The use of potassium and antioxidants to improve water use efficiency, yield and quality in potatoes 1- Evaluation of surface irrigation using gated pipes techniques in potato crop

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Abstract: Two field experiments were carried out at Mallawy, Water Requirements Research Station –Minia Governorate - Egypt. The present research was carried out to study the effect of irrigation systems, potassium sources and salicylic acid on water use efficiency, yield, saving of water and economic evaluation for potato crop ***(Solanum Tuberosum).*** The experiments were included two irrigation systems (a) (surface irrigation a_1 & improving surface by gated pipes a_2) and four sub treatments, potassium sulfate 200 kg/ fed (b_1), potassium nitrate 200 kg/fed (b_2) without potassium treatment (control b_3), potassium sulfate 200 kg / fed + salicylic acid with concentration 200 ppm spray on plant (b_4) and potassium nitrate + salicylic acid with concentration 200 ppm spray (b_5) on plant with four replications so that experiment was arranged in split plot design. The treatments of irrigation systems were randomly distributed in the main plots. While, the potassium and salicylic acid treatments were randomly distributed in sub plot. Results indicated that the planting potato crop by gated pipes with potassium fertilization96 kg/K_2O leads to an increase in productivity with rate equals 19.94 %, more water saving about by 25.62% per year, rising the total irrigation's efficiency to 72.87 %. It also saving water by about 31307419.60 million m3/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 that, the gated pipes with rate 96 kg/K_2O + SA200 ppm / fed recorded the highest values of field and crop water use efficiencies (6.40 and 10.62 kg/m^3) respectively. The highest values of total income, production, net return of each and water irrigation (L.E /m^3) 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 gated pipes with rate 96 kg/K_2O + SA 200 ppm / fed to produce high yield of potato with less amount of water applied under El Minia province conditions and other corresponding conditions.

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1. Introduction

Surface water resources are limited to Egypt's share of the flow of the River Nile. Nile water discharge constitutes more than 95 % of Egyptian total water supplies. With limited renewable fresh water resources and continuous increase in water demands for agriculture, the issue of satisfying such demands becomes for agriculture, the issue of satisfying such demands becomes very serious. Increasing the agricultural production per unit volume of water is the main goal through increasing the water use efficiency. On the other hand, Potato tubers ***(Solanium tuberosum)*** have a worldwide economic importance. According to global daily use and international economic importance; potato ranks the fourth position after wheat, rice and maize **(Howkes, 1990).** Andean mountains of South America are the origin place of potato plant. Nowadays, potato is one of the most important vegetable crops cultivated all over the world included Egypt.

In this connection **Israelsen and Hansen (1962)** stated that when the soil is wet, most of moisture will be consumed from the surface. The reason is that roots normally grow near the surface. However, when the moisture of soil surface decrease more moisture is extracted from lower depths. He also indicated that soil moisture begins to be a limiting factor as the plant began to with and that thereafter, the rate of transpiration is linear function of the soil moisture and added the evapotranspirtion rate increases to a peak and then diminishes as the crop matures. This peak of consumption of water comes at beginning of flowering and at end of the vegetative stage of growth **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 mm for 40, 55, 77 and 85% depletion

from available soil moisture, respectively. **EL-Nagger (1997)** showed that the seasonal amounts of consumed water during growth season were 306.40, 271.92 and 192.07 mm as measured gravimetrically method, and 285.74, 264.87 and 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 drip irrigation system. ***Smith et al. (1997)*** indicated that using gate pipe system provided many benefits.

1-Demonstrated that water applied more evenly and more efficiently could increase crop yields.

2-Provided controllable, consistent, and accurate delivery of the water right.

3-Reduced the need to divert 5.5 acre-feet per acre from the Clear-water ditch to 3.3 acre-feet per acre.

4-Improved water quality in the Lostine River by reducing tail water return flows and reducing sediment yield. ***El-Tantawy et al.(2000)*** stated that developed surface irrigation means using perforated pipe system and precision land leveling on sugarcane area in old valley in Egypt. ***Abo Soliman et al. (2002)*** found that using gated pipes could save irrigation water by 16.94% for maize crop compared to traditional surface furrow irrigation. ***Osman (2002)*** stated that using gated pipes, led to saving water by about (29.64%, 29.9%, 14.5% and 19.7%) in cotton, wheat, cornad rice respectively compared with traditional (flooding) system. **Kashayap and Panda (2003)** who found that water is a very important factor for increasing potato yield and production. ***Abo Soliman et al. (2008)*** reported that the grain yield of wheat and soybean crops were significantly increased with gated and concrete pipes and with shorter border length and width. **ICARDA** organization (**2000**) presented the alternate furrow irrigation technique as an able system to improve soil and water resources and increase economic outputs in the region. On the other hand, the traditional surface irrigation system can be improved using gated pipes with the furrows or basin irrigation system without major change in design or operating procedure of the current irrigation system. Gated pipes have low cost, relative high application and destruction efficiencies and it easily to be used by low experienced works **Abou El –Soud (2009**) showed that gated pipes is an aluminum or PVC pipe (6 inches diameter) and an orifice gated are distributed along the pipes with 75 cm spacing. Gated pipes are connected directly with a water pump to convey and distribute the water to the head of the irrigated fields (furrows or basins method). Gated pipes are easy to be used by the farmer and have low cost. The conveyance efficiency, application efficiency and distribution uniformity are relatively high with gated pipes. He also found that Traditional surface irrigation is used in most of field crops at North Delta as a conventional practice of irrigation at the Egyptian farmers. Developed surface irrigation using gated pipes and drip irrigation (Surface or subsurface) are new methods to be used for irrigation not only in the new land but also in Nile Delta and Valley areas as strategy based on water saving. This tendency is very important because Egypt is becoming more water poor country. ***Abou El-Soud (2009*)** also found that water application efficiency value increase as the amount of water applied with each irrigation decreases. The values of irrigation application efficiency for maize are 82.2 and 75.5% with gated pipes and traditional surface irrigation systems, respectively., while the values of water application efficiency for sugar beet are 79.5ad 71.7% for gated pipes and traditional surface irrigation systems, respectively. Using gated pipes technique in irrigation alternative furrows under cultivation of maize and sugar beet crops combined with application of nitrogen recommended does led to improve water and nitrogen use efficiencies and save more irrigation water without significant reeducation in maize and sugar beet yield specially, under limited of fresh water resources and high price of nitrogen fertilizers **Shabana (2010). *Sonbol et al. (2010*)** found that the irrigation by gated pipes system and surface drip irrigation (single lateral) systems achieved the highest values of water distribution efficiency. It can be recommended to use gated pipes as modified surface irrigation method to irrigate heavy clay soils especially under condition of salt affected soils, while subsurface drip irrigation can be used properly in case of water shortage. They also found that the highest root, sugar yield, sucrose percentage and quality of juice were produced when sugar beet plants were irrigated by gated pipes. While the lowest root and sugar yield were achieved with irrigation by double line of subsurface drip irrigation. ***Abd el Fattah (2011*)** showed that gated pipes technique is promising practice in improving surface irrigation the convenient irrigation method in Egypt. Several advantages could be obtained by using gated pipes:

- Good uniform distribution of irrigation water.
- Low energy needed in its operation
- High water saving
- Gained about 10 % from cultivated lands

***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 tubers yield under the experimental conditions. Water use efficiency increased from 5.129 to 7.379 kg m_3 for furrow irrigated treatments, and from 6.907 to 10.257kg 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 evapotrans pirations 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 were calculated as 8.32 kg/m^3 and 7.51 kg/m^3 in drip irrigation and 6.09 kg/m^3 and 5.76 kg/m^3 in sprinkler irrigation, respectively.. The aim of this work was to study the effect of irrigation regime and planting method (furrow and beds) on water use. ***Abd el Ati (2014)*** results indicate that the planting potato crop with irrigation until 80 % of F.C and planting 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 about 179.216320 million m^3 / area (Average area cultivated by Potato in Egypt) compared to the traditional method in this region. these results indicate also from the economic view point also these 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.

On the other hand, fertilization especially with potassium considered as one of the most important, factors affecting the growth and yield of potato. Many researcher recorded an increases of potato tubers yield resulting from increasing the levels of potassium (K) fertilization **(Shukla & Singh, 1976; Hojmark 1977, El Gamel, 1985, Humadi, 1986).** Such increases in the yield of potato tubers was either due to the formation of large size tubers **Boyd and dermott (1967)** or increasing of the number of tubers per plant **Hojmark (1977)** or both **Hojmark (1977); El Gamel, (1985)** the highest yield of potato tubers was achieved by adding 140- 160 kg K_2O /ha **(Smith, 1977). El –Shobaky *et al.* (2002)** declared that the application of K at the rate of 120 kg / fed. on potato **(Diamant)** significantly increased medium and large tubers / plant but had insignificant effect on small tubers plant.

Also, antioxidants play a major role in regulation of plant growth, development, flowering, heat, chilling and disease resistance **(Karadeniz *et al.*, 2005).** Also, antioxidants aid reduction and prevention of enzymatic browning of potatoes **(Maurice *et al.*, 2000).** Antioxidants are believed to be a good scavenger of activated oxygen **Bodannes and chan (1979)** and can oxidative decompose H_2O_2 **Nakano and Asada (1981).**

The aim of this work is to study the effect of irrigation systems and different sources of potassium fertilization on water use efficiency yield and saving water and economic efficiency for potato crop.

2. Material and Methods

Two field experiments were carried out at Mallawy, Water Requirements Research Station – Minia Governorate - Egypt. The present research was carried out to study the effect of irrigation system, potassium sources and salicylic acid on water consumptive use, water applied, water use efficiency, economic evaluation, yield and quality of potato crop.

The experiments were included two irrigation systems (a) (surface irrigation a_1& improving surface by gated pipes a_2) and four sub treatments, potassium sulfate 200 kg/ fed (b_1), potassium nitrate 200 kg/fed (b_2) without potassium treatment (control b_3), potassium sulfate 200 kg / fed + salicylic acid with concentration 200 ppm spray on plant (b_4) and potassium nitrate + salicylic acid with concentration 200 ppm spray (b_5) on plant with four replications so that experiment was arranged in split plot design. The treatments of irrigation systems were randomly distributed in the main plots. The recommended N fertilizer (180 kg N/fed) were given in form of ammonium nitrate (33.5 % N) and the quantity was divided into equal parts and applied at side dressing at 45 and 60 days after planting. While phosphorus (38 kg P_2O_5) was applied before cultivation during soil preparation in the form of the calcium super phosphate (15.5% P_2O_5).

Other cultural practices were done as recommended for potato production, all the agronomic practice except the irrigation treatment and potassium rates were applied as commonly use in growing.

Soil Physical analysis:

Soil analysis showed that the experimental soils was clay, the bulk density was determined using the undistributed core samples according to ***Klule (1986***), The field capacity (F.C%) was determined by field method according to ***Klule (1986)*** and Infiltration rate (IR): It was determined using blocked furrow infiltromter **(Salazar.1977).**

Soil- water relationships

Recorded data:

Irrigation Water Measurements

Improved surface irrigation (gated pipes) the quantity of water applied was measured by water

meters during every irrigation, ***(Brater and King, 1976***). On the other hand surface irrigation the quantity of water applied was measured in studied area by using a rectangular sharp crested weir. The discharge was calculated using the following formula.

$Q = CLH^{3/2}$ *(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.

Water consumptive use (CU):

The quantities of consumptive use were calculated for the 60cm 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 feddan ($4200m^2$) can be obtained by the following equation.

$$CU = \frac{\theta_2 - \theta_1}{100} \times b.d \times \frac{depth}{100} \times \text{area } (4200m^2)$$ which described by

Israelsen and Hansen (1962)

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.

$$C.W.U.E = \frac{\text{Yield (kg / fed.)}}{\text{Water consumptive use } (m^3 \text{ / fed.})} = (kg/\ m^3)$$

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:

$$F.W.U.E. = \frac{\text{Yield (kg/fed.)}}{= (kg/\ m^3)}$$

Application efficiency (E_a):

The values of application efficiency (E_a) in percent for each treatment were obtained by dividing the total consumptive use on the applied irrigation water (**Downy, 1970)**

$$E_a = \left(\frac{Ws}{Wd} \times 100\right)$$

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:=

$E_d = (1- y) \times 1d$

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 by dividing the total water storage on the amount quantity of irrigation water that must be added before irrigation **(Sharl, 1991)**

$$E_s = \left(\frac{W_s}{W_m} \times 100\right)$$

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:

$$\text{Economic efficiency} = \frac{\text{Net profit (L.E/ fed)}}{\text{Total costs (L.E /fed)}}$$

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.

3. Results and Discussion

Total yield (ton /fed.)

Data in Table (1) showed that total yield ton/fed of cv. Lady Rosetta significantly affected by irrigation systems and potassium fertilizer. The highest yield of potato (13.090 and 12.750 ton / fed.) was obtained by improving surface irrigation method with gated pipes in the first and second seasons, respectively. It was obvious that the highest values of yields were obtain from plants which irrigated by gated pipes system. This might be due to increase the cultivated of land instead of irrigation canals, reduce the spread of weed and diseases on the contrary, minimum total yield (12.180 and 12.045 ton / fed) in the first and second season, respectively. These results are similar to those size through cell enlargement and turgidity. These results are similar to those findings by ***Abd el Fattah (2011***).

Regarding the K and SA effects on this characters, data in Table (3) showed that the highest mean value (13.430) and (13.010) ton/fed was obtained from plants which treated with (potassium sulphat at rate200kg /fed 96 Kg/ fed k_2o. + Salicylic acid 200 ppm) in the first and second seasons, respectively. These results may be attributed to potassium affects the activity of many enzymes, thus influencing carbohydrate protein and organic acid metabolism, carbohydrate accumulation in tubers are important for increasing total yield of potato. These results are in line with those obtained by **El Gamel (1985) and Humadi (1986).**

Concerning the interactions between the two studied factors, data in Table (1) showed that the highest values were obtained from treatment which irrigated by gated pipes system A_2 and treated with (potassium sulphat at rate 96 Kg/ fed K_2O + Salicylic acid at rate 200ppm) and this treatment was the most superior treatments from point of view of water efficiency and production (14.150 and 13.450 ton / fed) in the first and second seasons, respectively.

In general, the improving irrigation by gated pipes produced the highest values of total yield, so meanwhile irrigated potato plants by gated pipes solves the problem of decreasing the productivity. It could be concluded that irrigate water becomes very important for planning where irrigation practiced by the farmers usually leads to low irrigation efficiency, water logging and high losses of water and fertilizer so the proper water management not only accurate determination of crop water requirements but also helps to know how, when and how much water should be applied to get high efficiency of each unit of water applied. Furthermore improving irrigation by gated pipes is responsible for obtaining a high productivity of potato with least possible amount of water applied.

Seasonal irrigation water applied

Average of the amount of applied water delivered (m^3/ fed) to different treatments of potato crop shown in Table (2) it is clear from data obtained that water requirements for potato plants under surface irrigation were 2582.56, 2637.26, 2896.92, 2519.68 and 2748.01 for b_1, b_2, b_3,b_4 and b_5 respectively, While, they were under improving irrigation by gated pipes 2209.56, 2224.28, 2405.08,2154.82 and 2274.71 for b_1, b_2,b_3,b_4 and b_5 respectively. It's obvious that the lowest values of water applied was 2154.82 m^3 / fed obtained from irrigation system by gated pipe with rate potassium fertilizer 96 kg k_2O /fed+ SA 200ppm (A_2b_4). Whereas, the highest values were 2896.92 obtained from irrigation surface +SA 200 ppm A_1b_3. In general, it is obvious that water applied decrease by 12.48% with development irrigation system by gated pipes under all sub treatments comparing with surface irrigation under the same sub treatments. This is due to the soil had a more of moisture content with development irrigation system by gated pipes.

Monthly and seasonal actual evapotranspiration (ETa)

Also, data presented in Table (3) and show that, average seasonal ETa was increased under surface irrigation system (38.56 cm/fed). This increases of ETa could be attributed to use over irrigation practice by this system usually leads to water logging and high losses of water then increase of evaporation at high available moisture, moreover supplying plants with sufficient moisture led to an increases in green cover and hence increase in transpiration. While, average seasonal Eta decrease under irrigation system by gated pipe (33.00 cm / season).

Regarding the effect of potassium fertilizer, data in Table (3) show that application of b4 (potassium sulphate 96 K_2O + salicylic acid 200 ppm) decreasing the monthly and seasonal ETa where the lowest value of average water consumptive use (34.57, 38.558 cm /fed) under surface irrigation and development irrigation by gated pipe respectively in the both seasons. The reducing of seasonal ETa by increasing potassium rates can be attributed to these plants may retain more water in their tissues to be faced the stress condition of the lack of water. The trudged cells of the stomata that are rich in K keep the stomata closed most of time so transpiration rate decreasing however, there is no need for more water to be absorbed by plant roots which in turn reduce the amount of absorbed water. This result is logical as K well known to preserve more in plant tissues, therefore it is absorbed less water. While, the highest value of average water consumptive use under surface irrigation and development irrigation (43.35 and 37.27 cm /fed.) were obtained from b_3 (salicylic acid 200 ppm), during both seasons. It is obvious from data that

an (A_1 b_4) treatment consumes more water than other treatments. While treatment A_2b_4 gave the lowest values of water consumptive use. These findings are in general similar to those obtained by Abd **El-Mottaleb (1987).**

Table (1): Total yield (ton /fed) of potato cv " lady Rosetta " as affected by irrigation systems and potassium fertilizer rates with /or without salicylic acid in the two studied seasons.

Treatments	**First season**			**Second season**		
A / B	Surface irrigation A_1	Gated pipes A_2	**Mean B**	Surface irrigation A_1	Gated pipes A_2	**Mean B**
b1	12.300	13.225	**12.76**	12.200	13.100	**12.65**
b2	12.125	13.175	**12.65**	11.725	13.150	**12.44**
b3	11.245	11.375	**11.31**	10.850	10.925	**10.89**
b4	12.705	14.150	**13.43**	12.572	13.450	**13.01**
b5	12.500	13.507	**13.00**	12.150	13.125	**12.64**
Mean A	**12.180**	**13.090**		11.899	12.75	
LSD A 0.306 B 0.128 AB0.407				LSD A 0.279 B0.114 AB0.317		

Source: Actual field measurements

Where; A1 = Irrigation surface b1= Potassium sulphate at rate 96 Kg/ fed K_2O

A2= Development irrigation by gated pipes b2 = Potassium nitrate at rate 96 Kg/fed. K_2O

b3= Without potassium treatment (control). b4 = Potassium sulphate at rate 96 Kg/ fed K_2O + Salicylic acid at rate 200 ppm.

b5 = Potassium nitrate at rate 96 Kg/fed. K_2O + salicylic acid at rate 200 ppm

Table (2): Average of the quantity of water applied (m^3/fed) for different treatments during the two studied seasons for potato crop.

Treatments No. of Irrigation	**Water applied m^3/ fed**									
	A1					**A2**				
	b1	**b2**	**b3**	**b4**	**b5**	**b1**	**b2**	**b3**	**b4**	**b5**
1	600.16	600.16	600.16	600.16	600.16	600.16	600.16	600.16	600.16	600.16
2	430.36	430.36	430.36	430.36	430.36	430.36	430.36	430.36	430.36	430.36
3	410..08	424.82	492.16	370.47	471.02	310.24	319.41	335.16	295.19	325.46
4	475.85	486.98	557.92	462.74	508..50	354.138	340.37	443.85	339.42	378.86
5	345.22	359.63	425.33	344.89	381.15	263.72	273.87	295.33	253	275.34
6	320.89	335.31	390.99	311.06	356.82	250.94	260.11	300.22	236.69	264.53
Total	**2582.56**	**2637.26**	**2896.92**	**2519.68**	**2239.51**	**2209.558**	**2224.28**	**2405.08**	**2154.82**	**2274.71**
Average	**2575.186**					**2253.69**				

Source: Actual field measurements

Where; A1 = Irrigation surface b1= Potassium sulphate at rate 96 Kg/ fed K_2O.

A2= Development irrigation by gated pipes b2 = Potassium nitrate at rate 96 Kg/fed. K_2O

b3= Without potassium treatment (control). b4 = Potassium sulphate at rate 96 Kg/ fed K_2O. + Salicylic acid at rate 200 ppm.

b5 = Potassium nitrate at rate 96 Kg/fed. K_2O + salicylic acid at rate 200 ppm.

Water saving (m^3 / area)

Water saving per cubic meter / area represents the different between the quantity of the best treatment by gated pipes A_2b_4 and surface irrigation (A_1b_3 control) by framer practice. Data in Table(4) show that average quantity of water applied (m^3 /fed) and total saving water irrigation (m^3 / fed.) was from the best irrigation treatment as it gave high yield with last amount of water applied among other irrigation treatments in the two studied seasons. Where the quantity of water applied for the best treatments was 2154.82 m^3/fed while, the quantity of convention irrigation using by farmer was 2896.92 m^3/fed. It could be concluded that (from view point of water and economic) when we using this treatment can be saved about 25.62 % compared with convention irrigation (A_1b_3 control). Also, data in Table (4) show also that, water irrigation can be saved as average about 313074179.6 million m3/area, than conventional irrigation, which represents the farmer practice. In the studied area under El–Minia condition this quantity of saving water could be enough to cultivate area about 48917.84 (fed.). These results reflex how much of irrigation water can be saved when using the reasonable irrigation treatments.

At the end of this study it could be concluded that water fast becoming an economically scarce resource in many area of the world. So, the use of irrigation system by gated pipes with rate of potassium fertilization at 96 kg k_2O/fed + 200 ppm salicylic acid (from view point of water and economic) to produce high yield with good quality, under EI – Minia conditions and the other corresponding conditions.

Irrigation efficiency

Irrigation efficiency for different treatments of potato is shown in Tables (5, 6). It is obvious that the highest values of total irrigation efficiency (72.87%) were obtained from irrigation system by gated pipes with rate 96 Kg K_2O /fed. of potassium fertilizer (A_2b_4) while the lowest values (48.30%) were obtained from surface irrigation with rate 200 ppm SA (A_1b_3). So it could be concluded that when using irrigation system by gated pipe with rate 96 Kg k_2O /fed of Potassium fertilizer the total irrigation efficiency increasing. Where the over irrigation practiced by the farmers usually lead to low irrigation efficiency and high losses water.

Table (3): Daily, Monthly and seasonal actual evapotranspiration (ET_a) (mm/ day - cm/ fed –m3/ fed) for potato plants as affected by irrigation systems and potassium fertilizer rates in the two studied seasons

Treatments		September			October			November			December			Total	
		mm/day	cm/fed	m3/fed	mm/day	cm/fed	m3/fed	mm/day	cm/fed	m3/fed	mm/day	cm/fed	m3/fed	cm/fed	m3/season
A_1	b1	2.98	4.77	200.34	2.82	8.74	367.08	5.96	17.88	750.96	2.40	6.00	252	37.39	1570.38
	b2	2.98	4.77	200.34	3.08	9.55	401.10	6.23	18.69	784.98	2.72	6.80	285.60	39.81	1672.62
	b3	2.98	4.77	200.34	3.40	10.54	442.68	6.68	20.04	841.68	3.20	8.00	336	43.350	1820.70
	b4	2.98	4.77	200.34	2.82	7.05	296.1	6.47	16.18	679.56	2.41	6.03	253.26	34.03	1429.26
	b5	2.98	4.77	200.34	2.91	9.02	378.84	6.05	18.15	762.3	2.50	6.26	262.92	38.21	1604.82
Average (A1)		2.98	4.77	200.34	3.006	8.98	377.16	6.278	18.188	763.896	2.646	6.618	277.956	38.558	1619.556
A_2	b1	2.98	4.77	200.34	2.60	8.06	109.20	5.14	15.42	647.64	2.35	5.88	246.96	34.10	1432.20
	b2	2.98	4.77	200.34	2.73	8.46	355.52	5.28	15.84	665.23	2.56	6.39	268.38	35.46	1489.32
	b3	2.98	4.77	200.34	2.94	9.11	382.62	5.28	16.39	687.96	2.80	7.00	294	37.27	1565.34
	b4	2.98	4.77	200.34	2.60	6.50	273.0	5.85	14.62	614.04	2.02	5.05	212.10	30.94	1299.48
	b5	2.98	4.77	200.34	2.70	8.38	351.96	5.25	15.75	661.50	2.47	6.18	259.56	35.08	1473.36
Average (A2)		2.98	4.77	200.34	200.34	8.102	294.46	5.36	15.604	655.274	2.44	6.1	256.2	34.57	1451.94

Source: Actual field measurements

Where;

A_1 = Irrigation surface ***b1= Potassium sulphate at rate 96 Kg/ fed k_2o.***

A_2= Development irrigation by gated pipes b2 = Potassium nitrate at rate 96 Kg/fed. k_2o.

b3= Without potassium treatment (control).

b4 = Potassium sulphate at rate 96 Kg/ fed k_2o. + Salicylic acid at rate 200 ppm.

b5 = Potassium nitrate at rate 96 Kg/fed. k_2o. + Salicylic acid at rate 200 ppm.

Table (4): Quantity of water saving (m^3/fed.) which obtained when comparison the best treatments A_2b_4 (from view point of water and economic) with control treatment (A_1b_3) for potato crop during the studied seasons.

Treatments	Increase of yield		% of increase in yield	Water applied (m3/fed)	Saved water		Average area cultivated plant potato crop in Egypt	To total of water saving m3/million /area	The area (fed.) of old land which can be cultivated as a resulting of saving water
	Ton/fed	Ton/fed.			m^3/fed	%			
A_2b_4	13.800	2.753	19.94	2154.82	742.10	25.62	421876	313074179.6	48917.84
A_1b_3(control)	11.047			2896.92					

*Source: - Central Agency for public mobilization and statistics A.R.E

Table (5): Average values of irrigation efficiency (%) (Application storage and distribution efficiency) and total irrigation efficiency for different treatments for potato crop in both studied seasons

No.of irrigation	A1																			
	Potassium fertilizer (B)																			
	b1				b2				b3				b4				b5			
	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	E_a%	E_s%	E_{wd}%	Total irrigation efficiency
1	65.93	76.80	98.55	49.91	65.93	76.80	98.55	49.91	65.93	76.8	98.55	49.91	65.93	76.80	98.55	49.91	63.90	72.46	99.05	54.86
2	67.92	78.50	97.00	51.74	67.92	78.50	97.00	51.74	67.92	78.5	97	51.74	67.92	78.50	97.00	51.74	64.01	37.75	99.09	46.78
3	70.86	80.95	98.30	56.10	71.09	81.57	99.05	59.44	68.79	97.75	98.8	54.2	75.91	86.33	9955	65.24	64.13	73.85	99.11	46.92
4	70.96	80.91	97.44	55.94	72.90	82.93	99.49	60.12	68.51	29.48	97.34	53	76.49	86.50	99.60	65.82	63.85	73.0	99.04	46.15
5	70.50	80.69	98.99	56.31	72.97	83.50	99.55	60.66	68.28	79.05	97.95	52.87	76.16	86.18	99.20	65.11	64.36	73.85	98.90	47.08
6	71.43	81.44	98.50	57.27	74.04	84.74	99.60	62.49	68	78	97.71	52.05	75.96	86.04	99.34	64.93	63.99	74.22	99.13	48.02
				54.54				57.39				52.29				60.45				48.30

Application efficiency (Ea):

(E_a): Application efficiency Total irrigation efficiency= $E_a \times E_s \times E_{wd}$

(E_{wd}): Water distribution efficiency (E_{wd}): (E_s): Storage efficiency

Table (6): Average values of irrigation efficiency (%) (Application storage and distribution efficiency) and total irrigation efficiency for different treatments for potato crop in both studied seasons

No. of irrigation	A2																			
	Potassium fertilizer (B)																			
	b1				b2				b3				b4				b5			
	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	E_a%	E_s%	E_{wd}%	Total irrigation efficiency
1	65.93	76.80	98.55	49.91	65.93	76.80	98.55	49.91	65.93	76.80	98.55	49.91	65.93	76.80	98.55	49.91	74.85	85.90	99.34	63.87
2	81.98	92.16	99.92	75.49	80.77	90.97	99.90	73.40	82.80	92.78	99.95	76.78	82.96	93.04	99.93	77.13	76.33	87.00	99.40	66.00
3	81.92	91.99	99.90	75.28	80.80	91.00	99.89	73.45	82.87	92.95	99.91	76.96	83.02	93.11	99.89	77.21	75.09	85.94	99.38	64.13
4	81.99	92.37	99.79	75.85	81.43	91.40	99.9	74.19	82.9	93.85	99.89	77.71	83.24	93.17	99.94	77.51	76.00	86.39	99.34	65.22
5	81.83	91.89	99.77	75.02	81.30	91.45	99.92	74.29	82.5	92.5	99.91	75.61	83.22	93.16	99.90	77.45	75.99	87.32	99.38	65.94
6	81.89	92.10	99.88	75.33	81.28	91.33	99.90	74.16	83.02	93.26	99.90	77.34	83.49	93.56	99.90	78.03	75.92	86.09	99.45	65.00
				71.14				69.9				72.38				72.87				65.02

E_a): Application efficiency Total irrigation efficiency= $E_a \times E_s \times E_{wd}$ (E_{wd}): Water distribution efficiency (E_{wd}):

(E_s): Storage efficiency **Water use efficiency (kg/m^3)**

Table (7): Values of total yield (kg/fed.) Potato crop, water applied (m^3/fed), water consumptive use (m^3/fed.), field and crop water use efficiencies in the studies seasons.

Treatments		Water applied (m^3/fed)	Total yield (kg/ fed.)	Field water use efficiency (kg/ m3)	Water consumptive use (m^3/fed)	Crop water use efficiency (kg/m^3)
Surface irrigation A_1	b1	2582.56	12.250	4.74	**1570.38**	7.800
	b2	2637.26	11.925	4.52	**1672.62**	7.13
	b3	2896.92	11.048	3.8	**1820.70**	6.07
	b4	2519.68	12.638	5.01	**1429.26**	8.84
	b5	2748.01	12.325	4.48	**1604.82**	7.68
	Average			4.51		7.55
Improving surface irrigation by (gated pipes) A_2	b1	2209.56	13.162	5.95	**1432.20**	9.19
	b2	2224.28	13.160	5.91	**1489.32**	8.83
	b3	2405.08	11.150	4.63	**1565.34**	7.12
	b4	2154.82	13.800	6.404	**1299.48**	10.62
	b5	2274.71	13.316	5.85	**1473.36**	9.03
Average				5.75		8.96

Data in Table (7) reveal that the average of field water use efficiency were 4.74 and 7.55 k/m^3 under surface irrigation systems in the two studied seasons respectively. while this average were 5.75and 8.96 kg/m3 under development irrigation surface by gated pipes in the two studied seasons respectively. It is obvious from data in Table (7) that field and crop water use efficiency increasing by development irrigation system by gated pipes this due to enhancement production of total yield tubers / fed and decreasing water applied and water consumptive use with gated pipes systems compared with surface irrigation system in the both seasons these result are similar to those reported by **El-Gindey et al., (2000).**

Regarding to the effect of interactions among the studied two factors data in Table (7) show that the maximum values of field and crop water efficiency (6.40 and 10.62 Kg / m^3) were obtained from plants irrigated by gated pipes (A_2) with k rate of 96 k2O /fed + 200 ppm (b_4) in the two studied seasons respectively.

This due to enhancement of total yield tubes /fed in the two studied seasons comparison in the other treatments, while the lowest values 3.80 and 6.07 kg /m3 obtained from plants irrigated by surface irrigation (A_1) with rate of 200 ppm SA (b_1) in the two studied seasons respectively.

From those results it could be recommended irrigated potato of c.v (lady Rosetta) by gated pipes systems with rate of 96 k_2o /fed +200 ppm SA) to produce high yield with good quality under El-Minia province conditions and other corresponding conditions.

The economic evaluation:-

Data in Tables (8&9) illustrate values of total costs, production, total income (L.E / fed) and net return from unit of irrigation water (L.E / m^3) as influence by different treatments for potato crop in the two studied seasons.

In general, data in Tables (8&9) Show that the maximum values of total income, net profit and net return from unit of water irrigation were obtained from plants which grown under development irrigation system (gated pipes). While, the lowest values of total income, net profit and net return from unit of water irrigation were obtained with surface irrigation system.

From this results it could be concluded that development irrigation system (gated pipes) increase yield, total income and net return from unit of water irrigation are mainly due to high yield production from plants which irrigated with this system compare with surface irrigation.

These results are in agreement with those reported by **(Frick 2000),** who found that irrigation is required to obtain positive income results. This might be irrigation gated pipes increase the cultivated area of land instead of irrigation canals reduce the spread of weed and diseases.

With regard to K fertilizer results in Table (8&9) declare that highest values of production, (13.800 Ton/fed) total income (14490 L.E/fed), net profit, (5900 L.E /fed) and net return from irrigation water (2.73 L.E / m^3) were obtained from plants irrigated under development irrigation system (gated pipes) with potassium sulphate (96 kg k_2o /fed + 200 ppm SA). Also this might be attributed to the effect of potassium in the total yield where the plants irrigated by gated pipes system with k at the rate of potassium sulphate (96 Kg K_2O /fed +200 ppm SA) gave the highest yield > (13.800 ton / fed) among other treatments in the two studied seasons.

Also, the results in Tables (8&9) show that the lowest values of yield (11.047 ton/fed), Total income (11599.35) L.E / fed. Net profit (3674.35 L.E / fed) and net return from unit irrigation of water (1.27 LE/m^3) where obtained from plant which irrigated by surface irrigation system and salicylic acid at rate 200 ppm, This due to surface irrigation system by the

farmers usually lead to low irrigation efficiency, water and high loses of water and fertilizer.

The previous discussion lead to the following tentative conclusions that it may be recommended irrigate potato plants C.V (Lady Rosetta) by irrigation system (gated pipes) and fertilized with K at rate of potassium sulphate at rate 96 k_2O/fed + 200 ppm SA to produce high economic yield with least of water applied and high profit and El Minia province conditions and other corresponding conditions.

The economic efficiency:-

Increasing net return or profit for crops refers to the decreasing of production costs or for increasing crop production.

So economic efficiency index to the agriculture and irrigation activities, which can give the highest return for each L.E unit, which can spend on crop production.

Concerning the economic efficiency, presented data in Table (10)refer that the highest economic efficiency (1.60 L.E) for each L.E spent was obtained from improving surface irrigation by gated pipes while the lowest values of economic efficiency were obtained from surface irrigation (0.52 L.E, for each L.E spend in the two studied seasons.

Concerning the interaction between the two studied factors data in Table (10) indicate that the highest values of economic efficiency (1.68 L.E) were obtained from plants which irrigated by gated pipes system with K of rate 96 Kg k2o / fed + 200 ppm SA (A_2b_4) these increase in economic efficiency due to the enhancement of net profit in the improving surface irrigation by gated pipes compared with other treatments in the two studied seasons. While, the lowest values (0.46 L.E) were obtained from plants which irrigated by surface irrigation system with 200 ppm SA ($A_1b_{3)}$ in the two studied seasons.

Table (8): Average values of total costs, production, total income (L.E) and net return per cubic meter a water (L.E /m3) by gated pipes and potassium fertilizer for potato crop (lady Rosetta) in the two studied seasons

Treatments		The total costs (L.E)														Yield (ton /fed)	Total return L.E /fed.				Water issues L.E/m3			
		Land preparation	Irrigation network	Leveling by laser	harvest and the transfer of seed	seed	Cultivate Labors	Rent	Chemical fertilizer	Service & tillage Labors	Fuel (oils + diesel	Harvest	Irrigation labors	Pesticides	**Total costs	Average total yield	Market price	Total income	Net profit	Water consumptive use (m3/fed)	Net return from unit water consumptive use	Water applied m3/fed	Net return from unit water applied L.E/m3
Gated pipes (A2)	(b1)	300	300	130	100	3200	525	1660	905	300	125	525	120	150	8340	13.162	1050	13820.10	5480.10	1432.20	3.82	2209.56	2.48
	(b2)	300	300	130	100	3200	525	1660	1155	300	125	525	120	150	8590	13.160	1050	13818	5228	1489.32	3.51	2224.28	2.35
	B3	300	300	130	100	3200	525	1660	655	300	125	525	120	150	8090	11.150	1050	11707.50	3617.5	1565.34	2.31	2405.08	1.50
	B4	300	300	130	100	3200	525	1660	1155	300	125	525	120	150	8590	13.800	1050	14490	5900	1299.48	4.54	2154.82	2.73
	B5	300	300	130	100	3200	525	1660	1155	300	125	525	120	150	8590	13.316	1050	13981.8	5391.80	1473.36	3.66	2274.71	2.37

Calculated the costs of network of irrigation gated pipes covered annually based on the life span for irrigation network is five years

Table (9): Average values of total costs, production, total income (L.E) and net return per cubic meter a water (L.E /m3) by surface irrigation and potassium fertilizer for potato crop (lady Rosetta) in the two studied seasons

Treatments		The total costs (L.E)														Yield (ton /fed)	Total return L.E /fed.				Water issues L.E/m3			
		Land preparation	Irrigation network	Leveling by laser	harvest and the transfer of seed	seed	Cultivate Labors	Rent	Chemical fertilizer	Service & tillage Labors	Fuel (oils diesel	Harvest	Irrigation labors	Pesticides	**Total costs	Average total yield	Market price	Total income	Net profit	Water consumptive use (m3/fed)	Net return from unit water consumptive use	Water applied m3/fed	Net return from unit water applied L.E/m3
Surface irrigation (A_1)	(b_1)	350	-	-	100	3000	525	1660	905	500	180	525	180	250	8175	12.250	1050	12862.5	4687.5	1570.38	2.98	2882.56	1.81
	(b_2)	350	-	-	100	3000	525	1660	1155	500	180	525	180	250	8425	11.925	1050	12521.25	4096.25	1672.62	2.44	2637.26	1.55
	B3	350	-	-	100	3000	525	1660	655	500	180	525	180	250	7925	11.047	1050	11599.35	3674.35	1820.70	2.01	2896.92	1.27
	B4	350	-	-	100	3000	525	1660	1155	500	180	525	180	250	8425	12.638	1050	13269.9	4844.9	1429.26	3.39	2519.68	1.92
	B5	350	-	-	100	3000	525	1660	1155	500	180	525	180	250	8425	12.325	1050	12941.25	4516.25	1604.82	2.81	2748.01	1.64

Calculated the costs of network of irrigation gated pipes covered annually based on the life span for irrigation network is five years

Table (10) Average values of total costs, total income, net profit (L.E/ fed) and economic efficiency as affected by irrigation systems and potassium fertilizer for potato crop in the two studied seasons:-

Treatments		Total return	Total cost LE/fed	Net profit (L.E/fed.)	Economic efficiency
A	B				
Surface irrigation (A_1)	b1	**13218.45**	**8175**	**4687.5**	0.57
	b2	**12521.25**	**8425**	**4096.25**	0.49
	b3	**11599.35**	**7925**	**3674.35**	0.46
	b4	**13269.9**	**8425**	**4844.9**	0.58
	b5	**2941.25**	**8425**	**4516.25**	0.54
Average					**0.52**
Improving surface irrigation (gated pipes) (A_2)	b1	**13820.10**	**8340**	**5480.10**	0.66
	b2	**13818**	**8590**	**5228**	0.61
	b3	**11707.50**	**8090**	**3617.5**	0.45
	b4	**14490**	**8590**	**5900**	0.69
	b5	**13981.8**	**8590**	**5391.80**	0.63
Average					

Conclusion

Results and analysis of the research presented showed that the use of gated pipes irrigation system had a positive impacts on crop production and on farm irrigation water saving. So this method becomes very important in saving water and obtaining high yield where this not need requires well trained skilled labour. Therefore, the introduction of this method lies primarily on the shoulder of government institutions, cooperatives and large companies then in the future the improving surface irrigation by gated pipes in beds will started to be widely introduced in Egypt. Results indicated that the planting potato crop by gated pipes system with Potassium salphat at rate 96 Kg/ fed k2o. + Salicylic acid at rate 200 ppm. would lead to an increase in crop productively by about 19.94% Moreover water use was reduced by about 25.62 % per year and improved total irrigation efficiency up to 72.87 Large scale application of the improved irrigation system combined with proper fertilizer applications would require some significant investments and buying in by relevant stakeholders. it could. however provide some substantial saving in the irrigation water used and increased potato production.

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