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Improvement of water use efficiency of Potato production

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ABSTRACT

Two field experiments were carried out at Mallawy Water Requirements Research station – El Minia , Governorate ; Egypt Water Management Research Institute – National Water Research Center during seasons 2012 and 2013 seasons. The present research was carried out to study the effect of water stress and planting method on water use efficiency, yield, saving of water and total irrigation efficiency for Potato crop (*Solanum tuberosum* L.). A split plot design with four replications was conducted. The main plots were assigned to four water stress treatments (100 % , 90 % , 80 % & 70 %) beside traditional of irrigation for potato in studied area (the farmers practices to compare with water applied and actual water consumptive use only) and the sub plot to two planting methods (furrow and beds). The treatments of irrigation were distributed at random in the main splits. While planting methods treatments were distributed at random in the sub –plots.

Results indicated that the planting Potato crop by irrigated until 80 % of F.C in beds (A_3 b_2) leads to an increase in productivity with rate equals 38.52 % , more water saving about by 29.72 % per year , decrease both the costs of irrigation and the irrigation time by 17.65 , 29.40, respectively and rising the total irrigation's efficiency by 71.00 % . It also saving water by about 179.216320 million m^3 / area (Average area cultivated by Potato in Egypt) compared with the traditional irrigation. This amount of saving water enough to cultivate area about (general) 208245 fed in old land or cultivates different areas of horticulture and field crops under El-Minia conditions. The results indicated also from the economic view point also this treatment recorded the highest values of field and crop water use efficiencies (7.02 and 11.45 kg/m^3, respectively). The highest values of total income, production , financial benefits (L.E/area) , net return of each and water of irrigation (L.E/m3) and economic efficiency were gained with it. Therefore, the economics of irrigation water becomes very important for planting irrigation management project where the over irrigation practices by farmers usually lead to low irrigation efficiency, water logging and high losses of water. It could be recommended to application irrigated potato crop until 80 % of field capacity and planting in beds instead of planting in furrow to produce high yield with less amount of water applied under El-Minia province conditions.

Key words: Water use efficiency, Potato production, El-Minia.

INTRODUCTION

Agricultural sector plays an important role in the economic development in Egypt. It is considered one of the national economy basis and the main income source for more than half of Egypt's population. Agriculture is responsible for satisfying the consumers' needs for clothing and food. In addition, it provides the industry sector with raw materials needed for various industries. The extension of this role requires achieving the economic development which is derived from two main sources: horizontal and vertical agricultural expansion. Horizontal agricultural expansion depends on the availability of the production resources. In arid regions, water resources are considered the scarcest element among other economic

production resources. Consequently, it is not only one of the man determinants but also the strategic one which determines the horizontal expansion through reclamation of new lands.

The optimal use of water is the corner stone of the agricultural development sector because the present water sources available in Egypt are not enough for the future horizontal agricultural expansion, in the scope of the present techniques and irrigation practices . Comprising the 21th century challenges arises under conflicts on water shares of Egypt , and the attempt to continue the policy of agricultural horizontal expansion , it gets worst . This matter shows the necessity of achieving the maximum efficiency of water sources in Egypt through some parameters which can be used in achieving the best use of the available water sources in Egypt .

Potato (*Solanum tuberosum* L.) was selected in this study for economic importance in Egypt. It is the leading export vegetable crop and one of the important cash crops in Egypt. One of major production problems of potato is the proper irrigation, because potato plants are drought sensitive and respondent to irrigation. Minting health crop and quality requires not only accurate crop water requirement determination, but also, when and how much water should be applied to get the optimum water use efficiency. Many researchers recorded in this content. Nagy *et al*. (1970) found that the average water consumption increased from 5051 m3/ha without irrigation to 5797 m3/ha the highest irrigation rate, and that the water consumption was highest in June, July and Aug. during flowering and tuber formation. Kazantsev (1973) growing potatoes in soil with moisture contents maintained, at 50,60,70 and 80% of field capacity with applying 3,5,7 and 10 irrigations, respectively. He found that the third level gave the highest tuber yields of 31.5 t/ha, compared to 20.2 , 25.3 and 30.5 t/ha for the first , second and fourth level, respectively. Mikhailov (1973) he obtained the highest tuber yield with soil moisture content of 80% field capacity in the 0.7 m soil layer .He added that a pre- planting irrigation increased yield, whereas its effectiveness was negligible when irrigations were applied during growth. Petrunin *et al*. (1975) reported that irrigations at the depletion of soil moisture contents 80% of field capacity gave the highest tuber yield. Tomar *et al.* (1976) found that the highest tuber yield was obtained with optimum irrigation to be at 55% available soil moisture in the top of 30 cm soil layer.

Gunbatiti (1986) found that irrigation at 20% or 35%depltion of available water was recommended as economic. Mackerrron and Jefferies (1988) found the drought of potato decreasing the yield. the main reason for lower yield in the drought crops was hat fewer tuber reached the min size ((40 mm). Rashid and Ahmed (1988) found that the actual water consumption of potatoes grown at Pakistan calculated using gravimetric method was 383 , 365, 333 and 288 for 40 , 55, 77 and 85 % depletion fro available soil moisture, respectively. Pisa *et al*. (1989) studied the effect of irrigation treatment with ratios of 50, 100 and 150 maximum evapotranspiration of potato yield, that tuber yield increased with increasing the volume of the irrigation water applied and with increasing evapotranspiration. Guseinoy (1990) studied irrigation regime of potato under condition of Azerbaidzhan. He found that irrigation at 60, 70 or 80% of field capacity (2,3 or 4 irrigations) gave tubers yields of (15.7 - 17.21) , (16.29-17.77) and (17.48-19.19t/ha), respectively , in the first season compared with 4.67t/ha under rain fed condition. In the second (dry year) 3, 4 and 7 irrigations gave yields of (16.26-17.59) , (16.62-18.24) and (18.00-21.58t/ha) respectively and gave no yield under rained conditions. Ali (1993) using irrigation as farmer irrigation level 0.5 bar, 1.0 bar 1.5 bar and at 50% depletion treatments found that 0.5 bar irrigation was the best in maximizing potato tuber yield Bonsiak and *et al.* (1997) found that tubers yield were highest in the 75-80% field capacity. This was equivalent to a water requirement of 460-480mm/ season. El-Nagger (1997) showed that the seasonal amounts of consumed water during growth season were 306.4.271.92 and 192.07 mm as measured gravimetrically method and 285.74.264.87 an 199.8 mm as measured by using neutron probe, when the added amounts of irrigation water

were 400.300 and 200 mm / season, respectively under drips irrigation system. El-Marsafawy *et al.* (2000) studied the response of potato crop productivity to different irrigation intervals (number of irrigation) by using SUBTOR-potato through DSSAT 3-5 model . They reported that result of simulation showed that the application of 10 days apart irrigation for potato crop could be recommended at Giza (Middle Egypt region) to obtain the best results potato tuber yield and other yield component. Balanger *et al*. (2000) studied the response of two potato cultivars to supplemental irrigation. They found that irrigation increased total yield from 31.9 to38.4 t/ha and marketable yield from 26.6 to 30.7 t/ ha. Frish (2000) carried out field experiments during (1995-96) in Germany to investigate the effect of irrigation (no, rescued and optimal) and N fertilizer (0-200 kg /ha), on yield , potato starch content and starch yield. Hen ported that irrigation is required to obtain positive economic result. Potato cultivation without irrigation is impossible entail conditions. Water use efficiency increased from 5.129 to 7.379 kg m^{-3} for furrow irrigated treatments, and from 6.907 to 10.257 kg m_3 for drip-irrigated treatments. Tolga *et al*. (2006) found that Potato was grown under furrow and drip irrigation methods and three regimens: irrigation applied when 30, 50, or 70% of the available water was consumed. The seasonal potato evapotranspiration ranged on 501 to 683 mm in 2003, and 464 to 647 mm in 2005. The furrow and drip irrigation methods had no significant effect on tuber yield for both years. Irrigation regimens influenced tuber yield ($P < 0.05$) in 2005, and the highest tuber yield was registered for 30% irrigation regimen, reaching 35.13 t ha-1 in 2003, and 44.56 t ha-1 in 2005. Water use efficiency values increased from 4.70 to 6.63 kg m-3 for furrow-irrigated treatments, and from 5.19 to 9.47 kg m-3 for drip-irrigated treatments Ati *et al.* (2012) found that, actual potato evapotranspiration ranged from 357.3 to 511.4 mm in the growth season for all treatments. Furrow and drip irrigation methods had no significant effect on tuber yield under the experiential conditions. Water use efficiency increased from 5.129 to 7.379 kg m_3 for furrow irrigated treatments, and from 6.907 to 10.257 kg m_3 for drip-irrigated treatments. Yavuz *et al.* (2012) found that the highest seasonal evapotranspiration through potato growth seasons was obtained from sprinkler irrigated plots with 670.23 mm when considering two years averages. The seasonal evapotranspirations were calculated as 618.30 mm and 572.17 mm in furrow irrigation and drip irrigation methods, respectively. Seasonal evapotranspirations were found 17.1% and 8.1% higher in sprinkler irrigation and furrow irrigation regarding to drip irrigation, respectively. The highest water use efficiency (WUE) and irrigation water use efficiency (IWUE) were obtained with drip irrigation plots while the lowest were obtained from sprinkler irrigation plots for both years. Mean WUE and IWUE was calculated as 8.32 kg/m3 and 7.51 kg/m3 in drip irrigation and 6.09 kg/m3 and 5.76 kg/m3 in sprinkler irrigation, respectively.. The aim of this work is to study the effect of irrigation regime and planting method (furrow and beds) on water use efficiency, yield and saving water for potato cane crop .

MATERIALS AND METHODS

Two field experiment were carried out for two seasons summer and winter of 2011 and 2012 seasons, at Mallawy, Water Requirements Research Station –El Minia Governorate; Water Management Research Institute- National Water Research Center. The present research was carried out to study the irrigation regime and planting method (furrow and beds) on water use efficiency, yield and saving water for potato cane crop.

A split plot design with four replication was conducted the main plots were assigned to four water stress treatments (100% , 90% , 80% & 70%) beside tradition of irrigation for potato in studied area (the farmers practices to compare with water applied and actual water consumptive use only) and the sub plot two planting methods (furrow and beds). Irrigation treatments were distributed randomly by in the main plots while planting method were

distributed at randomly in the sub-plots potato crop cultivate namely (c.v Cara) was planted on 10th September & 12th in 2012 and 2013 season, respectively. The experiment consists of 32 plots and each plot was 24 m^2 included 10 rows when planting in furrow and five beds when planting in beds 4 m in length and about 60 cm apart. Potato tubers were planted at spacing of 30 cm with in furrow & beds and 10 cm in depth.

Soil analyses showed that the experimental soil was silt clay loam containing (0.11 and 0.10 % of total N) , (11.8 and 11.0 ppm available P) and (0.44 and 0.40 meq/100 g soil K) with pH 8.10 , in both studied seasons, respectively. Other agricultural practices required for growing potato crop except irrigation were carried out as usually practiced in the region. Some physical properties of the experiments soil were and shown in Table (1)

Table (1) . Some physical properties of the experiments soil

Depth (cm)	Average for two studied		
	Bulk density g/ cm^3	Field Capacity	
		cm^3	%
0-15	1.19	43.40	7.75
15-30	1.24	37.90	7.05
30-45	1.28	35.15	6.82
45-60	1.41	31.99	6.76
Average	1.28	37.20	

- Bulk density was determined by using the undistributed core samples according to Kluke (1986).
- Field capacity (f.c%) was determined by field method according to (Black 1965).

Soil- water relationships
Recorded data :
Water Measurements

In the two growing seasons , water was measured by using a rectangular sharp crested weir. The discharge was calculated using the following formula :

$$\mathbf{Q = CLH^{3/2}}$$ (Masoud, 1967)

Where:
Q : The discharge in cubic meters per second.
L : The length of the crest in meters.
H : The head in meters.
C : An empirical coefficient that must be determined from discharge measurements .

The quantity of water was measured in studied area (the farmer practices) by cut throat Flume size (20 x 90 cm) where applied water was added during each irrigation and at the end of each growth season the total quantity of water applied was estimated (m^3/ fed.)

Water consumptive use (CU) :

The quantities of consumptive use were calculated for the 60 cm soil depth which was assumed to be the depth of the root zone as reported by many investigators. Monthly and seasonal water consumptive use were calculated by the summation of water consumed for the different successive irrigation through the whole growth season (Serry *et al*. 1980).Calculation of CU was repeated for all irrigation until the harvesting date. Water consumptive use per fed. (4200m^2) can be obtained by the following equation which described by Israelsen and Hansen (1962):

$$\mathbf{CU} = [(\theta 2 - \theta 1)/100] \times b.d \times (depth/100) \times area\ (4200 m^2)$$

Where :
CU= Amount of water consumptive use .
θ_2 = Soil moisture content % by weigh after irrigation .
θ_1= Soil moisture content % by weigh before the next irrigation
b.d = Bulk density (g/ cm^3)

Crop water use efficiency (C.W.U.E)

The crop water use efficiency is the weight of marketable crop produced per unit volume of water consumed by plants or the evapotranspition quantity. It was computed for the different treatments by dividing the yield(kg / fed) on units of evapotranspiration expressed as cubic meters of water per fed. (Abd El- Rasool *et al.*, 1971) It was calculated by the following formula.

C.W.U.E (m^3 / fed.) = Yield (kg / fed.) / Water consumptive use (m^3 / fed.)

Field water use efficiency (F.W.U.E.)

Field water use efficiency is the weight of marketable crop produced per the volume unit of applied irrigation which was expressed as cubic meters of water (Michael, 1978).
It was calculated by the following equation :

F.W.U.E. (kg/ m^3) = : [Yield (Kg/Fed.)]/ [Water applied (m^3/Fed.)]

Application efficiency (E_a) :

The values of application efficiency (E_a) in percent for each treatment were obtained by the equation of Downy (1970) as follow: **E_a = (Ws/Wd) x 100**
Where :
Ea = Water application efficiency (%)
Ws = Water stored in the root zone ($m^{3/}$ fed.)
Wd= Water applied to the field plot ($m^{3/}$ fed.)

Water distribution efficiency (Ed) : was calculated according to Jame (1998) as follow :
E_d = (1- y/d) x 100
where :
E_d = Water distribution efficiency (%)
d-Average of soil water depth stored in long the furrow during the irrigation (cm).
y = Average numerical deviation from d (cm).

Storage efficiency (E_s) :

Values of storage efficiency (E_s) in percent for each treatment were obtained as given by Sharl (1991) as follow: **E_s = (Ws/Wm) x 100**

Where :
E_s = water storage efficiency (%) .
W_s = water storage in the root zone (m^3/ fed.)
W_m= the amount of irrigation water that must be added before irrigation (m^3/fed.)

Economic efficiency :

The economic efficiency refers to the combination of inputs that maximize individual or social objectives. Economic efficiency is defined in terms of two condition : necessity and sufficiency. Necessary conditions are met in the production process when they are is

producing the same amount with fewer inputs or producing more with the same amount of inputs .But , the sufficient condition encompasses individual or social goals and values (John and Frenk 1987) It was calculated by the formula :

Economic efficiency = Net profit (L.E/ fed)/ Total costs (L.E /fed)

The financial benefits (LE/area) :

Data collection (from view point of economic) calculate economic befits financially (L.E / area) as result from saving of water + saving of yield + saving of quantity water + saving irrigation cists.

Statistical analysis :

The proper statistical analysis of all data was carried out according to Gomez and Gomez (1984). Homogeneity of variance was examined before combined analysis the differences between means of the different treatments were compared using the least significant difference (LSD) at 5% level.

RESULTS AND DISCUSSION

Total yield (ton/ fed) and quality :

Total yields as influenced by the different irrigation regimes and plating methods were presented in Table (2) . The highest yield of potato was obtained by irrigation until 80 % of filed capacity (13.507 ton/ fed) in the two studies seasons. On the contrary the lowest of total yields of potato were obtained when irrigated potato until 70 % of field capacity (7.750 ton / fed .) This results are similar to those Mikhailov (1973), Bonsiak and *et al.* (1989) and Ghosh *et al.* (2000)

Reading the plating methods effects on the yield , data in Table (2) show that the highest mean values were obtained when plating potato in beds (11.802 ton / fed) while the lowest values were obtained when plating potato in furrow (10.790 ton / fed) results are agreements with Melha (2002) and Abdel Rheem (2010). Concerning the interaction between the two studies factors data in the Table (2) show that the highest values obtained from treatments (A_3b_2) which irrigation until 80 % of field capacity and planting in beds (14.268 ton / fed). These results reflex how much of irrigation water can be save to reduce the highest yield with least possible amount of water applied.

Table (2): Effect of irrigation regions and plating methods on productivity of potato crop in both studied seasons.

Irrigation regime(A)	Total yield (ton/fed.)		Mean
	Planting method (B)		
	b1	b2	
A1	10.500	11.120	10.810
A2	12.445	13.820	13.133
A3	12.746	14.268	13.507
A4	7.500	8.00	7.750
Mean (B)	10.798	11.802	-
LSD 5%	A= 0.06	B =0.18	AB0.26
LSD 1 %	0.14	0.26	0.36

A1= irrigation until 100 % of field capacity
A2= irrigation until 90 % of field capacity
A3= irrigation until 80 % of field capacity
A4= irrigation until 70 % of field capacity

b1 = plating in furrow
b2 = plating in beds

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Seasonal irrigation water applied :

The amount of applied water delivered (m3/fed) to different treatments are shown in Table (3). It is cleared from the data which obtained that water applied for potato crop were 2709.01, 2527.11, 2350.07 and 2170.47 for A_1 , A_2, A_3 and A_4 respectively under irrigation regime in furrow , while were 2356.16, 2197.96, 2033.72 and 1856.47 for A_1 , A_2, A_3 and A_4 respectively under irrigation regime in beds, respectively in the both studied seasons .

Results indicated also that ,from view point water when we use the irrigation regime in that beds we can save irrigation water by about 328.09 m3/fed (13.45 %) under El-Minia conditions, compared with the common conventional methods in furrow .It could be concluded that the use of traditional irrigation regime (irrigation regime in furrow) by many farmers leads to use irrigation water with high rates than the recommended rates , that leads to negative effect on the environment soil , fertilizer and ground water over the long term . So the irrigation regimen in beds is responsible for obtaining a high productivity of potato with least possible amount of water applied. This result is in line with those reported by Meleha (2002) .

Table (3) : Average of the quantity of applied water applied (m^3/ fed) and save water (m^3/fed & %) of potato for different treatments in the two studied seasons .

Irrigation regime	Planting methods					
	b1			b2		
	Water applied (m3/fed)	Saved water		Water applied (m3/fed)	Saved water	
		m3/fed	%		m3/fed	%
A1	2709.01	184.57	6.36	2356.16	537.42	18.57
A2	2527.11	366.47	12.66	2197.96	695.62	24.04
A3	2350.07	543.51	18.78	2033.72	859.86	29.72
A4	2170.47	723.11	24.99	1856.47	1037.11	35.84
Average	2439.17			2111.08		

Average water applied (m3/fed) for conventional irrigation (by farmer practices) was 2893.58 in the two studies seasons (Source: Actual field measurements).

A_1 = irrigation until 100 % of field capacity
A2 = irrigation until 90% of field capacity.
A_3 = irrigation until 80% of field capacity.
A_4 = irrigation until 70% of field capacity.

b1 = plating in furrow
b2 = plating in beds

Water saving (m^3/ area) :

Data in Table (4) show the average quantity of water saving (m^3/ fed.) for the best treatment A_3b_2 (irrigated potato until 80% of field capacity and planting in beds) when compared it with conventional irrigation in furrow (common method in region).

The obtained results in present study show that when the best method is use (irrigated potato until 80% of field capacity and planting in beds) the irrigation water is saved more than the normal planting in furrow (common method in region) by about 29.72% .The results show also that , the amount of water irrigation which can be saved (as average) by about 179.216320 million m^3/ area compared to normal planning in furrow. This amount of saving water enough to cultivate area about (generally) 208245 feddan in old land or cultivate different areas of horticulture and field crops under El-Minia conditions. These results reflex how much irrigation water can be saved when using this treatments. In general, it could be concluded that water fast becoming an economically scarce resource in many area of the world. So, the use of transplanting method is very important to save water. The best method to plant Potato should give favorable crop yield and optimum amount of irrigation water. Therefore, estimating economic of irrigation water becomes very important for

planning irrigation management where the over irrigation by the farmers usually leads to low irrigation efficiency and high loss of water and fertilizer. These results reflex how much irrigation water can be save to produced the highest yield with least possible amount of water applied where the farmer's practices in potato (conventional irrigation treatment) utilized much water without giving higher productivity .

Daily , monthly and seasonal actual water consumptive use :

Daily water consumptive use values are presented in Table (5). The data obtained indicated, that daily consumptive use increased gradually until it reached to its maximum values on September in both seasons. The average amounts of water consumptive use by potato crop at the period of maximum daily consumptive use were 3.15 , 4.91 , 4.83 , and 4.59 mm/ day for A_1 , A_2 , A_3 , A_4 and A_5, respectively under irrigation regime in furrow while were 4.69 , 4.58 , 4.51 and 3.99 for same treatments, respectively under irrigation regime in beds . These results reveal that the water consumptive use reached its peak value in November (tuber formation period) which is considered the critical period in water demands of potato. Then, it declines by the end of growing and the water loss is almost due to evaporation from soil surface, while small amount lost by consumptive use. Data in Table (4) show also that the mean values of seasonal water consumptive use were 37.55 , 35.13, 32.93 and 30.39 cm/ season for A_1 , A_2 , A_3 and A_4 , respectively under irrigation system in furrow while were 32.81 , 31.50 , 29.71 and 24.60 cm/ season for same treatments, respectively under regime in beds .It obvious from data that seasonal water consumptive use reduced by irrigation regime in beds. These results are in agreement with those reported by Rashid & Ahmed (1988) and El-Nagger (1977).

Irrigation efficiencies :

Irrigation efficiency for different treatments of potato crop are shown in Tables (6 & 7) It is obvious that the highest values of total irrigation efficiency (71.01, 74.53 %) were obtained from when irrigate potato crop until (80% , 70 %) of field capacity and planting it in beds instead of furrow while the lowest values (54.61 %) were obtained from conventional irrigation in furrow (common method in region). So it could be concluded that when the best treatment A3b2 (from view point water and economic) the total irrigation efficiency increased from (54.61 %) to (71.01 %) compared with the conventional method in region where the over irrigation practiced by the farmers usually lead to low irrigation efficiency and high losses of water. It is obvious that the highest values of total irrigation efficiency (71.79%) were obtained from transplanting method in beds while the lowest values (51.58%) were obtained from normal planting in furrow (common method in experimental) .

So it could be concluded that when transplanting method used in beds the total irrigation efficiency increased from (51.73%) to (71.79%) compared with the conventional method in region where the over irrigation practiced by the farmers usually lead to low irrigation efficiency and high losses water.

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Table (4): Water saving (m^3/ fed) which obtained from the best treatment (A_3b_2) compared with conventional methods in the region for potato crop during the both studied seasons .

Treatment	Increase of yield		% of increase in yield	Water applied (m3/fed)	Saved water		*Average area cultivated of potato crop in Egypt	To total of water saving milliond/m3 /area	The area (fed.) of old land which can be cultivated as a resulting of saving water
	Ton/fed	Ton/fed.			m3/fed	%			
Normal planting in furrow (common method in region)	10.102	4.166	41.24 %	2893.58	859.86	29.72	208425	179.216320	28002.550
the best treatment from view point water and agriculture	14.268			2033.72					

Average of total yield (ton /fed) for conventional irrigation (by farmer practices) was 10.102 (ton/ fed) in the two studies seasons.
* Economic Bulletin, Ministry of Agriculture in 2013.

Table (5). Average actual water consumptive use values (daily, monthly and seasonal) Potato crop plants as affected by irrigation regime and planting methods (furrow & beds) in both seasons.

month	A_1						A_2						A_3						A_4					
	b_2			b_1			b_1			b_2			b_1			b_2			b_2			b_1		
	mm/day	cm/month	m3/fed.	mm/day	cm/month	m3/fed.	mm/day	cm/month	m3/fed.	mm/day	cm/month	m3/fed.	mm/day	cm/month	m3/fed.	mm/day	cm/month	m3/fed.	mm/day	cm/month	m3/fed.	mm/day	cm/month	m3/fed.
Sept.	2.42	4.60	193.20	1.87	3.55	149.10	2.15	4.09	171.78	1.73	3.29	138.18	2.03	3.86	162.12	1.72	3.27	137.34	1.82	3.46	145.32	1.48	2.81	118.02
Oct.	3.64	11.28	473.76	3.21	9.95	417.90	3.43	10.63	446.46	3.12	9.67	406.14	3.35	10.38	435.96	3.06	9.49	398.58	3.13	9.70	470.2	2.51	7.77	326.34
Nov.	5.13	15.39	646.38	4.69	14.07	590.94	4.91	14.73	618.66	4.58	13.74	577.08	4.83	14.49	608.58	4.51	13.53	567.84	4.59	13.77	578.43	3.99	11.96	502.32
Dec.	3.14	6.28	263.76	2.62	5.24	220.08	2.84	5.68	38.56	2.40	4.8	201.60	2.10	4.2	176.40	1.71	3.42	143.64	1.82	3.46	145.32	1.03	2.06	86.52
Total		37.55	1577.1		32.81	1378.02	13.33	35.13	1475.46		31.5	1323		32.93	1383.06		29.71	1247.4		30.39	1339.27		24.6	1033.2

Traditional irrigation :	Sept	Oct	Nov	Dec	Total / Season
cm /season	6.50	11.66	16.17	8.75	43.10
m3/fed	273	489.72	679.14	367.50	1810.20

Table (6): Average values of irrigation efficiency's (%) (application storage and distribution efficiency) and total irrigation efficiency for different irrigation regime under planting methods in furrow (b1) for Potato crop in both studied seasons .

No.of irrigation	Irrigation efficiency's (%)															
	A1				A2				A3				A4			
	E_a%	E_s%	E_{wd}%	Total irrigation efficiency	E_a%	E_s%	E_{wd}%	Total irrigation efficiency	E_a%	E_s%	E_{wd}%	Total irrigation efficiency	E_a%	E_s%	E_{wd}%	Total irrigation efficiency
1	68.9	81.85	97.7	55.10	73.90	78.80	98.1	57.10	75.20	83.50	98.9	62.01	76.49	84.50	99.10	65.55
2	67.77	82.91	96.90	54.45	70.77	82.12	97..90	56.89	74.20	84.84	98.10	61.78	77.01	86.17	99.0	65.70
3	66.74	82.63	97.9	53.99	71.20	81.40	98.2	56.90	75.01	83.54	98.39	61.66	76.90	86.51	99.2	66.00
4	68.10	81.81	98.74	55.01	70.40	81.90	98.10	56.70	74.10	84.43	99.10	62.00	77.1	84.84	99.35	64.99
5	68.7	80.64	99.10	54.90	70.90	82.24	99.3	57.90	73.94	84.39	9.20	61.90	76.90	85.90	99.40	65.66
6	69.0	79.18	99.2	54.20	72.70	80.54	99.4	58.20	74.01	84.03	9.5	61.88	77.01	85.03	99.60	65.22
Average				54.61				57.28				61.87				61.87

Source : Actual field measurements

E_a- application efficiency
E_s = storage efficiency
E_{wd}- water distribution efficiency

Table (7): Average values of irrigation efficiency's (%) (application, storage and distribution efficiency) and total irrigation efficiency for different irrigation regime under planting methods in beds (b2) for Potato crop in both studied seasons.

No.of irrigation	Irrigation efficiency's (%)															
	A1				A2				A3				A4			
	E_a%	E_s%	E_{wd}%	Total irrigation efficiency	E_a%	E_s%	E_{wd}%	Total irrigation efficiency	E_a%	E_s%	E_{wd}%	Total irrigation efficiency	E_a%	E_s%	E_{wd}%	Total irrigation efficiency
1	72.9	82.85	97.85	59.10	76.98	83.69	99.80	64.29	78.20	88.10	99.8	68.84	80.3	90.30	99.9	72.40
2	73.20	83.83 90	98.43	60.45	77.20	84.0	99.60	64.80	82.10	89.90	99.90	73.70	83.09	90.10	99.8	74.70
3	73.00	82.99	99.03	59.99	75.0	84.80	99.80	64.23	77.70	88.50	99.80	68.83	79.90	89.90	99.90	71.60
4	73.79	82.88	98.92	61.014	78.20	89.40	99.80	69.80	80.66	88.87	99.90	71.81	83.90	92.52	99.7	77.39
5	73.50	83.55	99.23	60.80	77.50	89.00	99.90	68.91	80.46	88.95	99.90	71.50	82.80	91.40	99.9	75.60
6	74.00	83.90	97.08	60.2	77.30	88.90	99.8	68.60	80.01	89.20	99.90	71.75	81.96	92.22	99.90	75.50
Average				60.11				66.74				71.01				74.33

Source : Actual field measurements

E_a- application efficiency
E_s = storage efficiency
E_{wd}- water distribution efficiency

Water use efficiency (WUE) :

The water use efficiency is obtained by evaluating the two parameters of total yield per unit of water applied and water consumptive use. WUE is a tool for maximizing crop production per each unit of water irrigation. Effect of the different planting methods and system irrigation on WUE is presented in Table (8). From the presented data , it is clear that values of WUE of potato differed from one treatment to anther .

That highest values of field and crop water use efficiencies (7.12 kg/m^3 and 11.45 kg/m^3) were obtained from treatment A_3b_2, respectively. This is mainly due to the higher yield of potato and decrease water applied and water consumptive using this treatments in the transplanting method compared with the other treatments. While the lowest value of and crop water use efficiencies (3.46 and 5.60 kg/m^3, respectively) were obtained from treatments A_1b_1 . These results indicated that irrigation potato crop until 80% of field capacity and planting in beds instead of furrow is the best treatment from the view point of water management for Potato yield.

Table (8) : Values of total yield (kg/ fed.) of potato crop , water applied (m^3/fed) , water consumptive use (m^3/fed.), field and crop water use efficiencies (kg/m^3) in both two studies seasons .

Treatments		Water applied (m3/fed)	Total yield (kg/ fed.)	Field water use efficiency (kg/ m3)	Water consumptive use (m3/fed)	Crop water use efficiency (kg/m3)
(A_1) conventional method (Control)	In furrow (b)	2709.01	10500	3.87	1577.10	6.66
	In beds(b_2)	2356.16	11120	4.72	1378.02	8.07
(A_2)	In furrow(b_1)	2527.11	12445	4.92	1475.46	8.29
	In beds(b_2)	2197.96	13820	6.29	1323	10.84
A3	In furrow b_1)	2350.07	12746	5.42	1383.06	9.21
	In beds (b_2)	2033.72	14268	7.12	1247.40	11.45
A4	In furrow(b_1)	2170.47	7500	3.46	1339.27	5.60
	In beds(b_2)	1856.47	8000	4.31	1033.20	7.74

Saving of irrigation time (minute / fed) and irrigation costs (L.E / fed)

Saving of irrigation time and irrigation costs as influenced by irrigation system and planting methods were presents in Table (9). The results in Table (9) show that irrigation time decreased by 25.17% by irrigation until 90 % and planting in beds A_3b_2 , compared with the conventional irrigation in region (conventional irrigation in region). Also, the results in Table (9) show that when we using this treatment the irrigation costs decreased from 25 L.E/ fed (costs of oils and diesel only) 17.65 L.E/fed equal about (29.40 %) compared with the common conventional irrigation. From these results it could be concluded that the using treatment A_3b_2 decreased irrigation time and irrigation costs /fed which will lead to reduction in the overall costs of production requirements for potato crop compared with traditional irrigation method.

The Economic Evaluation :

Total costs , production , total income (L.E / fed.), And Economic efficiency:

Data in Table (10) illustrated that values of total cost , production , total income (L.E / fed.) and net return from unit of irrigation water (L.E/ m^3) as influenced by irrigation regimes and different planting methods of potato crop in both studied seasons. The maximum values of total income and net profit (17121 and 7175.4L.E/ fed.) and return from a unit of irrigation water applied and consumptive (3.53 and5.75 L.E/m^3) were obtained from plants which irrigated until 80% of field capacity and planting in beds (A_3b_2), respectively . While , the lowest values of total income and net profit (9000 and -1005 L.E/fed) and net return from a unit of irrigation water (applied and consumptive use) -0.46 and -0.75 were obtained from the plants irrigated until 70 % of field capacity and planting in furrow (A_4b_1) respectively. Also, results indicated that the lowest values of economic efficiency was obtained from treatments A_4b_1 (-0.10) for each Egyptian pound (L..E) spend for production while , the highest economic efficiency (0.72) was obtained from plants which irrigated until 80 % of field capacity and planting in beds (A_3b_2). These increase in economic efficiency due to the enhancement of net profit in this treatment irrigation compare with other treatments.

From these results it could be concluded that treatment A_2b_3 lead to increase in total income , not profit and , net return of irrigation water and economic efficiency The data in Table (9) indicated that the highest values of yield (14.268 ton/ fed) were obtained from treatments A_3b_2 . While the lowest values of yield (10.500) were obtained from treatment (A_1b_1) . These results reflex how much irrigation water can be saved to produce the highest yield with least possible amount of water applied

Table (9) Comparison between saving of irrigation time (minute /fed & %) and saving of irrigation costs (L.E / fed & %) for conventional irrigation and the best treatment A3b2 for Potato crop in the to studied seasons .

No. of irrigation	Irrigation time (minute /fed) for conventional irrigation in furrow (the common method in region)	Time saving of irrigation (minute / fed & %)			Irrigation Costs (oil + diesel) L.E /fed for conventional irrigation in furrow (the common method in region	saving of irrigation Costs (L.E/ fed & %)		
		the best treatment A_3b_2				the best treatment A_3b_2		
		Irrigation time	Saving of irrigation time			Irrigation Costs	Saving of irrigation costs	
		minute / fed	minute / fed	%		minute / fed	L.E/ fed	%
1	375	280	95	25.33	25	17.95	7.05	28.20%
2	260	202	58	22.31	25	17.70	7.3	29.20%
3	280	210	70	25	25	17.50	7.5	30.00%
4	309	230	79	25.57	25	17.35	7.65	30.60%
5	274	195	79	28.83	25	17.85	7.15	28.60%
6	242	185	57	23.55	25	17.55	7.45	29.80%
Average	290	217	73	25.17	25	17.65	7.35	29.40%

The financial benefits (LE/ area) :

Data in Table (11) show that the values of financial benefits (L.E/ area) as a result of saving of water , yield , irrigation costs and irrigation time (L.E/ area) . From these results it could be concluded that using the best method (A_3b_2) get total of financial benefits as a result of saving water by about (6.631004 million L.E / area) + saving of yield (1.041958260 billion L.E / area) + saving of irrigation costs (9.191543 million L.E/ area) + saving of irrigation time (8.899748 million L.E/ area) = 1.066680555 billion L.E / area .

Table (10) : Average values of total costs , production , total income (L.E) and net return per cubic meter a water (L.E /m3) for different treatments for Potato crop in the two studied seasons .

Treatments		total costs (L.E)	Yield (ton /fed)	Total return L.E / fed.	Water issues L.E/m3						Economic efficiency
			Average total yield	Market price L.E	Total income	Net profit	Water consumptive use m3/fed)	Issu unit water consumptive	Water applied m3/fed	Net return Issu unit water applied L.E/m3 (c)	
(A_1)	in furrow (b_1)	10040	10.500	1.20	12600	2560	1577.10	1.62	2709.01	0.94	0.25
	in beds (b_2)	10022.70	11.120	1.20	13340	3317	1378.02	2.41	2356.4	1.41	0.33
(A_2)	in furrow (b_1)	10035	12.445	1.20	14934	4899	1475.46	3.32	2527.11	1.94	0.49
	in beds (b_2)	10016.70	13.820	1.20	16584	6567	1323	4.28	2197.96	2.99	0.66
(A_3)	in furrow	10020	12.746	1.20	15290	5270	1383.06	3.81	2350.07	2.24	0.53
	in beds	9945.60	14.268	1.20	17121	7175.4	1247.40	5.75	2033.72	3.53	0.72
(A_4)	in furrow	10005	7.500	1.20	9000	-1005	1339.	-0.75	2170.47	-0.46	0.10-
	in beds	9991.50	8.00	1.20	9600	-49.5	1033.20	-0.38	1856.47	-0.21	0.04-

Average of total costs (L.E / Fed) for conventional irrigation (by farmer practices) was 10050 LE/Fed

Table (11) : The total of finical benefits (L.E/ area) when the best methods (A3b2) using and compare it with conventional irrigation method in the region for potato crop in the two studied seasons.

Treatments	Saving of water L.E / area						Saving of yield L.E/ area					Saving of irrigation time (L.E/ acr)					Saving of irrigation costs (oils + diesel) (L.E/ area)				
	Water used (m3/fed)	Saving of water (m3/fed)	Ar. area cult. sugar cane in Egypt fed/ area	total water saving (m3 million /area)	* cost transp-orting m3 water	total water saving (million L.E/ area)	Total yield (ton/fed)	Incr-ease in yield (ton/ fed	Mar-ket price ton/ fed.	Saving of yield (L.E/ fed.)	Saving yield (billion L.E/ area)	time fir each irrig. (min. /irrig.)	Savin g time of (min./ irrig.)	tot al sav ing tim e of irri gati on (mi nut e / sea son)	total finical benefit (L.E/ fed.)	total finical benefit (L.E/ area)	cost fir each irrig. (L.E /irrig)	Savi ng of irrig. costs L.E/ irrig ation	Savi ng irrig costs L.E/ fed.)	Total saving of irrig. costs (L.E / area)	total of finical benefits (L.E billion /area)
Conventional irrigation	2093.58	859.86	280425	179.216329	0.037	0.830004	10.192	4.166	1200	4999.20	1.04999360	290	73	73+4=88	42.70	8.899748	25	7.35	7.35+6=44.1	44+280425=9.1915430	1.000000555
The best treatment (A3b2)	2033.72						14.268					217					17.65				

*Resource : Egypt : study on cost Recovery in the irrigation and Drainage sector , Ministry of irrigation and water Resources (KFW.) September 2004 Cairo

Conclusion

Considering the previous discussion and the use of irrigated potato until 80% of field capacity and planting in beds instead of furrow has a positive effect on increasing agricultural production in both vertically and horizontally ; vertically by increasing yield per unit of land area , horizontally by saving water in order to irrigate more old or new lands . Thus the method becomes very important in saving water and obtaining high yield. So we have search for applicable solutions and how to limit the potato consumption of water and keep the planted land as it is, and to expand the production of potato crop in new lands . One of these solutions is to study the effect of this treatment on water consumptive use and the water use efficiency for the crop in order to have a high yield and good quality with least quantities of water.

Results indicated that the planting Potato crop by irrigated until 80 % of F.C in beds (A_3 b_2) leads to an increase in productivity with rate equals 38.52 % and to more water saving about by 29.72 % per year , and rising the total irrigation's efficiency by 71.00 % . It also saving water by about 179.216320 million m^3 / area (Average area cultivated by Potato in Egypt) compared with the traditional method in this region . The results indicated also from the economic view point also this treatments recorded the highest values of field and crop water use efficiencies (7.02 and 11.45 kg/m^3 , respectively) . Therefore , the economics of irrigation water becomes very important for planting irrigation management project where the over irrigation practices by farmers usually lead to low irrigation efficiency , water logging and high losses of water .

It could be recommended to apply irrigated potato crop until 80 % of field capacity and planting in beds instead of furrow to produce high yield with less amount of water applied under El-Minia province conditions.

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تحسين كفاءة استخدام المياه على انتاجية محصول البطاطس

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اجريت تجربتين حقليتين خلال المواسم الزراعية لعامى 2012-2013 م بمحطة مقننات رى ملوى البحثيه التابعة لمعهد بحوث المياه – المركز القومى لبحوث المياه بهدف دراسة تاثير اسلوب الرى وطريقة الزراعة على الاحتياجات المائية الفعلية والاستهلاك المائى الفعلى وكفاءات الرى المختلفة وكفاءات استخدام المياه والكفاءة الكلية للرى الحقلى وانتاجية محصول البطاطس صنف كارا بالاضافة الى التقيم الاقتصادى ومقارنة ذلك بالطريقة التقليدية السائدة فى المنطقة . وقد اشتملت التجربة على اربعة معاملات لاسلوب الرى المضاف وهى) A_1 (الرى حتى الوصول الى 100 % سعة حقليه) ،A_2 (الرى حتى الوصول الى 90% سعة حقليه)A_3 (الرى حتى الوصول الى 80% سعة حقليه) ، A_4 (الرى حتى الوصول الى 70% سعة حقليه) بالاضافة الى الرى التقليدي السائد بالمنطقة وكذلك اشتملت التجربة على معاملتين رئيستين لطريقة الزراعة (الزراعة فى خطوط b_1 – الزراعة فى المصاطب b_2). لذا اشتملت التجربة على اربعة معاملات لاسلوب الرى المضاف ومعاملتين لطريقة الزراعة واربعة مكررات لذا صممت التجربة قطعه منشقه spilt- plots

وفى ضوء ما سبق يمكن تلخيص النتائج المتحصل عليها كالتالى :

1-اظهرت النتائج أن متوسط كميات المياه المضافه كانت بمقدار 2709.01 ، 2527.11 ، 2350.07 ، 2170.47 (م^3 / ف) للمعاملات A_4, A_3, A_2,A_1 , على التوالى تحت طريقة الزراعة فى خطوط بينما كانت 2356.16 ، 2197.96 ، 2033.72 ، 1867.47 لنفس المعاملات السابقة تحت طريقة الزراعة فى مصاطب . بينما اعطت الطريقة التقليدية السائدة فى المنطقة بمعرفة المزارع 2893.58 م3/فدان

2- ادت طريقة الزراعة فى مصاطب بصفة عامة تحت جميع معاملات الرى الرئيسة الى الحصول على وفر مائى قدر نحو 328.09 م3/فدان بما يوازى 13.45 % ذلك مقارنا بالزراعة فى خطوط .

2-كان متوسط قيم الاستهلاك المائى الفعلى للمحصول بمقدار 37.55 ، 35.13 ، 32.93 ،30.39 سم/ موسم للمعاملات الرئيسيةA_4,A_3, A_2,A_1 على التوالى تحت طريقة الزراعة فى خطوط b_1 بينما كانت بمقدار 32.81 ، 31.50 ، 29.71 ، 24.60 سم/ موسم لنفس المعاملات السابقة على التوالى تحت طريقة الزراعة فى مصاطب b_2 بينما اعطت الطريقة التقليدية السائدة فى المنطقة اعلى قيما للاستهلاك المائى الفعلى قدر بنحو 43.10 سم/الموسم .

4- أدى التفاعل للمعاملة الثالثة A_3b_2 (اضافة المياه حتى الوصول الى 80% من السعة الحقلية مع الزراعة فى مصاطب الى الحصول) أعلى انتاجية من المحصول الرئيسى (14.268 طن للفدان) بزيادة قدرها 41.24 % وذ1لك عند مقارنتها بالزراعة التقليدية السائدة فى المنطقة بمعرفة المزارع

5- أدى التفاعل للمعاملة الثالثة A_3b_2 (اضافة المياه حتى الوصول الى 80% من السعة الحقلية مع الزراعة فى مصاطب) الى الحصول وفر مائى قدر بنحو 859.86 م3/ فدان بما يوازى زيادة قدرها 29.72 % وذلك عند مقارنتها بالزراعة التقليدية السائدة فى المنطقة بمعرفة المزارع .

6 – وجد أن معدل الاستهلاك المائى الفعلى اليومى والشهرى يكون منخفض فى بداية المسوم ثم يزداد ذلك المعدل مع الوقت يصل إلى اقصاه خلال الفترات الحرجة لمحصول البطاطس (خلال شهر نوفمبر) ثم ينخفض ذلك المعل مرة أخرى فى نهاية موسم المحصول.

7- أعطى التفاعل للمعاملة الرابعة A_3b_2 (الزراعة فى مصاب تحت اسلوب الرى 80% سعة حقلية) أعلى كفاءات الانتفاع بالوحدة المائية على المستوى الحقلى والمحصولى وكان بمقدار 7.12 ، 11.45 كجم/م3 على التوالى ويرجع ذلك لزيادة الانتاجية المتحصل عليها من هذه المعاملة عن بقية المعاملات الأخرى انخفاض كميات المياه الماضافة والمتسهلكة.

8- اوضحت النتائج من الناحية الاقتصادية بأنه تم الحصول علي اعلي صافي ربح للفدان (جنيه/فدان) من المعاملة الثالثة A_3b_2 (الري حتي الوصول الي 80 % من السعة الحقلية مع الزراعة فى مصاطب) حيث كان بمقدار 7175.40 جـ/فدان بينما اعطت المعاملة الرابعة للتفاعلA_4b_1 خسارة اقتصادية قدرت بنحو -1005 جـ/فدان.

9- اعطي التفاعل A_3b_2 للمعاملة الثالثة اعلي القيم لكفاءات الانتفاع من الوحدة المائية المضافة والمستهلكة معبراً عنها جنيه /م3 حيث كانت بمقدار 5.75،3.53 جـ / م3 على التوالى بينما اعطى المعاملة الرابعة للتفاعل a4b1اقل القيم لكافاءت الانتفاع بالوحدة المائية المضافة و المستهلكة معبرا عناه ج /م^2 حيث كانت بمقدار - 0.46 ، -0.75 على التوالى.

10- اوضحت النتائج من وجهة النظر المائية والاقتصادية بان افضل اسلوب لري محصول البطاطس هو الري حتي الوصول الي 80 % من السعة الحقلية وان افضل طريقة للزراعة هي الزراعة فى مصاطب بدلا من الزراعة في حقول وان هذا الاسلوب ادي الي الحصول علي اجمالي وفر مائي بكميه مياه قدرها 179.216320 مليون م3 / المساحة المنزرعة بمحصول البطاطس علي مستوي الجمهورية وان هذه الكمية المتوفرة تكفي لزراعة مساحة من الاراضي القديمة بصفة عامة نحو 28002.550 فدان او يمكن توجيهها للتوسع في مساحات اخري مختلفة من المحاصيل الحقلية والبستانية الاخري طبقاً للمقنن المائي لكل محصول كما تشير النتائج ايضا بانه تم تقدير قيمة الوفر المائي مالياً الناتج عن الوفر في تكاليف نقل مياه الري بما يوازي 6.631004 مليون جـ / المساحة المنزرعة لمحصول البطاطس علي مستوي الجمهورية .

11- اعطي التفاعل A_3b_2 للمعاملة الثالثة أعلي قيم للعوائد الاقتصادية المالية والتي قدرت بنحو (6.63104 مليون جـ/المساحة ناتجة من الوفر المائي + 1.041958260 مليار جـ/المساحة ناتجة من الوفر الانتاجي + 8.899748 مليون جـ/المساحة من الوفر في زمن الري + 9.1915430 مليون جـ / المساحة من الوفر في تكاليف الري = 1.066680555 مليار جـ / المساحة

12- اعطت المعاملة الثالثة للتفاعل A_3b_2 (الري حتي الوصول الي 80 % من السعة الحقلية مع اتباع اسلوب الزراعة في مصاطب) اعلي القيم في الكفاءة الاقتصادية حيث كانت بمقدار+ 0.72 جـ لكل جنيه انفاقه في مستلزمات انتاج بينما اعطت المعاملة الرابعة (الري حتي الوصول الي 70%) إلي خسارة اقتصادية قدرت بنحو -0.1 ، -0.04 لكل جنيه تم انفاقه في مستلزمات انتاج تحت اسلوب الزراعة في خطوط ومصاطب علي التوالي