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Impact of Climate Change on Water Requirements and The Productivity on Potato Crop

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TWO field trials were carried out during the two consecutive seasons,of 2014/2015 and 2015/2016, at the Experimental Farm of Arid Land Agricultural graduate studies and Research Institute (ALARI), Faculty of Agriculture, Ain Shams University in Shubra el-Khaimah, Qalyubiah Governorate. The aim of the current investigation was to study the impact of three planting dates (18-Dec, 7-Jan and 27-Jan), three irrigation levels at 60, 80 and 100% of irrigation water requirements (IR) and their interaction on potato crop productivity. 9 treatments were obtained by combination of different planting dates and irrigation levels. Planting dates were arranged as the main plots, while, irrigation levels were arranged in the sub plots, The obtained results indicated that the highest tuber yield was obtained by the first planting date (18 Dec.) during both studied seasons, While, The highest plant growth parameters and tuber yield per plant were obtained by 100% followed by 80% irrigation level during both seasons. However, the interaction effectindicated that first planting date (18-Dec) combined with 100 % irrigation level gave the highest potato tuber productivity than the other treatments, whereas the interaction of first planting date 18-(Dec) combined with 80% irrigation level gave the best for water use efficiency compared to the other treatments during both tested seasons.

Keywords: Climate changes, Planting Date, Irrigation Level, Potato, Yield, Water requirements.

Introduction

Potato (*Solanum tuberosum* L.) is one of the perennial plants of the Solanaceae family which is considered as a non-grain food commodity (Rykaczewska, 2013). Globally, potato is one of the most grown tuber crops ranking as the fourth after main cereal crops i.e. rice, wheat and maize (Gul et al., 2011 and Hailu & Mosisa, 2019). Potato tubers are the subterranean swollen, and starchy tubers. Potato which is recognized as a fundamental food for hundreds of millions of the world population (FAO, 2017). Potato is considered the fastest growing essential food crop, it has a shorter crop cycle (mostly < 120 days) than major cereal crops like maize (Beliyu & Tederose, 2014 and Berhanu & Getachew, 2014). Over half of all potato production occurs in developing countries such as Egypt (Devaux et al., 2014), annually about 388 191 thousand tonnes are produced worldwide, leading to food supply stability (FAOSTAT, 2019). In developing countries, potato is one of the most cheaply nutrients source such as protein, vitamins, macro- and micronutrients, polyphenols, carotenoids and tocopherols, thus playing a fundamental role in food security ensuring and income generation (Abebe et al., 2017). Potatoes can be used in the production of ethanol, paper industry and provide raw material to the chemical industry (FAO, 2017).

Water is a precious and unrenewable natural resource. Insufficiency of water supply has

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become the main limitation for crop production (Murad et al., 2018 and Islam et al., 2019). Potato is one of the sensitive crops to soil moisture stress, which requires a systematic water supply schedule (Ayas, 2013). This means preventing the scarcity of soil water from falling below a certain threshold level for a specific crop and soil condition. Drip irrigation for potato with different levels (40, 60, 80, and 100%) of the crop evaporation acquired a significant increase in the vegetative growth and tubers yield by increased irrigation level (Badr et al., 2012, Abu Baker et al., 2014 and Dash et al., 2018). The management practices that affect soil moisture involving irrigation techniques, irrigation strategies and mulching practices either individually or in different combinations (Chukalla et al., 2015). Planting dates have an important role in potato productivity as manipulation of light and temperature. The best yields of potato crop require long day conditions during growth and short-day conditions during tuberization (Chadha, 2009). The optimum temperature for canopy growth and photosynthesis are 15-25°C and for tuberization 20°C. Temperature higher than 29°C leads to tuberization inhibition (Dahal et al., 2019). Potato growth is significantly affected by different planting dates (Sandhu et al., 2014, Thongam et al., 2017 and Dash et al., 2018). In Egypt, previous studies reported that main objectives besides all the mulches practices retained higher amount of soil moistureand and significantly increased the yield/ plant and total yield compared with bare soil (El-Zohiri & Samy, 2013 and Abouziena et al., 2015).

The main objective of the present study is to determine the effect of planting date, water requirement and their interaction on the productivity of potato crop using a drip irrigation system.

Materials and Methods

This study consisted of two field trials during the two consecutive seasons, 2014/2015 and 2015/2016, at the Experimental Farm of Arid Land Agricultural graduate studies and Research Institute (ALARI), Faculty of Agriculture, Ain Shams University in Shubra el-Khaimah, Qalyubiah Governorate. Latitude and longitude for this farm are 30.1155436, 31.2446941.

Soil samples

Soil samples were taken before soil preparation for cultivation. Both mechanical and chemical properties of the soil were measured as following:

The mechanical analysis was determined using the international pipette method according to (Gee and Bauder, 1986) summarized in Table 1. Chemical analysis of the soil including pH, nutrients and organic residues were determined as follows: the pH value was determined by using a pH meter in a soil water suspension (1:2.5). In addition, Electrical conductivity (Ec) and soluble ions were determined in the soil according to (Westerman, 1990). Available P was determined according to (Chapman and Pratt, 1982). Nitrogen was determined in soil by Micro-Kjeldahl method according to (Westerman, 1990). Also, available Fe, Zn, Mn and Cu were determined using Pu

TABLE 1. Mechanical and chemical properties of the soil before cultivation.

Soil depth (cm)	Sand (%)	Clay (%)	Silt (%)	Texture	FC* (%)	PWP** (%)
0-30	18.18	17.71	64.11	Silt loam	32.50	13.60

ECe (dS/m)	pH	milliequivalent/l						
		Cations				Anions		
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}
2.675	7.70	30.00	16.10	10.00	5.70	0.0	10.10	21.8

ppm								
N	P	K	Ca	Mg	Fe	Zn	Mn	Cu
323.96	21	1115.83	600	193.2	15.92	15.38	59.79	15.43

9100 Atomic Absorption Spectrometer according to (FAO SOIL BULLETIN, 1989). The organic residues were standardized then used.

Plant materials and treatments

Potato tubers (*Solanum tuberosum* L.) cv. Spunta, originated from Denmark, with an average size of 35/60 and treated with fungazilTM-100 were planted on different planting dates. The distance between plants was 0.30 m apart, and the distance between rows was 0.60 m. One meter was left between each two irrigation treatment as a border among the treatments.

The present experiment involved 9 treatments, which resulted from the combinations of 3 planting dates (18th of December, 7th of January, and 27th of January) and 3 irrigation levels (60, 80, and 100% of irrigation requirements. The irrigation level calculations were performed, while the irrigation control was done using the drip irrigation system practiced through the manual valves for each hose at the top of the lines in the experimental plots. The total amount of irrigation water was calculated by Food and Agricultural Organization (FAO) Penman-Monteith (PM) procedure, FAO 56 method (Allen et al., 1998). The potential evapotranspiration was calculated as follows:

$$ET_o = \frac{0.408\Delta\,(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34\,u_2)} \quad ..\ (1)$$

Where:

ET_o = Daily reference evapotranspiration [mm d^1], Rn =Net radiation at the crop surface (MJ m^{-2} day^{-1}),G = Soil heat flux density (MJ m^{-2} day^{-1}), T =Mean daily air temperature at 2 m height (°C), U_2 =Wind speed at 2 m height (m s^{-1}), e_s = Saturation vapor pressure (kPa), e_a = Actual vapor pressure (kPa), Δ =The slope of vapor pressure curve (kPa $°C^{-1}$), γ = The psychometric constant (kPa $°C^{-1}$).

The second step was obtained to get the values of crop water consumptive use (ET_{crop}), while the crop evapotranspiration (Et_{crop}) was calculated according to (Doorenbos and Pruitt, 1977) as follows:

$$ET_{crop} = ET_o \times Kc \quad \ldots\ldots \quad mm / day \ldots (2)$$

Where:

ET_o = The rate of evapotranspiration from an excessive surface of green cover of uniform height (8 to 15 cm), actively growing, completely shading the ground and did not suffer water shortage, Kc = Crop coefficient (between 0.2 to 1.2), Water requirements (WR) for each treatment were calculated as follows:

$$WR = ET_{crop} \times LR\ \% \ldots\ldots\ldots\ldots\ldots\ldots mm / day \quad \ldots(3)$$

Where:

LR % = Leaching requirement percentage (17.9 % of the water requirement based on the Leaching Fraction equation – according to equation5), Irrigation requirement (IR) was calculated as follows:

IR = WR × R *4200 /1000 (m3/ feddan / day) .. (4)

Where:

R = Reduction factor for drip irrigation that only covers a part of land and the rest dry leaves according to (Doorenbos and Pruitt, 1977), R value ranges between 0.25 and 0.9 for drip irrigation system. The total amount of irrigation water was measured by water flowmeter for each treatment. Table 2 shows the seasonal irrigation quantities for potato crop for the three planting dates at Shubra, al-Khaimah site during the two seasons. Plants were irrigated by using drippers of 2 l/hr. capacity, leaching requirements was calculated according to (Allen et al., 1998).

TABLE 2. Seasonal irrigation quantities under different water level treatments for potato Spunta cultivar under Shubra al-Khaimah experimental conditions in 2014/2015 and 2015/2016 seasons.

Irrigation	**m^3/feddan**							
Planting dates	**First season**				**Second season**			
	60%	**80%**	**100%**	**Mean**	**60%**	**80%**	**100%**	**Mean**
18th Dec.	466.8	622.4	778	622.4	488.9	651.9	814.9	651.9
7th Jan	568.9	758.6	948.2	758.6	614.4	819.2	1024	819.2
27th Jan	679.3	905.7	1132.1	905.7	735.7	980.9	1226.1	980.9
Mean	571.7	762.2	9528.		613	817.3	1021.6	

$$LF = EC_{iw} / EC_d \quad .... \quad (5)$$

Where:

LF = leaching fraction, EC_{iw} = Electrical conductivity of irrigation water (0.480 dS/m), EC_d = Electrical conductivity of drainage water 2.675 dS/m, LF = 0.480 / 2.675 = 0.179.

Recommended cultivation practices according to Ministry of Agriculture and Land Reclamation, Egypt in Bulletin No.1304/2014

Experimental design

The treatment of every experiment was arranged in split plot design in three replicates. Planting dates in the main plot and irrigation in sub plots (5 m length x 2 m width = 10 m^2).

The climatic factors were collected from automated weather station allocated at the experimental site and summarized in Table 3. The evapotranspiration (ET_o) during the experimental period was estimated by using Penman-Monteith method (Allen et al., 1998). The effect of climatic conditions with the planting dates on germination and establishment of potato seedlings, and the number of germinated hills and seedlings per plot were detected after 30 days from each sowing date for germination of 50%.

Samples of three plants from each plot were taken randomly after 35 days from germination date and measurements were repeated every 20 days for the following growth parameters: no. leaves/plant, average diameters of branches/plant by digital caliper, plant height and SPAD readings. At harvest time, dry matter percentage in tubers and specific gravity for tubers were recorded from random sample of three plants per plot. Meanwhile tuber yield was determined based on yield per plot area and converted to ton/fed.

Water use efficiency (WUE) of potato was calculated according to (Cantore et al., 2014) as follows: The ratio of crop yield (Y) to the total amount of irrigation water use in the field for the growth season (IR), WUE (kg/m^3) = Y (kg)/IR (m^3).

The macro and micronutrients were determined in the most recent fully mature collected at flowing stage of tubers. All samples were dried at 70 ^oC in forced air oven until the weight was fixed. Before analysis, the samples were re-dried overnight at 70 ^oC according to (FAO SOIL BULLETIN, 1989). Wet digestion was performed according to (FAO SOIL BULLETIN, 1989). Weighted 0.5g from oven-dry material and then added in 50 ml conical flask and digested with 10 ml H_2SO_4

TABLE 3. Average monthly climatic data of Shubra el-Khaimah location during potato growing seasons of 2014/2015 and 2015/2016.

	Max Temp.	Min Temp.	Max R. H.	Min R. H.	Avg. ST (10 cm)	Avg. WS	Precipitation	ETo
	° C	° C	%	%	° C	m/sec.	mm/day	mm/day
				2014/2015 season				
Dec-14	23.2	11.6	86.9	37.6	15.8	0.08	0.0	0.1
Jan-15	19.5	8.9	77.2	34.4	12.8	0.25	0.0	1.1
Feb-15	21.2	9.4	79.7	31.4	14.7	0.26	0.0	1.5
Mar-15	25.3	13.3	80.8	31.5	19.6	0.19	0.0	2.2
Apr-15	28.2	14.4	77.4	22.6	23.1	0.35	0.0	3.0
May-15	33.3	19.4	75.7	22.7	26.7	0.28	0.0	3.6
				2015/2016 season				
Dec-15	21.4	10.7	94.6	45.5	15	0.13	0.0	0.1
Jan-16	19.1	9.4	88	41.9	13.1	0.26	0.0	1.1
Feb-16	24.1	11.6	89.9	32.2	16.2	0.2	0.0	1.5
Mar-16	26.7	14.1	79.4	24.2	19.7	0.27	0.0	2.3
Apr-16	32.8	17.5	79	18.7	24.4	0.29	0.0	3.4
May-16	33.7	20	70	21.2	27.2	0.33	0.0	3.9

conc. on a hot plate at approximately 270 ^oC. Small quantities of H_2O_2 were added repeatedly until the digested solution became clear. The solution was left to cool and then diluted to 50 ml with redistilled water in a volumetric flask. Phosphorous concentration in acid digested tissue was determined by colorimeter method (ammonium molybdate). Total nitrogen content was determined using Micro-kjeldahle method, whereas potassium content was determined using flame photometer (Chapman and Pratt, 1982).

Statistical analysis

All the collected data were subjected to the proper statistical analysis of split plot design using SAS program (Statistical Analysis System, SAS User's Guide: Statistics. SAS Institute Inc. Editors, Cary, NC). The differences among means for all traits were tested for significance at 5 % level according to (Waller and Duncan, 1969).

Results and Discussion

The influence of planting dates and irrigation levels on plant growth parameters

Referring to the effect of planting date on the vegetative growth parameters of potato plants, the highest vegetative characters (plant height, number of leaves per plant, branch diameter and SPAD readings) were obtained by the earliest sowing date (18th of December) followed by the second planting date (7th of January) during the two studied seasons.

Regarding the effect of irrigation level on the vegetative growth characteristics of potato plants, data indicated that the best vegetative growth was obtained by 100% IR, and 80% IR came in as second option, while the lowest irrigation level led to the lowest plant growth characteristics during the two tested seasons for potato plants.

The interaction of planting dates and irrigation level significantly influenced the vegetative growth of potato plants. This influence included the number of leaves, plant height, branch diameters and SPAD readings. Data presented in Table 4 indicated that planting on 18th of December combined with irrigation level of 100% produced the best plant growth in the two studied seasons in terms of number of leaves, plant height and average branches diameters than the other planting dates and irrigation levels. The lowest plant height (36.7, 39.83 for first and second seasons, respectively) was obtained on the third planting date (27th of Jan) at the irrigation level 60%. Results of the present study results agree with those of (Dubey et al., 2011, Sawicka and Marczak, 2011, Darabi, 2013 and Ahmed et al., 2017). There are many factors (e.g. soil properties, soil moisture and nutrient availability as well as physiological age) which affect the vegetative growth, and hence the root growth, also affect leaf area and the canopy size. It appears that the relationship of vegetative growth to irrigation water supply in potato crops is greatly affected by growing conditions especially during the initial stages of growth. Severe water stress reduced the vegetative growth compared with those which were supplied by adequate irrigation water (Stalham and Allen, 2001).

The influence of planting dates and irrigation levels on potato tuber yield and its components

Data presented in Table 5 show significant effects of planting date on tuber dry matter, tuber specific weight and tuber yield during both studied seasons. Regarding tuber dry weight, there were no significant differences between the different planting dates during the first and the second season, the first season tuber dry weight was higher than the other planting dates. There were no significant differences between the second and third planting date during both tested seasons. Regarding the specific gravity of tuber during the planting dates, there were no significant differences between the planting dates during both tested seasons. Tuber yield/feddan of potato took another trend, the first planting date gave the highest tuber yield per feddan followed by the second planting date, while the third planting date gave the lowest tuber yield during both tested seasons.

As for the effect of irrigation level on tuber dry weight, it was not significant during the first season, but during the second season 100% IR was significantly higher than 60% irrigation level. There were no significant differences between 100 and 80% IR, nor between irrigation treatments in terms of specific gravity of tuber yield during both seasons. The tuber yield of potato/feddan was significantly different between the different irrigation levels during both seasons, the tuber yield of potato plants was slightly higher during the second season compared to the first season, the highest irrigation level (100% IR) gave the highest tuber yield per feddan (4200 square meter) followed by 80% IR while the lowest tuber yield was obtained by the lowest irrigation level (60%IR).

TABLE 4. The effect of planting dates and irrigation levels on leaf number per plant, plant height, branch diameter and SPAD readings of potato plants during 2014/2015 and 2015/2016 seasons.

Planting Dates	Leaf number/plant							
	Irrigation levels (%of IR)							
	First season				Second season			
	60%	80%	100%	Mean	60%	80%	100%	Mean
18th Dec	62.67 cde	78.67 b	84.33 a	75.22 A	66.67 b	85.67 a	87 a	79.78 A
07th Jan	61.67 d	64.67 cd	74.33 b	66.89 B	64 b	67.67 b	83.33 a	71.67 B
27th Jan	55.67 e	62 d	66.67 c	61.44 C	62.67 b	66.67 b	69.33 b	66.22 C
Mean	60 C	68.44 B	75.11 A		64.44 C	73.33 B	79.89 A	
Planting Dates	Plant height (cm)							
	Irrigation levels (%of IR)							
	First season				Second season			
	60%	80%	100%	Mean	60%	80%	100%	Mean
18th Dec	40.75 cd	45.83 b	49.62 a	45.41 A	42.44 cde	47.52 ab	51.3 a	47.1 A
07th Jan	39.50 de	42.61 bcd	45.35 b	42.49 B	40.27 de	44.58 bcd	47.22 ab	44.03 B
27th Jan	36.70 e	39.55 de	44 bc	40.09 C	39.83 e	41.81 cde	46.01 bc	42.56 B
Mean	38.99 C	42.67 B	46.33 A		40.85 C	44.64 B	48.19 A	
Planting Dates	Branch diameter (mm)							
	Irrigation levels (%of IR)							
	First season				Second season			
	60%	80%	100%	Mean	60%	80%	100%	Mean
18th Dec	14.06 bcd	15.22 a	15.23 a	14.84 A	14.29 bcd	15.37 ab	15.41 a	15.02 A
07th Jan	13.23 cd	14.22 abc	15.05 ab	14.17 B	13.22 d	14.33 abc	15.35 ab	14.3 B
27th Jan	13.13 d	13.38 cd	14.77 ab	13.77 B	13.21 d	13.58 cd	14.79 ab	13.86 B
Mean	13.48 C	14.28 B	15.02 A		13.58 C	14.43 B	15.18 A	
Planting Dates	SPAD readings							
	Irrigation levels (%of IR)							
	First season				Second season			
	60%	80%	100%	Mean	60%	80%	100%	Mean
18th Dec	54 a	50.33 abc	46.33 cde	50.22 A	55.33 a	52 ab	47 ce	51.44 A
07th Jan	53 a	47.66 bcd	45 de	48.56 AB	54.33 ab	52 ab	45 e	50.44 AB
27th Jan	51.67 ab	44.67 de	42.33 e	46.22 B	51.66 ab	50.67 bc	44.67 e	49 B
Mean	52.89 A	47.56 B	44.556 C		53.78 A	51.56 A	45.56 B	

TABLE 5. The effect of planting dates and irrigation levels on potato tuber dry matter, tuber specific gravity and tuber yield per feddan during 2014/2015 and 2015/2016 seasons.

Planting Dates	Tuber dry matter (%)							
	Irrigation levels (%of IR)							
	First season				Second season			
	60%	80%	100%	Mean	60%	80%	100%	Mean
18th Dec	18.53 a	19.2 a	19.6 a	19.1 A	21.45 b	21.84 ab	22.73 a	22.01 A
07th Jan	18.34 a	18.57 a	18.92 a	18.61 A	20.98 b	21.5 b	21.67 ab	21.38 B
27th Jan	18.3 a	18.47 a	18.76 a	18.51 A	20.83 b	21.08 b	21.63 b	21.18 B
Mean	18.39 A	18.75 A	19.09 A		21.09 B	21.48 AB	22.01 A	
Planting Dates	Tuber specific gravity (g/ml)							
	Irrigation levels (%of IR)							
	First season				Second season			
	60%	80%	100%	Mean	60%	80%	100%	Mean
18th Dec	1.051 a	1.074 a	1.084 a	1.07 A	1.067 a	1.087 a	1.088 a	1.081 A
07th Jan	1.037 a	1.055 a	1.061 a	1.051 A	1.055 a	1.068 a	1.08 a	1.068 A
27th Jan	1.036 a	1.046 a	1.057 a	1.046 A	1.045 a	1.058 a	1.071 a	1.058 A
Mean	1.041 A	1.058 A	1.067 A		1.055 A	1.071 A	1.08 A	
Planting Dates	Total tuber yield (kg/feddan)							
	Irrigation levels (%of IR)							
	First season				Second season			
	60%	80%	100%	Mean	60%	80%	100%	Mean
18th Dec	7537 d	11376 b	13911 a	10941 A	8757 d	12187 b	14774 a	11906 A
07th Jan	6534 e	7685 d	9567 c	7929 B	7034 e	8762 d	10650 c	8816 B
27th Jan	4946 f	6605 e	9023 c	6858 C	5371 f	7589 e	9439 d	7466 C
Mean	6339 C	8556 B	10834 A		7054 C	9513 B	11621 A	

Regarding the interaction effect between planting date and irrigation level, the highest dry matter content in potato tuber was obtained during the first planting date (18th of Dec) in both seasons combined with irrigation level 100% (19.6, and 22.73 for first and second seasons, respectively), and the lowest dry matter was obtained in the third planting date combined with 60% irrigation level (18.3, and 20.83 for first and second season, respectively). Specific gravity is an essential factor for maintaining the tuber quality and is directly associated with the dry matter content (Haase, 2003, Pedreschi and Moyano, 2005). In the present experiment, the highest specific gravity in the two seasons (1.084, and 1.088 for first and second season, respectively) was obtained during the first planting date combined with 100% irrigation level. This result is in agreement with (Solaiman et al*.,* 2015). The crop factors like height of the plant, number of leaves and quantity of tubers play a main role in yield contribution. The strong vegetative growth in terms of plant height and number of leaves led to better reproductive growth evidenced by a greater number of tubers. This was true in the first planting date 18th of Dec which favored getting higher yield at the irrigation level 100% in both seasons (13911, and 14774 for first and second season, respectively). Similar results were reached by (Thongam et al., 2017). Decreased irrigation water level led to a decrease in potato yield *via* reducing plant vegetative growth which might be attributed to the low tolerance of potato plants to soil moisture stress as explained by (Patel & Rajput, 2007 and Badr et al., 2012).

The influence of planting dates and irrigation levels on tuber nutrient percentages

As for the nutrient percentages in the potato tubers, the differences among the studied treatments were significant (Table 6). There were no significant differences between nitrogen percentages for potato tubers duringboth tested seasons. Phosphorus had the same trend as nitrogen during the first season, while there was a significant difference between phosphorus percentage of potato tuber during the second season. The highest phosphorus percentage was obtained by the third planting date, and there was no significant difference between the second and third planting date. However, the lowest phosphorus percentage was obtained by the first sowing date during the second season. Potassium and calcium took the same trend during the two

TABLE 6. The effect of planting dates and irrigation levels on the nutrients of potato tubers during 2014/2015 and 2015/2016 seasons.

Planting Dates	Nitrogen (%) in tuber – Irrigation levels (%of IR)							
	First season				Second season			
	60%	80%	100%	Mean	60%	80%	100%	Mean
18th Dec	1.82 d	2.17 b	2.5 a	2.16 A	1.66 e	2.14 d	2.53 ab	2.11 A
07th Jan	1.8 d	2.1 bc	2.73 a	2.21 A	1.83 e	2.11 d	2.43 bc	2.12 A
27th Jan	1.91 cd	2.22 b	2.61 a	2.24 A	1.62 e	2.21 cd	2.69 a	2.18 A
Mean	1.84 C	2.16 B	2.61 A		1.7 C	2.15 B	2.55 A	
Planting Dates	**Phosphorus (%) in tuber – Irrigation levels (%of IR)**							
	First season				Second season			
	60%	80%	100%	Mean	60%	80%	100%	Mean
18th Dec	0.145 c	0.209 b	0.314 a	0.223 A	0.161 d	0.216 c	0.316 a	0.231 B
07th Jan	0.162 c	0.222 b	0.318 a	0.234 A	0.168 d	0.234 bc	0.323 a	0.242 AB
27th Jan	0.163 c	0.235 b	0.326 a	0.241 A	0.172 d	0.248 b	0.339 a	0.253 A
Mean	0.157 C	0.222 B	0.319 A		0.167 C	0.233 B	0.326 A	
Planting Dates	**Potassium (%) in tuber – Irrigation levels (%of IR)**							
	First season				Second season			
	60%	80%	100%	Mean	60%	80%	100%	Mean
18th Dec	2.263 d	2.52 bc	2.779 a	2.521 B	2.344 f	2.727 de	3.049 abc	2.707 B
07th Jan	2.336 cd	2.528 bc	2.873 a	2.579 AB	2.403 f	2.823 cd	3.228 a	2.818 AB
27th Jan	2.429 cd	2.673 ab	2.836 a	2.646 A	2.568 ef	2.959 bcd	3.18 ab	2.902 A
Mean	2.343 C	2.574 B	2.829 A		2.438 C	2.836 B	3.152 A	
Planting Dates	**Calcium (ppm) in tuber – Irrigation levels (%of IR)**							
	First season				Second season			
	60%	80%	100%	Mean	60%	80%	100%	Mean
18th Dec	45.85 e	78.79 c	95.93 b	73.53 B	52.6 f	79.3 cd	97.09 b	76.33 B
07th Jan	58.09 d	72.01 c	108.72 ab	79.6 AB	59.75 ef	74.53 cd	121 a	85.09 A
27th Jan	59.92 d	78.11 c	114.98 a	84.34 A	69.2 de	84.38 c	119.14 a	90.91 A
Mean	54.62 C	76.3 B	106.54 A		60.52 C	79.4 B	112.41 A	

seasons. The highest K and Ca percentages were obtained by the third planting date while the lowest percentages were obtained by the first planting date during both tested seasons.

Regarding the effect of irrigation level on nutrient percentages of produced tubers, data in Table 6 illustrated that the highest N, P, K and Ca were obtained at the highest irrigation level during the two seasons followed by 80%, while the lowest nutrient percentages were obtained by 60% irrigation level.

The highest nitrogen percentage in the tuber was obtained in the last planting date with 100% irrigation level in both seasons. Meanwhile, Phosphorous percentage showed the same trend which gave the highest P percentage (0.32, and 0.33 for the first and second season, respectively). The highest potassium percentage was obtained in the third planting date with 100% irrigation level for the first and second season (2.83, and 3.18, respectively). There were slight differences in nitrogen, phosphorous and potassium with the different planting dates and irrigation levels. As well, potassium and calcium took the same trend such as N and P. However, the lowest calcium percentage was obtained in the first planting date with 60% irrigation level (45.85, 76.33 in the first and second season, respectively).

The influence of planting dates and irrigation levels on potato productivity and water use efficiency (WUE)

The effect of planting dates, irrigation levels and their interaction on water use efficiency (WUE) revealed that planting date affected water use efficiency in the two seasons. The first planting date resulted in the highest WUE value followed by second planting date. The third planting data introduced the lowest WUE value. The lowest WUE value was obtained with treatment 60% IR during the first season. Meanwhile, second season took another trend, the highest WUE was obtained with 80% IR followed by 60% IR.

The interaction effect between planting date and irrigation level on WUE value was significant, the second planting date with 80% IR had the highest WUE compared to other planting dates and irrigation levels treatments during both seasons. The lowest WUE was obtained by third planting date with 60% IR treatment during the two tested seasons as shown in Table 7. These results agree with those of (Kumar et al., 2007) who observed that expansion in yield was almost linear with ETc up to treatment 100% ETc.

Conclusion

Potato is one of the most widely cultivated vegetable crops in Egypt. Yield and productivity of potato are affected by different factors including planting date and irrigation level. The present study revealed that Increase of the irrigation level up to (100%) led to increase plant growth and yield of potato followed by second level of the irrigation (80 %) and finally the first level of the irrigation requirement (60%). The earliest plant date (18th of Dec) gave the positive impact on vegetative growth characteristics, yield parameters and nutrient contents of potato plant followed by the second planting date (7th of Jan) and finally the third planting date (27th of Jan) in decreasing order. The following recommendations can be extracted from current study: the optimum irrigation level was 100% combined with the first planting date were produced the highest vegetative growth, yield parameters and nutrient contents of

TABLE 7. The effect of planting dates and irrigation levels on water use efficiency during 2014/2015 and 2015/2016 seasons.

Planting Dates	Water use efficiency (WUE) (kg/m^3 water) Irrigation levels (%of IR)							
	First season				Second season			
	60%	80%	100%	Mean	60%	80%	100%	Mean
18^{th} Dec	16.1461	18.27763	17.88046	17.578728	17.9116384	18.6945851	18.1298319	18.263537
07^{th} Jan	11.48532	10.1305	10.08964	10.452149	11.4485677	10.6958008	10.4003906	10.761719
27^{th} Jan	7.281025	7.292702	7.970144	7.5720437	7.30053011	7.73677235	7.69839328	7.6113773
Mean	11.08798	11.2254	11.3707		11.5073409	11.6395448	11.3752937	

potato. Delay planting date or reduce the irrigation level negatively impacted the produced yield. The current work consider the base of the relation of potato productions under climate change conditions, the best planting date for potato production, maybe change under different climate change scenarios than the results of the current work. Moreover, irrigation water quantity will be also increase under climate change conditions due to increase air temperature in comparison with the current conditions.

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Conflict of interest

The authors declare that they have no conflict of interest.

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أثر التغيرات المناخية على الاحتياجات المائية وإنتاجية محصول البطاطس

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تم تنفيذ التجربة في تجربتين ميدانيتين خلال موسمين متتاليين ٢٠١٥/٢٠١٤ و ٢٠١٦/٢٠١٥ في المزرعة التجريبية بمعهد الدراسات العليا والبحوث للزراعة في المناطق القاحلة (ALARI)، كلية الزراعة، جامعة عين شمس، شبرا الخيمة بمحافظة القليوبية لدراسة تأثير ثلاثة مواعيد للزراعة وهي (١٨ ديسمبر و ٧ يناير و ٢٧ يناير) وثلاث مستويات للري عند ٦٠ و ٨٠ و ١٠٠٪ من احتياجات مياه الري (IR) وتفاعلها على إنتاجية محصول البطاطس. تم ترتيب مواعيد الزراعة كقطع رئيسية في التجربة، وكانت مستويات الري في قطع الفرعية للتجربة، وتم الحصول على ٩ معاملات من خلال التداخل بين مواعيد الزراعة المختلفة ومستويات الري. أشارت النتائج التي تم الحصول عليها إلى أن أعلى محصول للدرنات تم الحصول عليه في تاريخ الزراعة الأول (١٨ ديسمبر) خلال الموسمين. فيما يتعلق بمستوى الري تم الحصول على أعلى معامل نمو للنبات ومحصول الدرنات لكل نبات بنسبة لمعاملة الري ١٠٠ ٪يليه مستوى الري بنسبة ٨٠٪ خلال الموسمين. و فيما يتعلق بالتفاعلات اشارت النتائج التي تحصل عليها إلى أن تاريخ الزراعة الأول (١٨ ديسمبر) مع مستوى الري ١٠٠٪ أعطى أعلى إنتاجية لدرنات البطاطس عن المعاملات الأخرى. بينما أعطت تفاعلات تاريخ الزراعة الأول (١٨ ديسمبر) مع مستوى الري ٨٠٪ أفضل كفاءة في استخدام المياه مقارنة بالمعاملات الأخرى خلال الموسمين.

الكلمات الدالة: التغيرات المناخية، ميعاد الزراعة، مستوى الري، البطاطس، المحصول، الاحتياجات المائية.