MAXIMIZING OF SURFACE IRRIGATION PERFORMANCE ON GROWTH AND PRODUCTION OF COWPEA IN CLAY SOIL

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ABSTRACT

Alternate furrow irrigation (AFI) is gaining interest as a mean of saving water while minimizing loss in crop production. Field experiment was conducted in the Experimental Farm, Faculty of Agriculture, Kafrelsheikh University, Egypt, during growing season of 2016-2017. The present work included the following: Irrigation systems (Furrow surface irrigation and surface drip irrigation (SDI)). However, different techniques had been investigated with surface irrigation (alternative furrow (AFI) and conventional furrow irrigation (CFI) with a furrow length of 20, 30 and 40 m. The experiment was designed as split plot with three replications, where irrigation systems used as the main plot and furrow length as sub-plot. The ranges of mean cowpea yield gained from irrigation system were 932.33, 910.52 and 1179.52 kg/fed for CFI, AFI and SDI respectively. The effect of furrow length and their interaction with irrigation system on yield were non-significant but the irrigation system has significant effect on yield (P<0.01). The maximum and minimum yield was obtained at length of 20 m for SDI and length of 40 m for AFI, which were 34.37 kg and 25.26 kg, respectively. The effect of irrigation system on the water use efficiency (WUE) was significant (p<0.01). The average WUE was decreased from 11.57 to 8.10 kg/m^3 when the furrow length increased from 20 m to 40 m. The range of mean values of WUE due to the effect of furrow length from 20 to 40m was highly significant (P<0.01) only. The average of WUE was increased from 5.81 to 9.87 and 13.41 kg/m^3 for CFI, AFI and SDI systems, respectively. The highest and lowest values of irrigation depth (ID), water application efficiency (WAE), water distribution efficiency (WDE) and applied water (AW) were 17.65-10.12cm, 75.25-52.46 %, 73.37 -36.45% and 61.20.

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INTRODUCTION

Water shortage is the most important factor constraining agricultural production in arid and semi-arid regions. Thus, new irrigation strategies must be established to use the limited water resource more efficiently. The growing pressure on fresh water resources has been widely acknowledged, and there is need for water resources to be managed better ***(Sander and Lucie 2010).*** In most Egyptian areas irrigated agriculture has been faced with increased limitations of water supply in the last few decades. To reduce the disproportion between water demand and supply, water management is required, particularly aimed at water saving and conservation in irrigated agriculture. One main way is demand management by reducing the irrigation water demand by improved crop irrigation management. In this perspective specially improved furrow irrigation alternatives such as AFI. CFI have been developed to enable intensive production in the ASALs ***(Montoro et al. 2011).*** In Egypt, Cowpea ***(Vigna unguiculata L. Walp)*** is grown on 14,830 feddan with production 17248 tons with (an average yield of 1.163 ton/feddan), according to the Agricultural economic bulletin ***(El-Shaieny 2017)***. Cowpea regarded as a major pulse crop amongst the vegetable legumes that existing at West Africa. Further, belongs to family, and had a little seedling establishment and growth duration ***(Chiulele, 2010).*** The cheapest and easiest adaptations are those of furrow irrigation. An important adaptation of furrow irrigation is Alternate Furrow Irrigation (AFI) in which furrows are irrigated alternately rather than consecutively during irrigation water application. This is a form of partial root-zone drying (PRD) system which has been found to increase the production of crops in the ASAL areas ***(Stickic et al. 2003)***. Alternate Furrow Irrigation (AFI), is a modified form of Regulated Deficit Irrigation technique which can improve the water use efficiency of crop production without significant yield reduction ***(Fereres and Soriano 2007). Du et al. (2010) and Horst et al.(2005)*** indicated that the efficiency of conventional furrow irrigation (CFI), referred to be some as every furrow irrigation, can be improved by converting it to alternate furrow irrigation (AFI). The AFI technique is essentially the same as CFI, except that instead of irrigating every furrow, irrigation is applied to alternate furrows, while the in-between furrows remain dry. This means each ridge receives water from only one side, and the side receiving irrigation water could be changed with each irrigation if the field is set up to facilitate this change. Irrigating just one side of the ridge means there is significant potential to save irrigation water compared to CFI. There is however, also potential in some cases for a reduction in crop yield ***(Mashori 2013). Felipe et al. (2011)*** stated that alternate furrow irrigation (AFI) reduced applied water by 25% without a decrease in yields, compared with every furrow irrigation for Tomato plants and Agronomic water use efficiency was 30% higher in alternate furrow irrigation than every furrow irrigation. Alternate furrow irrigation is a way to use less water without a decrease in yield or fruit quality, and without investment in technology such as drip irrigation. ***Mulei (2015)*** stated that (AFI), is a practical water saving technique that can enable at least 42% to 46% water savings. In agreement with other studies in the past, this study supports the conclusion that AFI is a practical water saving system that if adopted can enable increase to horticulture production in arid areas because most of these ASAL areas face diminishing water resources**.** ***Yigezu and Narayanan (2016)*** showed that the use of different furrow length and flow rate has shown different outcomes. The use of short furrow length was the major contributor of water loss through surface runoff and reduced yield. Hence, in the utilization of fragmented farm size, the combination of 48m furrow length and 0.79l/s flow rate can be used for better crop yield, and irrigation efficiency. In addition, the users should give much emphasis in reducing furrow gradient in order to improve the distribution uniformity. In open-ended short furrow utilization, runoff losses were greater over deep percolation loss. ***Siyala et al. (2016)*** indicated that the total irrigation water applied with AFI treatment was roughly half (248 ± 2.9 mm) that applied to the CFI treatment (497 ± 1.7 mm). Despite the very significant reduction in irrigation water used with AFI there was a non-significant ($p > 0.05$) reduction (7.3%) in okra yield. As a result, we also obtained a significantly ($p < 0.001$) higher crop water productivity (CWP) of5.29 ± 0.1 kg m−3with AFI, which was nearly double the 2.78 ± 0.04 kg m−3obtained with CFI. While this reduction in yield and/or potential income may appear small, it could be critical to the welfare of individual farmers, who may as a result hesitate to make changes from CFI to AFI if they are worse off than farmers who do not adopt AFI. ***Bahrani and Pourreza (2016)*** found that the Irrigation techniques (AFI and FFI) reduced rapeseed yields by 20 and 25% compared to FI irrigation. The AFI and FFI irrigation strategies were equally effective in saving irrigation water. Alternate furrow irrigation practice for rapeseed provides water use efficiency benefit compared to full irrigation (CFI). The value of benefits from water saving should be balanced with the value of yield reductions and the cost of implementing alternative irrigation system compared to conventional systems. ***Assefa S et al. (2017)*** showed that the interaction effects of furrow lengths and flow rates were significantly ($p<0.05$) different in influencing application efficiency. Also it was significantly affected ($P<0.01$) by interaction of furrow length and flow rate with highest value of 89.32% for 200 m length and 6 lit/s. Storage efficiency was significantly affected ($P>0.01$) by the interaction with highest value of 100% for treatment combination of 200 m furrow length and 4 lit/s; lowest value of 99.06% for 100 m and 6 lit/s effect of furrow length and flow rate. ***Golzardi et al. (2017)*** found that the potential of AFI for development of water-saving strategies for maize production in semi-arid climates where, Implementation of AFI resulted in a significant saving in irrigation water. At I70, 31% less water was used with AFI than with EFI. Regardless of irrigation regime, IWUE under AFI was always greater than under EFI. In addition, plants were shorter with a longer root system under AFI. Yield reduction due to water stress was attributed to decline in both kernel number and kernel weight. Improvement of water productivity in irrigation system can be achieved by applying the required amount of crop water at the right time. This includes proper design of furrow length and irrigation period. It has been observed that farmers prefer to stick with traditional furrow irrigation system due to its simplicity, ease of operation and maintenance and low installation/construction cost from other systems such as pressurized drip irrigation (PDI). If the conventional furrow irrigation system (CFI) is transformed into alternate furrow irrigation (AFI) then it might be readily accepted by farmers. However, before introducing and advocating this system to local farmers for adoption, the system needs to be evaluated under soil and climatic conditions representative of the areas being targeted for its introduction.

The objectives of this study were to evaluate the effect of alternate furrow irrigation (AFI) water saving technique on growth and yield compared with conventional furrow (CFI) and surface drip irrigation (SDI) to maximizing of surface irrigation performance on growth and production of cowpea in clay soil of north Delta in Egypt.

MATERIALS AND SYSTEMS

2.1 Site Description

The field experiments were conducted at experimental farm of Faculty of Agriculture, Kafrelsheikh University, Kafrelsheikh Governorate, Egypt that located at 31^{o} 6N latitude, 30^{o} 50E longitude and altitude 6m, during the summer season 2016/2017. The experimental site was ploughed four times by using chisel plough (7 shares). Cowpea (Vigna unguiculata L. Walp Strain 2) was planted in manually on the 30 of June 2016 after Egyptian clover crop. The distance between rows was 60 cm and between plants was 25 cm included four rows of cowpea. The upper 45 cm of soil profile is considered to be the root zone which gives the most of moisture requirements of the cowpea plants. Cowpea was harvested after 90 days as a first stage, after 105 days as a second stage and after 120 days as a final stage from planting. The mean monthly maximum and minimum temperature was 36.10 °C and 12.1 °C respectively during the planting season. The soil type of the experimental site was clayey with field capacity, permanent wilting point, and bulk density of 40.61%, 21.81%, and 1.2 g/cm^3, respectively as summarized in **Table 1** and **Table 2**.

Composite soil samples were analyzed for texture, field capacity, permanent wilting point and bulk density using standard procedures. Soil moisture samples before irrigation were taken at 10 m interval along the furrows from each plot at three depths, 0-15 cm, 15-30 cm and 30-45 cm, using soil auger (0-45 cm before hilling up irrigation events and at three depths for after hilling up irrigation events) and were determined using gravimetric system. The source of irrigation water was available from nearby canal serving the irrigation scheme. Water to irrigate farms on the lower side of the canal is supplied using gravity flow through smaller channels. The field experiments were conducted in the periods June-Oct 2016.

Table 1: Some physical properties of the experiment soil

Sampling sector depth, cm	Particle size distribution, %			Texture class	Bulk density, kg/ m^3	F. C, %	W. P, %	Available Water, %
	Sand	Silt	Clay					
0 – 15	19.50	23.45	57.05	clay	1140	43.00	22.00	21.00
15 – 30	18.22	22.74	49.04	clay	1240	40.00	21.00	19.00
30 – 45	17.37	22.31	60.32	clay	1320	39.00	21.00	18.00
Mean	18.36	19.16	55.47	clay	1233	40.66	21.33	19.33

F.C = Field capacity. W.P = Wilting point.

Table 2: Some chemical properties of the experiment soil

Sector depth (cm)	Ec, S/m	ESP	PH (1:1)	Soluble cations, meq/ l (soil paste extract)				Soluble anions, meg/l (soil paste)					
				Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Co^{-}_{3}	Hco_3	Cl^{-}	So_4^{--}	O.M %	$CaCo_3$ %
0 - 15	3.85	5.42	8.78	8.09	13.47	14.09	0.54	0.0	7.90	15.33	11.45	0.97	1.58
15 - 30	3.40	6.01	8.76	6.32	10.66	15.54	0.30	0.0	10.24	10.95	11.73	0.87	1.58
30 - 45	3.78	8.58	8.84	5.99	10.36	20.68	0.33	0.0	12.74	16.82	7.80	0.93	1.60
Mean	3.67	6.67	8.97	6.80	11.38	16.77	0.34	0.0	10.29	14.36	10.32	0.92	1.58

2.2 Experimental Design and treatment setup

This study conducted on the growth and productivity of Cowpea under Conventional Furrow Irrigation (CFI), Alternate Furrow Irrigation (AFI) and Drip Irrigation (SDI) of water saving technology. The Experimental treatments were irrigation systems and furrow lengths. The irrigation systems were CFI, AFI and SDI while the furrow lengths were 20m, 30m and 40m. The CFI and AFI systems consisted of (pump unit (water electric pumps with 5 hp with maximum discharge 500 ℓ/min and was connected to the main line by flexible quick hoses)-Control unit (valves on/off-Screen filter 250 mesh-Pressure gauges 2 m head accuracy-Fertilization unit)-P.V.C pipes as main lines (63 mm, inner diameter and 55 m length)-P.V.C pipes as sub-main lines (63 mm, inner diameter and 12 m length)-T shape P.V.C pipes (25.4 mm, inner diameter and 4 m length)-T shape control valve FC700 used with 1/2" polyethylene tubing was located in the beginning of each furrow line to control the irrigation line).The SDI system consisted of (Electrical valve on/off with flow rate 0.7 to 150 ℓ/min with a pressure 1 bar to control pressure head and flow- P.V.C pipes as main lines (63 mm, inner diameter and 55 m length)- P.V.C pipes as sub-main lines (63 mm, inner diameter and 12 m length)- T shape P.V.C pipes (25.4 mm, inner diameter and 4 m length)-Lateral lines (16 mm, inner diameter and 20 m, 30 m, 40 m length), wire and bars were used to support laterals to avoid the occurrence of any deflection. Each lateral line was joining to the sub main line by a PLD-BV-16 16mm bar screw ball screw – on line emitters 4 ℓ/h (BLACK)). The experiment was divided into three main fields (plots) separated with buffer zones of 1.4 m. The first plot was (4 m wide x 20 m long), the second was (4 m wide x 30 m long) and the third was (4 m wide x 40 m long). The experimental plots were shown in **Figure 1** and **Table 3** show field layout for the experiment. The experimental field was arranged in a split plot design with three replications where irrigation systems used as a main plot factor and furrow length as sub plot factor. The main plot factor initially assigned randomly in to three sub-blocks. The three furrow length levels randomly assigned within each sub-blocks. The block and plot spacing was 2.0 m and 1.4 m respectively. The furrow spacing was equal to row spacing of the cowpea crop. The experimental field had a total number of 36 furrows. Volumetric system was applied to measure flow rate for furrow irrigation. The time required to fill a known volume container of (5 liters) was measured. The flow rate is determined by dividing the volume of the container by the time required to fill it by using stop watch.

Table 3: Experimental treatments

Irrigation systems	Irrigation Technique	Irrigation length, (P)		
		20 m	30 m	40 m
Furrow	Alternative (AFI) A	A_1P_{20}	A_2P_{30}	A_3P_{40}
	Conventional (CFI) C	C_1P_{20}	C_2P_{30}	C_3P_{40}
Surface drip	Conventional (SDI) B	B_1P_{20}	B_2P_{30}	B_3P_{40}

2.3 Climatic Data Collection

Climatic data were collected from Rice Research & Training Center, Sakha, Kaferelsheik, for the year 2016. Evapotranspiration was calculated using Cropwat version 5.7 computer program depending on the average of climatic data of **Table 4.**

Table 4: Daily maximum and minimum temperature, wind speed and average daily reference evapotranspiration (ETo) mm/day for the experimental site

Reference evapotranspiration ETo **according to Penman – Monteith**							
Country : EGYPT				Meteo Station : Sakha			
Altitude: 20 meter				Coordinates**:** 31.11 N.L 30.95 E.L			
Month	T mean, °c		RH, %	U2, Km/day	SH, h	SR, MJ/m³/day	**ETo,** mm/day
	T_{max}	T_{min}					
April	29.3	12.1	63.53	89.70	12.50	30.8	4.29
May	29.6	16.7	56.05	99.30	13.00	31.5	5.62
June	33.5	18.3	61.35	107.5	13.90	31.9	6.49
July	33.0	19.7	65.10	102.0	13.75	32.7	6.24
Aug	36.1	20.2	67.20	105	14.85	35.4	5.50
Sep	31.6	20.2	60.47	98	13.56	33.7	4.60
Oct	30.1	19.3	58.62	109	13.28	31.9	3.60

RH – Relative humidity %, U2 – Wind velocity Km/day, SH – Sunshine hr, SR – Solar Radiation MJ/m³/day

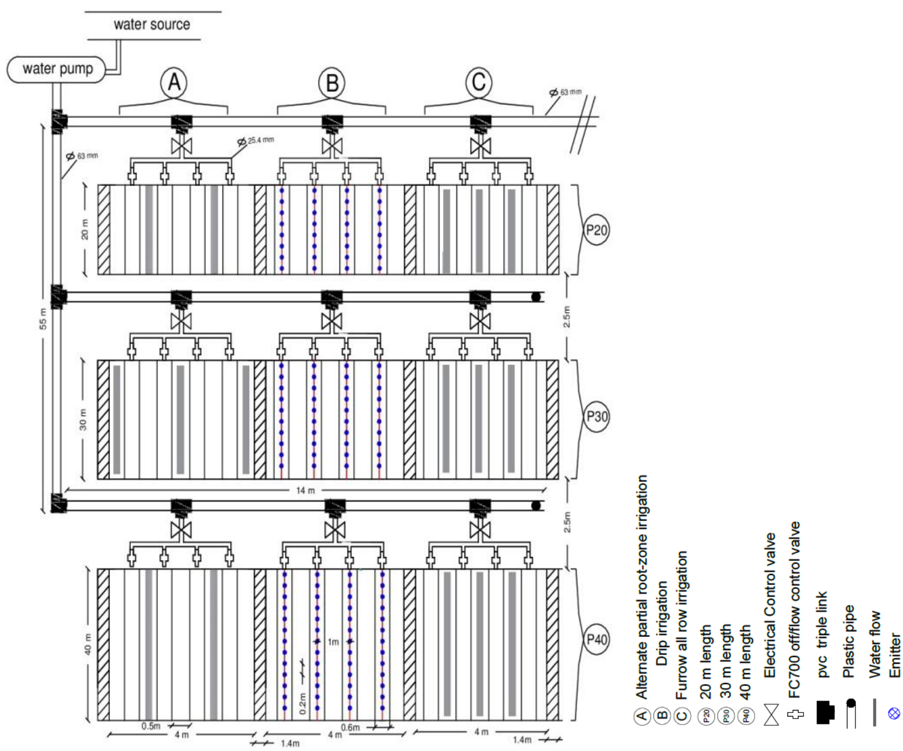

Figure 1: Experimental layout and Design

2.4 Gross irrigation requirements

It was calculated by using the following equation according to ***FAO (1980).***

$$IR_g = \frac{IR_n}{E_a} \text{......................................}(1)$$

Where:

IRg: gross irrigation requirements, mm/day; Ea: irrigation system efficiency (assumed 80 % by ***Habib 1992***) and IR_n: net irrigation requirements (mm/day). It was calculated by using the following equation.

$$IR_n = ET_{crop} + Lr \text{......................}(2)$$

Where:

Lr: leaching requirements mm/day and ET_{crop}: crop water requirements (mm/day).

Inflow time (T)

In order to irrigate each furrow, the time of application was determined by using formula of ***Hart et al, (1980):***

$$T = \frac{F_g \times W \times L}{60 \times Q_0} \times 100 \text{.........................}(3)$$

Where

T: Inflow time of cutoff, min; L: Furrow length, m; W = Furrow spacing, m; Qo: Flow rate, l/s and Fg: Gross depth of application, mm

Discharge

The head required to divert each flow rate was determined using the following formula ***Michael et al (1978):***

$$Q = Cd \times A \times \sqrt{(2gH)} \times 10^{-3} \text{...............}(4)$$

Where

Q: Flow rates, l/s; A: Cross sectional area of pipe, cm^2; g: Gravitational acceleration, 981 cm/s^2; H: Effective head, cm and Cd: discharge coefficient 0.584.

2.5 Soil Moisture content (SMC)

It was calculated on dry base as follows according to ***Peters, 1965 and Michael, 1978.***

$$SMC = \frac{(W - w_d)}{W_d} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where

SMC: Soil moisture content, %; W: Weight of the wet soil sample, g and Wd: weight of the dried soil sample, g.

2.6 Irrigation Performance Indicators

Available water (AW)

The readily available water was determined by the following equation according to ***Michael, 1978.***

$$AW = \frac{(FC - PWP) \times \rho_s \times E_d}{100} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where

AW: Available water ،cm; Fc: Soil moisture content at the field capacity %; PWP: Soil moisture content at the wilting point %; Ps: Soil specific density and Ed: Depth of the roots effective (cm).

Depth of irrigation water required

The Depth irrigation water requirement was determined by the following equation.

$$Dw = F\,(FC - WP) \times Ps \times Ds \times P \ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Where:

Dw: Depth of irrigation water to be add it (cm); F: Allowable percentage of depletion from available water (30-70%); FC: Field capacity, %; WP: wilting point, %; Ds: Depth of the soil effective (cm) and P: Wetted area ratio from the total field area (33 %).

Water Application efficiency (WAE)

It was defined as the percentage of the stored water in the root zone to the total amount of water applied to the soil. It was determined according to ***Michael, 1978 and James, 1988*** by using the following equation:

$$WAE = \frac{W_s}{W_f} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Where:

WAE: Water application efficiency, %; Ws: Amount of water stored in the root zone, m^3 and Wf: Amount of water applied to the field, m^3.

Water distribution efficiency (WDE)

Water distribution efficiency describes how evenly an irrigation system distributes water over the field. It was calculated according to ***James, 1988*** as follows:

$$WDE = \left[1 - \frac{y}{d}\right] \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

Where:

WDE: Water distribution efficiency, %; y: Average numerical deviation from d, cm. and d: Average of soil water depth stored along the furrow during the irrigation, cm.

Leaf area index (L.A.I)

It was measured by the leaf area meter and the following equation was used to calculate the leaf area index according to ***El-Zeiny et al. (1989):***

$$L.A.I = \frac{\text{Leaf area per plant, cm2}}{\text{Spacing area per plant, cm2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

2.7 Yield and Water Use Efficiency (WUE)

Water use efficiency has been used to describe the relationship between the cowpea production and the total amount of water used of CFI, AFI and DI. It was determined according to ***Tennakoon et al., 2003*** by using the following equation:

$$WUE = \frac{Y}{W_a} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

Where:

WUE: Water use efficiency, kg/m^3; Y: Total yield, kg/fed and Wa: Total applied water, m^3/fed.

2.8 Statistical analyses:

The obtained data were subjected to analysis of variance according to the procedures out lined by Snedecor and Cochran (1980). The mean value of treatments was compared according to Duncan's multiple range test, Duncan (DMRT) (1955). The data was analyzed using CoStat software for windows (version 6.3).

RESULTS AND DISCUSSION

Irrigation Depth (ID)

The mean Water Irrigation Depth (ID) was 16.17, 12.58 and 10.68 cm for CFI, AFI and DI irrigation system, respectively. The effect of irrigation system on the ID was significant ($p<0.01$). The mean ID was reduced when the furrow length increased from 20 m to 40 m. Mean ID with respect to furrow length were 14.09, 13.24, and 12.11 cm for length of 20, 30 and 40 m, respectively. The highest ID was 17.65 cm through the use of furrow irrigation system at the treatment C_1P_{20} furrows length, while the lowest value was 10.12 cm for the treatment B_3P_{40} furrows length with drip irrigation system. Mean values due to the effect of length P20 and P40 on ID were highly significant ($p<0.01$) as summarized in **Table 5**. Interaction effect between irrigation system and furrow length on ID was significant ($p<0.05$). The highest value was obtained for treatment interaction of smallest furrow length P20 for CFI with mean value of 17.65 cm. The least was recorded for treatment interactions of longer furrow length P40 and SDI with mean value of 10.12 cm. The results of the study indicated that, SDI and AFI systems recorded less water irrigation depth than CFI system by about 51.40 and 28.53 %, respectively. And also the water irrigation depth decreased by increasing the furrow lengths line from 20 m to 40 m respectively for all systems. It is an evident that by using long furrow length combined with SDI or AFI system, the ID will decrease for all treatments.

Water Application Efficiency (WAE)

Water application efficiency, WAE, obtained was in the order of 52.46% to 75.25% and it was significantly affected ($p<0.01$) by irrigation system and furrow length. The average application efficiency was increased from 63.48 to 66.77 % when the furrow length increased from 20 m to 40 m and also the average application efficiency was increased from 54.60

to 66.32 and 74.54 % for CFI, AFI and SDI irrigation system, respectively. The maximum application efficiency attained by ***Eldeiry et al (2005)*** was 75.25% through the use of SDI system at the treatment B_3P_{40}, while the lowest value was 52.46% for the treatment C_1P_{20} with CFI system. WAE increased by about of 40.64 and 22.39% in case of SDI and AFI systems at the treatments P20 furrow length compared with furrow irrigation, while they were 32.62 and 20.40 % at the treatments P40 furrow length, respectively. Mean values due to the effect of length P20 and P40 were highly significant ($P<0.01$) only as summarized in **Table 5 and Fig 2**. Interaction effect between irrigation system and furrow length on WAE was also highly significant ($p<0.01$). The highest value was obtained for treatment interaction of longer furrow length P40 for DI with mean value of 75.25%. The least was recorded for treatment interactions of smallest furrow length P20 and CFI with mean value of 52.46%. The results of the study indicated that, the SDI and AFI systems recorded higher application efficiency than CFI by about 36.52 and 21.46%, respectively. And also the water application efficiency increased by increasing the furrow lengths line from 20 m to 40 m respectively from all systems. It is an evident that by using long furrow length combined with SDI or AFI system, WAE can be enhanced. This is in agreement with the result of ***Eldeiry et al 2005 and Khalifa, (2009).***

Water Distribution Efficiency (WDE)

WDE was highly significant ($p<0.01$) influenced by irrigation system and furrow length. The mean WDE was reduced when the furrow length increased from 20 m to 40 m. Mean WDE with respect to furrow length were 60.26, 58.29, and 53.33 %, for 20, 30 and 40 m furrow length, respectively. Usually the variation of furrow dimensions and contact times in the use of short furrows are very low as compared to longer furrows. As a result, more uniformity occurred in short furrows and the relationship between WDE and furrow length was reverse. The WDE was significantly ($p<0.01$) influenced by the irrigation system. Unlike to furrow length, the rise in mean irrigation system from 39.97 to 61.23 and 70.67 % for CFI, AFI and SDI irrigation system, respectively improved the WDE. The increasing trend of WDE with flow rate which achieved by using different irrigation systems was in agreement with ***[Sewnet***

EshetuAnmut, 2007] and ***[Melaku, M., 2005]***. Mean values due to the effect of length P20 and P30 on WDE were not significant (p>0.01), whereas that of length P40 and P20 were highly significant (P<0.01) as summarized in **Table 5** and **Figure 2**. Interaction effect between irrigation system and furrow length on WDE was also highly significant (p<0.01). B_1P_{20} has resulted highest mean WDE (73.37%) due to the fast advancing rate and low contact time variation of short furrow length. Whereas, furrow irrigation system combined with the longest furrow length (C_3P_{40}) could result the lowest WDE, 36.45%.

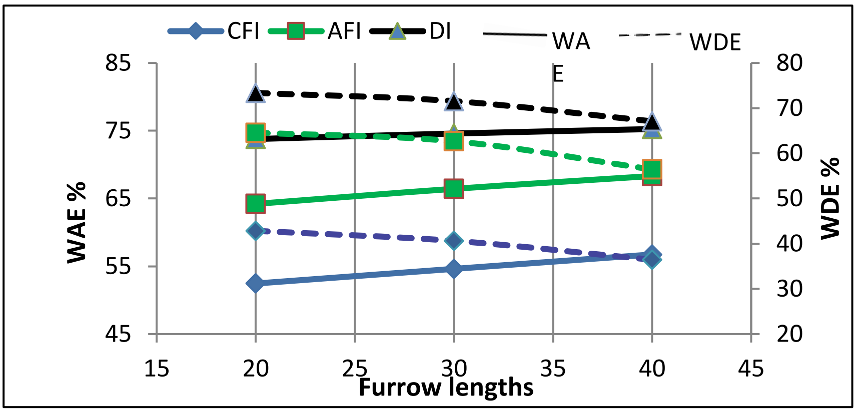

Figure 2: Relationships between Furrow lengths, WAE and WDE

The results demonstrated that in case of increasing furrow length line, the water distribution efficiency will decrease for all treatments. Therefore, the P20 treatment gave the best values of water distribution efficiency compared with the other treatments. And also the WDE developed by using SDI and AFI systems under all treatments compared with CFI system by about 76.80 and 53.18 %, respectively. This attributes to ability to deliver the decided amount of water to the plants at the proper time. Values of water distribution efficiency were agreement with ***Khalifa, (2009).***

Applied Water amounts under investigated technique (AW)

The maximum value of the total applied water (AW) was 1891.01 m^3/fed with CFI system, while 1086.01 and 1057.56 m^3/fed was applied to the AFI and SDI systems. This shows that the subplots under AFI used roughly half the amount of water compared to the subplots under CFI. It is concluded that, the SDI give the lowest values of amount of the water applied during the growth season comparing with all treatments. The WA was significantly affected ($p<0.01$) by irrigation systems and irrigation technique. The average of water applied was increased from 33.11 to 38.34 and 43.88 m^3 when the furrow length increased from 20 m to 30 m and 40 m and also the average AW was decreased from 54.06 to 31.04 and 30.23 m^3 for CFI, AFI and SDI irrigation system, respectively as summarized in **Table 5** and **Figure 3**.

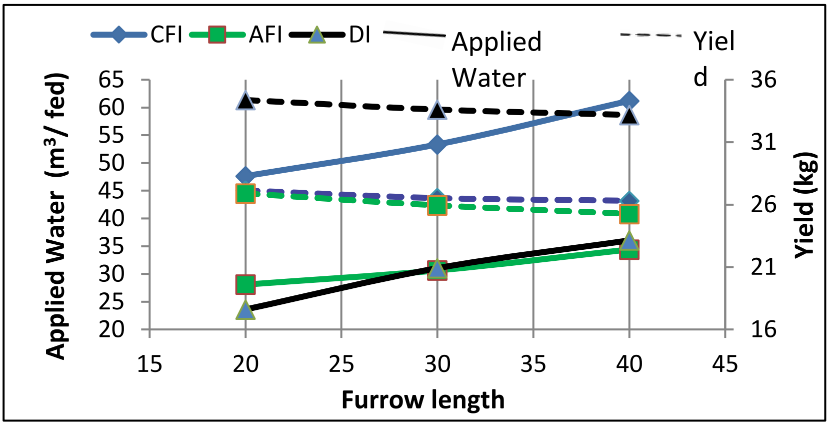

Figure 3: Relationships between Furrow lengths, Applied Water and Yield

Interaction effect between irrigation systems and furrow lengths on AW was not significant. The maximum AW was 61.20 m^3 through the use of CFI system at the treatment C_3P_{40}, while the lowest value was 23.61 m^3 for the treatment B_1P_{20} with SDI system. The average WA was increased by about of 15.79 and 32.52% by using length P30 and P40 compared length P20 but it was decreased by about of 42.58 and 44.08 % by using AFI and SDI systems, respectively. Mean values due to the effect of AFI and SDI system on WA were not significant ($p>0.01$), whereas that of CFI and AFI system were highly significant ($P<0.01$). Our results align with the 40 to 46% water savings obtained using AFI and DI compared with CFI which were agree with ***Slatni et al. (2011).***

Generally, when compared to CFI, the saved water obtained with AFI technique was about 42.58 % and the saved water obtained with DI was about 44.08 %. When compared to AFI, the saved water obtained with DI was about 2.6 %. Fig 3.3 showed the water saving between treatments according to length 40 m. The statistical analysis of the cowpea water saved obtained in our experiment showed that the difference in water saved obtained with AFI and SDI was non-significant ($p>0.01$) as summarized in **Figure 4**.

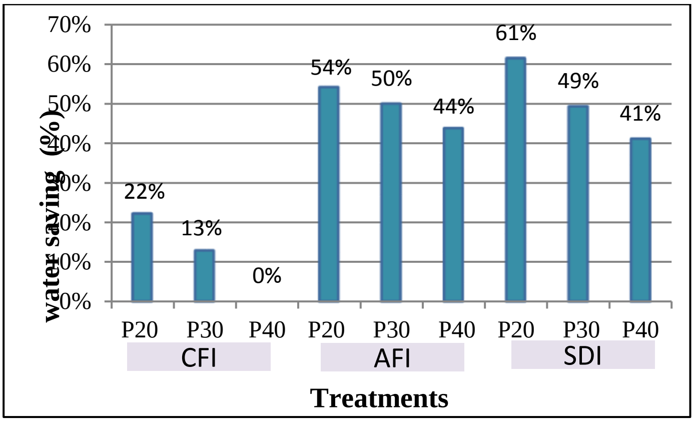

Figure 4: Water saving between treatments according to length 40 m

Leaf area index

Leaf area index obtained was in the order of 2.99 to 2.37 and it was significantly affected ($p<0.05$) by irrigation system only. The average leaf area index was decreased from 3.94 to 2.48 and 1.59 for CFI, AFI and SDI, respectively. Mean values due to the effect of irrigation system on plant leaf area was highly significant ($P<0.01$) as summarized in **Table 5.** Interaction effect between irrigation system and furrow length on Leaf area index was also highly significant ($p<0.05$). The highest value was obtained for treatment interaction of smallest furrow length P20 and CFI with mean value of 2.99 and the least Leaf area index was recorded for treatment interactions of longer furrow length P40 and SDI with mean value of 2.37. The results of the study indicated that, the CFI system recorded higher leaf area index than SDI and AFI systems.

Cowpea Grain Yield

The effect of irrigation system on cowpea grain yield was significant ($p<0.01$). The average cowpea yield gained was 1179.52 kg/fed. The maximum and minimum yield was obtained from the treatment B_3P_{20} (34.37 kg) and A_3P_{40} (25.26 kg) respectively. When the maximum yield obtained, greater performance in application efficiency and water use efficiency was recorded. The mean cowpea yield was 932.33, 910.52 and 1179.52 kg/fed for CFI, AFI and SDI, respectively. The average cowpea yield was increased from 26.65 to 33.72 kg for CFI and SDI by about of 26.52 %. The effect of furrow length and its interaction with irrigation system could not show significant effect (P<0.05) on the cowpea yield. It was decreased from 29.46 to 28.25 kg for length P20 and P40 by about of 4 %, respectively. Mean values due to the effect of irrigation system on cowpea yield between CFI and AFI systems were not significant (p>0.01), whereas that between SDI and CFI or AFI were highly significant (P<0.01) as summarized in **Table 5, Figures 3 and 5.**

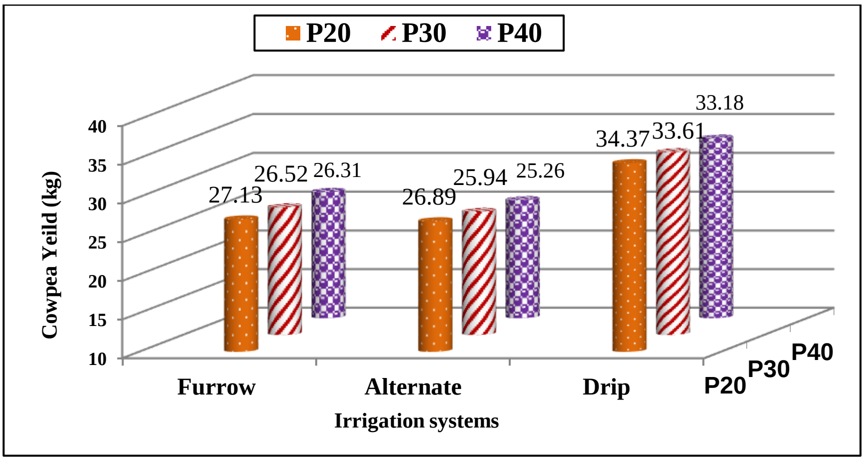

Figure 5: Relationships between irrigation systems and furrow length on cowpea yield

However, the rise of water applied for CFI could not increases the yield because most of the water has turned in to surface runoff. The effect of furrow length and its interaction with irrigation system between CFI and AFI could not show significant effect (P<0.01) on the cowpea yield. Better cowpea yield was obtained at SDI system. This happens due to the fact that better irrigation uniformity was attained in higher water use and application efficiency. The results of the study indicated that, SDI recorded higher cowpea yield than AFI or CFI system by about 26 % and also the result indicated that no significant difference of cowpea yield between CFI and AFI systems. The cowpea yield decreased by increasing the furrow lengths line from 20 to 30 and 40 m but not significant effect. The results agree with the result of ***Rafiee et al. (2010).***

Water Use Efficiency (WUE)

The mean water use efficiency (WUE) was 16.90 kg/m^3. The effect of irrigation system on the WUE was significant (p<0.01). The average WUE was decreased from 11.57 to 8.10 kg/m^3 when the furrow length increased from 20 m to 40 m. Mean values due to the effect of length P20 and P40 was highly significant (P<0.01) only. The average WUE was increased from 5.81 to 9.87 and 13.41 kg/m^3 for CFI, AFI and SDI systems. The highest WUE was 16.90 kg/m^3 which attained by B_1P_{20} due to the presence of more moisture in the root zone as compared to the other treatments for SDI, while the less WUE was 5.81 kg/m^3 was attained by c_3P_{40} due to the presence of less moisture in the root zone as compared to the other treatments for CFI. Mean values due to the effect of irrigation system on WUE was highly significant (P<0.01) as summarized in **Table 5 and Fig 6**. Similarly, the effect of furrow length was not significant on the WUE between P30 and P20 or P40 and also the interaction effect between irrigation system and furrow length on WUE was also highly significant (p<0.01).

The results of the study indicated that, DI recorded higher WUE than AFI by about 35.54% and AFI recorded higher WUE than CFI by about 74.73%. And also the WUE decreased by increasing the furrow lengths line from 20 to 40 m for all systems. It is an evident that by using long furrow length combined with DI or AFI system, the WUE will increase for all treatments. This is in agreement with the result of ***Ibrahim et al. 2010, Slatni et al. 2011, Acar et al. 2014 and Sahin et al. 2014.***

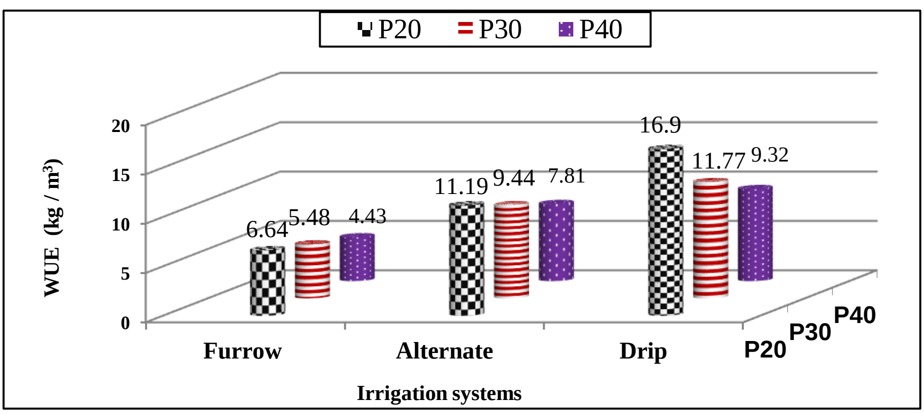

Figure 6: Relationships between irrigation systems and furrow length on cowpea yield

Table 5: Irrigation depth (cm), Applied water (m^3/fed), Water application efficiency %, Water distribution efficiency %, Leaf area index, Yield (kg/fed) and Water use efficiency (kg/m^3) accumulation of cowpea as affected by the interaction between Irrigation system and length

Irrigation systems	Irrigation Technique	Length (L)	Irrigation Water Indices				Yield Indices		WUE
			ID	AW	WAE	WDE	LAI	Yield	
Furrow Irrigation System	Conventional CFI	20	17.65 a	47.64	52.46 g	42.84 e	2.99 a	27.13 dc	6.64 e
		30	16.52 b	53.34	54.62 f	40.63 e	2.94 a	26.52 d	5.48 e
		40	14.35 c	61.20	56.74 e	36.45 f	2.89 ab	26.31 d	4.43 e
	Alternative AFI	20	13.42 c	28.09	64.21 d	64.57 c	2.52 abc	26.89 d	11.19 c
		30	12.46 c	30.64	66.43 c	62.68 c	2.49 abc	25.94 de	9.44 d
		40	11.87 d	34.41	68.32 b	56.45 d	2.42 abc	25.26 de	7.81 d
Surface Drip	Conventional SDI	20	11.20 de	23.61	73.78 a	73.37 a	2.42 abc	34.37 a	16.90 a
		30	10.74 ef	31.04	74.59 a	71.56 a	2.39 bc	33.61 ba	11.77 b
		40	10.12 f	36.05	75.25 a	67.09 b	2.37 c	33.18 b	9.32 b

Means in each column designated by the same letter are not significantly different at 5% level using Duncan's Multiple Range Test

CONCLUSION

This study showed that the use of different irrigation systems and techniques have shown different outcomes. Irrigation system has a significant effect of on the yield, crop water use efficiency, irrigation performance indicators and vegetative growth. The DI and AFI systems have improved certainly the yield, WAE, WDE, WS and WUE. The use of CFI was seen with highest WA and ID, lowest adequacy of water and low yield production. In the situation of furrow length rise from 20 m to 40 m the yield, WUE, WDE and ID were decreased, while the WAE and WA were increased. Hence, in the utilization of fragmented farm size, the combination of 40m furrow length with using DI or AFI systems can be used for better crop yield, and irrigation efficiency because furrow length could not show significant effect ($P<0.05$) on the cowpea yield. In addition, the users should give much emphasis in reducing furrow gradient in order to improve the distribution uniformity.

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الملخص العربي

تعظيم أداء الري السطحي على نمو وإنتاج محصول اللوبيا في الأراضي الطينية

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يعتبر محصول اللوبيا من المحاصيل الحيوية والرئيسية بين البقوليات النباتية الموجودة في مصر حيث تستهلك كميات كبيرة من مياة الري وان النظام الشائع فى ري هذا المحصول هو الري السطحي بالخطوط. وقد واجهت الاراضي الزراعية في معظم المناطق المصرية قيودا متزايدة على إمدادات المياه في الاونة الاخيرة لذلك يجب وضع تقنيات جديدة للري لاستخدام الموارد المائية المحدودة بكفاءة أفضل واتباع اساليب الري الحديثة لزيادة كفاءة استخدام مياة الري . ولهذا تم تطوير نظام الري السطحي بالخطوط عن طريق استخدام تقنية الري التبادلي حيث تروى فيه الخطوط بالتبادل وليس بالتتابع و هو شكل من أشكال التجفيف الجزئي لمنطقة الجذر. ويستخدم كوسيلة لتوفير مياة الري دون انخفاض كبير في إنتاجية المحصول.

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ولقد أجريت التجارب الحقلية في المزرعة التجريبية، كلية الزراعة جامعة كفر الشيخ خلال موسم النمو٢٠١٦-٢٠١٧م وذلك لتقييم تأثير تقنية الري التبادلي مقارنة بالري التقليدي والري بالتنقيط تحت ظروف التسوية التقليدية من ناحية كفاءات الري واستخدام المياه وذلك لإنتاج محصول اللوبيا في الأراضي الطينية ذات الخطوط القصيرة.

وقد اشتملت الدراسة على المعاملات التالية :

١- نظام الري :

أ- نظام الري السطحي بالخطوط (التقليدي-التبادلي)

ب- نظام الري بالتنقيط السطحي

٢- أطوال الخطوط :

تم استخدام ثلاث اطوال مختلفة للخطوط وكانت أطوال الخطوط ٢٠ – ٣٠ – ٤٠ متر.

وتم استخدام تصميم القطع المتعامدة كتصميم إحصائي للتجربة مع ثلاث مكررات. وكانت اهم النتائج المتحصل عليها هي كالتالي :

١) اوضحت ان كفاءة إضافة مياة الري بنظام الري بالتنقيط و الري التبادلي كانت أعلى من الري السطحي بالخطوط بنحو ٣٦,٥٢ و ٢١,٤٦ ٪ عند طول الخط ٤٠م وإزدادت بنسبة ٥,١٨ ٪ بزيادة خطوط الري ذات الأطوال من ٢٠ م إلى ٤٠ م.

٢) كانت ان اقصي كفاءة لتوزيع مياه الري ٧٦,٨٠ ٪ لنظام الري بالتنقيط ثم الري التبادلي ٥٣,١٨ ٪. وفي حالة زيادة اطول خطوط الري فإن كفاءة توزيع المياه تنخفض لجميع الأطوال لذلك أعطت خطوط الري ذات الأطوال ٢٠ م أفضل القيم مقارنة مع الاطوال الأخرى.

٣) متوسط كميات مياة الري المضافة انخفض بحوالي ٤٢,٨٥ و ٤٤,٠٨ ٪ على التوالي فى حالة استخدام الري التبادلي والري بالتنقيط بالمقارنة مع الري السطحي بالخطوط التقليدي وازدادت بحوالي ١٥,٧٩ و ٣٢,٥٢ ٪ باستخدام خطوط الري ذات الأطوال ٣٠ و ٤٠ م مقارنة باطوال ٢٠م.

٤) ازدادت انتاجية محصول اللوبيا الجافة عند استخدام نظام الري بالتنقيط بالمقارنة مع الري التبادلي او التقليدي بنحو ٢٩,٥٤ و ٢٦,٥٢ ٪ على التوالي وايضا انخفضت الانتاجية بزيادة خطوط الري ولكن لم تظهر اى فروق معنوية.

٥) اوضحت النتائج ان الري بالتنقيط اعطى كفاءة استخدام لمياه الري أعلي من تقنية الري التبادلي بحوالي ٣٥,٥٤ ٪ ،وتقنية الري التبادلي اعطي كفاة استخدام لمياة الري أعلي من الري التقليدي بحوالي ٧٤,٧٣ ٪ وانخفض بزيادة خطوط الري ذات الأطوال من ٢٠ م إلى ٤٠ م على التوالي فى جميع أنظمة الري المستخدمة.

ومن النتائج السابقة نجد ان الري بالتنقيط هوافضل الاختيارات وفى حالة تعذر تطبيقه يكون البديل هو استخدام تقنية الري بالخطوط التبادلية.