrigation scheduling involves two questions, when (frequency) and how much (quantity) to irrigate a crop. Quantitative irrigation scheduling methods are based on three approaches, namely, crop monitoring, soil monitoring and water balance technique.

Schuerger et al. (2003) summarized that healthy and stressed plants were measured with two hyper spectral imagers, laser -induced fluorescence spectroscopy (LIFS), and laser-induced fluorescence imaging (LIFI) systems , if the four handheld remote sensing instruments were equally capable of detecting plant stress and measuring canopy chlorophyll levels in bahia grass. However unique capabilities of LIFS and LIFI instruments continue to argue for the development of laser-induced fluorescence remote sensing technologies.

Sander and Wim (2004) found that the measured average of Crop Water Productivity (CWP) per unit water depletion was 1.80 kg m^{-3} for maize**.** The range of CWP is very large and lays between 1.1–2.7 kg m^{-3} for maize crop. They also showed that the variability of CWP could be ascribed to: (i) climate; (ii) irrigation water management and (iii) soil (nutrient) management, among others.

Francisco et al. (2004) stated that the canopy temperature differences between plants and a well-watered control about 1, 2, 3, 4 and 5±0.5°c were tested. Plants irrigated when their canopy temperature was 3±0.5°c above the control had their relative growth rate mean value increased up to 59.7%, yielding 2,260.2 kg ha^{-1}, with a reduction of 38.0% in the amount of water used. Plants irrigated when their canopy temperature was 4±0.5°c yielded 1,907.6 kg ha^{-1}.

Oweis et al. (2005) revealed that water use efficiency (WUE), was known as water productivity, was determined as the ratio of crop yield per unit area, in terms of grain or total aboveground dry matter (biomass), to crop evapotranspired (mm). WUE is usually expressed either in kg/ha mm or in kg/m^3 (kg of grain or biomass per unit of consumed or evapotranspired Water).

Saito et al. (2006) stated that the Broad of laser-induced fluorescence (LIF) spectrum 400 nm to 800 nm gave information about pigments inside the leaves. Plant leaves can emit fluorescence in response to laser irradiation which is called laser-induced fluorescence (LIF). Therefore, LIF will be a good indicator to monitor plant status. LIF spectrum of a poplar's green leaf representative LIF spectrum with two peaks at 685 and 740 nm and small ones at 460 and 530 nm are observed.

Webber et al. (2006) mentioned that increasing (WUE), which was defined as amount of plant material produced per unit of water transpired, is way for arid and semi-arid areas to increase their agricultural production where there is little or no prospect for expansion of water resources.

According to **Shock (2007)** growers irrigation using one of several criteria; (1) intuition; (2) calendar days since the last rainfall or irrigation; (3) crop evapotranspiration ; (4) soil water monitoring.

Javaid and Khalid (2009) said that the total evapotranspiration of maize was 451 mm for the whole growing season. The highest grain yield i.e. 2993 kg/ha of maize was obtained from T_2 treatment and lowest i.e.1993 kg/ha was obtained when farmer's practices (To) were followed. All irrigations were applied before soil reached to the desired MAD. The application efficiency ranged between 50-81. The average application efficiency of 70% was obtained with treatment T_1 i.e. (0.5 Epan). The yield per unit volume of irrigation water applied is most significant measure for evaluating the judicious use of water. The average water use efficiency of maize ranged from 0.7 to 1.8 kg/m^3.

Edward (2009) reported that the infrared readings will often measure soil temperature when canopy cover is sparse. These readings usually result in higher temperature readings since the soil tends to heat up quickly. The improvement of on-farm irrigation systems and the introduction of low cost water saving irrigation technologies have been identified as key components of reducing agricultural water demand.

Masoud and Ghodratolah (2010) mentioned that for increasing water use efficiency in corn (*Zea mays* L.) crop at different planting densities and decrease water wastes in usual methods of surface irrigation. Three irrigation methods include: conventional furrow irrigation (CFI), fixed every other furrow irrigation (FFI) and alternate every other furrow irrigation (AFI) and three different plant densities (7, 8 and 9 plant mG2) were used. The results showed that there were no difference between both FFI and AFI, but the performance of them decreased irrigated water at the rates of 26.2% and 23%, respectively comparing with control and then yield at the rates of 11% and 13.6%, respectively.

Yang (2012) concluded that it is possible to implement deficit irrigation strategies for reducing agricultural water consumption by increasing the interval between irrigations during the periods other than around flowering.

Hirich et al. (2012) indicated that under deficit irrigation during vegetative growth stage of maize applying 75% of ETm lead to increasing of 19.4% in terms of fresh ear yield, 9.4% in terms of dry grain yield, 10.5% in terms of number of ears per plant, 11.5% for the 1000 grains weight and 19% in terms of crop water productivity compared with fully irrigated treatment. Meanwhile, those parameters in addition to root, shoot and plant height, have been affected by deficit irrigation during vegetative growth stage when increasing water stress degree more than 50% of ETm.

The objectives of this study were : 1) Determine optimal time for irrigation, 2) Estimate water requirements of autumn maize crop using visible laser, and 3) Calculate water use efficiency to irrigate autumn maize crop.

MATERIAL AND METHODS

The present investigation was conducted at the farm of the Faculty of Agriculture, Cairo University, Giza, Egypt. The carried experiments aimed at studying the possibility of scheduling irrigation for maize crop using laser technology, compared to ordinary method for managing irrigation water application.

The experiments of field

The cultivated area of maize crop was 0.5 feddan (2100 m^2) divided into three plots. Each plot consists of 82 rows- 70 cm apart and 12 m in length with buffer zone between plots. Two irrigation systems (furrow and drip) and controlled water applied were used. The traditional modified surface irrigation system was used as a control using gated pipe. Irrigation regimes were based on soil moisture depletion (SMD) and consumptive use (WCU) calculations. Maize kernels (11 hybrid variety) were planted at spacing of 25 cm within row in autumn season (from 15 August to 15 November), on the year 2012. All the agronomic practices were applied as commonly used according to the recommendation of the Ministry of Agriculture.

Irrigation systems:

Water source: is a well of 50 m depth and water static head of 3 m

Pump: The pump used was an electrical centrifugal pump. Its discharge reached 20m^3/h at 3 bar pressure head with 2/2 inch inlet/outlet diameter.

Control head: control head consisted of screen filters 2/2 inch inlet / outlet, 20 m^3/h discharges and 120 meshes with pressure gauge before the filter. Venture was used for fertigation, with commutative meter 2/2 inch outlet diameter, and air vent vacuum relief valve, 2 inch.

Main and sub main lines: main line was PVC pipe of 90 mm in diameter, with up to 6 atm pressure, 24m length and sub main line is PVC pipe of 63 mm diameter, up to 6 atm pressure. Manifold was PVC pipe of 50 mm diameter, with up to 6 atm pressure for drip irrigation and manifold of 3 inch for surface irrigation methods.

Plots representing the irrigation systems:

1- Furrow Irrigation (F). This system consisted of riser with valve of 3 inch and a gated pipe orifice of 1 inch used to irrigate each furrow.

2- Surface Drip Irrigation (SD). Lateral in each plot consisted of riser with valve and pressure gauge. Drip lines of 16 mm diameter (with built-in emitters), 30 cm emitter distance, and emitter discharge L hr^{-1}, and the discharge calibration indicated that actual average discharge was 4.15 Lhr^{-1}.

3- Conventional irrigation (control treatment): to represent the traditional furrow irrigation system.

Irrigation regimes:

Soil moisture depletion (SMD)

Three irrigation application regimes were used as water applied when the soil moisture depletion (SMD) was reached 10%, 25% and 50%. Irrigation water was applied to reach field capacity at all levels. Soil moisture sensor, based on Time Domain Refractometery (TDR) theory, was used to control water level in the soil.

Consumptive use (CU)

The CROPWAT software program was used to calculate ET_c values for maize crop under the experimental condition. The CROPWAT is a decision support system by the land and Water Development Division of **FAO (1995)** based on the use of calculating reference evapotranspiration (ET_o) it uses Penman Monteith equation. The ET_c is calculated within the program using coefficient (k_c value according to **Allent et al., 1998**).

The data indicate the values of crop and irrigation water requirements calculated using CROPWAT program. The obtained values of crop water requirements are found to be 423 mm, 338 mm and 254 for three levels of irrigation regimes,1.25, 1.00 and 0.75 from ET_c, respectively.

Soil and Water Analysis

The soil samples were collected from three soil depths (0-15, 15-30, and 30-45cm) before cultivation and harvesting to determine the physical and chemical characteristics of the experimental soil site.

Soil physical analysis:

Soil mechanical analysis was carried out using pipette method, using NH OH as dispersing agent and soil bulk density of soil was determined using the undisturbed soil cores according to methods described by ***Klute* (1986)**, as shown in Table (1).

Field capacity (FC) and permanent wilting point (PWP) were determined using the pressure cooker and pressure membrane apparatus. A saturated undisturbed and disturbed soil samples were equilibrated at suction pressures of 0.33 and 15.0 bar, respectively, according to ***Shawky* (1976),** and the values of the available water (AW) were calculated as the difference between the (FC) and (PWP).

Table 1: Some soil physical characteristics of the investigated soil layers.

Soil depth (cm)	Particle size distribution (%)				Texture class	Soil bulk density kg/m^3
	Coarse sand	Fine sand	Silt	Clay		
0-15	1.63	33.89	30.97	31.89	Clay loam	1118
15-30	1.68	33.71	30.78	31.74	Clay loam	1245
30-45	0.17	43.23	26.81	28.93	Clay loam	1395

Soil chemical analysis

Total soluble salts, soil reaction (pH), and soluble cations and anions (extract 1 : 2.5) and total calcium carbonate were determined according to **Page (1982)**, as shown in Table (2).

Table 2: Some soil chemical characteristics of the investigated soil layers.

Soil depth (cm)	pH*	EC_e* $dS.m^{-1}$	Soluble cations (meq/L)				Soluble anions (meq/L)		
			Na^+	K^+	Ca^{++}	Mg^{++}	Cl^-	CO_3^+ + HCO_3^-	SO_4^-
0-15	7.46	1.56	5.19	0.41	4.92	5.96	4.39	11.93	0.10
15-30	7.62	2.51	4.32	0.28	8.43	13.29	7.28	9.43	9.60
30-45	7.53	1.78	4.07	0.26	6.89	7.27	8.95	1.45	8.10

* in soil paste extract

Chemical analysis of irrigation water

Water reaction (pH), electric conductivity (EC), and soluble cations and anions were determined according to **Page (1982),** as shown in Table (3).

Table 3: Some chemical analysis of irrigation water.

pH	EC		Soluble cations (meq/L)				Soluble anions (meq/L)			SAR
	PPm	dSm^{-1}	Ca^{++}	Mg^{++}	Na^+	K^+	CO_3^+ HCO_3^-	$SO4^=$	Cl^-	
7.15	530.80	0.79	3.50	2.40	0.80	0.16	4.00	1.24	1.00	0.50

Time Domain Refractometery (TDR)

TDR measures the volumetric moisture percentage based on theory of applying the frequency of time domain refractometery (TDR) technique to determine soil moisture contents in different soil layers for soil moisture depletion (SMD) treatments in drip and furrow irrigation systems **(*Kaffka et al., 1997; Iles and Dosmann, 1999*).**

The setup of laser beam transmission (LBT) device

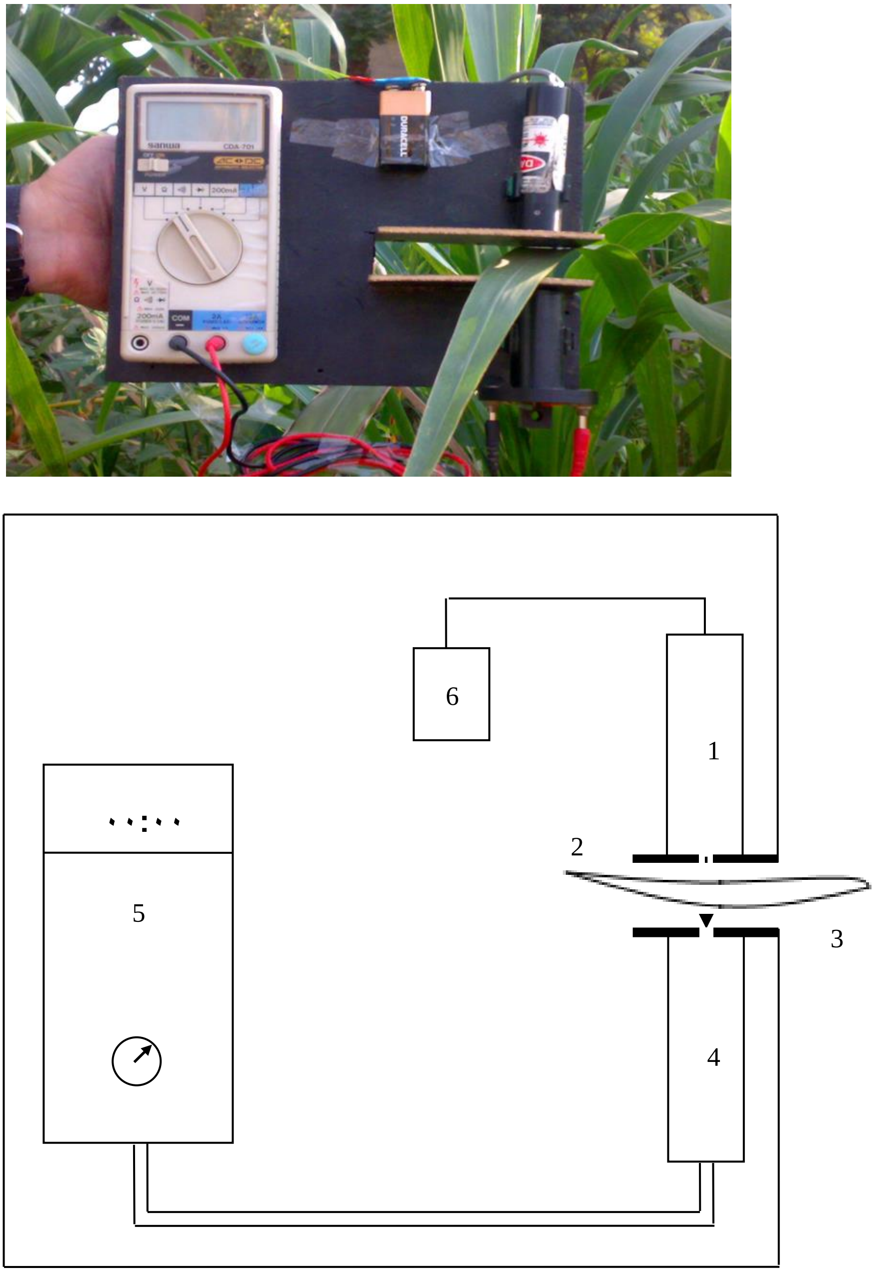
The experimental setup (Fig. 1) was developed and assembled in the laboratory of laser applications in agricultural applications, National Institute of Laser Enhanced Science (NILES), Cairo University and consists of laser source, holders, photovoltaic avometer and woody base: to measure laser beam transmission through maize leaf.

Diode laser: The diod laser specification (table 4) (Semi conductor laser type) with wavelength from 600-700 nm (visible laser) was used in the present work as light source. The diode laser was sitting on parallel holder on woody base by plastic holder.

Table 4: The specifications of diode laser.

Item	**Diode laser**
Source of manufacture	USA
Model	Laser max, inc
Type	Semiconductor
Wavelengths, nm	600-700 nm
Beam	Continuous wave
Output power, mW	$\leq 4.25 mW$
Beam diameter, mm	1
Beam divergence, mrad	0.62
Polarization ratio	Random
Class	III a laser product

Holders: The plastic holders were used to fix diode laser and photovoltaic parallel on woody base. Plastic holders with diameter 50 mm was parallel and fixed on woody base by screw blot.



1	Diode laser.	4	Photovoltaic cell.
2	Laser beam.	5	Avometer.
3	Maize leaf.	6	Power supply

Fig. 1: Assembled setup of laser beam transmission (LBT) device.

Photovoltaic cell: Photovoltaic cell was fixed on a woody base by plastic holder and its efficiency was about 30%. It converted light beam into electrical signals transferred to an avometer from maize leaf.

Avometer: Avometer was used to measure the electrical signals as volt resulting from converting the transmission of light through maize leaf by a photovoltaic cell. The light intensity transmission through maize leaf passes to the photovoltaic cell. The avometer has the following specifications as shown in table (5).

Table 5: The specifications of the AVO meter.

Item	Specification
Model	Digital, l millimeter mod. CDA-701
Source of manufacture	Japan
Accuracy	0.1 mV (DC)
Range	1 mV to 1000 V
Limit of error	± (0.6 % rged + dgt)

Scheduling of irrigation

Procedure to manage the irrigation water was applied as follows:

Laser beam transmission (LBT)

The intensity of transmission through maize leaves at different ages was calculated from the following equation with negligible light reflection because the laser beam was reflected on itself according to the low of conservation of energy (1):

$$I = T + R + A \text{ ------------ } (1)$$

Where: I = the incident beam, volt; T = transmission beam;
R = reflection; and A = absorption.

Irrigation efficiency (Ei)

Furrow irrigation system efficiency was computed, according to the method described by **James (1988)**, and according to equations (2 and 3), also surface and subsurface drip irrigation systems were evaluated according to the method described by **Merriam and Keller (1978).**

$$E_a = \frac{R_Z}{d_w} \times 100 \text{ ------------ } (2)$$

$$R_Z = \frac{D(\theta fc - \theta_i)}{100} \text{ --------- } (3)$$

Where : E_a = efficiency of application [%];

RZ = amount of water stored in the root zone [mm];

d_w = depth of water applied [mm];

D = depth of root zone [mm];

θfc _and _θi = volumetric water contents in percent at field capacity and prior to irrigation, respectively.

Irrigation water requirements and traditional methods

According to **Borham (2001)**, the depth of irrigation water requirements was calculated by using the following equation (4):

$$I = \frac{(\theta_{FC} - \theta_v) \times d_s + L_f}{E_1} \text{--------} (4)$$

Where: I = total depth of irrigation water requirements [mm/interval];

$\theta_{F.C}$ = soil water content at Field Capacity on volume basis [%];

θ_V = percentages of soil moisture content at irrigation time on volume basis depending on the irrigation treatment (level of Soil Moisture Depletion)[%];

d_s = depth of soil layer [mm];

L_f = leaching factor.

E_i = irrigation efficiency.

Yield and yield components

At harvesting, two meter lengths for one row were chosen randomly from each plot and harvested to estimate the yield components as follows: Number of plants, average mass (g), and total yield (ton/fed).

Water Use Efficiency (WUE)

Water use efficiency of crop was calculated according to **Giriappa (1983)** using the following equations (5 and 6:

$$CWUE = \frac{Yield}{ETa} \text{------} (5)$$

$$IWUE = \frac{Yield}{IWRa} \text{-------} (6)$$

Where:

ETa = actual evapotranspiration, ($m^3.fed^{-1}$)

IWRa = actual irrigation water requirement, ($m^3.fed^{-1}$)

CWUE = crop water use efficiency,

IWUE = irrigation water use efficiency, ($kg.m^{-3}$)

RESULTS AND DISCUSSIONS

This study aims at using a new technique to determine when to irrigation and how much water to apply, (irrigation scheduling) for maize crop. To achieve the aim of this research; the simple and accurate application methods used the TDR to control the SMD and laser beam methods.

Laser beam transmission (LBT)

The laser beam transmission setup was used to measure the transmission through the leaf of maize.

Furrow irrigation

The data in figs. (2 and 3) represent the LBT for furrow irrigation under different regimes of SMD and ETc. The data indicate that the absorption of the laser beam is more than the transmission. The data also exhibited that the LBT were 41.4, 42.8 and 46 mV for 10, 25 and 50% SMD, respectively before irrigation. Meanwhile, they were 38.2, 38.6 and 40.6 mV at the same different SMD, respectively after irrigation. In the same time the LBT increased before irrigation than after irrigation. Also the data exhibited that the LBT under ET regimes is more than SMD, The LBT values were 51.8, 56.6 and 59.8 mV for 1.25, 1 and 0.75 ET.

Drip irrigation

The data in figs. (4 and 5) represent the LBT under drip irrigation for different water regimes. Generally, they take the same trend for furrow irrigation. Dealing with water regimes, the LBT increased under deficit irrigation than full irrigation. Also the data exhibit the trend under high water regimes of 10 % SMD and 1.25 ET, the difference in LBT is very small. But under low water regimes of 50% SMD and 0.75 ET, but the LBT is more than high water regimes. This means that the LBT increased as the CWSI increased. Dealing with irrigation system the LBT under high regimes are the same. However, for low water regimes, the LBT increased under furrow irrigation than drip irrigation. Meanwhile, the LBT under ET regimes is more than SMD regimes.

It is clear that the LBT ranged from 40 to 42 mV under high water regimes while the LBT ranged from 50 to 75 mV under low water regimes. The LBT is the same for high water regimes with the furrow and drip irrigation while the LBT was different under two water regimes.

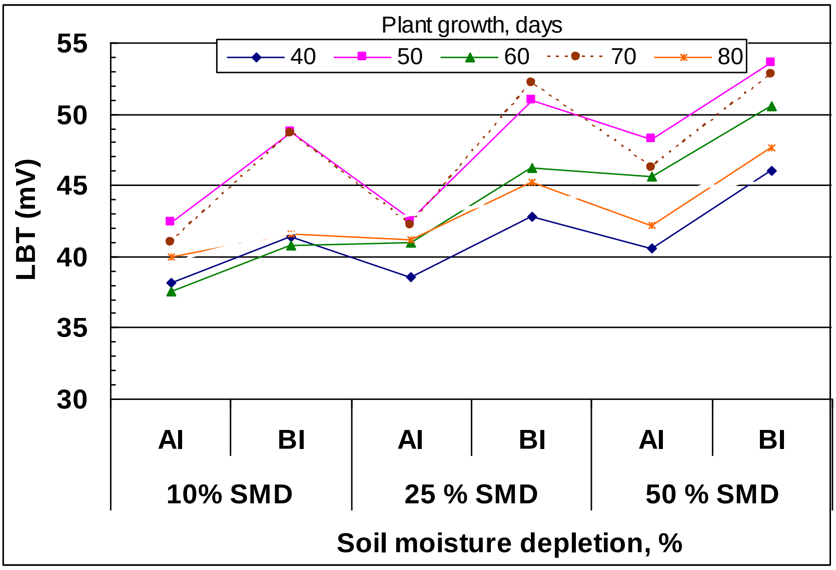


Fig. 2: Relationship between soil moisture depletion (SMD) and laser beam transmission (LBT) after and before irrigation at different plant growth stages under furrow irrigation.

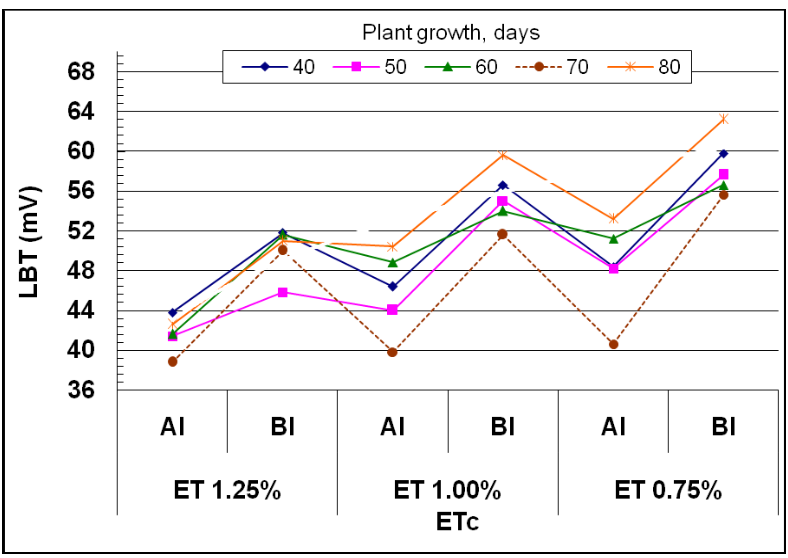


Fig. 3: Relationship between laser beam transmission (LBT) and crop evapotranspiration (ETc) after and before irrigation at different plant growth stages under furrow irrigation.

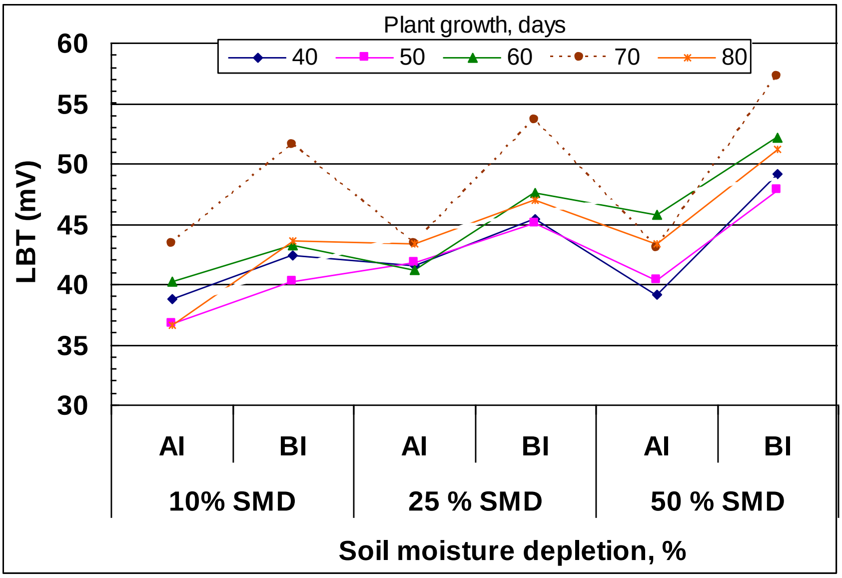


Fig. 4: Relationship between soil moisture depletion (SMD) and laser beam transmission (LBT) after and before irrigation at different plant growth stages under drip irrigation**.**

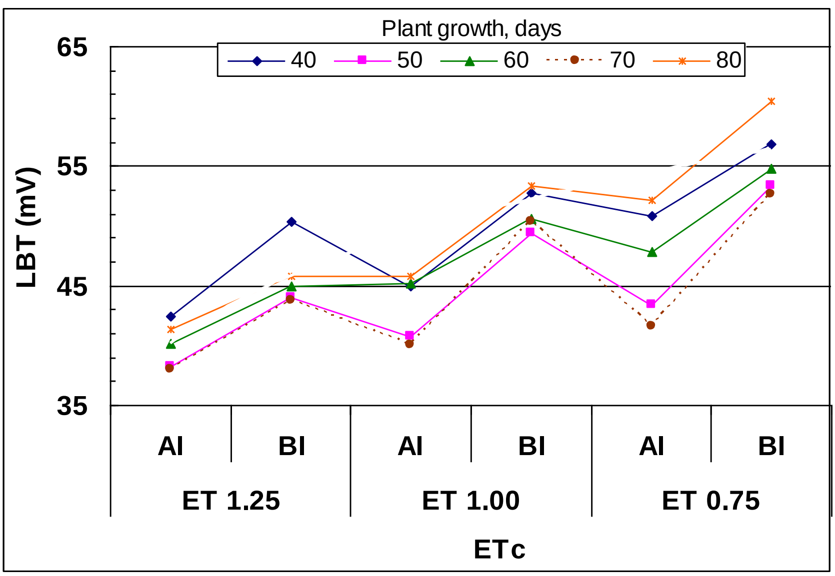


Fig. 5: Relationship between laser beam transmission (LBT) and crop transpiration (Etc) after and before irrigation at different plant growth stages under drip irrigation.

Comparison between SMC and LBT under furrow and drip irrigations:

The figures (6, 7, 8 to 9) present the relationship between LBT and SMC for furrow and drip irrigation for different regimes. It is clear from the data that the LBT increased as SMC decreased. The LBT ranged from 42 to 48 mV while the SMC ranged from 33 to 35% for SMD 10 under furrow irrigation. Meanwhile, the LBT ranged from 42 to 52 mV when SMC ranged from 32 to 33%. At same time, the LBT ranged from 48 to 55 mV when SMD ranged from 25 to 31%. Dealing with ETc regimens, the LBT were 52, 60, 65 mV respectively. Dealing with drip irrigation system, the figures present the relationship between LBT and SMC for different regimes. The data take the same trend for furrow irrigation. But the LBT values for drip irrigation were less than far furrow irrigation, the LBT were 50, 53 and 58 mV for 10, 25 and 50% SMD.

Dealing with ET regimes under drip irrigation the LBT value is more than for SMD.

LBT and SMC were as follows:

1 -The Laser beam transmission increased as SMC decreased.

2 -The Laser beam transmission is less than absorption beam.

3 -The LBT ranged from 35 to 75 mV is considered the best time for irrigation, and

4 -There is a good relationship between SMD and CWSI which affected the LBT.

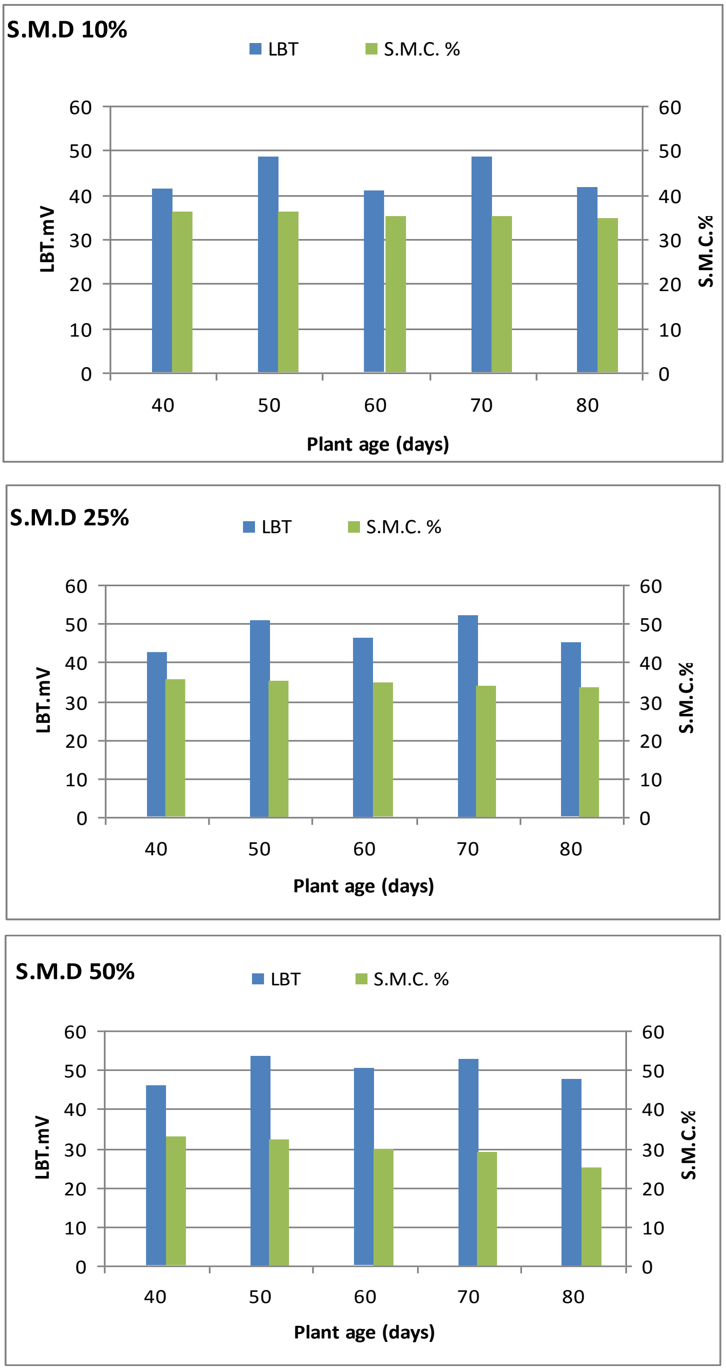


Fig. 6 : Relationship between laser beam transmission (LBT) and soil moisture content (SMC) at different soil moisture depletions (SMD) under furrow irrigation.

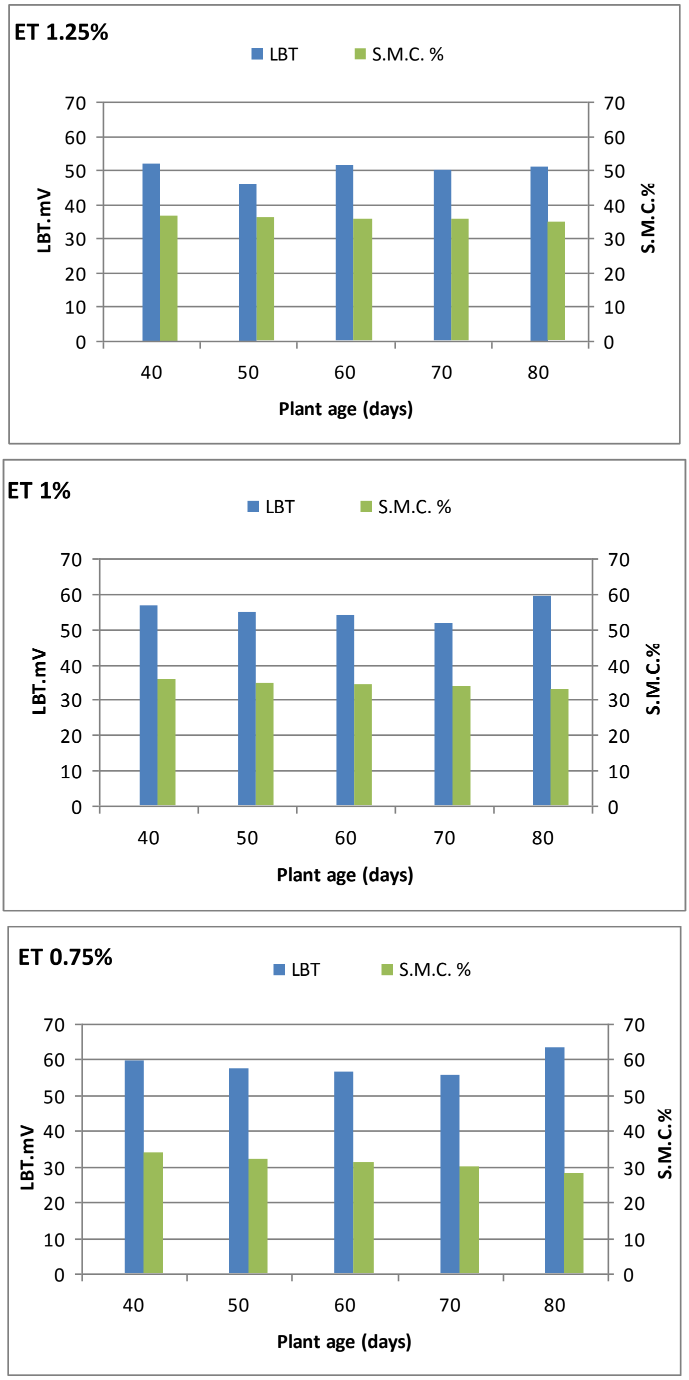


Fig. 7 : Relationship between laser beam transmission (LBT) and soil moisture content (SMC) at different crop evapotranspirations (Etc) under furrow irrigation.

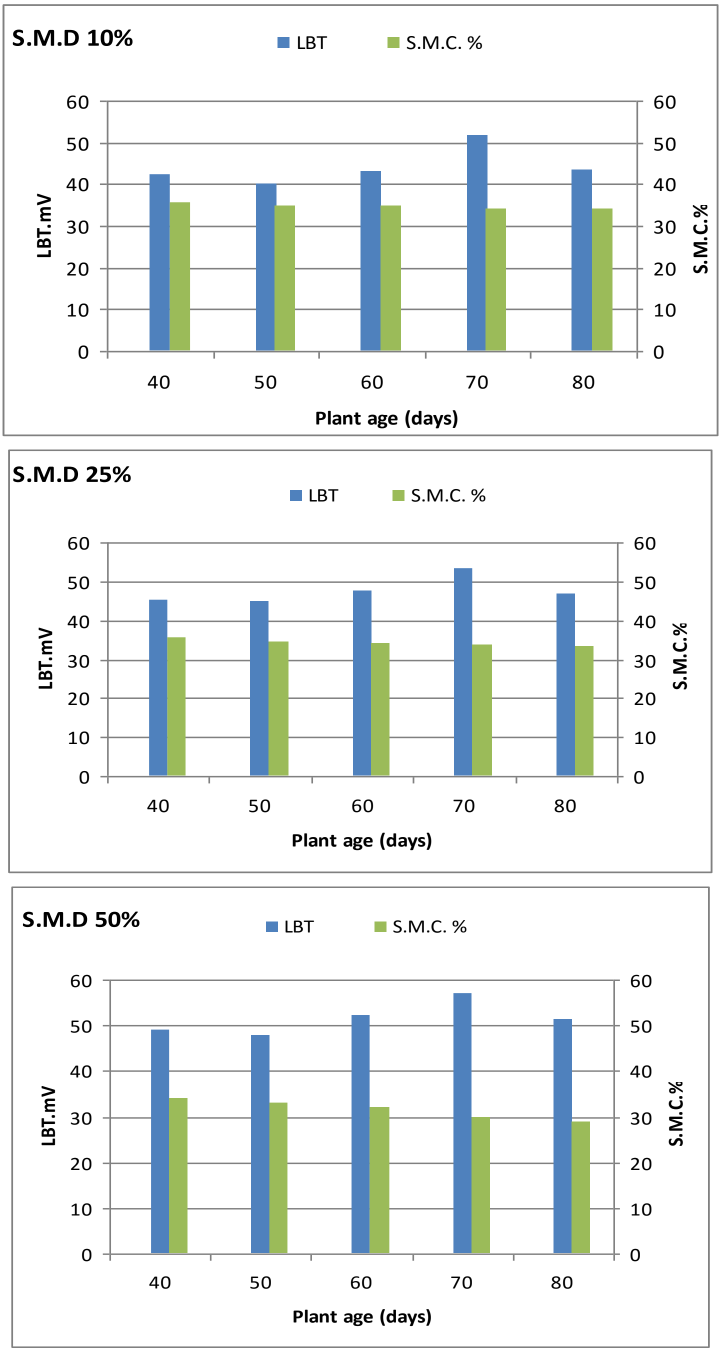


Fig. 8 : Relationship between laser beam transmission (LBT) and soil moisture content (SMC) at different soil moisture depletions (SMD) under drip irrigation.

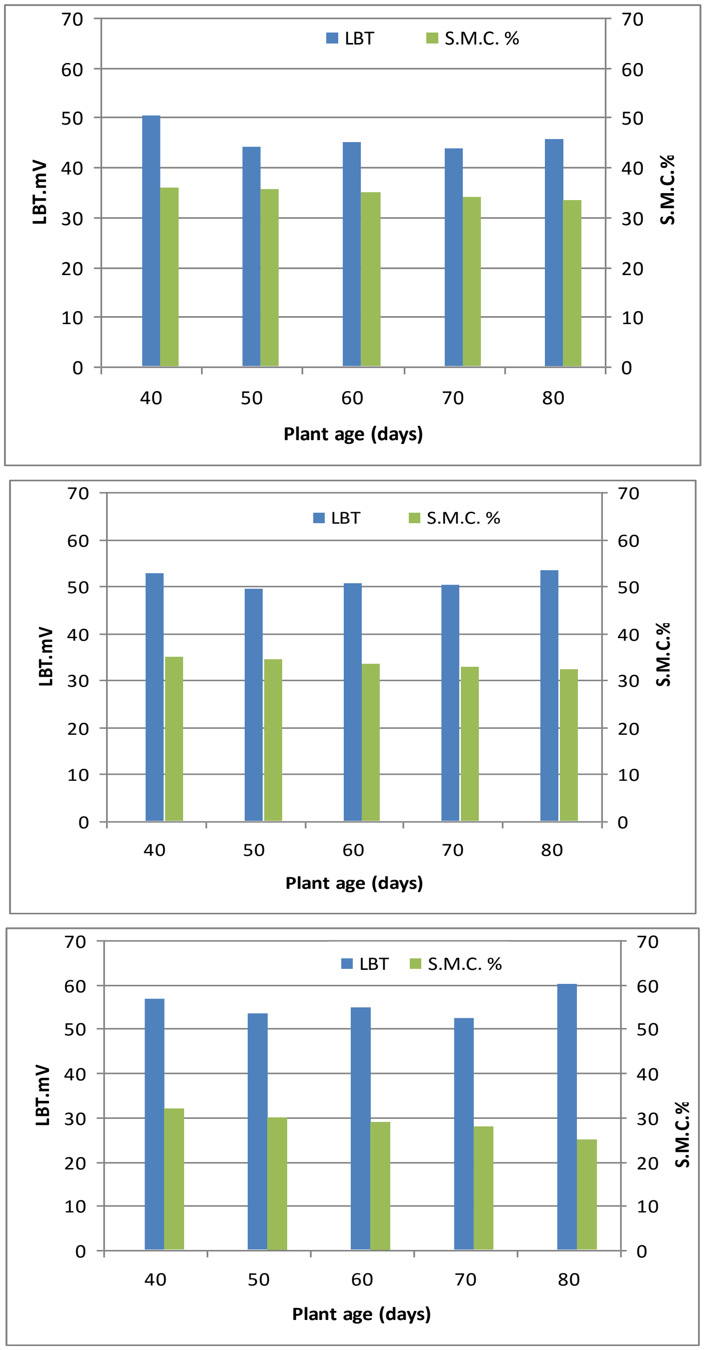


Fig. 9 : Relationship between Laser beam transmission (LBT) and soil moisture content (SMC) at different crop evapotranspirations (Etc) under drip irrigation.

Yield and crop water use efficiency:

Response of maize grain yield to irrigation regimes:

Figs. (10 and 11) and Table (6) show that the mean values of grain yield were 2881.23, 2346.12and 1605.24 kg/fed for10 , 25 and 50% SMD, respectively, under furrow irrigation, while the mean values of grain yield were 2166.71 , 1968.60 and 1332.50 kg/fed for 1.25 , 1 and 0.75 Etc, respectively, under furrow irrigation.

At the same time, the mean values under drip irrigation were 3205.46, 2469.60 and 1605.73 kg/fed for 10, 25 and 50% SMD, respectively, while the mean value were 2492.64, 2005.35 and 1476.80 kg/fed for 1.25, 1 and 0.75 ET, respectively.

From the data of grain yield it can be conclude that:

a- The high grain yield is with high water regimes of 10% and 1.25 ET.

b- The mean value of grain yield for drip irrigation is more than furrow irrigation.

c- The mean grain yield of 10, 25% SMD and 1.25 ET is more than the traditional methods.

Crop Water Use Efficiency (CWUE):

Table (6) shows that the highest CWUE value was 1.66 kg/m^3 under drip irrigation with 10% SMD, while the highest CWUE under furrow irrigation was 1.40 kg/m^3 with 10% SMD, while the CWUE was 1.44 kg/m^3 for drip irrigation with 1.25 ETc. At the same time, the CWUE was 1.22 kg/m^3 under furrow irrigation, with 1.25 ET water regimes. This may be due to the good control of water management and the low consumption of water. Dealing with irrigation regimes, the highest value of CWUE is obtained with 10% of SMD.

The highest value of CWUE is 1.66 kg/m^3 under drip irrigation system. This may be due to that this treatment gives higher grain weight, quite high in total yield (856.70 kg/fed). At the same time, with water regimes of Etc, the highest value is with 1.25 ET, the value was 1.44 kg under drip irrigation system. This is maybe due to the low consumption of water compared to other treatments.

The crop yield increased 856.70 and 531.57 Kg/fed, with save water 167 and 40 m^3/fed for drip and furrow irrigation system at 10% SMD respectively, compared with traditional furrow method.

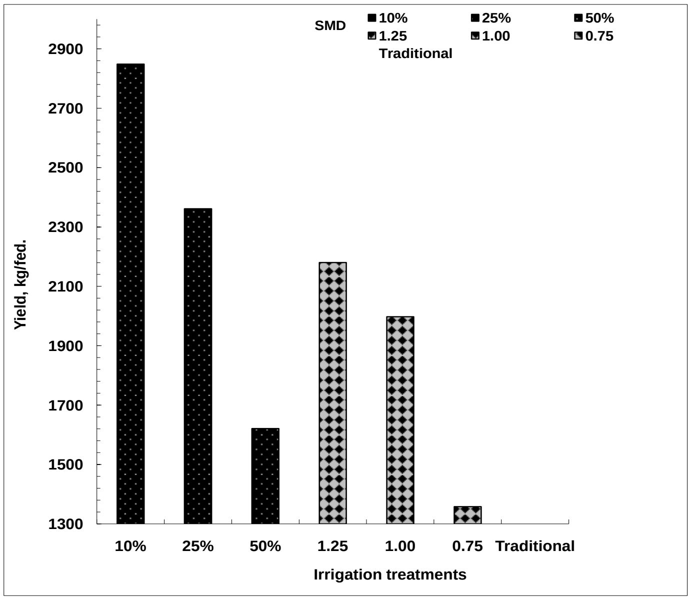


Fig. 10: Average maize production under different irrigation treatments with furrow irrigation.

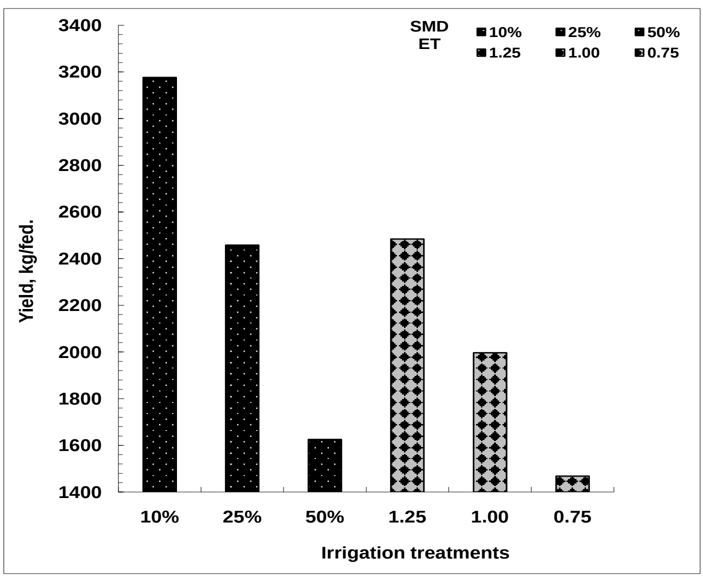


Fig. 11: Average maize production under different irrigation treatments with drip irrigation.

Comparing the CWUE with different regimes, the value exhibited big differences from 1.66 to 1.13 kg/m^3 under drip irrigation for 10 and 50% SMD. Also, the CWUE ranged from 1.44 to 1.42 kg under 1.25 and 0.75 ET. This may be due to the non-stressed 10% SMD and 1.25 ET and the stressed treatment 50% SMD and 0.75 ET.

Table 6: Interaction between irrigation systems and water regimes (water stress) on yield and crop water use efficiency.

Irrigation system	Treatments	Yield kg/fed	Water apply m^3/fed	CWUE, kg/m^3
Furrow	SMD 10%	2881.23	2058	1.40
	SMD 25%	2346.12	1764	1.33
	SMD 50%	1605.24	1638	0.98
	ET (1.25)	2166.71	1776	1.22
	ET (1)	1968.60	1419	1.40
	ET(0.75)	1332.50	1065	1.25
Drip	SMD 10%	3205.46	1931	1.66
	SMD 25%	2469.60	1680	1.47
	SMD 50%	1605.73	1421	1.13
	ET (1.25)	2492.64	1731	1.44
	ET (1)	2005.35	1383	1.45
	ET (0.75)	1476.80	1040	1.42
Traditional furrow		2349.76	2098	1.12

CONCLUSIONS

The obtained results were as follows:

1-The value of both the transmission and absorbed beam into the leaf of plant affected the value of the leaf moisture content, which is affected with soil moisture content

2-The values of laser beam transmission increased by decrease of the SMD so the best time to irrigate according to use of LBT is between 30 to 35 mV at water regimes 10% of SMD and 1.25 ETc.

3-The crop water use efficiency (CWUE) was 1.40 and 1.66 kg/m^3 under furrow and drip irrigation systems with fully irrigation regimes, while, the traditional methods of furrow irrigation gave low CWUE.

4-The crop yield increased 856.70 and 531.57 kg/fed, with water saving of 167 and 40 m^3/fed for drip and furrow irrigation systems at 10% SMD respectively, compared with traditional furrow method.
5- Laser technique can be used as a water management tool with acceptable accuracy.

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الملخص العربى

المقننات المائية لمحصول الذرة النيلى باستخدام شعاع الليزر

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يعتبر محصول الذرة محصول غذائى فى مصر ويزرع سنويا حوالى ٢ مليون فدان . ويهدف البحث الى استخدام شعاع الليزر فى جدولة مياة الرى لمحصول الذرة (الصنف هجين فردى ١١) بهدف التحكم فى أدارة أنظمة مياة الرى لزيادة كفاءة أستخدام الري.

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أجريت الدراسة الحقلية فى حقل التجارب بمزرعة كلية الزراعة – جامعة القاهرة اثناء العروة النيلى ٢٠١٢. وقد تم تصميم التجربة الحقلية بنظام القطع المنشقة بمكررين للري وضعت نظم الري بالخطوط والرى بالتنقيط السطحى ووضع تحت كل منهما نظامان لآضافة مياة الرى وهم النقص في المحتوي الرطوبي للتربه SMD والبخر نتح ETc على أعتبار أنه الاستهلاك المائى للنبات . وتحت كل نظام وضعت ثلاثة مستويات معاملات للرى وفى نظام SMD وضعت ثلاث معاملات هى ١٠ , ٢٥ , ٥٠% وفى نظام البخر نتح كانت المعاملات ١,٢٥ , ١ , ٠,٧٥% من قيمة البخرنتح .. وقد أستخدم نوعان من الآجهزة فى التجارب للحكم فى متى يتم الري والكميات الواجب أضافتها. وهذه الأجهزه هى : جهاز TDR لحساب الرطوبة النسبية فى التربة وحساب البخرنتح من خلال برنامج CROPWAT ، جهاز LBT لقياس نفاذية وأمتصاص أشعة الليزر داخل الورقة .. حيث تم بناء الجهاز وتركيبة بالمعهد القومى لعلوم الليزر – جامعة القاهرة.. ويمكن تلخيص النتائج فيما يلى :.-

- أن قيمة كلا من الاشعة النافذة او الممتصة داخل الورقة تتأثر بالتغير فى قيمة المحتوي الرطوبى للورقة والذي يتأثربقيمة المحتوي الرطوبي للتربة .
- تزداد قيمة نفاذية شعاع الليزر بنقص قيمة المحتوى الرطوبى للتربة ، حيث وجد أن أنسب وقت للرى كان عند قيمة نفاذية لشعاع الليزر ٣٠ – ٣٥ مللى فولت على مقياس جهاز LBT.
- تبين النتائج أن أعلى كفاءة أستخدام المياه WUE كانت أعلى ما يمكن تحت نظام الري بالتنقيط حيث بلغت ١,٦٦ كج/ م٣ بينما كانت ١,٤٠ كج/فدان للري السطحى بالخطوط.
- أظهرت النتائج أن أعلى قيمة WUE كانت مع أعلى قيم لمعاملات الري وهى ١٠% من النقص فى المحتوي الرطوبى ١,٢٥ من البخرنتح .
- وكانت أعلى انتاجية للمحصول بنظام الري بالخطوط ٢٨٨١,٢٣ كج/فدان عند معاملة النقص فى المحتوى الرطوبى ١٠ % وكانت ٢١٦٦,٧٢ كج/فدان عند معاملة البخرنتح ١,٢٥ % ..بينما كانت أقل انتاجية ١٦٠٥,٢٤ كج/ فدان عند معاملة النقص فى المحتوى الرطوبى ٥٠% وكانت ١٣٣٢,٥٠ كج / فدان عند المعاملة ٠,٧٥ من البخرنتح.
- أعطى الرى بالتنقيط أعلى انتاجية للمحصول ٣٢٠٥,٤٦ كج/فدان عند معاملة النقص فى المحتوى الرطوبى ١٠ % وكان ٢٤٩٢,٦٤ كج/فدان عند معاملة البخرنتح ١,٢٥ % . بينما كان أقل انتاجية للمحصول ١٦٠٥,٧٣ كج/فدان عند المعاملة ٥٠% من نقص فى المحتوي الرطوبى, كانت ١٤٧٦,٨٠ كج/فدان عند المعاملة ٠,٧٥ من البخرنتح .
- زادت انتاجية المحصول ٨٥٦,٧٠ ، ٥٣١,٥٧ كج/فدان مع توفير فى كمية المياه ١٦٧ ، ٤٠ م٣ لنظامى الرى بالتنقيط والخطوط عند معاملة النقص فى المحتوى الرطوبى ١٠ % مقارنة بطريقة الرى التقليدية بالخطوط .