Potato response to phosphorus fertilizer and its effect on the quality and chemical composition under water regime conditions

Nahed A. A. Azab[1], Wafaa M. Hashes[1], Ebtisam, I. Eldardiry[2] Amal M. Aziz[1] and Hani A. Mansour[2]

[1] Soils and Water Use Dept., Agricultural and Biological Research Institute, National Research Centre, El Behoos St., Dokki, Giza, Egypt.

[2] Water Relations and Field Irrigation Dept., Agricultural and Biological Research Institute, National Research Centre, El Behoos St., Dokki, Giza, Egypt.

Corresponding author, Email: mansourhani2011@gmail.com

ABSTRACT

In terms of worldwide consumption, potatoes are the most significant food crop and are regarded as a key crop for food security. Potatoes require a significant amount of plant nutrients, especially phosphorus (P), due to inefficient soil P availability, making phosphorus management essential in potato production. A field experiment was conducted at Nubaria district (NRC Experimental and Production Station), El-Behera Governorate, Egypt, to evaluate the effects of different phosphorus rates (30, 40, and 50 kg/fed) and irrigation system (drip and sprinkler) under varying water regimes (85% and 70% of ETo) on potato nutrient content, growth, yield, and yield characteristics. The results indicated that drip irrigation had a significant positive effect on potato growth and yield, particularly under the 85% water regime. Increasing phosphorus levels improved yield and yield components, with the greatest improvements observed at 50 kg/fed. Future Perspective: Future research should focus on long-term studies exploring sustainable phosphorus management practices and the use of precision irrigation technologies. Additionally, exploring the interaction between phosphorus rates and other essential nutrients, as well as the role of advanced water-saving irrigation techniques, could further enhance potato yield and quality, contributing to more efficient agricultural practices and improved food security.

Keywords: *Irrigation system, Nutrient content, Phosphorus fertilizer, Potato, Water regime, Yield parameters*

INTRODUCTION

In terms of worldwide consumption, potatoes are the most significant food crop and are regarded as a crop for food security. Potatoes require a lot of plant nutrients especially phosphorus (P), due to mainly soil P inefficiently, so managing P in fertilizer is essential to potato production methods. Phosphorus's significance for potato plant growth fertilization with P is essential for the profitable production of potatoes (Solanum tuberosum L.) since many soils do not contain enough P to support crop growth. In general, potatoes are thought to be inefficient in absorbing soil P due to their relatively high P need (Grant et al., 2001), particularly in arid and semiarid circumstances indicated by a high $CaCO_3$ content (Abd El-Hady et al., 2018). They also mentioned that phosphorus's function in cellular energy transpiration plays a significant role in plant metabolism.

Optimizing tuber output, solids content, nutritional quality, and resistance to specific diseases, all depend on the uptake of enough P. Additionally, phosphorus serves to retain nutrients in seeds as phytic acid and is a structural component of phospholipids, nucleic acids, coenzymes, and phosphoproteins (Bundy et al. 2005). Thus, from the beginning of growth until maturity, the plant needs a sufficient supply of P (Grant et al. 2001). Also, P affects potato development and yield in many ways, including rapidening the growth of every plant part during a few weeks following emergence, since final tuber yields depend on tuber set, tuber growth rate, and the length of tuber growth (Eleiwa et al., 2012). Jenkins and Ali, (2000) have demonstrated that more rapid and complete canopy development, including larger leaves, is one of the main advantages of sufficient

P supply.

Balanced fertilization is found to enhance the potato crop yield significantly (Moussa and Shama, 2019). Potato tubers are rich in starch so require relatively higher potassium than any other vegetable crop. Sometimes, potato is also regarded as an indicator crop for potassium availability because of their high requirements (Ati and Nafaou, 2013). Potato is a nutritious food riches in carbohydrates and sugar and vitamins (A, B; C) and micronutrients (Zaheer and Akhtar, 2016).

Potato yield and yield components were affected by many factors such as the application not only potassium but also Nitrogen and phosphorus fertilizers (Singh and Lal, 2012) where potato parameters were reported as significantly affected by fertilizer application and positively yield correlated parameters. Also, Dia et al. (2016) found that yield components are complex traits, which exhibit polygenic or quantitative inheritance patterns. Yield and quality of potato tubers are influenced by many distinct factors such as genetics (cultivar peculiarities), soil fertility, K/P ratio, weather conditions, and chemical treatments (Karam et al., 2011).

One of the contributing factors that caused a reduction in potato yield was the poor use of unbalanced plant nutrition, which led to excessiveness or shortage. Achieving optimum applications for plant nutrients is a pre-requisite substitute strategy as it determines yield and varies with soil, crop and water available to the crop for optimum return and farm profit. Potatoes respond to inorganic and organic fertilizers. Furthermore, information about potassium fertilizer and its levels on potato product is also scarce. Even though the crop requirement of potassium is higher than N and P rates (Bansal and Trehan 2011). . Potato is a high nutrient mining crop and needs a higher amount of N, P, and K for its economic tuber production. It needs sufficient mineral fertilizer addition with heavy manure application (Chillot and Hassan 2010). Widespread potassium deficiency and low replenishment are the major reasons behind the lower productivity of potatoes especially under semi-arid conditions. Despite the application of sufficient N and P, a lack of potassium has limited yields expected, especially under poor soils (Salim et al., 2014).

Specific gravity and tuber dry matter percentage are important quality measures of potato tubers that are positively correlated with K and P fertilization (Malik and Gouch 2002). The higher the specific gravity the higher will be the quantity of dry matter. Potatoes with high specific gravity are preferred for chips and French fries. Khan et al., (2010) conducted field experiments comprising of three K_2O levels, 0, 60 and 90 kg acre^{-1}, they reported that specific gravity was positively affected by both P and K fertilization. There is an increase in the volume of tuber and tuber size due to the function of K in facilitating the translocation of assimilates from leaves to tubers, (Karam et al., 2011). According to Trehan (2007), K activates several enzymes involved in photosynthesis, carbohydrate metabolism, protein synthesis, and assists in the translocation of carbohydrates from leaves to tubers, which increases the size of tubers but not the number.

The main objective of this study was to evaluate the effects of P rates and irrigation systems under different water regimes on potato nutrient content, growth, yield, and yield characters.

MATERIALS AND METHODS

Field experiment was conducted at Nubaria district (National Research Centre Experimental and Predication Station, El-Behira Governorate, Egypt) to study the effect of irrigation system (drip and sprinkler), and P fertilizer rates (30, 40; 50 kg fed^{-1}) under water regime (85 and 70 % from ETo). Sprinkler irrigation (12 x 12 m, with discharge 0.85 m^3 h^{-1}) and drip irrigation (JR 30 cm among dripper, discharge, 4 liter/h) were employed. The study area is characterized by an overall hot and dry climate with few opportunities for precipitation, with an average annual rainfall of 38 mm between December and April. Average evaporation rates range from 2.3 to 7.6 mm/day, with January and July typically recording the lowest and highest air *temperature values, respectively.*

Before soil preparation, farmyard manure, ammonium sulfate (20.5% N), single superphosphate (15.5% P_2O_5), elemental sulfur, and potassium sulfate (50% K_2O) were applied to the soil surface at the rates of 15 m^3, 50, 200, 150, and 50 kg fed-1, respectively. They were well mixed with the upper layer (30 cm). For uniformity, potatoes (Solanum tuberosum L. Spunta) were chosen, and they were treated with fungicide (Fita fax capita 1%, 1.25 kg/ton). The land preparation regulation for potato fields was followed in preparation of the experimental soil. Tubers were planted with a 75 x 30 cm spacing and at a depth of 10 cm. Fertilizer dosages as advised by the Agricultural Ministry were administered. The sources of fertilizer utilized were potassium nitrate (33 % N and urea, which contained 46% N).

Irrigation water (0.58 dSm^{-1}, 7.65 pH) was added as a ratio from ETo (NRC Farm Production Meteo Station) at 85 and 70%. The total water consumption during the potato growing season was 623.7 and 747.2 $m^3 fed^{-1}$, according to (Ghazzawy et al., 2022; Hellal et al., 2019; Abd-Elmabod et al. 2029a,b; Mansour and Abdullah 2012, Mansour and El-Melhem 2015; Mansour 2015a,b; Mansour et al., 2015 a-d; Mansour et al., 2019 a-f).

The experimental soil had the following average values: 7.98, 2.85, 1.65, 4.25, 0.15, 1.50, and 6.92; soil EC in 1:1 (dSm^{-1}); bulk density (g/cm^3); $CaCO_3$ (%); total available nitrogen and organic matter percentage; and available P (ppm). Before cultivation, the experimental soil's $CaCO_3$ (4.56%), OM (0.86%), ECe (2.35 dSm^{-1} in a 1:1 soil extract, and pH (8.08 in a 1:2.5 soil:water ratio) were measured (Klute et al., 1986). The texture of soil is loamy sand. After determining the soil water retention at 0.1 (field capacity) and 15.0 (wilting point) bars, the amount of water that was projected to be available was subtracted (Klute, 1986). Water availability in the soil was determined by subtracting. Following Cottenie et al., macronutrients (N, P, K, and Ca) and micronutrients (Fe, Mn, and Zn) were identified.

Potato dry matter (Oven), starch, Carbohydrate, total sugar, starch, and total sugar were determined according to standard methods described by (AOAC, 2012).

Specific gravity was determined after (Murphy and Goven. 1959) and was computed using as follow:

$$\text{Specific gravity} = \frac{\text{Weight of tuber in air}}{(\text{Weight of tuber in air} - \text{Weight of tuber in water})}$$

Potato tubers were planted on 25 October 2023 and harvested at 15 April 2024 with a total growth period of 142 days. Tuber yield parameters such as length, diameter, fresh and dry weight as well as moisture content were recorded.

The data were subjected to the analysis of variance (ANOVA) appropriate to the split plot in a randomized complete block design applied after testing the homogeneity of error variances according to the procedure outlined by Snedecor and Cochran (1990). The significant differences (LSD) between treatments were compared with the critical difference at 5% probability level (SAS, 2009).

RESULTS AND DISCUSSSION

Data in table (1 a, b; c) showed the effect of the irrigation system and P fertilizer rate under different water regimes (85 and 70 % from ETo) on some potato yield characters (weight of tubers/plant, no. of tuber/plant, average tuber weight, yield, marketable yield and unmarketable yield). The highest values of the studied potato characters were recorded at drip irrigation, WR

70 % and 50 kg P fertilizer, whereas, the lowest ones were attained at sprinkler irrigation, 85 % WR and 30 kg P fertilizer. Regarding to the main yield potato characters (yield ton/fed, marketable and unmarketable), data on hand revealed that P fertilizer 50 kg + water regime 85% gained higher than water regime 70% under drip irrigation for potato yield and marketable yield per ton/fed. Meanwhile the lowest values of unmarketable potato yield (required) were noticed at 30 kg P+ 85% water regime under drip irrigation system, but 40 Kg P +70%WR under sprinkler irrigation have got the lowest values at all (0.601 ton/fed).

Data in Table (1 a, b; c) represented some potato yield characters (tuber diameter, tuber length, tuber volume and specific gravity as affected irrigation system s and P fertilizer rate under different water regime. One can be noticed that the highest values of the previous potato yield parameters were found the water regime 85% + 50 P kg followed by the water regime 70 % under drip irrigation. The same trend was attained under sprinkler irrigation. Also, data cleared that increased P kg was associated with the increase of the instigated potato yield characters mentioned above. Meanwhile, the lowest values of the yield, marketable and unmarketable were recorded at sprinkler irrigation+ 70 % water regime and 30 Kg P.

Data in Table (1 a, b; c) represented the effect of the irrigation system s and water regime and P fertilizer rate on the potato dry matter, starch, carbohydrate, and sugar. The maximum values were obtained at 50 kg P+85 % water regime followed by 70 % water regime under drip irrigation while the opposite was true in minimum values which found sprinkler irrigation + 30 kg P + 85 % water regime, 30 kg P (70 %water regime), 30 kg P (70 % water regime) and 30 kg P (85% water regime) under sprinkler irrigation, respectively. Also, data noticed that the increase of P fertilizer led to increase in DM, starch, carbohydrate and total sugar under both studied irrigation system regardless applied water regime.

Data manifested in Table (2 a, b; c) showed the effect of the irrigation system and water regime and P fertilizer application rate on some macro and micronutrients in potato leaves. Data on hand pointed out that 50kg P under 85% water regime followed by 70% water regime gained the highest values except Fe and Mn, where 40 kg P under 85 % water regime and water regime gained the highest values of the previous potato characters. Same trend was observed under sprinkler water regime without exception. It is easy to arrange values of the macro and micro nutrients in ascending order as follows: 50 kg P+85% WR +drip irrigation >50 kg P+70% WR +drip >50 kg P+85% water regime + sprinkler irrigation > 30 kg P+70% WR + sprinkler irrigation. Also, it is clear to mention that 30 kg P + 70 %WR + sprinkler irrigation recorded the lowest values of the previous potato plant characters.

Table 1a: Effect of irrigation methods and phosphorus application rates on the potato yield, quality and water use efficiency under different water regime conditions.

Irrigation method	Water regime %	P Kg	Tuber characteristics					No of tubers /plant	Average tuber weight g	Tuber Yield ton/fed		Water use efficiency Kg/m^3
			Diameter (cm)	Length (cm)	Volume (cm3/tuber)	Specific gravity (g/cm^3)	Weight/plant (g)			Marketable	unmarketable	
Drip	85	30	6.20	7.10	180.20	0.850	564.25	6.30	89.56	7.895	0.955	4.836
		40	7.80	8.90	215.60	1.020	852.15	7.50	113.62	9.895	3.855	7.514
		50	8.10	9.60	231.80	1.050	955.45	8.60	111.10	12.589	3.261	8.661
		Mean	**7.37**	**8.53**	**209.20**	**0.973**	**790.62**	**7.47**	**104.76**	**10.126**	**2.690**	**7.004**
	70	30	5.80	6.70	180.50	0.810	554.30	6.22	89.12	7.458	0.692	4.454
		40	6.80	8.40	210.40	1.020	895.68	7.85	114.10	10.250	1.733	6.548
		50	7.60	8.90	227.30	1.040	968.25	9.85	98.30	12.380	1.490	7.579
		Mean	**6.73**	**8.00**	**206.07**	**0.957**	**806.08**	**7.97**	**100.50**	**10.029**	**1.305**	**6.194**
Mean			**7.05**	**8.27**	**207.63**	**0.965**	**798.35**	**7.72**	**102.63**	**10.078**	**1.998**	**6.599**
Sprinkler	85	30	5.94	6.85	174.23	0.782	554.25	6.22	89.11	6.785	1.673	3.349
		40	6.45	7.85	181.12	0.965	865.35	6.89	125.60	8.550	2.708	4.458
		50	7.34	8.67	186.21	1.032	935.44	8.12	115.20	10.985	1.910	5.106
		Mean	**6.58**	**7.79**	**180.52**	**0.926**	**785.01**	**7.08**	**109.97**	**8.773**	**2.097**	**4.304**
	70	30	5.88	6.88	166.25	0.798	510.23	6.18	82.56	7.345	1.007	3.307
		40	6.50	7.13	175.63	1.004	812.39	6.88	118.08	10.258	0.601	4.300
		50	7.44	7.44	184.23	1.023	889.74	8.55	104.06	9.854	2.102	4.734
		Mean	**6.61**	**7.15**	**175.37**	**0.942**	**737.45**	**7.20**	**101.57**	**9.152**	**1.237**	**4.114**
Mean		Mean	**6.59**	**7.47**	**177.95**	**0.934**	**761.23**	**7.14**	**105.77**	**8.963**	**1.667**	**4.209**
LSD5%	Irrig. X water regime X P		**0.07**	**0.12**	**3.54**	**0.341**	**11.31**	**0.78**	**3.85**	**1..13**	**0.78**	**1.71**

Table 1b :Effect of phosphorus application rates on the potato yield, quality and water use efficiency under different water regime conditions.

Water regime %	P Kg	Tuber characteristics					No of tubers /plant	Average tuber weight g	Tuber Yield ton/fed		Water use efficiency Kg/m^3
		Diameter (cm)	Length (cm)	Volume (cm3/tuber)	Specific gravity (g/cm^3)	Weight/plant (g)			Marketable	unmarketable	
85	30	6.07	6.98	177.22	0.82	559.25	6.26	89.34	7.34	1.31	4.09
	40	7.13	8.38	198.36	0.99	858.75	7.20	119.61	9.22	3.28	5.99
	50	7.72	9.14	209.01	1.04	945.45	8.36	113.15	11.79	2.59	6.88
Mean		**6.97**	**8.16**	**194.86**	**0.95**	**787.82**	**7.27**	**107.36**	**9.45**	**2.39**	**5.65**
70	30	5.84	6.79	173.38	0.80	532.27	6.20	85.84	7.40	0.85	3.88
	40	6.65	7.77	193.02	1.01	854.04	7.37	116.09	10.25	1.17	5.42
	50	7.52	8.17	205.77	1.03	929.00	9.20	101.18	11.12	1.80	6.16
Mean		**6.67**	**7.58**	**190.72**	**0.95**	**771.77**	**7.59**	**101.04**	**9.59**	**1.27**	**5.15**
LSD 5%	Water relation	0.11	0.37	0.98	ns	7.89	0.21	1.19	0.11	0.89	0.09
P		0.17	1.12	1.54	0.09	13.25	0.98	1.37	0.72	1.72	0.26
Interaction		0.65	1.84	2.01	0.17	17.38	1.37	2.15	1.34	2.11	0.41

Table 1c: Effect of irrigation methods on the potato yield, quality and water use efficiency under different water regime conditions.

Irrigation methods	Water regime %	Tuber characteristics					No of tubers /plant	Average tuber weight g	Tuber Yield ton/fed		Water use efficiency Kg/m^3
		Diameter (cm)	Length (cm)	Volume (cm3/tuber)	Specific gravity (g/cm^3)	Weight/plant (g)			Marketable	Unmarketable	
Drip	85	7.37	8.53	209.20	0.97	790.62	7.5	104.76	10.15	2.69	80.20
	70	6.73	8.00	206.07	0.96	806.08	7.9	100.5	10.03	1.31	88.49
Mean		**4.70**	**5.51**	**138.22**	**0.64**	**532.231**	**5.1**	**68.422**	**6.72**	**1.33**	**56.23**
Sprinkler	85	6.58	7.79	180.52	0.95	785.01	7.1	109.97	8.77	2.10	80.45
	70	6.61	7.15	175.37	0.94	737.45	7.2	101.57	9.15	1.24	88.10
Mean		**4.39**	**4.98**	**118.63**	**0.62**	**507.49**	**4.7**	**70.51**	**5.97**	**1.11**	**56.18**
LSD5%	Irrigation methods	0.21	0.45	4.25	ns	11.23	1.2	0.98	0.67	0.09	0.13
Water relation		0.38	0.67	6.12	0.04	14.98	1.7	1.38	0.98	1.13	0.21
Interaction		0.51	0.87	8.39	0.11	17.22	2.1	1.58	0.109	1.64	0.38

In reference to the impact of water regime system on the dry matter, starch, carbohydrate, and total sugar content, available data showed that the highest values of the radius but parameters were achieved at the water regime method with increase percentages of 8.57, 12.76, and 2.21 percent, respectively. In the meantime, increased P rate was linked to an increase in the study yield but parameters where the increase in P fertilizer from 30 to 14 kg verified then combined with increase the percentage by about 6.45, 10.95, 1.79, 3.09% and from 40 to 50 d kg that have then to increase the led to increase the percentage why about eight point three, 97.97 comma 3.76 comma minus 1 going to all six percent respectively in the same sequences (Table 2 a, b;c).

According to the effect of water regime system on investigated macro and the micro nutrients contains data in table o showed that the highest values will record it at 50 Kg P and the lowest one was obtained after application of 30 kg P. Also, data noticed that the percentage of a change where 29.3 18.83 14.86, 32.4, second to all three, a living sex boy in 73, 29.03, 15.10% and 5.665, 4.69, 4.220 18.50 3 and it 0.69 comparing 40 kg P with 30 kg P and 50 with 40 kg P, respectively

The data presented in Table 1 demonstrated how irrigation methods and P fertilizer application rate interacted to affect WUE. It was observed that sprinkler irrigation was used in the same order as drip irrigation + 50 kg P fertilizer under 85% water regime. Additionally, the lowest WUE values were found when using sprinkler irrigation with 70% water regime. Potato WUE is significantly impacted by drip irrigation, which outperforms sprinkler irrigation by roughly 36.21%. In reference to the influence of P fertilizer application rates on potato WUE, the results demonstrated that an increase in P fertilizer was correlated with an increase in potato WUE values, with percentage increases of 34.11 and 14.29 following 40 and 50 kg of P fertilizer, respectively, compared to 30 kg P fertilizer (table 2 a, b; c).

Also, data showed the effect of various irrigation methods on quality and quantity of potato, such as no, of tuber/plant, tuber weight/plant and mean tuber weight, yield increased with increase P rates. Besant marketable tuber pointed out that irrigation method was superior and the recorded the highest values for all study yield parameters except average tuber with the rate of each change in percentage comparing drip with sprinkler irrigation were 4.65, 7.501, - 3.05, 11.97, 11.06 and 16.506% that is big table meanwhile increasing P a combined with increase in all the study yield characters that in table showed that increase in percentage by about 56.9, 16.85, 34.65, 41.50 for 50, 30 kg P fertilizer and 12, 105.62 comparing 40 kg P with control treatment and 9.44 20.60 – 9.06, 14.05, 17.60 and - 1.51 % comparing by 40 kg P, respectively. Jenkins and Ali (2000) state that potato has strong requirement for phosphorus and adequate available phosphorus in the soil is critical for the early development of potato plants, tuber setting, and tuber maturity enhancement. They added phosphorus deficiency, in contrast, will markedly decrease tuber yield, quality, and size.

The results presented in Table (2 a, b; c) showed how the water regime and P application rates interacted to affect the DM, starch, carbohydrates, and total sugar content. The highest and lowest values were recorded after water regimes of 85% and 50% kg P application rate and 70% and 30% kg P application rate. It was found that increasing P by 20 kg increased the aforementioned potato yield attributes by around 16, 30, 7,: 6% for water regime 85% and 14, -2, 4, -2 for water regime 70%, respectively. The macro and micronutrient table (000) illustrates the relationship between P application rates and water regime. Based on the available data, all stated values were better when P increased.

Table 2a: Effect of irrigation methods and phosphorus application rates on the potato yield, quality and water use efficiency under different water regime conditions.

Irrigation methods	Water regime %	P kg/fed	Dry matter	Starch	Carbohydrate	Total Sugar
			%			
Drip	85	30	13.25	44.32	50.23	0.615
		40	13.85	55.63	57.65	0.654
		50	15.22	58.47	61.25	0.669
		Mean	14.11	52.81	56.38	0.646
	70	30	11.75	38.64	45.16	0.633
		40	12.98	41.15	46.88	0.645
		50	13.65	42.68	52.13	0.580
		Mean	12.79	40.82	48.06	0.619
Mean			**13.45**	**46.82**	**52.22**	**0.633**
Sprinkler	85	30	11.35	41.31	48.32	0.601
		40	12.12	50.23	45.35	0.611
		50	13.41	52.67	44.16	0.623
		Mean	12.29	48.07	45.94	0.612
	70	30	11.85	41.08	47.12	0.612
		40	12.36	36.45	44.36	0.627
		50	13.15	35.08	44.01	0.638
		Mean	12.45	37.54	45.16	0.626
Mean			**12.37**	**42.80**	**45.55**	**0.619**
LSD5%	Interaction		**1.55**	**3.14**	**3.91**	**0.041**

Table 2b: Effect of phosphorus application rates on the potato yield, quality and water use efficiency under different water regime conditions.

Water regime %	P kg	Dry matter	Starch	Carbohydrate	Total Sugar
		%			
85	30	12.30	42.82	49.28	0.61
	40	12.99	52.93	51.50	0.63
	50	14.32	55.57	52.71	0.65
Mean		**13.20**	**50.44**	**51.16**	**0.63**
70	30	11.80	39.86	46.14	0.62
	40	12.67	38.80	45.62	0.64
	50	13.40	38.88	48.07	0.61
Mean		**12.62**	**39.18**	**46.61**	**0.62**
LSD5%	Water regime	0.98	1.12	1.87	0.06
P		1.67	1.85	2.71	0.11
interaction		1.89	2.34	3.85	0.31

Table 2c: Effect of phosphorus application rates on the potato yield, quality and water use efficiency under different water regime conditions.

Irrigation method	Water regime %	Dry matter	Starch	Carbohydrate	Total Sugar
		%			
Drip	85	14.107	52.807	56.377	0.646
	70	12.793	40.823	48.057	0.619
Mean		**8.967**	**31.210**	**34.811**	**0.422**
Sprinkler	85	12.293	48.070	45.943	0.612
	70	12.453	37.537	45.163	0.626
Mean		**8.249**	**28.536**	**30.369**	**0.412**
LSD5%	Irrigation method	0.387	1.231	1.85	0.011
Water regime		0.741	2.015	2.34	0.027
interaction		0.977	2.312	2.871	0.041

CH: Carbohydrate

According to Stark and Love (2003), P cell division plays a major influence in how water regime affects P deficient plants, which typically show decreased root development. They also mentioned that P has been connected to the production of tuber starch.

Application of P fertilizer often increases the number of tubers per plant (Jenkins and Ali 2000; Allison et al. 2001). Rosen et al. (2014) stated that the increase in tiny tuber count was countered by a decrease in large tuber count, although Freeman et al. (1998) reported that application P enhanced the proportion of large tubers harvested. Furthermore, while finding yield responses, Mohr and Tomasiewicz (2011) noted that P did not influence the overall number of tubers.

Tuber Caliber P can affect tuber quality in a number of ways, one of which is by raising the tuber's specific gravity or dry matter (Laboski et al., 2007). The effects of P on tuber specific gravity that have been measured have been inconsistent, although it seems that if soil test P

Potato yield and yield component varied with N, P and K balanced , variety and soil characteristics (Naz et al. 2011). The interaction of K and N also produced significantly different marketable tuber numbers and plant height while K and P interaction provided significantly different total and marketable tuber numbers. The interaction of nitrogen and variety was also highly significant. Stark and Love (2003) state that P deficient plants, which generally exhibit reduced root development, are significantly impacted by P cell division in terms of water regime. Additionally, they claimed that P has been linked to the tuber starch manufacturing process. The number of tubers per plant increases when P fertilizer is applied (Jenkins and Ali 2000; Allison et al. 2001). Although Freeman et al. (1998) found that application P increased the proportion of large tubers harvested, Rosen et al. (2014) claimed that the rise in small tuber count was offset by a decrease in large tuber count. Furthermore, Mohr and Tomasiewicz (2011) observed that P had no effect on the total number of tubers while discovering yield responses.

Data in Table (3 a, b; c) showed the interaction effect of three studied factors (irrigation methods, water regime and P application rates) on the macro (N, P, Ca and S) and micronutrients (Fe, Mn; Zn) contents in potato leaves. Data pointed out that the highest values of the studied plant nutrient were attained at 50 kg P+ Drip irrigation under 85 % water regime treatments. While the lowest ones were observed at 30 kg P + sprinkler irrigation under 70 water regime treatment. With respect to the interaction effect of the P fertilizer application rates on the macro (N, P, Ca and S) and micronutrients (Fe, Mn; Zn) contents in potato leaves, data manifested in table 4b indicated that values under water regime at 85, 70, 85; 85 % for macronutrients, respectively.

Table 3 a: Effect of irrigation methods and phosphorus application rates on the macro and micronutrients in potato leaves under different water regime conditions.

Irrigation method	Water regime %	P kg	Macronutrients %				Micronutrients ppm		
			N	P	K	Ca	Fe	Mn	Zn
Drip	85	30	1.23	1.22	3.31	0.82	210.30	23.01	26.15
		40	1.63	1.41	4.02	1.12	254.36	30.18	30.15
		50	1.75	1.62	4.83	1.44	287.31	36.77	32.23
	Mean		1.54	1.42	4.05	1.13	250.66	29.99	29.51
	70	30	1.22	1.20	3.28	0.80	211.35	22.11	26.06
		40	1.56	1.48	3.37	1.19	246.22	28.39	28.44
		50	1.61	1.57	4.33	1.54	234.12	32.45	32.15
		Mean	1.46	1.42	3.66	1.18	148.49	27.65	28.88
Mean			**1.50**	**1.42**	**3.86**	**1.15**	**199.57**	**28.82**	**29.20**
Sprinkler	85	30	1.21	1.16	3.35	0.78	201.31	22.11	25.16
		40	1.54	1.38	3.83	0.98	231.25	29.34	29.85
		50	1.68	1.48	4.25	1.21	244.38	32.15	31.24
	Mean		1.48	1.34	3.81	0.99	225.65	27.87	28.75
	70	30	1.25	1.20	3.32	0.81	208.14	22.03	25.64
		40	1.63	1.41	4.01	0.96	238.35	27.26	30.12
		50	1.68	1.51	4.45	1.32	245.16	35.14	33.24
	Mean		1.52	1.37	3.93	1.03	230.55	28.14	29.67
Mean			**1.50**	**1.36**	**3.87**	**1.01**	**228.10**	**28.01**	**29.21**
LSD5%	Interaction		**0.12**	**0.16**	**0.65**	**0.45**	**11.35**	**4.56**	**1.67**

Table 3b: Effect of P fertilizer application rates on the macro and micronutrients content in potato leaves under different water regime conditions.

Water regime %	P kg	Macronutrients %				Micronutrients ppm		
		N	P	K	Ca	Fe	Mn	Zn
85	30	1.22	1.19	3.33	0.80	205.81	22.56	25.66
	40	1.59	1.40	3.93	1.05	242.81	29.76	30.00
	50	1.72	1.55	4.54	1.33	265.85	34.46	31.74
	Mean	**1.51**	**1.38**	**3.93**	**1.06**	**238.15**	**28.93**	**29.13**
70	30	1.24	1.20	3.30	0.81	209.75	22.07	25.85
	40	1.60	1.45	3.69	1.08	242.29	27.83	29.28
	50	1.65	1.54	4.39	1.43	239.64	33.80	32.70
	Mean	**1.49**	**1.40**	**3.79**	**1.10**	**230.56**	**27.90**	**29.28**
LSD 5%	Water regime	0.12	ns	0.11	0.04	1.36	0.18	0.09
	P	0.17	0.10	0.15	0.11	2.47	0.27	0.16
	Interaction	0.29	0.13	0.31	0.19	3.61	2.41	1.27

Table 3c: Effect of irrigation methods on the macro and micronutrients content in potato leaves under different water regime conditions.

Irrigation method	Water regime %	Macronutrients %					Micronutrients ppm		
		N	P	K	Ca	S	Fe	Mn	Zn
Drip	85	1.53	1.417	4.053	1.127	0.270	250.66	29.99	29.51
	70	1.46	1.417	3.660	1.177	0.320	230.56	27.65	28.88
	Mean	**1.00**	**0.944**	**2.571**	**0.768**	**0.197**	**160.41**	**19.21**	**19.46**
Sprinkler	85	1.4	1.340	3.810	0.990	0.257	225.65	27.87	28.75
	70	1.520	1.373	3.927	1.030	0.290	230.55	28.14	29.67
	Mean	**0.99**	**0.904**	**2.579**	**0.673**	**0.182**	**152.07**	**18.67**	**19.47**
LSD 5%	Irrigation	ns	0.137	0.06	0.112	0.089	1.023	0.351	Ns
	Water regime	0.12	0.271	0.117	0.214	0.121	1.031	0.457	0.108
	Interaction	0.138	0.387	0.210	0.354	0.231	1.125	0.567	0.148

Whereas 85, 85; 70 % water regime gained the highest values of the Fe, Mn and Zn content, respectively. Also, it is clear to mention that P fertilizer application rate at 50 kg still gained the highest values for the previous plant nutrients and the opposite was true in case of 30 kg P.

Table (3 c) showed the interaction effect of irrigation methods and water regime on the macro (N, P, Ca and S) and micronutrients (Fe, Mn; Zn) contents in potato leaves. Resulted data cleared that drip irrigation has a superior effect on the macro and micronutrients and scored the highest values of N, P; S and sprinkler irrigation got the highest values of the other studied nutriments.

According to Abd El-Latif (2011), whereas potassium levels have enhanced potato tuber yields, phosphorus *levels have increased the number of tubers per plant. The increasing tuber size, quantity of tubers per plant, or both may be the cause of this rise in potato yields. In addition to internal characteristics like dry matter content, growth cracks, hollow hearts, and internal bruises, tuber quality also includes external characteristics like tuber size, shape, skin and flesh color, depth of eyes, greening, and mechanical damage (Olanya, et al. 2014). They also mentioned how farming techniques, such as plant density, irrigation schedule, and fertilizer control, affect the quality of tubers. An appropriate phosphorus supply at tuber initiation guarantees that the right amount of tubers are generated.*

CONCUSION

These findings indicate that whereas the interaction between the irrigation system and water regime treatments had a highly significant impact on the quantity of marketable tubers and plant height, the water regime alone did not influence any of the assessed parameters under investigation. An essential ingredient that improves potato output and quality is phosphorus. Because potatoes are a highly nutrient-rich crop, they require a suitable amount of mineral fertilizer for healthy growth and development. Research has been done on the effects of P on growth, specific gravity, sugar reduction, shelf life, yield, and others under different water regimes. Both of phosphate and irrigation systems had a considerable impact on the specific gravity of potato tubers. The growth, development, yield and quality of potatoes was found to be significantly affected by P application. The optimum dose of P was found to perform well; higher rates did not affect the parameters significantly.

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