Optimizing Potato Yield and Quality through Balanced Potassium and Nitrogen Fertilization

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ABSTRACT

Potato (Solanum tuberosum L.) is one of the most important food crop in terms of global consumption, and it is the second exported crop in Egypt so it a source of hard current. Management of fertilizer nitrogen (N) is a critical component of potato production systems as potato has a relatively high potassium (K) requirement and inefficiently use soil K. A field experiment was conducted at Nubaria district (National Research Centre experimental Station), El-Behera Governorate, Egypt. The main objective of this study was carried out to study the effects of K (80; 60 kg fed^{-1} that represent 200, 150 kg ha^{-1}) and N fertilizers (40, 50; 60 kg fed^{-1} that represent 100, 125; 150 kg ha^{-1}) application rate on potato growth, yield, and yield characters.

Resulted data cleared that increasing nutrient concentrations in leaves as well as nutrient uptake by potatoes. Such a response indicated that NPK plus micronutrients were necessary for the plant to express its yield potential. Potassium effects on the yield and potato weight of various grades (ton/fed) where decrease K fertilizer by 25 kg led to a reduction in values by 12.1, 10.8 and 28.61 %, except potato grades less than 200 mm that increased by 10 %. Increase both K and N fertilizers and individually enhanced potato tuber characters (diameter, length, volume and specific gravity). Interaction between K and N have a significant effect between K and N from side and the investigated tubers characters, where 80 kg K and 60 kg N gained the highest values and the opposite was recorded after 60 kg K and 40 kg N. Increasing K and N fertilizers led to an increase in both macro and micronutrients content. Whereas 80 kg K enhanced macronutrient content and the opposite was true in the case of 60 kg K there is an increase in micronutrient content resulting by an increase N fertilizer from 40 to 50 and 60 kg. Application 80 kg K fertilizer led to an increase in the previous parameters, while 60 kg K caused a decrease by 9.0, 20.8, 13.9 and 1.8 %, in the same sequence. Potassium fertilizer effect, N fertilizer has a superior effect on dry matter, starch, carbohydrates and total sugar with increase percentages 11.1, 18.4, 11.0; 3.2 % and 39.5, 28.9, 24.1 and 0.1 % for 50 and 60 kg N above 40 kg N, respectively. In summary, the best way to achieve high growth, yield, chemical composition, and quality of potato is to mineral fertilize potatoes by 80 kg of K and 60 kg of N as a soil application.

Resulted data concluded that balanced N and K fertilizer was very important factor to maximize yield and yield parameter to enhance export feature of potato.

Keywords: *Growth parameters, Potato, N-K fertilizers, yield, quality.*

INTRODUCTION

Potato (Solanum tuberosum L.) is one of the major export vegetable crops of Egypt. Balanced fertilization is necessity to enhance the potato crop yield significantly. Potato tubers are rich in starch so *require relatively higher amount of potassium (K).*

Potato is a highly consumed fertilizer crop that needs more N and K for its economic tuber production. Despite applying a sufficient amount of N, a lack of K has limited yields expected, especially under poor soils (Regmi et al., 2002). One of the contributing factors that caused the reduction in potato yield was the poor use of unbalanced plant nutrition, which led to excessiveness or shortage. Even though the crop requirement of K is higher than N rates (Bansal and Trehan 2011). Potassium is considered a major osmotically active cation of plant cells (Mehdi et al., 2007). K is crucial for several physiological processes, including osmoregulation, protein synthesis, photosynthesis, stomata movement, energy transfer, phloem transport, cation-anion balance, and stress resistance (Wang et al., 2013 and Salami and Saadat, 2013). To maximize crop output and farm profit, it is imperative to apply the right amount of fertilizer to the plants. This is because crop productivity is influenced by soil fertility, crop health, and crop water availability. Numerous factors, including the application of N and K fertilizers, had an impact on potato yield and yield components. According to Singh and Singh (1996), potato parameters were found to be significantly impacted by fertilizer application and positively yield correlated parameters, indicating that higher potato plant height was a contributing factor to higher potato yield.

Abd El-Latif et al., (2011) reported that the highest emergence percentage was observed at 60 kg K_2O acre^{-1}, and decreased with more than 60 kg N acre-1. They attributed this result to the negative impacts of excess o fertilization. Ati and Nafaou (2012) and Moussa and Shama (2019) on the other hand, noted that high K levels associated with fertilizer application caused an increase in the vegetative growth of potato plants. They attributed this to one or more of the following significant roles in photosynthesis, regulation of stomata opening and closing, and favors high energy status, which aids in timely and appropriate nutrient translocation and water uptake.

Important indicators of potato tuber quality, specific gravity, and tuber dry matter % have a positive correlation with K fertilization (Malik and Gouch 2002). The amount of dry matter will increase with a higher specific gravity. High-specific gravity potatoes are the best for making chips and french fries. Khan et al. (2010) carried out fieldwork

Numerous different elements, including soil fertility, weather, cultivar characteristics, and chemical treatments, affect the yield and quality of potato tubers (Rytel et al., 2013). However, in order to sustain production and provide high-quality tubers, potatoes need significant nutrient inputs. According to Czajkowski et al. (2011), a potato's resistance to disease may be enhanced by a sufficient supply of vital components. They also stated that proper nutrient management is essential to achieving good tuber output and quality. A sufficient supply of different nutrients is necessary for the crop to be able to synthesize significant amounts of carbohydrates. The three main plant nutrients that affect crop yields are nitrogen, phosphorus, and potassium. The function of K in the biochemistry of starch production, potato plant growth, and tuber

Trehan (2007) reported that K facilitates the transport of carbohydrates from leaves to tubers, increasing tuber size but not quantity, by activating multiple enzymes involved in photosynthesis, carbohydrate metabolism, and protein synthesis. The average tuber size increases considerably with K nutrition (Singh and Bansal, 2005). The majority of plant growth traits, such as leaf area duration, were raised by nitrogen fertilizers, which therefore increased mean tuber weight and tuber production. Put differently, Khan et al. (2010) found that K increased the amount of dry matter that was directed toward the tubers and increased the number of tubers per plant.

Ismail (2009) reported that there was a considerable increase in tuber number and yield due to the interaction between K and N. Furthermore, it was shown that applying K up to 120 kg K_2O/ha increased the yields of potato tubers (Singh and Bansal, 2005). Eleiwa et al. (2012) reported that increasing NPK fertilizer led to a yield increase, with the best yield being obtained at (120:80:100) rates. In addition to producing significantly varied numbers of marketable tubers and plant height, the interaction between K and N also created significantly different numbers of total and marketable tuber numbers. Therefore, the present work aims to investigate the effect of different N and K application rates on yield, yield components, and nutrient content in potatoes.

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 methods (drip and sprinkler), and P fertilizer rates (30, 40; 50 kg fed^{-1}) under water regime (85 and 70 % from ETo). Canal irrigation water was used. Drip irrigation was installed 75 cm between laterals (JR 30 cm among dripper, discharge, 4 liter/h). The study area is characterized by a hot and dry climate in general with scanty rainfall drops that may occur between December-April with an annual average of 38 mm, whereas the evapotranspiration average ranged between 2.3 to 7.6 mm/day recorded in January and July, respectively.

Farmyard manure, ammonium sulfate (20.5 % N), single superphosphate (15.5 % P_2O_5), elemental sulfur, and potassium sulfate (50 % K_2O) at rates of 15 m^3, 50 kg, 200 kg, 150 kg, and 50 kg fed^{-1}, respectively were spread in the soil surface before soil preparation and mixed well with the upper layer (30 cm). Potato (Solanum tuberosum L. Spunta) was selected for uniformity and fungicide treated (Fita fax capita 1%, 1.25 kg/ton). Planting tubers were planted at 10 cm depth and 75x30 cm spacing.

The recommended doses of fertilizers according to the Agricultural Ministry were applied. The fertilizer sources used were urea (46% N) and ammonium nitrate (33%N) with rates 1/3 and 2/3, respectively after month from planting date and the second month to 10 days before harvesting, weekly doses. Potassium sulphate (50% K_2O) at 120 kg /fed. Potassium nitrate (13 % N and 46 % K_2O) was sprayed to times after 45 and 60 from germination.

Irrigation water (0.58 dSm^{-1},7.65 pH) was added depending on the local reference evapotranspiration (NRC Farm Production Meteo Station) at 85%. The total water consumption during the potato growing season was 623.7 and 747.2 m^{3}fed^{-1}.

The average soil pH H_2O (1:2.5), soil EC in 1:1 (dSm^{-1}), bulk density (g/cm^3), $CaCO_3$ (%), total available nitrogen and % organic matter, available P (ppm) were 7.98, 2.85, 1.65, 4.25, 0.15, 1.50 and 6.92 respectively for experimental soil. Some soil characteristics of the experimental soil before cultivation are determined after (Klute et al., 1986) i.e. *$CaCO_3$ (4.56%), OM (0.86%), ECe (2.35 dSm^{-1} in 1:1 soil extract), pH (8.08 in soil: water 1:2.5). Soil is loamy sand in texture. Soil water retention were 19.70 and 4,85%wb at 0.1 bars (field capacity) and 15.0 bars (wilting point), respectively were determined and Available water (14.85%) was estimated by subtracting after (Klute, 1986). Macro (N, P, K, and Ca) and micronutrients (Fe, Mn; Zn) were determined after Cottenie et al. (1982).*

Additional procedures were carried out in accordance with the guidelines suggested by the Agricultural Research Center for the production of potatoes. At the appropriate physiological maturity (75 percent of the leaves withering), tubers were harvested once. Marketable tubers had a diameter of more than 30 mm and were devoid of cracks, illnesses, pests, and mechanical damage. Using a ruler, the height of ten (10) randomly chosen plants from the center rows of each treatment was measured at 75% of flowering. This measurement was averaged to produce one representative treatment plant height. The following data were gathered: total number of tubers per plot, weight of different grades of tuber yields in tons/fed, height of plants in centimeters at maturity, and tuber fresh weight in tons/fed. A few growth characteristics of potato plants

Potato dry matter (Oven), starch, Carbohydrate, total sugar, starch, and total sugar were determined according to standard methods described by (AOAC, 2000). Specific gravity was determined after (Murphy and Goven. 1959) and was computed using the following equation:

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

Potato tubers were planted on 25 October 2023 and harvested on 15 April 2024 with a total growth period of 142 days. Tubers 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 factorial analysis (potassium and nitrogen fertilizers rates) in a randomized complete block design applied after testing the homogeneity of error variances according to the procedure outlined by (Snedecor and Cochran, 1990). SAS (2009) statistical program was used to estimate the significant differences (LSD) between treatments, which were compared with the critical difference at 5% probability level.

RESULTS AND DISCUSSION

Data in Table 1 showed the effect of the K (80; 60 kg/fed) and N fertilizer (40, 50, 60 kg/fed) on some potato yield characters (weight of tubers /plant, no. of tubers /plant, average weight of tuber). It was noticed that the highest values of those parameters were obtained at 80 kg K and 60 kg N followed by 70 kg N fertilizer. While the lowest values were recorded at 75 kg K and 40 kg N fertilizer. Potato yield after application 80 kg K varied between 11.155 and 16.155 under 40; 60 N and 10.179, 14.628 ton fed-1 under 60 kg K and 40, 60 kg N, respectively. Regarding to the K fertilizer effect on the previous potato parameters, data pointed out, that although K has an appositive effect on the investigated potato parameters, a decrease K from 80 to 60kg caused a reduction estimated in percentage were 10.7, -3.4, 13.0 % for the weight of tubers/plant, and average tuber weight, except no of tubers/plant that increases by 3.4%. Also, there is a significant increase of the weight of tubers /plant, no. of tubers /plant, and average weight of tuber with increasing P fertilizers with values 53.4, 34, 11 and 60.1, 67.1, 34.0 % after 50 and 60 kg N comparing with 40 kg N, respectively.

Table 1: Effect of potassium and nitrogen application rates on yield and yield characters of potato leaves.

Potassium kg	Nitrogen Kg	*Tuber weight /plant*	*No of tuber/plant*	*Average tuber weight*	*Potato yield*	*The percentage of various grades of tuber ton/fed*			*Water use efficiency*
		g			*Ton/fed*	*>200*	*100-200*	*<100*	*Kg/m³*
80	*40*	*643.25*	*5.20*	*95.15*	*11.155*	*8.123*	*2.374*	*0.658*	*6.096*

	50	912.45	6.60	105.36	14.931	10.556	3.754	0.621	8.159
	60	988.36	8.50	138.25	16.155	10.822	4.756	0.577	8.828
	Mean	**848.02**	**6.77**	**112.92**	**14.080**	**9.834**	**3.628**	**0.619**	**7.694**
60	40	521.68	5.10	88.25	10.179	6.102	2.442	0.635	5.562
	50	874.30	7.20	98.25	12.319	9.653	2.015	0.651	6.732
	60	876.58	8.70	108.30	14.628	10.557	3.315	0.756	7.993
	Mean	**757.52**	**7.00**	**98.27**	**12.375**	**8.771**	**2.591**	**0.681**	**6.762**
LSD5%	K	34.23	0.21	7.45	1.752	1.109	0.873	0.451	1.023
	N	41.32	0.23	8.44	1.987	1.123	0.975	0.532	1.097
	KxN	43.25	0.31	9.21	2.034	1.283	1.102	0.567	1.123

Data manifested in Table 1 illustrated that potato yield (ton/fed) and potato weight of various grades (ton/fed). Obtained data revealed that the highest values were recorded after application 80 kg K and 60 kg N and the opposite was true for the lowest values that fulfilled after 60kg K and 40 kg N fertilizer. It is clear to mention that 80 kg K and 60 Kg N scored the highest potato yield (16.155 ton/fed) and lowest yield was obtained after 60kg K and 40 kg N. Regarding to the K fertilizer effect on the yield and potato weight of various grades (ton/fed), data pointed out that decrease K fertilizer by 25 kg led to reduction in values by 12.1, 10.8 and 28.61 %, except potato grades less than 200 mm that increased by 10 %. Various potato grades and the percentage of increase were 27.0, 42.1, 19.8; -1.6 % for 50 kg P and for 60 kg N values were 44.3, 50.3, 67.6 and 3.1% comparing with 40 kg N fertilizer for yield, > 200, 200-100; < 100 mm, respectively.

According to the water use efficiency (WUE), data in Table 1 indicated that its values ranged between 6.096 and 8.828 and 5.562, 7.993 kg/m^3 for 80; 60 kg K and 40, 60 kg N fertilizers, respectively. Also, it is mentioned that the highest values are strongly correlated by the highest rates of both investigated fertilizers (80 kg K and 60 kg N). Regarding to the effect of the K, data pointed out that increasing K from 60 to 80 kg led to an increase in percentage in WUE value by 13.8%. With respect to the N fertilizer rates, data observed that an increase N by 10 kg led to an increase in percentage in WUE values by 27.7 and 44.3 % after 50 and 60 kg compared with 40 kg N, respectively.

The total and marketable tuber yields were impacted by the potassium application rates. The obtained results is consistent with the findings of Bansal and Trehan (2011), who reported that an increase in tuber number and size led to a yield rise when potassium was applied. They went on to say that the K and balance in the fertilization program and timing were mostly responsible for tuber quality (tuber size, shape, and flesh color), mechanical damage, and interior characteristics. Plant density, irrigation, and fertilizer management are among the farming techniques that affect tuber quality (Olanya, et al. 2014). According to Tawfik (2001) and Abd El-Latif (2011), raising the K level has enhanced potato tuber yields. They added that either a larger tuber or more tubers per tuber could be the cause of this rise in potato production.

According to Nandekar (2005), higher K treatment rates increased the yield of potato tubers weighing less than 25 g, but had no effect on tubers weighing between 25 and 50 g and 51 and 75 g. However, there has also been a report of a non-significant effect of K on the yield of tubers weighing less than 25 g. Additionally, Tawfik (2001) noted that the yield of the cultivar "Spunta" planted in sandy soil with drip irrigation rose by approximately 15% and 40%, respectively, under a higher K rate for 28–60 mm and >60 mm diameter *tubers. An increase in tuber volume and size is anticipated because of K's role in aiding the transport of assimilates from leaves to tubers (Karam et al., 2011). Dalia Selim et al., (2021) reported that the interaction of K and N also produced significantly different marketable tuber numbers and plant height. Also, Singh and Lal (2012) stated that the interaction of N and K has significantly affected the plant height, tuber number, and size. Moinuddin et al., (2005) found in field experiments, there is an increase in potato tuber yields and attributed this result to K application up to 120 kg K_2O/ha (48 kg K_2O acre $^{-1}$) was observed in.*

Also, K has been shown to increase potato tubers characters (diameter, length, volume and specific gravity). Table 2 illustrated the effect of the K and N fertilizers application rates. The resulted data cleared that increasing both or individually K and N fertilizers enhanced potato tubers characters (diameter, length, volume and specific gravity), there is a significant effect between K and N from side and the investigated tubers characters, where 80 kg K and 60 kg N gained the highest values and the opposite was recorded after 60 kg K and 40 kg N. With respect to the specific gravity, 80 kg K and 60 kg N scrod the highest value and its values ranged between 0.785 – 1.055 and 0.809 – 1.045 g cm^{-3} after 80 kgK+60kg P and 60kg K + 40 kg N, respectively.

Also, K fertilizer at 80 kg has a superior effect on the potato tubers parameters than 60 kg that caused an increase in percentage as follow: 6.9, 2.4, 2.9; 0.6% for diameter, length, volume and specific gravity comparing 80 kg with 60kg K. according to the P fertilizer application rates, there is a significant increase with increase N rates from 40 to 60 kg and the increase percentage were 22.5, 26.4, 21.4, 25.5% and 31.3, 32.9, 28.1; 31.7 % for (diameter, length, volume and specific gravity after 50 and 60 kg N comparing with 40 kg, respectively.

Table 2: Effect of potassium and nitrogen application rates on yield and yield characters of potato crop.

Potassium kg	N kg	Diameter	Length	Volume	specific gravity	Dry matter	Starch	Carbohydrate	Total Sugar
		Cm		cm^3	g/cm^3	%			
80	40	6.15	7.05	179.24	0.785	13.45	43.11	48.85	0.605
	50	7.54	8.95	213.55	1.015	14.22	53.75	56.88	0.617
	60	7.98	9.45	223.45	1.055	17.22	60.12	63.11	0.655
	Mean	**7.22**	**8.48**	**205.41**	**0.952**	**14.96**	**52.33**	**56.28**	**0.63**
60	40	5.68	6.95	168.25	0.809	11.00	37.88	44.91	0.622
	50	6.95	8.75	208.35	0.985	12.95	42.15	47.17	0.649
	60	7.55	9.15	221.65	1.045	16.88	44.31	53.22	0.573
	Mean	**6.73**	**8.28**	**199.42**	**0.946**	**13.61**	**41.45**	**48.43**	**0.61**
LSD5%	K	0.31	0.22	3.24	0.011	1.02	4.21	3.25	0.02
	N	0.56	0.23	3.89	0.018	1.13	4.68	3.84	0.08
	KxN	0.64	0.41	4.11	0.022	1.21	5.01	4.09	0.13

The importance of K in potato quality can be attributed to its role in promoting photosynthesis and translocation of photosynthates and conversion into starch and protein as well (Koch et al., 2019). They added that despite improved starch synthesis and translocation, K could reduce dry matter content by increasing the water content of tubers. Zaheer and Akhtar (2016) reported that application K improved the

percentage of dry matter and starch content by activating the starch synthase enzyme
.

As shown in Table 3, dry matter, starch, carbohydrate and total sugar as affected by the application of K and N fertilizers. Data on hand indicated that both examined fertilizers has a pronounced effect on the potato components and their values ranged between 11.00-17.22, 37.88-60.12, 44.91-63.11 and 0.605-0.655 % for DM, starch, carbohydrate and total sugar, after application 40, 60 kg N and 80, 60 kg K fertilizer, respectively. Concerning the K fertilizer, application 80 kg led to increasing the previous parameters, while 60 +kg K caused a decrease by 9.0, 20.8, 13.9 and 1.8 %, in the same sequence. Regardless K fertilizer effect, N fertilizer has a superior effect on dry matter, starch, carbohydrates and total sugar with increase percentages 11.1, 18.4, 11.0; 3.2 % and 39.5, 28.9, 24.1 and 0.1 % for 50 and 60 kg N above 40 kg N, respectively.

Data presented in Table (3) observed that increasing K and N fertilizers led to an increase in both macro and micronutrients content, which ranged between 1.21-1.77, 1.21-1.63, 3.35-4.65 and 0.83-1.45 for N, P, K and Ca after 75, 40 kg N and 80 kg K + 60 kg N, respectively. Whereas, 80 kg K enhanced macronutrients content and the opposite was true in the case of 60 kg K which increased by 31.8, 24.0, 17.1 and 40.2 and 41.7, 29.3, 35.3 and 65.1 after 50 and 60 kg N fertilizer comparing with 40 kg N in same sequences. The same trend was observed in the case of micronutrients (Fe, Mn and Zn) where the application 60kg K caused a reduction by 5.6, 6.3 and 3.5 % compared with 80 kg K, respectively. Also, data in Table 3 pointed out that the increase in micronutrient content was resulted by an increase N fertilizer from 40 to 50 and 60 kg and the rates of increase were 20.8, 30.8; 18.0 and 23.4, 59.2; 32.8% for Fe, Mn and Zn comparing with 40 kg N, respectively.

From the aforementioned results, the increment in nutrient concentrations in potato leaves highly correlated with increasing K rates. Such a response indicated that NPK plus micronutrients were necessary for the plant to express its yield potential (Asmaa and Hafez, 2010). They attributed this phenomenon to the increase of plant physiological processes which led to more nutrient absorbance by roots (Shaaban and Abou El-Nour, 2014). Potassium is a part of many important regulatory roles in the plant. It is essential in nearly all processes needed to sustain plant growth and reproduction, i.e. photosynthesis, translocation of photosynthesis products, protein synthesis, control of ionic balance, regulation of plant stomata, turgor maintenance, stress tolerance and water use, activation enzymes and many other processes (Cakmak, 2005). Abd El-Baky et al., (2010) mentioned that balanced fertilization is a must to consider; especially under unsuitable conditions; to find out the best fertilizer balance to produce the optimum yield.

Also, there is a greater positive effect of K fertilization on tuber quality than on yield (Karam et al., 2011). Abdelgadir et al. (2003) found that the application of 215 kg K2O ha-1 (86 kg K2O acre-1) was adequate to optimize economic yield and specific gravity. Job et al. (2019) reported that the maximum tuber yield was obtained with an estimated fertilization rate of 325 kg of K2O ha-1 (13. kg) in soil with low exchangeable K (27 mg kg-^{1}), while the tuber yield increased only up to the rate of 200 kg K_2O ha^{-1} in the soils with 62 and 144 mg kg-1 exchangeable soil K. Singh and Singh (2012) and Dalia Selim et al., (2021) observed a progressive increase in some potato growth characters as K fertilization rates increased four time with reasonable N levels. whereas, Asmaa and Hafez (2010) found that the growth parameters of potatoes gradually increased as rates of K increased from 40 to 120 kg K_2O acre^{-1} by 150 %.

Singh and Lal (2012) conducted a study to determine the optimum K fertilization rate for maximum yield, nutrient use efficiency and quality of potato under irrigation on sandy loam soil. They found that tuber yield, in the form of increased large and medium tubers and decreased small (<25 g) tubers, was strongly correlated with K application. Mineral fertilizing with 60% of the recommended doses recorded the highest *values of vegetative growth characters, total marketable tubers yield/fed, total soluble solids percentage and vitamin-C content in fresh potato in both cultivated seasons (Abdel Naby et al., 2018). They added that the highest values of total carbohydrates and starch percentages in fresh potato tubers were obtained from fertilizing with 80 % of the recommended doses in both seasons.*

The potassium rates affected the total tuber yield and marketable tuber yield ton/ha significantly. Bansal and Trehan (2011) mentioned that yield increment due to applied K through increasing tuber number and size. The interaction of K and N, also produced significantly different marketable tuber numbers and plant height while K and variety interaction provided significantly different total and marketable tuber numbers. The interaction of N and variety was also highly significant. According to Ismail and Abu-Zinada (2009) who found that there is an interaction of K and N significantly increased tuber number and ***yield****. Singh and Lal (2012) conducted a study to determine the optimum K fertilization rate for maximum yield, nutrient use efficiency and quality of potatoes under irrigation on sandy loam soil with 179 mg kg^{-1} exchangeable soil K content. Tuber yield, in the form of increased large and medium tubers and decreased small (<25 g) tubers, was directly increased by increasing K application rate.*

Table 3: Effect of potassium and nitrogen application rates on the uptake of macro and micronutrients in potato leaves.

K kg	N kg	N	P	K	Ca	Fe	Mn	Zn
		%				Ppm		
80	40	1.21	1.25	3.45	0.83	203.15	22.12	25.45
	50	1.58	1.53	4.11	1.15	255.36	29.58	31.24
	60	1.77	1.63	4.65	1.45	275.25	36.85	33.64
	Mean	**1.52**	**1.47**	**4.07**	**1.14**	**244.59**	**29.52**	**30.11**
60	40	1.21	1.21	3.35	0.86	211.36	21.85	25.16
	50	1.61	1.52	3.85	1.22	245.35	27.95	28.47
	60	1.66	1.55	4.55	1.34	236.25	33.15	33.56
	Mean	**1.49**	**1.43**	**3.92**	**1.14**	**230.99**	**27.65**	**29.06**
LSD5%	K	0.04	0.02	0.04	NS	5.32	1.84	0.87
	N	0.09	0.05	0.70	0.23	6.24	1.96	1.02
	KxN	0.14	0.08	1.02	0.36	6.91	2.12	1.34

Singh and Lal (2012) state that the majority of plant growth characteristics, including height, tuber number, and size, are significantly impacted by the interplay of K and N. Asmaa and Hafez (2010), Karam et al. (2014), Singh and Bansal (2005), and others have noted that potatoes generated by K application had a stronger resistance to illnesses and less weight loss. Therefore, any improvement in potato tuber yields brought about by K treatment up to 120 kg K2O/ha was the consequence of either higher tuber sizes, higher tuber numbers per plant, or both. They also mentioned how N fertilizers affected yield by lengthening the leaf area, which raised mean tuber weight and, consequently, tuber yield.

According to Silva and Fontes (2016), even though the plants continue to absorb K through the delayed release of application, the rise in potato biomass and tuber output stops at a particular external K level. Numerous elements, including temperature, K fertilizer, sunshine, and others, influence the occurrence of starch and sugar interconversion in potatoes. In low doses, the opposite was true. In addition to internal characteristics like dry matter content, growth cracks, and internal bruising, tuber quality also includes external characteristics like tuber size, shape, skin, greening, and mechanical damage (Olanya, et al., 2014). Farming practices also have an impact on tuber quality, including plant density, irrigation, and nutrient management.

Potassium's beneficial effects on enzyme activity, protein synthesis, and assimilate translocation have been linked to its ability to promote leaf expansion during the early stages of growth and delay leaf shedding throughout maturity (Abd El-Latif et al., 2011). They also mentioned that increasing K fertilizer improved plant height, chlorophyll content in plants, leaf area, tuber K concentration, and carbohydrates (Khan et al., 2010). According to Singh and Bansal (2005), K improves the plants' general development and makes it easier for assimilates to translocate to the tubers, which may lead to an increase in the tubers' capacity to bulk up, biomass, and yield. Heavy metal buildup in tubers may result from extensive fertilizer and soil amendment applications made for the production of potatoes.

Water stress and decreased productivity are the results of inadequate watering, but drip irrigation is improved by scheduling water application to increase water usage efficiency (Wang et al., 2006). When compared to surface drip irrigation, Abdel-Moneim and Salem (2014) discovered that certain potato cultivars responded significantly better to subsurface drip irrigation. They also stated that research was done on the effects of surface and subsurface drip irrigation systems on potato output and growth. According to Amer et al. (2016), potatoes used 35% less water during the fall growth season than they did throughout the spring. For partial furrow irrigation, water savings were 28%, 18%, and 11% during the spring growing season and 17.5%, 11.0%, and 7.0% during the fall.

CONCLUSION

Potato is a cash crop and a source of hard current. it needs a high amount of mineral fertilization for its proper growth and development. Potassium was found to affect the growth parameters of potatoes like plant height, leaf area index, and chlorophyll significantly. Specific gravity in potato tubers was significantly affected by potassium application rates. The growth development, yield, and quality of potatoes were found to be significantly affected by irrigation requirements. Optimum K rate was found to perform well and higher rates did not affect the parameters significantly. The resulting data pointed out that the nitrogen without interaction effect did not affect any measured parameters of the varieties under experiment, but the interaction of potassium and nitrogen was highly significant in affecting the marketable tuber number and plant height. The producers should follow the recommendations of the agriculture research centers that concern maximize production by more suitable fertilizers management that contribute in reduction in fertilizers and soil pollution and improve crop production.

REFERENCES

1. Abd El-Baky, M.M.H., Ahmed, A.A., El-Nemr M. A. and Zaki, M.F. (2010). Effect of potassium fertilizer and foliar zinc application on yield and quality of sweet potato. Research Journal of Agriculture and Biological Sciences, 6(4): 386-394.
2. Abd El-Latif, K.M.; Osman, E.A.M.; Abdullah, R.; Abd El-Kader, N. (2011). Response of potato plants to potassium fertilizer rates and soil moisture deficit. Adv. Appl. Sci. Res. 2, 388–397.
3. Abdel Naby, H. M. ; El-Gamily, E. L. and Gab, A. A. A. (2018). Allah Response of Potato Plants to Sources and Rates of Potassium Fertilizer. Vegetables & Floriculture Department, Faculty of Agriculture, Mansoura Uni., J. Plant Production, Mansoura Univ.,. 9 (1): 67 – 71.
4. AbdelGadir, A.H., Errebhi, M.A., Al-Sarhan, H.M., and Ibrahim, M. (2003). The effect of different levels of additional potassium on yield and industrial qualities of potato (*Solanum* tuberosum L.) in an irrigated arid region. Am J of Pot. Res., 80: 219-222.
5. Abdel-Moneim , S.K. and A.A. Salem, (2014) Effect of two Drip Irrigation Methods (Surface and Subsurface) in Growth and Yield of three Potato (Solnum Tuberosuml) Cultivars Australian Journal of basic and applied Sciences, 15 September 2014,Pages : 252 – 258.
6. Amer, K.H.; A.A. Samak, and J.L. Hatfield, (2016) Effect of irrigation method and non-uniformity of irrigation on potato performance and quality.Journal of water Resource and Protection, 8:277-292
7. Asmaa, R.M. and Hafez, M.M. (2010). Increasing productivity of potato plants (*Solanum* tubersom L.) by using potassium fertilizer and humic acid application. Int. J. Acad. Res. 2, 83–88.
8. Ati A.S. and Nafaou S.M. (2013). Effect of potassium fertilizers application on growth, yield and water use efficiency of potato under regulated irrigation treatments. AL-TAQANI 26: E1-E6.

9. Bansal S.K. and Trehan S.P. (2011). Effect of potassium on yield and processing quality attributes of potato. Karnataka J. Agric. Sci., 24 (1), 48-54.
10. Cakmak, I. (2005). The role of potassium in alleviating detrimental effects of abiotic stresses in plants. J. Plant Nutr. Soil Sci., 168: 521– 530.
11. Dalia Selim, Md Ebadat Ali, Petropoulos, S. A. and M. Elbagory (2021). Plant Growth, Yield and Quality of Potato Crop in Relation to Potassium Fertilization. Agronomy 11(4):675-682.
12. Dia M., Wehner T.C, Hassell R., Price D.S., Boyhan G.E., Olson S., King S., Davis A.R., Tolla G.E., (2016). Genotype x environment interaction and stability analysis for watermelon fruit yield in the United States. Crop Sci., 56: 1645-1661.
13. Eleiwa M.E., Ibrahim S.A. and Mohamed M.F. (2012). Combined effect of NPK levels and foliar nutritional compounds on growth and yield parameters of potato plants (*Solanum tuberosum* L.). African Journal of Microbiology Research, 2012, 6(24), 5100-5109.
14. Ismail A.I., Abu-Zinada (2009). Potato Response to Potassium and Nitrogen Fertilization Under Gaza Strip Conditions. J. Al Azhar University-Gaza (Natural Sciences), 11, 15-30.
15. Job, A.L., Soratto, R.P., Fernandes, A.M., Assuncao, N.S., Fernandes, F.M. and Yagi, R. (2019). Potassium fertilization for fresh market potato production in tropical soils. J. Agron. 111, 3351–3362.
16. Karam, F., Massaad, R., Skaf, S., Breidy, J. and Rouphael, Y. (2011). Potato response to potassium application rates and timing under semi-arid conditions. Adv. Hortic. Sci. 265–268
17. Khan M.Z., Akhtar M.E., Mahmood-ul-Hassan M., Mahmood M.M. and Safdar, M.N. (2012). Potato tuber yield and quality as affected by rates and sources of potassium fertilizer. J plant nutria 35: 664-677.
18. Khan M.Z., Akhtar M.E., Safdar M.N., Mahmood M.M., Ahmad S. and Ahmed N. (2010). Effect of source and level of potash on yield and quality of potato tubers. Pak J Bot 42: 3137- 3145.
19. Koch, M., Busse, M., Naumann, M., Jakli, B., Smit, I. Cakmak, I., Hermans, C. and Pawelzik, E. (2019). Differential effects of varied potassium and magnesium nutrition on production and partitioning of photoassimilates in potato plants. Physiol. Plant. 166, 921–935.
20. Li, S., Duan, Y., Guo, T., Zhang, P., He, P., Johnston, A. and Shcherbakov, A. (2015) Potassium management in potato production in Northwest region of China. Field Crops Res 174: 48-54.
21. Lobato, M.C.; Daleo, G.R.; Andreu, A.B. and Olivieri, F.P. (2018). Cell wall reinforcement in the potato tuber periderm after crop treatment with potassium phosphite. Potato Res. 61, 19–29.
22. Malik, G.C. and Ghosh, D.C. (2002). Effect of fertility level, plant density and variety on growth and productivity of potato. Potato Glob. Res. Dev. 2, 866–871.
23. Mehdi, S. M., Sarfraz, M. and Hafeez, M. (2007). Response of rice advance line PB-95 to potassium application in saline sodic soil. Pak. J. Biol. Sci., 10:2935-2939.
24. Mohr, R.M. and Tomasiewicz, D.J. (2012) Effect of rate and timing of potassium chloride application on the yield and quality of potato *(Solanum tuberosum* L.'Russet Burbank'). Can J of Plant Sci 92: 783-794.
25. Singh M., K. and Bansal, S.K. (2005) Growth, yield, and economics of potato in relation to progressive application of potassium fertilizer. J of plant nutria 28: 183-200.
26. Moussa, S. and Shama, M. (2019). Mitigation the adverse effects of irrigation water salinity on potato crop using potassium silicate foliar application. Middle East J. Appl. Sci. 9, 804–819.
27. Nandekar, D.N. (2005). Effect of seedling tuber size and fertilizer levels on growth, yield and economics of potato production. Potato J. 32, 71–73.
28. Naz F., Ali A., Iqbal Z., Akhtar N., Asghar S. and Ahmad B. (2011). Effect of different levels of NPK fertilizers on the proximate composition of potato crop at Abbottabad. Sarhad J. Agric., 27(3), 353-356.
29. Olanya, O.M., Larkin, R.P., Halloran, J.M. and He, Z. (2014). Relationships of crop and soil management systems to meteorological variables and potato diseases on a Russet Burbank cultivar. J. Agric. Meteorol. 70, 91–104.
30. Regmi, A., Ladha, J., Pasuquin, E., Pathak, H., Hobbs, P., Shrestha, L. and Duveiller E. (2002). The role of potassium in sustaining yields in a long-term rice-wheat experiment in the Indo Gangetic Plains of Nepal. Biol and Fertil of Soils 36: 240- 247.
31. Rytel, E.; Lisinska, G. and Tajner-Czopek, A. (2013). Toxic compound levels in potatoes are dependent on cultivation methods. Acta Aliment. 42, 308–317.
32. Salami, M. and Saadat, S. (2013). Study of potassium and nitrogen fertilizer levels on the yield of sugar beet in jolge cultivar. Journal of Novel Applied Sciences, 2(4):94–100.
33. Salim, B.B.M.; Abd El-Gawad, H.G. and Abou El-Yazied, A. (2014). Effect of foliar spray of different potassium sources on growth, yield and mineral composition of potato (*Solanum tuberosum* L.). Middle East J. Appl. Sci. 4, 1197–1204.
34. SAS (2009). SAS Institute Inc., SAS 9.2 stored processes developer's guide. Cary, NC, USA,.
35. Shaaban, M.M. and Abou El-Nour, E.Z.A. (2014). Macro and micro-nutrients concentrations

and uptake by maize seedlings irrigated with fresh or saline water as affected by K-silicate foliar fertilization. Am. J. Plant Physiol. 9, 95–102.

36. Silva, H.R.F. and Fontes, P.C.R. (2016). Potassium fertilization and its residual effect on productivity and quality of potato tubers. Pesqui Agropecu Bras. 51, 842–848.
37. Singh S.K. and Lal S.S., (2012). Effect of Potassium Nutrition on Potato Yield, Quality and Nutrient Use Efficiency under Varied Levels of Nitrogen Application. Potato J., 39(2), 155-165.
38. Singh, V.N.; Singh, S.P. (1996). Influence of split application of potassium on qualitative attributes of potato. J. Indian Potato Assoc. 23, 72–74.
39. Snedecor, G. W. and Cochran, W. G. (1990). Statistical Methods 7th. Ed. Iowa State Univ., press. Ames,. Iowa, U.S.A
40. Tawfik, A.A. (2001) Potassium and calcium nutrition improves potato production in drip-irrigated sandy soil. African Crop Sci J 9: 147-155.
41. Trehan, S.P. (2007). Efficiency of potassium utilization from soil as influenced by different potato cultivars in the absence and presence of green manure (Sesbania aculeata). Advances. Horti. Sci., 21(3), 156-164.
42. Umar, S. (2006). Alleviating adverse effects of water stress on yield of sorghum, mustard and groundnut by potassium application. Pak J Bot 38: 1373-1380.
43. Wang, F.; Y. Kang and S. Liu, (2006) Effects of Drip Irrigation Frequency on Soil Wetting Pattern and Potato Growth in North China Plain. Agricultural Water Management, 79:248 - 264.
44. Zaheer, K.; Akhtar, M.H. (2016). Potato production, usage, and nutrition—A review. Crit. Rev. Food Sci. Nutr. 56, 711–721.