

Improvement of Water Use Efficiency on Potato Production

3- Response yield and quality of potato plants to moisture deficit and planting method

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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 2012 and 2013 seasons. The present research was carried out to study the effect of water stress and planting methods on yield, saving water and quality for Potato crop (*Solanum tuberosum* L). A split plot design with three replicates was conducted. The main plots were assigned to five irrigation treatments traditional irrigation (the farmers practices), 100%, 90%, 80% and 70% of field capacity for potato crop and the sub plots into two planting methods (furrow and beds). The treatments of irrigation were distributed at random in the main plots. While planting methods treatments were distributed at random in the sub-plots. Results indicate that irrigation regime significantly affected total yield in both seasons, where values of total yield/fed. were increased as water stress increased until 80% of field capacity then decreased with 70% of field capacity in both seasons. Also planting method was significantly affected this character in both seasons. The highest yield of potato was obtained with planting in beds and saving water about 14.42% compare to planting in furrow in both seasons. The obtained results in present study show that when the best method was used (irrigated potato until 80% of field capacity and planting in beds A₄b₂) the irrigation water is saved more than the normal planting in furrow (common method in region) by about 29.72% in both seasons. This treatment was the most superior treatments (from view point water and production) on this character. Starch content values were significantly increased as water stress was decreased where the highest values of starch content (based on dry weight) were obtained when plants irrigated by conventional irrigation (72.820 and 74.400) in the first and second seasons, respectively. Planting method significantly affected this character in both seasons, where the highest values were obtained from plants which planting in beds in both seasons. The interactions between the studied factors significantly affected starch content in both seasons. Irrigation regime significantly affected the protein content in both seasons, where the highest value was obtained from plants which irrigated with conventional irrigation (6.958 and 7.035%) in the first and second seasons, respectively. Irrigation regime significantly affected total soluble solids percentage (TSS) and dry matter content in both seasons, where they were increased with increasing water stress in both seasons, and the maximum values of (TSS) and dry matter content were recorded when plants grown at the lowest level of water supply i.e. irrigation at 70% depletion of available water. Irrigation regime was significantly affected the specific gravity (g/cm³) of potato in both seasons, where the specific gravity was increased significantly as water stress was increased. Planting methods significantly affected on this character the second season only. The higher values were obtained from plants which cultivated in beds 1.312 and 1.274 (g/cm³) in the first and second seasons, respectively. Irrigation regime significantly affected nitrite concentration in both seasons where was increased with increasing water stress in both seasons results show that, when water stress increased, nitrite concentration was decreased. It could be recommended that irrigated potato crop until 80% of field capacity and planting in beds instead of planting in furrow to produce high yield and quality with less amount of water applied under El-Minia province conditions.

Key words: Irrigation regime, potato crop, planting method, production.

INTRODUCTION

Egypt is facing the steady increase of its population and in the meantime; it facing the stability of both agricultural areas and available water supply, this fact caused the increase of

the food gap between its production and consumption. Therefore, the state is considering carrying out horizontal expansion programs in order to add new areas to the current agricultural areas, taking in consideration, its protection against random urban extensions. Also, the state is giving its attention to water resources development; it's securing, increasing its usage efficiency and maximizing its returns. Therefore, the state is following scientific methods to fulfill such aims in order to meet the increasing demand for water in different usages. The Egyptian water budget is confined to the country's share of Nile water, which is fixed at 55.5 billion m³/year, in addition to minor quantities of rainfall in the coastal regions. So irrigation is one of the most important cultural practices in the production of vegetable crops to determine the best irrigation practices for vegetable crops. It is necessary to ascertain to what extent the water in the root zone be depleted to produce high yield and quality with using little water applied.

Potatoes may be more sensitive to water stress than many other crops because it has a sparse root system that is concentrated in the upper-30 cm soil layer Van Loon (1981) so irrigation can be improve the yield and quality of poptato. However irrigation must be planned, taking account of the crop, soil and weather conditions. There are many authors showed that yield and quality of potato increase with increasing irrigation. Mikhailov (1973) obtained the highest tubers yield with soil moisture content at 80% field capacity in the 0.7m soil layer. He added that a pre-planting irrigation increased yield, whereas its effectiveness was negligible when irrigations were applied during growth. Pertrunin *et al.* (1975) reported that irrigations at the depletion of soil moisture contents 80% of field capacity gave the highest tubers yield. Wiese *et al.* (1975) found that adequate water supply up to the end of flowering ensured a high final tuber yield. Tomar *et al.* (1976) found that the highest tuber yield obtained with optimum irrigation to be at 55% available soil moisture in the top of 30 cm soil layer. Gunbatili (1986) found that irrigation at 20% or 35% depletion of available water was recommended as most economic. Mackerron and Jefferies (1988) found the drought of potato decreasing the yield. The main reason for lower yield in the droughted crops was had fewer tubers reached the min size (40mm). Bosnjak *et al.* (1997) found that tubers yield were highest in the 75-80% field capacity. This was equivalent to water requirement of 460-480 mm/season. Uppal *et al.* (1997) studied the withdrawal of irrigation on yield of potato on a sandy loam soil during autumn season. They found that withdrawal of irrigation 2-4 weeks before harvesting did not significantly affect tubers yield on potato and increased water expense efficiency. Ghosh *et al.* (2000) found that tubers yield decreased with decreasing soil moisture with the greatest reduction at 45% F.C.. Jefferies and Mackerron (1987) and Jefferies (1992) reported that the specific gravity was increase with decreasing water amount of irrigation. Davies *et al.* (1989) found that the imposition of water stress in field grown potato plants decreased tubers growth rate and increased tubers starch and protein contents. Bailey (1990) found that potato tubers and quality can be reduced by water stress occurring at any time during the growing season. Amer *et al.* (1992) found that the fresh and dry matter yield of potato responded positively to the increased quantity of irrigation water but tubers yield was not affected by excess irrigation. Exclusion of late season irrigation reduced tubers yield. Gunel and Karadogaun (1998) studied the effect of irrigation applied at different growth stages and length period irrigation on quality of potato tubers. The irrigation treatments were imposed when available water in soil dropped to 25%, 50% or 75% of field capacity and irrigation ceased 10 or 20 days before maturing . They found that frequent irrigation significantly increased specific gravity, dry matter, starch content, chip yield, and significantly decreased protein content at growth stages of stolen initiation and stolen initiation tubers bulking. Frequent irrigations at final growth stage had deleterious effect on specific gravity, dry matter, starch content and chip especially when irrigation continued until maturity. Gregory *et al.* (1999) indicated that high irrigation

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treatments significantly reduced specific gravity and increased tubers size . Ramnik *et al.* (1999) found that potato tubers yield protein content increased with increased irrigation and rates up to 150 kg N/ha Al- Banna *et al.* (2001) stated that specific gravity of the tuber was significantly increased with decreasing irrigation rate. Eremeev *et al.* (2001) pointed out that the higher starch content of cvs. “Sulev” and “Zvilkav” was caused by a favorable moisture and water regime over the growing period. Meleha (2002) showed that the highest values of water applied were recorded with the furrow irrigation system and 50% depletion of a available soil moisture content. While, the lowest values were recorded with bed irrigation system and 80% depletion of available soil moisture content. Mushtaq *et al.* (2012) evaluated four planting method; raised bed, ridging, drilling and broadcasting. Results revealed that raised bed and ridge sowing methods of wheat plantation saved 22.47 and 13.26% irrigation water, respectively over flat sowing either by drilling or broadcasing. Nigus (2013) recommended that applying irrigation water 75% of full irrigation depth throughout the whole growing season of potato with frequency based on Cropwat model scheduling-2 days resulted better yield, saved significant depth of water and improved WUE which can be taken as optimum irrigation depth and frequency. Cantore *et al.*, (2014) reported that Water stress significantly affected yield response. Abubaker *et al.* (2014) showed that the tubers yield was increased during the first season on the behalf of water supplied as compared to other. Present work was evaluated the effect of irrigation regime and planting method on water applied, water saving and yield and quality for potato crop.

MATERIALS AND METHODS

Two field experiments were carried out at two Winter seasons of 2012 and 2013, at Mallawy, Water Requirements Research Station – El Minia Governorate; Water Management Research Institute - National Water Research Center. The present research was carried out to evaluate the irrigation regime and planting method (furrow or beds) on water applied, water saving, yield and quality for potato crop c.v. Cara. The experiment was included five irrigation treatments and two planting methods with three replicates so that the experiment was arranged in a split plot design. The treatments of irrigation were distributed at random in the main plots (the farmers practices, 100%, 90%, 80% and 70% of field capacity). While, planting method treatments furrow and beds were distributed at random in the sub-plots. The experiment consists of 30 plots and each plot was 24 m² included 10 rows when planting in furrow and five when planting in bed. Potato tubers were planted at spacing of 20 cm and 10 cm in depth with in (furrow was 4 m in length and about 60 cm in width, beds were 4 m in length and about 120 cm in width). The recommended N fertilizer (150 g N/fed) were given in a form of ammonium sulphate (20.6% N) (at rate 50 ammonium sulphate kg/fed) was added before planting during soil preparation to stimulate germination and ammonium nitrate (33.5% N) was divided into two equal parts (at rate 200 kg ammonium nitrate in every part/fed) and applied at side dressing at 45 and 60 days after planting and phosphorus (62 kg P₂O₅/fed) was applied before cultivation during soil preparation in a form of calcium super phosphate (15.5% P₂O₅). While, potassium was applied in a form of potassium sulphate (48%K₂O) at two rates 200 kg/fed was divided into two equal parts and applied with leaching irrigation at side dressing at 45 and 60 day after planting. Other cultural practices were done as a recommended for potato production. All the agronomic practices except the irrigation treatments it was applied as a commonly use in growing potatoes. Potato tubers (cv.Cara) were planed on September 10th and arvesting date for the two seasons was 30 December in 2012 and 2013 seasons .

Soil samples were taken randomly from depths of 0-15, 15-30, 30-45 and 45-60 cm before planting during the two studied seasons to determine the physical and chemical properties of the experimental soils. Some physical properties of the experimental soil (Table 1).

Table (1): Mean of some mechanical and physical properties of the experimental soil before planting date:

Soil depth (cm)	Particle size distribution			Texture	Infiltration rate (mm/hours)	Bulk density (g/cm ³)	Soil moisture characteristics		
	Sand%	Silt%	Clay%				Field capacity%	Wilting point%	Available water%
0-15	16.91	25.25	57.84	clay		1.17	43.40	22.30	21.10
15-30	17.91	26.51	55.59	clay	10	1.24	38.90	21.10	17.80
30-45	19.31	27.41	53.28	clay		1.33	36.51	19.51	17.00
45-60	20.98	28.3	50.72	clay		1.37	33.99	18.09	15.90
Average	18.78	26.87	54.36	clay		1.28	38.2	20.25	17.95

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

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 of (Masoud, 1967):

$$Q = CLH^{3/2}$$

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 m³/fed. Early A.C (1975).

Total yield (ton/fed):

At harvest date ten plants were randomly taken from each experimental plot to determine weight of tubers /plot (kg) then calculated total yield (ton/fed).

Quality characters:

- Dry matter of tubers was estimated by drying 100 grams of fresh harvested tubers from each treatment at 70° C till the weight became constant and the percentage of dry matter content was calculated.
- Total soluble solids (TSS) percentage in tuber was estimated by hand refractometer (Cox and Pearson, 1962).
- Specific gravity of tubers was determined from samples weighted in air and water and S.G. was calculated as follows:

$$S.G = \frac{\text{Tuber weight in air}}{\text{Tuber weight in air} - \text{Tuber weight in the water}}$$

It was determined according to methods of Smith (1970).

- Starch content was determined according to the method described by Clegg (1956).
- Protein (%) was calculated according to Ranganna (1977), using:

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$$\text{Protein (\%)} = \text{Nitrogen (\%)} \times 6.25$$

- f. Nitrite concentration was determined using a spectrophotometric method after color reaction with Griess reagent (Polish standard method, 1992).

Data obtained from experimental treatments were subjected to the analysis of variance and treatments means were compared using the L.S.D method according to Steel and Torrie (1980).

RESULTS AND DISCUSSION

Water applied (m³/fed.)

Data in Table (2) show that the irrigation regimes are significantly decrease as water stress increase where the highest quantity of water applied are obtain by conventional irrigation farmer practices A₁ (2640.58 m³/fed) in both studied seasons. On the contrary, minimum of water applied in the two studied seasons was obtained when irrigated potato at 70% of field capacity A₅ (2013.47 m³/fed). Regarding to the planting methods significantly affecte in both both seasons where the highest values are obtaine from plants which planting in furrow (2530.07 m³/fed) in two studies seasons while, the lowest value of water applied are obtain from plants which cultivated in beds (2165.18 m³/fed). It is clear from data (from view point of water) when planting in beds we can save water of irrigation about 364.89 m³/fed (14.42%) under all treatments compare to planting method in furrow. It could be conclude that 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 soil environment, fertilizers and ground water over the long term. So the irrigation regime in beds is responsible for obtaining a high productivity of potato with least possible amount of water applied. These results are similar to those findings by Meleha (2002) and Mushtaq *et al.* (2012). Concerning the interactions between the two studied factors , data in Table (2) show that all interactions have a significant effect in both seasons.

Table (2): Average of the quantity of applied water (m³/fed) and saved water (m³/fed and %) of potato for different treatments in the two studied seasons 2012 and 2013.

Treatments Irrigation regimes (A)	Water consumptive use (cm/season)		Mean (A)
	Planting method (B)		
	b1	b2	
A1	2893.58	2387.58	2640.58
A2	2709.01	2356.16	2532.59
A3	2527.11	2197.96	2362.56
A4	2350.07	2033.72	2325.40
A5	2170.47	1856.47	2013.47
Mean (B)	2530.07	2165.18	
L.S.D. 5%	A = 10.08 *	B=18.77	
	AB=14.26*		

A1- Conventional irrigation by farmer practices.

A2- Irrigation until 100% of field capacity.

A3- Irrigation until 90% of field capacity.

A5- Irrigation until 70% of field capacity.

B1- Planting in furrows.

B2- Planting in beds.

A4- Irrigation until 80% of field capacity.

Total yield (ton/fed.)

Data in Table (3) show that total yield (ton/fed.) significantly decrease as a water stress increase until 80% of field capacity then decrease with increasing water stress. The

highest yield of potato are obtain when irrigation until 80% of field capacity (13.505 and 13.600 ton/fed) in the first and second seasons, respectively. On the contrary, minimum of total yield in the two studied seasons are obtain when irrigation potato until 70% of field capacity (7.750 and 7.710 ton/fed) in the first and second seasons, respectively. It can be terminated that, total yield of tubers increased with water stress . This might be attributed to positive effect of this treatment on number of cells through cell division as on cell size through cell enlargement and turgidity. These results are similar to those findings by Mikhailov (1973) & Nigus (2013) *and* Cantore *et al.* (2014).

Regarding the planting method effect on this character, data in Table (3) show that the highest mean value are obtain when planting potato in beds (11.631 and 11.558 ton/fed) while the lowest mean values are obtain when plating potato in furrow (10.658 and 10.662 ton/fed) in the first and second seasons, respectively. These results are similar to those findings by Meleha (2002).

Concerning the interactions between the two studied factors, data in Table (3) show that the highest values are obtain from treatment which irrigated until 80% of field capacity and planting in beds A₄b₂ in the two stuided seasons. This treatment are the most superior treatments (from view points water and production) on this character are 14.256 and 14.150 ton/fed. in the first and second seasons, respectively.

Also, data in Table (3) show that the percentages of increasing in tubers yield are increase more than the conventional irrigation method compared to irrigation until 80% of field capacity and planting in beds (41.24 and 38.32%) in the first and second seasons, respectively. These results reflex how much irrigation water can be save to produce the highest yield with least possible amount of water applied.

Table (3): Effect of irrigation regimes and planting methods on productivity (ton/fed) of potato in the two studied seasons (2012 and 2013).

Treatments	1 st season			2 nd season		
	B1	B2	Mean (A)	B1	B2	Mean (A)
A1	10.100	10.950	10.525	10.230	10.820	10.525
A2	10.500	11.120	10.810	10.220	11.520	10.870
A3	12.445	13.820	13.133	11.950	13.740	12.845
A4	12.745	14.265	13.505	13.050	14.150	13.600
A5	7.500	8.000	7.750	7.860	7.560	7.710
Mean (B)	10.658	11.631		10.662	11.558	
L.S.D. 5%(A)			0.43*			0.79*
(B)			1.01*			1.13*
(AB)			0.61*			1.12*

* Significant

ns non-significant

A1- Conventional irrigation by farmer practices.

A2- Irrigation until 100% of field capacity.

A3- Irrigation until 90% of field capacity.

A4- Irrigation until 80% of field capacity.

A5- Irrigation until 70% of field capacity.

B1- Planting in furrows.

B2- Planting in beds.

Water saving (m³/area)

Data in Table (4) show that the average quantity of water saving (m³/fed.) between the best treatment A₄b₂ (irrigated potato until 80% of field capacity and planting in beds) and conventional irrigation in furrow (common method in region).

The obtaine results in present study show that when the best method are using (irrigated potato until 80% of field capacity and planting in beds) the irrigation water is save more than the normal planting in furrow (common method in region) by about 29.72%. These

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results show also that, the amount of water irrigation which can be saved (average area cultivated by potato in El- Minia region) about 179.216.320 million m³/area compared to normal planning in furrow. This amount of saving water enough to cultivate area about (generally) 28002.550 feddan in old land under El-Minia conditions. These results reflect how much irrigation water can be save when using this treatment. 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 cultivate 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 fertilizers. These results reflect how much irrigation water can be save to produce the highest yield with least possible amount of water applied where the farmer's practices in potato (conventional irrigation treatment) utilize much water without giving higher productivity.

Table (4): Water saving (m³/fed) which obtained from the best treatment (A₄b₂) compared to conventional methods in the region for potato crop during the both studied seasons 2012 and 2013.

	Normal planting in furrow (common method in region)	The best treatment from view point water and economic
Increase of yield (ton/fed)	10.102	14.268
		4.166
% of increase in yield		41.24%
Water applied (m ³ /fed)	2893.58	2033.72
Saved water		859.86 m ³ /fed
		29.72%
*Average area cultivated of potato crop in Egypt (fed)		208425
Total of water saving million/m ³ /area		179.216.320
The area (fed.) of old land which can be cultivated as a resulting of saving water		28002.550

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 2015.

Quality characters

a- Starch content (%)

Data of starch percentage in potato tubers as affected by irrigation water levels and planting methods during 2012 and 2013 seasons are present in Table (5).

Data in Table (5) reveal that irrigation regime significantly affect this character, in both seasons. Starch content values are significantly increase as water stress decrease. It could be concluded that the highest values of starch content (based on dry weight) are obtain under conventional irrigation treatment (practice by farmers) (72.820 and 74.400%) in the first and second seasons, respectively. These results indicate the importance the first irrigation treatment (A₁) on this character. These results are in line with those obtained by Gunel and Karadogaun (1998) and Eremeev *et al.*, (2001) who found that starch content of tubers are increase with increasing the irrigation frequency. On the other hand, these results disagree with Davies *et al.* (1989). They found that starch content of tubers was decreased with increasing the irrigation frequency. It is worthy to mention that starchy tubers are desired

for some potato processing activities, such as chips and deep frying, but not for potato boiling because the tubers breaks down during the process.

Regarding to planting methods effect on this character, data in Table (5) show that planting method significantly affect starch content (%), in both seasons. Starch content increase with planting in beds where the highest value are obtain from plants which cultivate in beds (70.580 and 71.424%) in the first and second seasons respectively. While, the lowest value are obtain from plants which cultivate in furrow (69.282 and 69.994%) in the first and second seasons, respectively.

Data in Table (5) indicate that the interactions among the studied factors significantly affected starch content in both seasons.

Table (5): Effect of irrigation regimes and planting methods on starch content (%) of potato in the two studied seasons (2012 and 2013).

Treatments	1 st season			2 nd season		
	B1	B2	Mean (A)	B1	B2	Mean (A)
A1	72.230	73.410	72.820	73.350	75.450	74.400
A2	70.150	72.380	71.265	71.150	73.450	72.300
A3	69.780	70.070	69.925	70.030	71.090	70.560
A4	68.150	69.170	68.660	68.290	69.200	68.745
A5	66.100	67.870	66.985	67.150	67.930	67.540
Mean (B)	69.282	70.580		69.994	71.424	
L.S.D. 5%(A)			0.12*			0.12*
(B)			0.24*			0.86*
(AB)			0.17*			0.17*

* Significant ns non-significant

A1- Conventional irrigation by farmer practices.

A2- Irrigation until 100 % of field capacity.

A3- Irrigation until 90% of field capacity.

A5- Irrigation until 70% of field capacity.

B1- Planting in furrows.

B2- Planting in beds.

A4- Irrigation until 80% of field capacity.

b- Protein content (%)

Data concerning the total protein in potato tubers with different irrigation water levels and planting methods are present in Table (6). The obtain results show that, when water stress increase, total protein are decrease. The values of protein content varied from 6.030 to 6.958% with conventional practice by farmer in the first season and 5.888 to 7.035 in the second seasons, respectively. It could be concluded that the highest values are obtain with irrigation treatment which have relatively higher amount of irrigation water, while the lower values are observe under treatments which have relatively less amount of irrigation water. This increase can be attributing to high absorption nitrogen with favorable moisture conditions. The obtain results are confirmed with those reported by Ramnik *et al.* (1999). They found that protein content increased with increasing irrigation, but these results are disagree with those reported by Davies *et al.* (1989).

Table (6): Effect of irrigation regimes and planting methods on protein content (%) of potato in the two seasons studied (2012 and 2013).

Treatments	1 st season			2 nd season		
	B1	B2	Mean (A)	B1	B2	Mean (A)
A1	6.905	7.010	6.958	6.960	7.110	7.035
A2	6.845	6.935	6.890	6.885	6.915	6.900
A3	6.705	6.800	6.753	6.740	6.840	6.790
A4	6.200	6.400	6.300	6.335	6.500	6.418
A5	5.960	6.100	6.030	5.825	5.950	5.888
Mean (B)	6.463	6.209		6.549	6.663	
L.S.D. 5%(A)			0.20*			0.13*
(B)			0.22^{ns}			0.14^{ns}
(AB)			0.29^{ns}			0.18^{ns}

* Significant ns non-significant

A1- Conventional irrigation by farmer practices.

A2- Irrigation until 100% of field capacity.

A3- Irrigation until 90% of field capacity

A5- Irrigation until 70% of field capacity.

B1- Planting in furrows.

B2- Planting in beds.

A4- Irrigation until 80% of field capacity.

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Also in Table (6) data show that the effect of planting methods on protein content have insignificant effect, in both seasons. With regard to the interactions among the studied factors, data in Table (6) indicate that the interactions among the studied factors insignificantly affect protein content (%) in both seasons.

c- Dry matter of tubers (%)

Data in Table (7) show that the effect of irrigation treatments and planting methods on dry matter of potato tubers. These results reveal that dry matter content of potato tubers reached its maximum value at the lowest level of water supply, irrigation after 70% of field capacity (21.917 and 22.634%) in the first and second seasons, respectively. That means, the values of dry matter increase with increasing water stress. These results are in agreement with those reported by Amer *et al.* (1992), Ali (1993) and Gunel and Karadogaun (1998).

Regarding to planting methods effect on this character, data in Table (7) show that planting methods significantly affect on dry matter of potato tubers in both seasons. Dry matter of potato tubers are significantly increase when planting potato crop in beds. The highest values (20.373 and 21.497%) are obtain from plants which cultivate in beds.

Data in Table (7) indicate that all the interactions among the studied factors are significantly affect dry matter of potato tubers in the two seasons.

Table (7): Effect of irrigation regimes and planting methods on dry matter of potato (%) of potato in the two studied seasons (2012 and 2013).

Treatments	1 st season			2 nd season		
	B1	B2	Mean (A)	B1	B2	Mean (A)
A1	18.300	18.600	17.450	18.700	19.850	19.275
A2	18.233	19.367	18.800	19.100	20.600	19.850
A3	18.733	20.200	19.467	19.500	21.800	20.650
A4	19.767	21.433	20.600	20.000	22.133	21.067
A5	21.567	22.267	21.917	22.167	23.100	22.634
Mean (B)	18.920	20.373		19.893	21.497	
L.S.D. 5%(A)			0.14*			0.11*
(B)			0.14*			0.05*
(AB)			0.20*			0.15*

* Significant *ns* non-significant

A1- Conventional irrigation by farmer practices.

A2- Irrigation until 100% of field capacity.

A3- Irrigation until 90% of field capacity

A5- Irrigation until 70% of field capacity.

B1- Planting in furrows.

B2- Planting in beds.

A4- Irrigation until 80% of field capacity.

d- TSS percentage

Data presented in Table (8) show that the effect of different irrigation treatments and planting methods on percentages of TSS of potato tubers after harvesting in both seasons.

Data in Table (8) reveal that the total soluble solids of potato tubers increase with reduction in water content of soil. The maximum values of TSS are record when plants grown at the lowest level of water supply, irrigation until 70% of field capacity in both seasons.

In general, it can be reported that TSS became high with reduction in water content of soil. These results are in accordance with those reported by Uppal *et al.*, (1997) on different crop plants. Regarding to planting methods effect on T.S.S, data in Table (8) show that planting methods affect TSS in both seasons, where the percentages of TSS are increase as planting in beds compare to planting in furrow are (6.668 and 6.708%) in the first and second seasons, respectively.

Concerning the interactions among the studied factors data in Table (8) shows that all interactions among the studied factors have insignificant effects on percentages of TSS in potato tubers, in both seasons.

Table (8): Effect of irrigation regimes and planting methods on total soluble solids (%) of potato in the two studied seasons (2012 and 2013).

Treatments	1 st season			2 nd season		
	B1	B2	Mean (A)	B1	B2	Mean (A)
A1	6.140	6.130	6.135	6.030	6.280	6.155
A2	6.300	6.310	6.305	6.160	6.470	6.315
A3	6.750	6.650	6.700	6.410	6.580	6.495
A4	6.960	7.100	7.030	6.880	7.000	6.940
A5	7.130	7.250	7.190	7.190	7.210	7.200
Mean (B)	6.656	6.688		6.534	6.708	
L.S.D. 5%(A)			0.12*			0.17*
(B)			0.04^{ns}			0.15*
(AB)			0.17^{ns}			0.24^{ns}

* Significant ns non-significant

A1- Conventional irrigation by farmer practices

B1- Planting in furrows.

A2- Irrigation until 100% of field capacity.

B2- Planting in beds.

A3- Irrigation until 90% of field capacity.

A4- Irrigation until 80% of field capacity.

A5- Irrigation until 70% of field capacity.

e- Specific gravity (g/cm³)

Concerning specific gravity of tubers with different available soil moisture depletion levels and planting methods are present in Table (9).

The obtain results show that when water applied increase, specific gravity are decrease. Average values of specific gravity ranged from 1.105 to 1.440 and from 1.075 to 1.400 in the first and second seasons, respectively. The relatively higher values of the present study with the fifth irrigation treatment (70% of field capacity) in both seasons may be due to accumulation of more starch in tubers. These results are in harmony with those obtained by Gunel and Karadogun (1998). They found that frequent irrigation significantly increased specific gravity.

Regarding to the effect of planting methods on this character. Data in Table (9) show that planting methods significantly affect specific gravity of potato tubers in the second season only. The higher values are obtain from plants which cultivated in beds 1.312 and 1.274 (g/cm³) in the first and second seasons, respectively.

Data illustrate in Table (9) show that the interactions between the two studied factors are insignificantly affect this traits.

Table (9): Effect of irrigation regimes and planting methods on specific gravity (g/cm³) of potato in the two studied seasons (2012 and 2013).

Treatments	1 st season			2 nd season		
	B1	B2	Mean (A)	B1	B2	Mean (A)
A1	1.090	1.120	1.105	1.070	1.080	1.075
A2	1.170	1.200	1.185	1.160	1.180	1.170
A3	1.280	1.340	1.310	1.250	1.310	1.280
A4	1.380	1.420	1.400	1.350	1.390	1.370
A5	1.400	1.480	1.440	1.390	1.410	1.400
Mean (B)	1.264	1.312		1.244	1.274	
L.S.D. 5%(A)			0.12*			0.17*
(B)			0.04^{ns}			0.15*
(AB)			0.17^{ns}			0.24^{ns}

* Significant ns non-significant

A1- Conventional irrigation by farmer practices.

B1- Planting in furrows.

A2- Irrigation until 100% of field capacity.

B2- Planting in beds.

A3- Irrigation until 90% of field capacity.

A4- Irrigation until 80% of field capacity.

A5- Irrigation until 70% of field capacity.

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f- Nitrite concentration

Data concerning the nitrite concentration in potato tubers with different irrigation regimes and planting methods are present in Table (10). The obtain results show that, when water stress increase, nitrite concentration are decrease. It could be concluded that the highest values are obtain with irrigation treatment which have relatively higher amount of irrigation water, while the lower values are observe under treatments which have relatively less amount of irrigation water. This increase can be attributing to high absorption nitrogen with favorable moisture conditions.

Table (10): Effect of irrigation regimes and planting methods on nitrite concentration (ppm) of potato in the two studied seasons (2012 and 2013).

Treatments	1 st season			2 nd season		
	B1	B2	Mean (A)	B1	B2	Mean (A)
A1	0.585	0.590	0.578	0.590	0.605	0.580
A2	0.590	0.610	0.518	0.600	0.620	0.525
A3	0.505	0.520	0.513	0.530	0.540	0.530
A4	0.490	0.495	0.493	0.500	0.520	0.495
A5	0.475	0.480	0.478	0.490	0.510	0.480
Mean (B)	0.516	0.515		0.527	0.517	
L.S.D. 5%(A)			0.02*			0.02*
(B)			0.02^{ns}			0.01^{ns}
(AB)			0.03^{ns}			0.03^{ns}

* Significant ns non-significant

A1- Conventional irrigation by farmer practices.

B1- Planting in furrows.

A2- Irrigation until 100% of field capacity.

B2- Planting in beds.

A3- Irrigation until 90% of field capacity.

A4- Irrigation until 80% of field capacity.

A5-

Irrigation until 70% of field capacity.

Also, in Table (10) data show that the effect of planting methods on nitrite concentration have insignificant effect, in the first and second seasons. Nitrite concentration are increase with planting potato in furrow compare to planting in beds where the highest values obtain from plants which cultivate in furrows (0.516 and 0.527 ppm) in the first and second seasons, respectively.

With regard to the interactions among the studied factors, data in Table (10) indicate that the interactions among the studied factors insignificantly affect nitrite concentration in both seasons.

CONCLUSION

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

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إستجابة إنتاجية وجودة محصول البطاطس للنقص الرطوبي وطريقة الزراعة

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المستخلص

أجريت تجربتين حقليتين خلال موسم الزراعة لعامي 2012-2013م بمحطة مقننات رى ملوى البحثية التابعة لمعهد بحوث ادارة المياه - المركز القومي لبحوث المياه بهدف دراسة تأثير أسلوب الري وطريقة الزراعة على الإحتياجات المائية الفعلية وإنتاجية وجودة محصول البطاطس صنف كارا وقد إشتملت التجربة على خمس معاملات لأسلوب الري المضاف وهي A₁ الري التقليدي السائد فى المنطقة A₂ (الري حتى الوصول إلى 100% سعة حقلية)، A₃ (الري حتى الوصول إلى 90% سعة حقلية)، A₄ (الري حتى الوصول إلى 80% سعة حقلية)، A₅ (الري حتى الوصول إلى 70% سعة حقلية) بالإضافة إلى الري التقليدي السائد بالمنطقة وكذلك اشتملت التجربة على معاملتين رئيسيتين لطريقة الزراعة (الزراعة على خطوط b₁ - الزراعة على المصاطب b₂) لذا اشتملت التجربة على خمس معاملات لأسلوب الري المضاف ومعاملتين لطريقة الزراعة ولثلاثة مكررات لذا صممت التجربة قطع منشقة spilt- plot.

وفي ضوء ما سبق يمكن تلخيص النتائج المتحصل عليها كالتالى:

- أظهرت النتائج بأن هناك تأثيراً معنوياً لأسلوب الري على الإحتياجات المائية الفعلية للمحصول حيث إنخفضت الإحتياجات المائية للمحصول كلما زاد الإجهاد المائي خلال موسم الدراسة كما كان لطريقة الزراعة تأثيراً معنوياً على الإحتياجات المائية الفعلية خلال موسم الزراعة حيث أدت طريقة الزراعة على مصاطب بصفة عامة تحت جميع معاملات الري الرئيسية إلى الحصول على وفر مائي قدر بنحو 364.89 م³/فدان بما يوازي 14.42% ذلك مقارنة بالزراعة على خطوط.

- أدى التفاعل للمعاملة الرابعة A_4b_2 (إضافة المياه حتى الوصول إلى 80% من السعة الحقلية مع الزراعة على مصاطب) إلى الحصول على أعلى إنتاجية من المحصول الرئيسي (14.268 طن للفدان) خلال موسمي الزراعة كما أدى التفاعل للمعاملة الرابعة A_4b_2 (إضافة المياه حتى الوصول إلى 80% من السعة الحقلية مع الزراعة على مصاطب) إلى الحصول وفر مائي قدر بنحو 859.86 م³/فدان بما يوازي زيادة قدرها 29.72% وذلك عند مقارنتها بالزراعة التقليدية السائدة في المنطقة بمعرفة المزارع A_1b_1 .
- كان لأسلوب الري تأثيراً معنوياً على المحصول حيث تم الحصول على أعلى إنتاجية من المحصول من المعاملة الرابعة (13,505 و13,600 طن/فدان) في الموسمين الأول والثاني على التوالي. كما كان لطريقة الزراعة تأثيراً معنوياً على المحصول في كلا الموسمين، حيث تم الحصول على أعلى قيمة محصولية من المعاملة b_2 (الزراعة في مصاطب) (11,558 و11,631 طن/فدان) في الموسمين الأول والثاني على التوالي.
- كما كان لأسلوب الري تأثيراً معنوياً على النسبة المئوية لمحتوى النشا خلال موسمي الزراعة لدرنات البطاطس حيث إزدادت نسبة النشا في الدرنات مع انخفاض الإجهاد المائي وقد تم الحصول على أعلى القيم لمحتوى النشا بالدرنات (على أساس الوزن الجاف) من معاملة الري وهي الري التقليدي بمعرفة المزارع A_1 وكانت تلك القيم (72.820، 74.400) خلال الموسم الأول والثاني على التوالي. كما كان لتأثير طريقة الزراعة تأثيراً معنوياً على هذه الصفة حيث تم الحصول على أعلى القيم عند الزراعة في مصاطب في موسمي الزراعة.
- كما كان لأسلوب الري تأثيراً معنوياً على النسبة المئوية لمحتوى البروتين للدرنات حيث تم الحصول على أعلى القيم من معاملة الري الأولى وهي الري التقليدي بمعرفة المزارع وكانت تلك القيم 6.958، 7.035% خلال الموسم الأول والثاني على التوالي كما كان لتأثير طريقة الزراعة تأثيراً معنوياً على هذه الصفة.
- كما تأثرت النسبة المئوية للمادة الجافة بدرنات البطاطس بأسلوب الري المتبع تأثيراً معنوياً في موسمي الدراسة حيث أعطت المستويات المنخفضة وهي الري حتى الوصول إلى 70% من السعة الحقلية أعلى القيم المتحصل عليها خلال موسمي الزراعة كما كان تأثير طريقة الزراعة تأثيراً معنوياً على هذه الصفة وكذلك كانت جميع التفاعلات بين عوامل الدراسة معنوية التأثير على هذه الصفة في موسمي الزراعة.
- كما كان لتأثير أسلوب الري تأثيراً معنوياً على الكثافة النوعية للدرنات حيث إزدادت الكثافة النوعية مع زيادة التوتر الرطوبي خلال موسمي الزراعة وكان تأثير طريقة الزراعة تأثيراً معنوياً للموسم الثاني فقط على هذه الصفة كما كانت جميع التفاعلات بين العوامل غير معنوية على هذه الصفة خلال موسمي الزراعة.
- كما كان لأسلوب الري تأثيراً معنوياً على نسبة النترت في الدرنات حيث إنخفضت النسبة بزيادة الإجهاد المائي ولم يكن لطريقة الزراعة تأثيراً معنوياً على هذه الصفة وأيضاً كانت جميع التفاعلات بين عوامل الدراسة غير معنوية التأثير على هذه الصفة في موسمي الزراعة.
- ومن ثم توصي الدراسة برى محصول البطاطس صنف كارا حتى الوصول إلى 80% من السعة الحقلية مع الزراعة على مصاطب بدلاً من خطوط للحصول على أعلى إنتاجية وجودة للمحصول بأقل كميات مياه مضافه تحت ظروف محافظة المنيا والمناطق الأخرى المماثلة لها في الظروف الجوية.