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Effect of Phosphate and Potassium Fertilizer Rates on Potato Plants Grown under Water Stress Conditions

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Authors' contributions

All researchers have contributed in all parts of research equally. All authors read and approved the final manuscript.

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ABSTRACT

The effect and relationship between water stress, potassium (K) and phosphorus (P) fertilizers rates on water consumptive use, water requirements, and yield of potato cv. Valor was studied under field conditions at Dokki Protected Cultivation Experimental Site, Agricultural Research Center (ARC), Giza Governorate, Egypt. The study concerned with the use of different rates of K fertilization (50, 100 and 150 kg K_2O/fed) and P fertilization (50 and 100 kg P_2O_5/fed) under different irrigation scheduling (100, 75 and 50% of irrigation requirements by Penman-Monteith method) on potato crop cultivated in alluvial soil. The highest plant growth was recorded when water irrigation level reached 75% of irrigation requirement in the presence of 100 kg P_2O_5/fed and 150 kg K_2O/fed. Results also revealed that more or less similar values of macronutrient uptake were found in plant leaves at different treatments. Finally, results obtained indicated that this treatment is the most effective treatment on growth parameters also recorded the highest tuber yield and its content from carbohydrates and protein. Thus, farmers should not supply water irrigation of potatoes more than 75% of irrigation requirement to obtain economic tubers.

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1. INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most important field crops grown under a wide range of climates. Hence, it is one of the world's prime sources of human nutrition. The protein/carbohydrate ratio in potato is higher than in most cereals and even higher than those of the other tuber and root crops [1]. In terms of composition, potato tuber contains 70–82% water, 17–29% dry matter, 11–23% carbohydrate, 0.8–3% protein, 0.1% fat and 1.1% minerals. In addition, production per hectare of important vitamins, such as thiamine, riboflavin, niacin and vitamin C is higher in potato than in other major crops such as rice, maize and wheat [2].

Water is considered an economical scare resource in many areas of the world, especially in arid and semi arid regions like Egypt. Therefore, improving water use efficiency for new hybrids is one of the major objectives in plant breeding programs for crops grown in dry areas. Kijne et al*.* [3] declared that the economic tuber yield divided by the volume of water consumed in the production of that yield expressed by kg tuber/m^3 water. Shock [4] found that all growing stages of potato, especially tuber formation stage, were very sensitive to water deficit stress. Similar conclusion was previously found by [5] who added that the number of tubers/plant and tuber yield are reduced by water stress. On the other hand, stolonization and tuberization stages were more sensitive than bulking and tuber enlargement stages [6]. Water saving may be achieved by drip irrigation, and even improved results seemed to be possible with partial root zone drying [7] which is a new water-saving irrigation strategy being tested in many crop species.

In the concept of crop nutrition, phosphorus is considered one of the necessary elements for the complete function of plants, especially for potato tubers and dry matter as well as contribution to growth of roots. It also enhances the root hair distribution and the hardening of stalks of crops [8]. Moreover, potassium fertilization is considered one of the most important factors affecting the growth and yield of potato. Many researchers recorded an increase of potato tuber yield as a result of increasing the levels of K fertilization [9]. Such increase in the yield of potato tubers was either due to the formation of large sized tubers, increasing the number of tubers per plant or both. Potassium also played a key role in improving the quality of the product [10]. Talal et al*.* [11] mentioned that K^+ regulates the amount of water in the plant and plays a role in maintaining turgidity of plant cells and osmotic adjustment. In the absence of sufficient K, crops do not use water efficiently and become less able to withstand water stress during drought periods. Addition of K fertilizer improved water relations of different crops under water stress conditions [12]. Muhammad et al*.* [13] previously reported that to achieve high tuber quality, it is recommended to fertilize using NPK fertilizers with less N than P and K.

Production of potato (*Solanum tuberosum* L.) takes a very important place in the world agriculture; it is a water-stress-sensitive crop. Potato plants are more productive and produce higher tuber quality when watered precisely using soil water tension than if they are under or over irrigated. Thus, the aim of this study was to evaluate the effect of different levels of phosphate and potassium fertilizers on growth and yield of potato plants grown under different irrigation water levels.

2. MATERIALS AND METHODS

The present study was carried out during the two successive autumn seasons of 2013 and 2014 under open field conditions at Dokki Protected Cultivation Experimental Site, Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center (ARC), Giza Governorate, Egypt. Climatic data at Dokki site during the autumn seasons of 2013 and 2014 are shown in Fig. 1. The cultivation period took about 17 weeks during the studied seasons without any significant difference on the environment that affect negatively on the plant growth and yield. Average air temperature in the field 19±5.6°C, relative humidity 60±8% and ET_o 3.7±1.5 mm/day, in the both studied seasons.

2.1 Plant Material

Tuber seeds of potato (*Solanum tuberosum* L. cv. Valor) were sown on 25th and 27th September 2013 and 2014, respectively. The potato plants started to emerge after ten days from sowing.

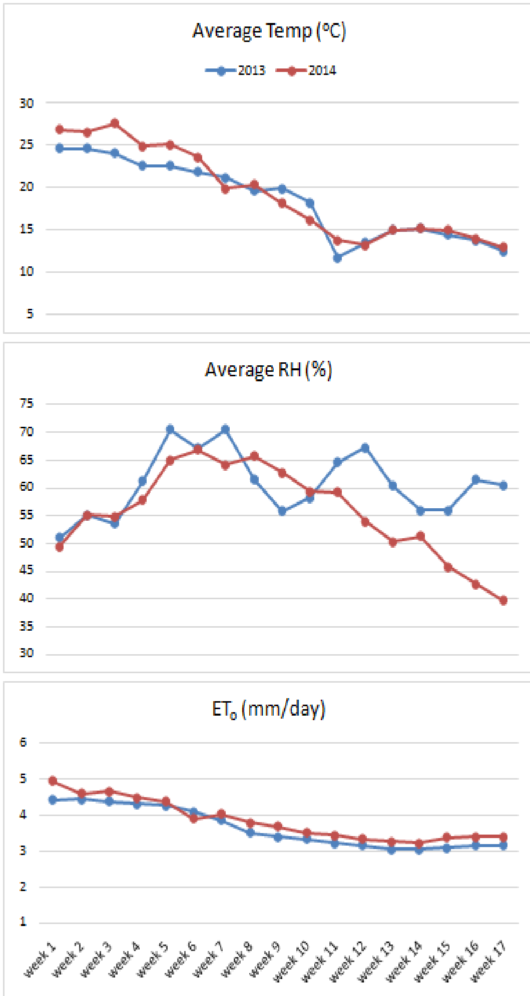

Fig. 1. Climatic data at Dokki site during the two studied seasons of 2013 and 2014

2.2 Treatments

The experiment was laid out in a split-split-plot design with three replications. The treatments included three factors with different levels i.e. three levels of irrigation water (50, 75 and 100% of irrigation requirements IR) which were assigned in the main plots, two rates of phosphate fertilizer (50 and 100 kg P_2O_5/fed) in the form of calcium superphosphate (15.5% P_2O_5) which occupied the sub plots, the recommended rates as suggested by the Ministry of Agriculture were 60-75 kg P_2O_5/fed in form of calcium superphosphate were applied to the soil before plant cultivation, and three rates of potassium fertilizer (50, 100 and 150 kg K_2O/fed) in the form of potassium sulphate (48% K_2O) in the sub-sub plots, the recommended rates as recorded by the Ministry of Agriculture were 72-96 kg K_2O/fed and applied to the studied soil on two batches; the first before plant cultivation and the second after the completion of germination and start to format the new tubers.

2.3 The Field Experiment

Plot area was 15 m^2, consisted of four rows each row was 75 cm in width and 5 m in length. Flow meter was installed for each irrigation level treatment; two meters were left between each two irrigation levels. Potato plants were irrigated by using drippers of 4 L/h capacity; distance between plants was 0.5 m. The chemical fertilizers were injected within irrigation water system. The fertigation was programmed to three times weekly and the duration of irrigation time depending upon the treatments. All other agriculture practices of potato cultivation were in accordance with the standard recommendations for commercial growers by the Ministry of Agriculture, Egypt.

2.4 Estimation of Water Requirements

Calculations of irrigation levels were performed whereas the irrigation control was practiced via manual valves for each experimental plot. The total amount of irrigation requirement was calculated by FAO, Penman-Monteith procedure [14]. 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 day^{-1}),
R_n = 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 (℃),
U_2 = Wind speed at 2 m height (m s^{-1}),
e_s = Saturation vapor pressure (k Pa),
e_a = Actual vapor pressure (k Pa),
Δ = The slope of vapor pressure curve (k Pa ℃$^{-1}$)
γ = The psychometric constant (k Pa ℃$^{-1}$).

The second step was to obtain values of crop water consumptive use (ET_{crop}) as described by [14]; it was calculated as the following:

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

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 from water shortage.

K_c = Crop coefficient (ranged from 0.6 to 1.2).

Water requirements (WR) for each treatment were calculated as follows, see Table 1.

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

Where:

%LR = Leaching requirement percentage (22% of the water requirement based on the leaching fraction equation).

Irrigation requirement (IR) was calculated as follows:

$$IR = WR \times R * 4200/1000 \ (m^3/fed/day) \qquad (4)$$

Where:

R = Reduction factor for drip irrigation that only covers a part of land and the rest dry leaves. It was recommended by [14] to use R value which ranged between 0.25 and 0.9 for drip irrigation system.

2.5 Measurements

Soil sample was taken before carrying out the field experiment for some physical and chemical analyses (Table 2) according to [15]. The permanent wilting point (PWP) and field capacity (FC) of the trial soil were determined according to [16]. The water use efficiency (WUE) was calculated according to [17] as follows; the ratio of crop yield (Y) to the total amount of irrigation water used in the field for the growth season (IR).

$$WUE\ (kg/m^3) = Y\ (kg)/IR\ (m^3) \qquad (5)$$

Samples of five plants of each experimental plot were taken at the end of the both studied seasons to determine growth parameters, i.e. plant height, number of stems per plant, fresh and dry weights of whole plant and potato yield. Chlorophyll readings were recorded in the fourth upper leaf after 90 days from cultivation by using Minolta chlorophyll meter SPAD 501, also, number of leaves per plant counted at the same time. For mineral analysis, the dried youngest mature leaves were digested in the mixture of H_2SO_4/H_2O_2 according to the method described by [15]. Total nitrogen and protein were determined by Kjeldahl method according to the procedure described by [18]. Phosphorus content was determined using Spectrophotometer according to [19]. Potassium content was determined photometrically using Flame photometer as described by [20]. Carbohydrate content was determined according to the procedure described by [21].

Table 1. The average of weekly irrigation water requirements under different irrigation levels for potato at Dokki site

Weeks after planting	Year 2013			Year 2014		
	m³/feddan			m³/feddan		
	50%	**75%**	**100%**	**50%**	**75%**	**100%**
1	39	49	59	41	52	62
2	43	53	64	44	55	66
3	44	55	66	47	59	71
4	49	61	74	52	65	78
5	54	67	80	56	69	83
6	57	71	85	58	73	88
7	60	75	89	61	76	91
8	64	80	96	67	84	101
9	71	89	107	74	93	112
10	77	97	116	81	101	121
11	81	102	122	78	97	117
12	75	94	113	72	90	108
13	70	87	105	67	83	100
14	35	43	52	61	76	91
15	60	75	91	61	76	91
16	58	73	87	58	72	86
Total	**937**	**1172**	**1406**	**977**	**1221**	**1465**

Table 2. Some physical and chemical properties of the surface layer (0-20 cm) of studied soil

Particle size distribution %			**Texture class**	**SP**	**FC %**	**PWP**	**BD g cm^{-3}**	**$CaCO_3$ %**	**OM**
Sand	Silt	Clay							
14.2	16.5	69.3	Clay	89.5	75.6	29.9	1.37	1.51	1.03
pH	**EC_e**	**Soluble ions, meq L^{-1}**							
(1:2.5 soil: water suspension)	**dS m^{-1}**	**Ca^{2+}**	**Mg^{2+}**	**Na^{+}**	**K^{+}**	**CO_3^{2-}**	**HCO_3^{-}**	**Cl^{-}**	**SO_4^{2-}**
7.65	2.67	6.89	4.84	9.65	5.32	0	6.08	12.1	8.52

Statistical analysis was determined using SAS program. The differences among means for all traits were tested for significance at 5% level according to the procedure described by [22].

3. RESULTS AND DISCUSSION

3.1 Growth Characters

Data in Tables 3, 4 and 5 represented the influence of different water supply treatments along with different rates of P and K fertilizers as well as their interactions on some growth parameters of potato plants. Results revealed that the most effective treatment in water irrigation was up to 75% of irrigation requirement. It gave the highest values of plant height, number of stems/plant and number of leaves/plant in the first and second seasons, whereas the lowest values of such traits were more pronounced when depletion of water reach up to 50% of irrigation requirement. Generally, water stresses hasten leaf senescence whilst in most cases, growth parameters delay this phenomenon. In this regard, [23,24] reported that shortage of water decreased most growth characters. Regarding the P and K fertilization, the treatment of 100 and 150 kg/fed, respectively, recorded the highest values. The interaction among the studied treatments showed that water irrigation up to 75%, P fertilization at 100 kg/fed and K fertilization at 150 kg/fed from the recommended rates gave the highest values of growth parameters. It may be due to that with increasing fertilization from P and K, which considered necessary nutrients for plant growth, the plant vigor and growth parameters increased; these benefits increased with suitable amount of irrigation water not less than it which put the plant under stress conditions or over than it which leaches the fertilizers from the soil profile [25].

Data presented in Tables 6 and 7 showed that the haulm fresh and dry weights varied significantly due to the different treatments. The highest values were obtained when 75% of irrigation water was applied compared to other treatments. Average fresh weight per plant increased with increasing P and K applications; the linear and quadratic components were both significant (Table 6). Regarding the interaction among the studied treatments, the haulm fresh weight ranged from 262 and 286 g/plant by application of 75% irrigation level, 100 kg P_2O_5/fed and 150 kg K_2O/fed fertilization, in the first and second seasons, respectively. The dry weight per plant varied from 18.4 to 54.9 g according to the studied treatments (Table 7). The mean values of dry weight per plant ranged from 42.5 to 48.6 g in the treatment of irrigation level up to 75% of irrigation requirement interacted with 100 kg P_2O_5/fed and 150 kg K_2O/fed fertilization in the first and second seasons, respectively. This agrees with results reported by [26].

3.2 Nutrient Percentages and Chlorophyll Content in Leaves

Data presented in Table 8 indicated that the N percent of potato leaves differed significantly due to the application of different levels of P and K fertilizers and irrigation level; value ranged from 2.99 to 4.31%. The maximum N percent in potato leaves was observed by the treatment of 50% of irrigation water level, 100 kg/fed for P and 150 kg/fed for K fertilization; the lowest one was obtained by 100% of irrigation water level, 50 kg/fed for P and K fertilization. The results indicated that increasing fertilizer application rate increased the N percent in potato leaves; such results confirmed the data reported by [27,28].

The percent of P in potato leaves was generally not affected by irrigation level. This is in line with the results obtained by [29] who declared that although water is the main medium through which soil nutrients are made available to plants, the mobilization of the individual nutrient to other plant parts depends on the amount of nutrients present. There was a significant variation in P uptake by potato leaves due to the application of fertilizer (Table 9). Phosphorus content in plant varied from 0.21 to 0.48%. The highest P value was found by application of 100 kg/fed for P and 150 kg/fed for K fertilization in the second season.

The potassium percent of potato leaves was influenced significantly due to the studied treatments (Table 10). Logically, the maximum concentration of K was obtained by the treatment of 150 kg K_2O/fed. On the other hand, data showed that increasing irrigation level led to decrease N, P and K percentages during the two studied seasons.

Data in Table 11 showed that the highest value of chlorophyll content was obtained by 50% of irrigation water level combined with 100 kg P_2O_5/fed and 150 kg K_2O/fed. In this concern, [30] mentioned that increasing chlorophyll content in plant leaves indicates that plant suffer from stress.

Table 3. Effect of different levels of P, K and irrigation requirement on potato plant height (cm) during the two studied seasons of 2013/2014

Irrigation level of ET_c	P levels (kg/fed)	First season (2013)				Second season (2014)			
		K levels (kg/fed)				K levels (kg/fed)			
		50	100	150	Mean	50	100	150	Mean
50%	50	17.5 k	18.5 i	25.1 d	**20.4 d**	16.5 m	17.3 l	21.6 i	**18.4 a**
	100	18.2 ij	21.1 g	27.9 c	**22.4 bc**	17.8 l	20.0 j	29.0 c	**22.2 c**
	Mean	**17.9 f**	**19.8 e**	**26.5 b**	**21.4 B**	**17.1 f**	**18.7 e**	**25.3 c**	**20.3 C**
75%	50	20.0 h	24.6 e	29.9 b	**24.8 b**	19.9 j	26.2 f	29.8 b	**25.3 b**
	100	23.3 f	27.8 c	33.9 a	**28.3 a**	22.6 h	25.8 f	34.2 a	**27.5 a**
	Mean	**21.6 d**	**26.2 b**	**31.9 a**	**26.6 A**	**21.3 d**	**26.0 c**	**32.0 a**	**26.4 A**
100%	50	18.1 j	21.2 g	25.0 d	**21.4 cd**	16.7 m	24.5 g	27.5 e	**22.9 c**
	100	20.2 h	25.0 d	29.6 b	**24.9 b**	19.2 k	25.9 f	28.3 d	**24.5 b**
	Mean	**19.1 e**	**23.1 c**	**27.3 b**	**23.2 A**	**18.0 e**	**25.2 c**	**27.9 b**	**23.7 B**
					P levels * K levels				
	50	**18.5 e**	**21.4 d**	**26.6 b**	**22.2 B**	**17.7 e**	**22.7 c**	**26.3 b**	**22.2 B**
	100	**20.6 d**	**24.6 c**	**30.5 a**	**25.2 A**	**19.9 d**	**23.9 c**	**30.5 a**	**24.7 A**
	Mean	**19.5 C**	**23.0 B**	**28.6 A**		**18.8 C**	**23.3 B**	**28.4 A**	

This is a factorial experiment from three factors: irrigation water levels (A), P fertilization (B), K fertilization (C) in a spilt plot design, letters A B C D among the main factors, letters a b c d … among the interaction between the three factors (A×B×C), and different letters means significant

Table 4. Effect of different levels of P, K and irrigation requirement on number of stems per potato plant during the two tested seasons of 2013/2014

Irrigation level of ET_c	P levels (kg/fed)	First season (2013)				Second season (2014)			
		K levels (kg/fed)				K levels (kg/fed)			
		50	100	150	Mean	50	100	150	Mean
50%	50	3.04 l	3.15 j	3.75 e	**3.31 e**	3.01 m	3.48 h	3.88 c	**3.46 c**
	100	3.10 k	3.20 ij	4.21 a	**3.50 c**	3.13 l	3.60 g	3.90 c	**3.54 c**
	Mean	**3.07 h**	**3.17 g**	**3.98 a**	**3.41 B**	**3.07 f**	**3.54 e**	**3.89 b**	**3.50 B**
75%	50	3.10 k	3.39 h	3.67 f	**3.39 d**	3.71 e	3.62 fg	3.86 c	**3.73 b**
	100	3.16 j	3.51 g	4.06 b	**3.58 b**	3.38 ij	3.79 d	4.39 a	**3.85 a**
	Mean	**3.13 g**	**3.45 e**	**3.87 c**	**3.48 A**	**3.55 e**	**3.70 c**	**4.12 a**	**3.79 A**
100%	50	3.22 i	3.76 e	3.86 d	**3.61 b**	3.35 j	3.40 i	3.30 k	**3.35 d**
	100	3.35 h	3.87 d	3.99 c	**3.74 a**	3.96 b	3.66 f	3.95 b	**3.86 a**
	Mean	**3.29 f**	**3.82 d**	**3.93 b**	**3.68 A**	**3.66 cd**	**3.53 e**	**3.62 d**	**3.60 B**
					P levels * K levels				
	50	**3.12 d**	**3.43 c**	**3.76 b**	**3.44 A**	**3.36 d**	**3.50 c**	**3.68 b**	**3.51 B**
	100	**3.20 d**	**3.53 c**	**4.09 a**	**3.61 A**	**3.49 c**	**3.68 b**	**4.08 a**	**3.75 A**
	Mean	**3.16 C**	**3.48 B**	**3.92 A**		**3.42 B**	**3.59 B**	**3.88 A**	

See footnotes of Table 3

Table 5. Effect of different levels of P, K and irrigation requirement on number of leaves per potato plant during the two studied seasons of 2013/2014

Irrigation level of ET_c	P levels (kg/fed)	First season (2013)				Second season (2014)			
		K levels (kg/fed)				K levels (kg/fed)			
		50	100	150	Mean	50	100	150	Mean
50%	50	26.3 i	26.6 i	39.6 f	**30.8 d**	25.1 m	29.0 j	32.3 h	**28.8 e**
	100	25.3 j	34.1 g	43.4 d	**34.3 c**	26.1 l	30.0 i	45.0 c	**33.7 d**
	Mean	**25.8 g**	**30.4 e**	**41.5 b**	**32.6 C**	**25.6 g**	**29.5 f**	**38.7 cd**	**31.3 C**
75%	50	34.2 g	38.9 f	44.9 c	**39.3 b**	30.9 i	38.5 f	40.5 de	**36.6 c**
	100	34.6 g	45.9 b	47.0 a	**42.5 a**	36.5 g	39.9 e	53.2 a	**43.2 a**
	Mean	**34.4 d**	**42.4 b**	**45.9 a**	**40.9 A**	**33.7 e**	**39.2 c**	**46.9 a**	**39.9 A**
100%	50	26.8 i	31.3 h	40.5 e	**32.9 c**	27.9 k	36.7 g	41.3 d	**35.3 cd**
	100	30.8 h	40.6 e	44.6 c	**38.7 b**	32.7 h	38.9 f	47.1 b	**39.5 b**
	Mean	**28.8 f**	**36.0 c**	**42.6 b**	**35.8 B**	**30.3 f**	**37.8 d**	**44.2 b**	**37.4 B**
					P levels * K levels				
	50	**29.1 e**	**32.3 d**	**41.7 b**	**34.4 A**	**28.0 e**	**34.7 c**	**38.0 b**	**33.6 A**
	100	**30.2 e**	**40.2 c**	**45.0 a**	**38.5 B**	**31.8 d**	**36.2 bc**	**48.4 a**	**38.8 B**
	Mean	**29.7 C**	**36.3 B**	**43.3 A**		**29.9 C**	**35.5 B**	**43.2 A**	

See footnotes of Table 3

Table 6. Effect of different levels of P, K and irrigation requirement on total plant fresh weight (g/plant) during the two studied seasons of 2013/2014

Irrigation level of ET_c	P levels (kg/fed)	First season (2013)				Second season (2014)			
		K levels (kg/fed)				K levels (kg/fed)			
		50	100	150	Mean	50	100	150	Mean
50%	50	135 m	214 j	240 g	**196 d**	156 m	237 i	248 gh	**214 e**
	100	198 k	217 ij	270 d	**228 c**	200 l	245 h	249 g	**231 d**
	Mean	**167 f**	**216 d**	**255 c**	**212 C**	**178 g**	**241 e**	**249 d**	**223 C**
75%	50	218 i	268 d	280 b	**255 b**	261 e	285 c	294 b	**280 b**
	100	222 h	275 c	309 a	**269 a**	238 i	297 b	340 a	**292 a**
	Mean	**220 d**	**271 b**	**295 a**	**262 A**	**250 d**	**291 b**	**317 a**	**286 A**
100%	50	180 l	256 f	263 e	**233 c**	214 k	232 j	255 f	**234 d**
	100	214 j	263 e	274 c	**251 b**	254 f	249 gh	271 d	**258 c**
	Mean	**197 e**	**260 c**	**268 b**	**242 B**	**234 f**	**240 e**	**263 c**	**246 B**
					P levels * K levels				
	50	**178 e**	**246 c**	**261 b**	**228 B**	**210 e**	**251 c**	**266 b**	**243 B**
	100	**212 d**	**252 bc**	**284 a**	**249 A**	**231 d**	**264 b**	**287 a**	**260 A**
	Mean	**195 C**	**249 B**	**273 A**		**221 C**	**258 B**	**276 A**	

See footnotes of Table 3

3.3 Yield, Carbohydrates and Protein of Tubers

Data clearly showed gradual significant reduction in line with increasing water stress treatments in most of yield, carbohydrates and protein (Tables 12, 13 and 14). The highest decrease was detected at the highest stress level, when water irrigation was supplied up to 50% of irrigation requirement. Such effect was expected since the irreversible effect was early detected in most of plant growth parameters. On the other hand, adequate water supplies up to 75% of irrigation requirement promoted growth (Tables 3, 4, 5, 6 and 7) and resulted in higher yield and thereby increased the rate of photosynthesis and better translocation of carbohydrates from leaves and stems to the sink; this in turn, favorably influenced tuber weight and production per feddan. In this concern biological yield and water use efficiency were also affected by the same treatments and the same function tended to seem the same trend. These findings are in agreement with those reported by [31,32] who reported that low soil moisture content caused an irreversible loss in yield potential.

In respect of fertilization treatments, results presented in Tables 12, 13 and 14 showed the effect of the studied treatments on potato yield and the tuber contents of carbohydrates and protein. More P and K applied to the studied soil improved significantly yield production of potatoes and tuber contents of carbohydrates and protein in the two studied seasons. Similar conclusion was also reported by [33] who found that P and K fertilization markedly increased production of potato and improved tuber quality. Regarding the interaction among the studied treatments, the treatment of 75% water irrigation, 100 kg/fed for P and 150 kg/fed for K fertilization were superior in increasing the tuber contents of carbohydrates and protein which were reflected on potato quality and its yield production. It is obvious that carbohydrates and protein percentages increased with decreasing irrigation water level but increased with increasing P and K fertilization especially K fertilization up to 150 kg/fed. Protein percent matched with N percent inside the plant under water stress conditions. It may be due to the role of P and K in encouraging the plant cells to exudates and rapidly make carbohydrates and amino acids chains to form protein like proline to increase their osmotic pressure to face the water stress. Many researchers confirmed the role of K in justifying the osmotic and water potential inside the plant cells to face the stress outside them. Ati and Nafaou [34] mentioned that K has the ability to regulate the water status of potato plants under conditions of drought, and that the protective effect of K under drought stress conditions was achieved by increasing the water uptake capacity of the root system. This fact can insure by subtract plant dry weight from its fresh weight, the highest difference between them is due to increase water uptake by the plant to face the stress (as declared in Tables 6 and 7).

Table 7. Effect of different levels of P, K and irrigation requirement on total plant dry weight (g/plant) during the two studied seasons of 2013/2014

Irrigation level of ET_c	P levels (kg/fed)	First season (2013)				Second season (2014)			
		K levels (kg/fed)				K levels (kg/fed)			
		50	100	150	Mean	50	100	150	Mean
50%	50	18.4 k	37.7 f	38.1 f	**31.4 e**	24.3 m	43.2 f	43.2 f	**36.9 a**
	100	34.2 i	35.7 gh	42.7 e	**37.5 d**	34.6 l	43.9 f	37.0 k	**38.5 c**
	Mean	**26.3 f**	**36.7 d**	**40.4 c**	**34.4 C**	**29.4 g**	**43.5 c**	**40.1 e**	**37.7 C**
75%	50	36.1 g	45.0 b	44.8 bc	**42.0 a**	47.4 d	49 .0 c	49.7 c	**48.7 a**
	100	35.5 h	44.3 c	49.1 a	**42.9 a**	39.0 ij	51.5 b	54.9 a	**48.5 a**
	Mean	**35.8 d**	**44.6 b**	**47.0 a**	**42.5 A**	**43.2 c**	**50.2 b**	**52.3 a**	**48.6 A**
100%	50	29.4 j	44.7 bc	42.8 e	**39.0 c**	38.1 j	36.3 k	40.5 h	**38.3 c**
	100	36.1 g	43.3 d	42.7 e	**40.7 b**	45.6 e	39.8 hi	42.1 g	**42.5 b**
	Mean	**32.8 e**	**44.0 b**	**42.8 b**	**39.8 B**	**41.8 d**	**38.0 f**	**41.3 d**	**40.4 B**
					P levels * K levels				
	50	**28.0 e**	**42.5 b**	**41.9 bc**	**37.5 B**	**36.6 d**	**42.8 b**	**44.5 a**	**41.3 A**
	100	**35.2 d**	**41.1 c**	**44.8 a**	**40.4 A**	**39.7 c**	**45.0 a**	**44.7 a**	**43.1 A**
	Mean	**31.6 B**	**41.8 A**	**43.4 A**		**38.2 B**	**43.9 A**	**44.6 A**	

See footnotes of Table 3

Table 8. Effect of different levels of P, K and irrigation requirement on total nitrogen percentage in leaves of potato plants during the two studied seasons of 2013/2014

Irrigation level of ET_c	P levels (kg/fed)	First season (2013)				Second season (2014)			
		K levels (kg/fed)				K levels (kg/fed)			
		50	100	150	Mean	50	100	150	Mean
50%	50	3.34 i	3.68 d	3.89 a	**3.64 a**	3.25 jk	3.70 f	4.16 b	**3.70 bc**
	100	3.41 h	3.71 cd	3.86 b	**3.66 a**	3.26 jk	3.84 e	4.31 a	**3.81 a**
	Mean	**3.38 d**	**3.70 b**	**3.88 a**	**3.65 A**	**3.26 f**	**3.77 c**	**4.24 a**	**3.75 A**
75%	50	3.06 m	3.20 k	3.60 e	**3.28 c**	3.31 i	3.34 i	3.66 f	**3.44 d**
	100	3.52 f	3.59 e	3.71 cd	**3.61 a**	3.50 g	3.80 e	3.91 d	**3.74 a**
	Mean	**3.29 e**	**3.40 d**	**3.65 b**	**3.45 B**	**3.40 e**	**3.57 d**	**3.79 c**	**3.58 B**
100%	50	3.14 l	3.28 j	3.51 f	**3.31 c**	2.99 l	3.43 h	4.02 c	**3.48 d**
	100	3.13 l	3.69 cd	3.47 g	**3.43 b**	3.22 k	3.27 ij	4.27 b	**3.59 c**
	Mean	**3.14 f**	**3.48 c**	**3.49 c**	**3.37 B**	**3.10 g**	**3.35 ef**	**4.15 b**	**3.53 B**
					P levels * K levels				
	50	**3.18 c**	**3.39 b**	**3.67 a**	**3.41 B**	**3.18 e**	**3.47 d**	**3.95 b**	**3.53 B**
	100	**3.36 b**	**3.66 a**	**3.68 a**	**3.57 A**	**3.33 de**	**3.64 c**	**4.17 a**	**3.71 A**
	Mean	**3.27 C**	**3.53 B**	**3.67 A**		**3.25 C**	**3.56 B**	**4.06 A**	

See footnotes of Table 3

Table 9. Effect of different levels of P, K and irrigation requirement on total phosphorus percentage in leaves of potato plants during the two studied seasons of 2013/2014

Irrigation level of ET_c	P levels (kg/fed)	First season (2013)				Second season (2014)			
		K levels (kg/fed)				K levels (kg/fed)			
		50	100	150	Mean	50	100	150	Mean
50%	50	0.31 i	0.39 e	0.52 b	0.41 b	0.29 i	0.45 c	0.48 b	0.41 b
	100	0.37 f	0.46 c	0.55 a	0.46 a	0.42 d	0.44 c	0.52 a	0.46 a
	Mean	0.34 d	0.43 b	0.53 a	0.43 A	0.35 e	0.45 b	0.50 a	0.43 A
75%	50	0.25 k	0.33 h	0.44 d	0.43 c	0.25 k	0.33 g	0.35 f	0.31 c
	100	0.32 hi	0.38 ef	0.46 c	0.39 b	0.31 h	0.35 f	0.48 b	0.38 b
	Mean	0.28 e	0.36 cd	0.45 b	0.36 B	0.28 f	0.34 e	0.41 c	0.34 B
100%	50	0.21 l	0.32 hi	0.32 hi	0.28 d	0.23 l	0.29 i	0.36 f	0.29 c
	100	0.28 j	0.35 g	0.43 d	0.35 c	0.27 j	0.29 i	0.40 e	0.32 c
	Mean	0.25 f	0.33 d	0.38 c	0.32 B	0.25 g	0.29 f	0.38 d	0.31 B
					P levels * K levels				
	50	0.26 d	0.35 c	0.43 b	0.34 B	0.25 d	0.36 c	0.40 b	0.34 B
	100	0.32 c	0.40 b	0.48 a	0.40 A	0.33 c	0.36 c	0.47 a	0.39 A
	Mean	0.29 C	0.37 B	0.45 A		0.29 C	0.36 B	0.43 A	

See footnotes of Table 3

Table 10. Effect of different levels of P, K and irrigation requirement on total potassium percentage in leaves of potato plants during the two studied seasons of 2013/2014

Irrigation level of ET_c	P levels (kg/fed)	First season (2013)				Second season (2014)			
		K levels (kg/fed)				K levels (kg/fed)			
		50	100	150	Mean	50	100	150	Mean
50%	50	3.04 f	2.86 gh	3.29 d	3.06 b	2.57 h	3.53 c	3.79 a	3.30 b
	100	3.06 f	3.17 e	3.86 a	3.35 a	2.92 f	3.64 b	3.78 a	3.45 a
	Mean	3.05 c	3.01 c	3.58 a	3.21 A	2.74 d	3.59 b	3.78 a	3.37 A
75%	50	2.27 i	2.70 j	3.44 c	2.80 c	2.84 g	2.91 f	3.34 d	3.03 c
	100	2.76 ij	2.85 h	3.54 b	3.05 b	3.25 e	3.33 d	3.83 a	3.47 a
	Mean	2.52 f	2.78 e	3.49 b	2.93 B	3.04 c	3.12 c	3.59 b	3.25 B
100%	50	2.67 j	2.86 gh	2.92 g	2.81 c	2.45 i	2.80 g	3.49 c	2.91 d
	100	2.77 i	2.86 gh	3.08 f	2.90 c	2.55 h	2.85 g	3.52 c	2.98 cd
	Mean	2.72 f	2.86 d	3.00 c	2.86 B	2.50 e	2.83 d	3.50 b	2.94 C
					P levels * K levels				
	50	2.66 e	2.81 d	3.22 b	2.89 B	2.62 d	3.08 c	3.54 a	3.08 B
	100	2.86 cd	2.96 c	3.49 a	3.10 A	2.91 c	3.28 b	3.71 a	3.30 A
	Mean	2.76 C	2.88 B	3.35 A		2.76 C	3.18 B	3.62 A	

See footnotes of Table 3

Table 11. Effect of different levels of P, K and irrigation requirement on leaf chlorophyll reading (SPAD) of potato plants during the two studied seasons of 2013/2014

Irrigation level of ET_c	P levels (kg/fed)	First season (2013)				Second season (2014)			
		K levels (kg/fed)				K levels (kg/fed)			
		50	100	150	Mean	50	100	150	Mean
50%	50	41.7 j	51.1 e	53.0 b	48.6 b	50.4 f	54.7 d	56.1 c	53.7 a
	100	42.1 i	52.2 c	58.5 a	50.9 a	45.3 k	56.9 b	64.4 a	55.5 a
	Mean	41.9 e	51.6 b	55.7 a	49.8 A	47.9 d	55.8 b	60.3 a	54.6 A
75%	50	34.3 m	49.0 g	49.9 f	44.4 c	41.3 m	43.7 l	48.3 gh	44.5 c
	100	41.0 k	50.1 f	51.7 d	47.6 b	49.0 g	47.2 ij	51.2 e	49.1 b
	Mean	37.7 f	49.6 c	50.8 b	46.0 B	45.2 f	45.4 f	49.8 c	46.8 B
100%	50	25.2 n	41.2 jk	45.5 h	37.3 d	29.5 o	45.9 k	47.6 hi	41.0 d
	100	38.0 l	41.4 ij	51.0 e	43.5 c	38.4 n	47.2 ij	46.8 j	44.1 c
	Mean	31.6 g	41.3 e	48.2 d	40.4 C	34.0 g	46.5 e	47.2 de	42.6 C
					P levels* K levels				
	50	33.7 e	47.1 c	49.5 b	43.4 B	40.4 e	48.1 c	50.7 b	46.4 B
	100	40.4 d	47.9 c	53.7 a	47.3 A	44.2 d	50.4 b	54.1 a	49.6 A
	Mean	37.0 C	47.5 B	51.6 A		42.3 C	49.3 B	52.4 A	

See footnotes of Table 3

Table 12. Effect of different levels of P, K and irrigation requirement on potato yield production (ton/fed) during the two studied seasons of 2013/2014

Irrigation level of ET_c	P levels (kg/fed)	First season (2013)				Second season (2014)			
		K levels (kg/fed)				K levels (kg/fed)			
		50	100	150	Mean	50	100	150	Mean
50%	50	5.88 l	6.06 k	7.66 g	**6.53 e**	5.50 l	5.76 k	7.19 g	**6.15 e**
	100	5.96 kl	6.54 i	9.31 c	**7.27 d**	6.07 j	6.25 i	9.34 b	**7.22 d**
	Mean	**5.92 e**	**6.30 e**	**8.49 c**	**6.90 B**	**5.79 f**	**6.00 d**	**8.26 c**	**6.68 B**
75%	50	6.66 h	8.21 f	8.71 d	**7.86 c**	6.86 h	8.73 c	8.38 e	**7.99 b**
	100	7.75 g	8.31 ef	11.3 a	**9.12 a**	7.92 f	8.60 d	11.4 a	**9.30 a**
	Mean	**7.21 d**	**8.26 c**	**10.0 a**	**8.49 A**	**7.39 d**	**8.66 c**	**9.89 a**	**8.65 A**
100%	50	5.66 m	8.25 ef	8.81 d	**7.58 c**	5.58 l	8.69 c	8.37 e	**7.55 c**
	100	6.31 j	8.34 e	9.88 b	**8.18 b**	6.18 ij	8.63 cd	9.42 b	**8.07 b**
	Mean	**5.99 e**	**8.29 c**	**9.34 b**	**7.88 A**	**5.88 f**	**8.66 c**	**8.90 b**	**7.81 A**
					P levels * K levels				
	50	**6.07 e**	**7.51 c**	**8.40 b**	**7.32 A**	**5.98 e**	**7.73 c**	**7.98 b**	**7.23 A**
	100	**6.68 d**	**7.73 c**	**10.2 a**	**8.19 A**	**6.72 d**	**7.82 c**	**10.1 a**	**8.20 A**
	Mean	**6.37 C**	**7.62 B**	**9.28 A**		**6.35 C**	**7.77 B**	**9.02 A**	

See footnotes of Table 3

Table 13. Effect of different levels of P, K and irrigation requirement on total carbohydrates percentage of potato tubers during the two studied seasons of 2013/2014

Irrigation level of ET_c	P levels (kg/fed)	First season (2013)				Second season (2014)			
		K levels (kg/fed)				K levels (kg/fed)			
		50	100	150	Mean	50	100	150	Mean
50%	50	56.1 lm	62.3 h	67.8 d	**62.1 c**	50.6 m	60.9 g	69.7 b	**60.4 b**
	100	58.3 j	69.1 b	71.3 a	**66.2 a**	55.3 k	66.1 d	71.0 a	**64.1 a**
	Mean	**57.2 g**	**65.7 c**	**69.6 a**	**64.2 A**	**52.9 g**	**63.5 d**	**70.4 a**	**62.3 A**
75%	50	56.4 l	57.5 k	66.5 f	**60.1 d**	53.6 l	57.3 i	62.3 f	**57.7 c**
	100	62.1 h	66.9 g	68.1 cd	**65.7 a**	59.4 h	64.7 e	68.0 c	**64.1 a**
	Mean	**59.2 f**	**62.2 e**	**67.3 b**	**62.9 B**	**56.5 f**	**61.0 e**	**65.2 c**	**60.9 B**
100%	50	57.3 k	59.3 i	65.9 g	**60.8 d**	49.5 n	57.4 i	66.9 d	**57.9 c**
	100	56.0 m	68.3 c	66.2 fg	**63.5 b**	55.7 jk	56.2 j	69.9 b	**60.6 b**
	Mean	**56.6 g**	**63.8 d**	**66.1 c**	**62.2 B**	**52.6 g**	**56.8 f**	**68.4 b**	**59.3 B**
					P levels * K levels				
	50	**56.6 d**	**59.7 c**	**66.8 b**	**61.0 B**	**51.2 e**	**58.5 d**	**66.3 b**	**58.7 B**
	100	**58.8 c**	**68.1 a**	**68.6 a**	**65.1 A**	**56.8 d**	**62.3 c**	**69.6 a**	**62.9 A**
	Mean	**57.7 C**	**63.9 B**	**67.7 A**		**54.0 C**	**60.4 B**	**68.0 A**	

See footnotes of Table 3

Table 14. Effect of different levels of P, K and irrigation requirement on total protein percentage of potato tubers during the two studied seasons of 2013/2014

Irrigation level of ET_c	P levels (kg/fed)	First season (2013)				Second season (2014)			
		K levels (kg/fed)				K levels (kg/fed)			
		50	100	150	Mean	50	100	150	Mean
50%	50	20.9 g	23.0 b	24.3 a	**22.7 a**	20.3 lm	23.0 g	26.0 c	**23.1 b**
	100	21.3 f	23.2 b	24.1 a	**22.9 a**	20.4 kl	24.0 f	27.0 a	**23.8 a**
	Mean	**21.1 d**	**23.1 b**	**24.2 a**	**22.8 A**	**20.4 f**	**23.5 c**	**26.5 a**	**23.4 A**
75%	50	19.1 k	20.0 i	22.5 c	**20.5 c**	20.7 j	20.7 j	22.9 g	**21.4 d**
	100	22.0 d	22.5 c	23.2 b	**22.6 a**	21.9 h	23.8 f	24.4 e	**23.4 b**
	Mean	**20.6 e**	**21.2 d**	**22.8 b**	**21.5 B**	**21.3 e**	**22.2 d**	**23.7 c**	**22.4 B**
100%	50	19.6 j	20.5 h	21.9 de	**20.7 c**	18.7 n	21.4 i	25.1 d	**21.7 d**
	100	19.6 j	23.0 b	21.7 e	**21.4 b**	20.1 m	20.5 jk	26.7 b	**22.4 c**
	Mean	**19.6 f**	**21.8 c**	**21.8 c**	**21.1 B**	**19.4 g**	**20.9 e**	**25.9 b**	**22.1 B**
					P levels * K levels				
	50	**19.9 d**	**21.2 b**	**22.9 a**	**21.3 B**	**19.9 e**	**21.7 cd**	**24.7 b**	**22.1 B**
	100	**21.0 c**	**22.9 a**	**23.0 a**	**22.3 A**	**20.8 de**	**22.7 c**	**26.0 a**	**23.2 A**
	Mean	**20.4 C**	**22.0 B**	**23.0 A**		**20.3 C**	**22.2 B**	**25.4 A**	

See footnotes of Table 3

Table 15. Effect of irrigation levels, P and K fertilizer rates on water use efficiency (kg/m^3) of potato plants during the two studied seasons of 2013/2014

Irrigation level of ET_c	P levels (kg/fed)	First season (2013)				Second season (2014)			
		K levels (kg/fed)				K levels (kg/fed)			
		50	100	150	Mean	50	100	150	Mean
50%	50	6.28 h	6.47 g	8.18 c	**6.97 b**	5.63 j	5.90 i	7.36 c	**6.29 d**
	100	6.36 gh	6.98 e	9.94 a	**7.76 a**	6.21 h	6.40 g	9.56 a	**7.39 b**
	Mean	**6.32 e**	**6.72 d**	**9.06 a**	**7.37 A**	**5.92 e**	**6.15 d**	**8.46 a**	**6.84 A**
75%	50	5.68 j	7.01 e	7.43 d	**6.71 c**	5.62 j	7.15 d	6.86 f	**6.54 c**
	100	6.61 f	7.09 e	9.63 b	**7.78 a**	6.49 g	7.04 e	9.33 b	**7.62 a**
	Mean	**6.15 e**	**7.05 c**	**8.53 b**	**7.24 A**	**6.05 d**	**7.10 c**	**8.10 b**	**7.08 A**
100%	50	4.03 l	5.87 i	6.27 h	**5.39 e**	3.81 l	5.93 i	5.71 j	**5.15 f**
	100	4.49 k	5.93 i	7.03 e	**5.82 d**	4.22 k	5.89 i	6.43 g	**5.51 e**
	Mean	**4.26 g**	**5.90 f**	**6.65 d**	**5.60 B**	**4.01 f**	**5.91 e**	**6.07 d**	**5.33 B**
					P levels* K levels				
	50	**5.33 e**	**6.45 c**	**7.29 b**	**6.36 B**	**5.02 e**	**6.33 c**	**6.65 b**	**6.00 B**
	100	**5.82 d**	**6.67 c**	**8.87 a**	**7.12 A**	**5.64 d**	**6.44 bc**	**8.44 a**	**6.84 A**
	Mean	**5.57 C**	**6.56 B**	**8.08 A**		**5.33 C**	**6.38 B**	**7.54 A**	

See footnotes of Table 3

3.4 Water Use Efficiency (WUE)

Data in Table 15 showed the effect of studied treatments on WUE by potato plants cultivated at Dokki site in the two tested seasons. Increasing irrigation quantity over 50% of ET_c led to decrease in WUE for all irrigation treatments. These results agree with those obtained by [35]. There was a significant interaction between irrigation water treatments and inorganic fertilizer ones for WUE. The highest WUE value was obtained by 50% of ET_c combined with 100 kg P_2O_5/fed and 150 kg K_2O/fed. Importance of fertilizers for good yield and better utilization of water can be attributed to the role of P and K in improving crop resistance to water stress [17,36,37]. Fabeiro et al*.* [38] previously reported that WUE values for potato crops in Spain ranged between 6.3 and 8.6 kg m^{-3}, while [39] reported values ranging between 4.8 and 7.4 kg m^{-3}, as a function of both irrigation method and nitrogen level.

4. CONCLUSION

It could be concluded that application of K fertilizer with rate 150 kg/fed, from the recommended amount by the Ministry of Agriculture of Egypt, is optimal for good potato growth and tuber quality. Also, application of P fertilizer at rate of 100 kg/fed proved to be superior in terms of characteristics under study with low irrigation water level 75%.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. FAO. FAOSTAT Database. Available:http://faostat.fao.org/
   Glenn EP, Huete AR, Nagler PL, Nelson SG. Relationship between remotely-sensed vegetation indices, canopy attributes and plant physiological processes: What vegetation indices can and cannot tell us about the landscape. Sensors; 2008 (Basel, Switzerland). 2011;8:2136–2160.
2. Rosen CJ, Kelling KA, Stark JC, Porter GA. Optimizing phosphorus fertilizer management in potato production. Am J Potato Res. 2014;91:145–160.
3. Kijne JW, Barker R, Molden D. Water productivity in agriculture: Limits and opportunities for improvement. CAB International, Wallingford, UK; 2003.
4. Shock CC. Efficiency irrigation scheduling. Malheur Experiment Station, Oregon State University, USA; 2004.
5. Deblonde PMK, Ledent JF. Effects of moderate drought conditions on green leaf number, stem height, leaf length and tuber yield of potato cultivars. Europ J Agron. 2001;14:31-41.

6. Hassan AA, Sarkar AA, Ali MH, Karim NN. Effect of deficit irrigation at different growth stages on the yield of potato. Pakistan J Biol Sci. 2002;5:128-134.
7. Shahnazari A, Liu F, Andersen MN, Jacobsen SE, Jensen CR. Effects of partial root-zone drying on yield, tuber size and water use efficiency in potato under field conditions. Field Crops Res. 2007; 100:117–124.
8. Kahlon MS, Khera KL. Irrigation water productivity and potato (*Solanum tuberosum* L.) yield in different planting methods under mulch conditions. J Agric Ecol Res Int. 2015;3:107–112.
9. Ati AS, Al-Sahaf F, Wally DH, Thamer ThE. Effects of potassium humate fertilizers and irrigation rate on potato yield and consumptive use under drip irrigation method. J Agric Sci Technol. 2013;3:803-810.
10. Manolov I, Neshev N, Chalova V, Ordanova N. Influence of potassium fertilizer source on potato yield and quality proceedings. 50th Croatian and 10th International Symposium on Agriculture, Opatija, Croatia. 2015;363–367.
11. Talal D, Ali F, Safaa B, Ihab J, Mohamad A, Zeina H, Ousama H, Therese A. Potato performance under different potassium levels and deficit irrigation in dry sub-humid Mediterranean conditions. E-ifc. 2015;43:14-20.
12. Islam MS, Haque MM, Khan MM, Hidaka T, Karim MA. Effect of fertilizer potassium on growth, yield and water relations of bush bean (*Phaseolus vulgaris* L.) under water stress conditions. Japan J Agric. 2004;48:1-9.
13. Muhammad A, Amans EB, Babaji BA, Kuchinda NC, Gambo BA. Effects of NPK fertilizer and irrigation intervals on tuber composition of potato (*Solanum tuberosum* L.) in Sudan savannah of Nigeria. J Agric Res. 2015;1:1-9.
14. Alva AK. Water management and water uptake efficiency by potatoes: A review. Archives Agron Soil Sci. 2008;54:53–68.
15. Page AL, Miller RH, Keeney DR. Soil analysis, part 2: Chemical and microbiological properties. ASA, SSSA, Madison, Wisconsin, USA; 1982.
16. Israelsen OW, Hansen VE. Irrigation principles and practices. 3rd ed, John Wiley and Sons Inc., New York, London; 1962.
17. Cantore V, Wassar F, Yama SS, Sellami MH, Albrizio R, Stellacci AM, Todorovic M. Yield and water use efficiency of early potato grown under different irrigation regimes. Int J Plant Production. 2014;8:409-428.
18. FAO. Compost: Thai version. Filmstrip in colour and printed commentary, Rome, FAO 65 photographs; 1980.
19. Watanabe FC, Olsen SR. Test of an ascorbic acid method for determining phosphorus in water and $NaHCO_3$ extracts from soils. Soil Sci Soc Am Proc. 1965;29:677-678.
20. Chapman HD, Pratt PF. Methods of analysis for soils, plants and waters. Division Agric Sci, Berkeley, Univ California, USA; 1961.
21. AOAC. Official methods of analyses, 18th ed. Association of Official Analytical Chemists; 2005.
Available: http://www.aoac.org/
22. Snedecor GW, Cochran G. Statistical methods. 8th ed, Iowa State University Press; 1989.
23. Abelardo NB, Gerrit H, Dennis SN. Drought stress and the distribution of vegetative and reproductive traits of a bean cultivar. Scientia Agricola Piracicaba. 2005;62.
24. Alderfasi AA, Refay YA. Integrated use of potassium fertilizer and water schedules on growth and yield of two wheat genotypes under arid environment in Saudi Arabia: 1- effect on growth characters. Am-Euras J Agric Environ Sci. 2010;9:239-247.
25. Wu JD, Wang D, Rosen CJ, Bauer ME. Comparison of petiole nitrate concentrations, SPAD chlorophyll readings and Quick Bird satellite imagery in detecting nitrogen status of potato canopies. Field Crops Res. 2007;101:96–103.
26. Mekhled A, Wahb-Allah MA, Abdel-Razzak HS, Ibrahim AA, Alsadon A. Water regimes and humic acid application influences potato growth, yield, tuber quality and water use efficiency. Am J Potato Res. 2016;93:1–11.
27. Baniuniene A, Zekaite V. Effect of mineral and organic fertilizers on potato tuber yield and quality. Agronomijas Vēstis (Latvian J Agron. 2008;11:202-206.
28. Saravial D, Farfán-Vignolo ER, Gutiérrez R. Yield and physiological response of potatoes indicate different strategies to

cope with drought stress and nitrogen fertilization. Am J Potato Res. 2016;93:288–295.
29. Pereira AB, Shock CC. Development of irrigation best management practices for potato from a research perspective in the United States. Sakia.org e-Publish. 2006;1:1-20.
30. Abul-Soud MA, Abd-Elrahman Shaimaa H. Foliar selenium application to improve the tolerance of eggplant grown under salt stress conditions. Int J Soil Sci. 2016;9:1-10.
31. Costa-Franca MG, Thi AT, Pereyra RO, Zuily-Fodil Y, Laffray D. Differences in growth and water relations among *Phaseolus vulgaris* cultivars in response to induced drought stress. Environ Exp Botany. 2000;43:227-237.
32. Amede T, Kittlitz EV, Schubert S. Differential drought responses of faba bean (*Vicia faba* L.) inbred lines. J Agron Crop Sci. 2001;183:35-45.
33. Moinuddin, Singh K, Bansal SK. Growth, yield and economics of potato in relation to progressive application of potassium fertilizer. J Plant Nutr. 2005;28:183-200.
34. Ati AS, Nafaou SM. Effect of potassium fertilizers application on growth, yield and water use efficiency of potato under regulated irrigation treatments. Al-Taqani, 2012;25(8).
Available:www.altaqani.org/en/download.php?id=10
35. Sefer B, Mansuroğlu GS. The effects of drip line depths and irrigation levels on yield, quality and water use characteristics of lettuce under greenhouse condition. African J Biotech. 2011;10:3370-3379.
36. Ati AS, Iyada AD, Najim SM. Water use efficiency of potato (*Solanum tuberosum* L.) under different irrigation methods and potassium fertilizer rates. Annals Agric Sci. 2012;57:99–103.
37. Kumari S. Influence of drip irrigation and mulch on leaf area maximization, water use efficiency and yield of potato (*Solanum tuberosum* L.). J Agric Sci. 2012;4:71-80.
38. Fabeiro C, Olalla FM, de Juan JA. Yield and size of deficit irrigated potatoes. Agric Water Manag. 2001;48:255-266.
39. Ünlü M, Kanber R, Senyigit U, Onaran H, Diker K. Trickle and sprinkler irrigation of potato (*Solanum tuberosum* L.) in the Middle Anatolian region in Turkey. Agric Water Manage. 2006;79:43-71.

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