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Effectiveness of Potassium Fertilization and Proline Exogenous Application on Potato Growth, Yield and Quality at Arid Regions

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ABSTRACT

Two field experiments were conducted during winter seasons of 2019/2020 and 2020/2021 in the Experimental Farm, Faculty of Agriculture and Nature Resources, Aswan University, Aswan, Egypt. The main objective behind this study is to investigate the effectiveness of potassium fertilization and proline exogenous application on potato growth, yield and quality at arid regions. Nine treatments were as follows: control, soil application with potassium at 50 and 100 kg K_2O/feddan singly or in combined with three proline levels (50, 100 and 200 mg/l). The experimental layout was Randomized Complete Blocks Design with three replications. Generally, the obtained results indicated that soil application with 100 kg K_2O/feddan (200 kg potassium sulfate) with proline foliar application at 200 mg/l recorded the highest average values of vegetative growth, yield and chemical composition of leaves and tubers and might be considered as an optimal treatment to produce high yield and good quality of potato plants under the environmental conditions of Aswan governorate and other similar regions.

Keywords: Potato, potassium fertilization, proline exogenus application.

INTRODUCTION

Potato (*Solanum tuberosum* L.) considered one of the vital cultivated crops in the world besides wheat, rice and corn (Dowling, 1995) because of its importance as a source of minerals, carbohydrates, and vitamins. Potato tuber has a lot of nutritional energy and protein per unit (McGill *et al.*, 2013) and, in this case, it is considered one of the major food sources for people having thus a great socio-economic impact. The yearly worldwide potatoes production is around 370436581 metric tons, reaped from a territory that came to about 17340986 hectares (ha). In Egypt, the potato has a significant situation among every single vegetable harvest, where about 20% of the complete region of vegetable production is committed to potato. While, the complete developed territory of potatoes arrived at 175161 ha, which created 5078374 tons (FAO, 2019).

Balanced use of nutrients is essential for sustainable productivity of crops. In many potato producing areas nitrogen and phosphorus fertilizers are being used while, the use of potassium fertilizer is almost negligible in Egypt which has led not only to stagnation of crop yield, but also the quality of the crop and decrease in potassium status in soils of potato growing areas (Pervez *et al;* 2013). The role of K in photosynthesis is well known and can improve photosynthate translocation, enzyme activities, and the synthesis of proteins, carbohydrates, and fats, and is responsible for higher crop productivity (Mello *et al*., 2018). Additionally, K is highly involved in potato plant growth and development (Kumar and Chandra, 2018; Abdel Naby *et al*., 2018), and can support plants in adapting to biotic and abiotic stressors such as pathogens, drought, and temperatures (Naumann *et al*., 2020). Application of potassium brought about several advantages on vegetative characteristics, yield and its quality, and the biochemical and molecular levels (Noor, 2010; Abay and Sheleme, 2011; Abubaker *et al;* 2011; Zorb *et al;* 2014).

Increasing the potato yield and tubers quality are crucial factors for this important crop, especially at arid regions in winter season, where the high temperature at day and low at night (temperature difference between day and night) exerts an adverse effect on the growth of the whole plant, especially during tuber formation stage *via* restricting the supply of water and mineral nutrients and increasing transpiration rate, affecting the metabolism, growth and development (Boyer, 1982). For that plant cells produce enzyme and antioxidants to reduce heat stress damage (Balla *et al*., 2007). Free proline accumulates as response of heat stress (Jiang and Huang, 2001). Proline is a kind of nitrogen storage (Brugiere *et al*., 1999). Consider one of the osmoprotectant compounds. Which, a mechanism of stresses tolerance, free enzyme regulator, increase the activity of antioxidant enzymes, protect cell membrane and enhanced the leaves water content (Ashraf and Foolad, 2007). When plants exposed to abiotic stress, they accumulate proline as a physiological reaction works to maintain the osmotic in the cell (Iba, 2002). Resistance of stresses dehydration and salinity by balancing the cell osmotic, allowing the plant to absorb water and nutrients (Amini and Ehsanpour, 2005). Exogenous application of proline improves plant tolerance to avoid the temperature stress harmful effect (Cong *et al*., 2008). Thus, prevents the occurrence of physiological damage (Kahlaoui *et al*., 2018).

Therefore, the main objective behind this study is to investigate the effectiveness of potassium fertilization and proline exogenus application on the performance of potato Spunta cv. under arid conditions to overcome or alleviate the

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heat stress (temperature difference between day and night) during winter season at Aswan governorate, Egypt.

MATERIALS AND METHODS

Two field experiments were conducted during winter seasons of 2019/2020 and 2020/2021 in the experimental farm, faculty of agriculture and nature resources, Aswan university, Aswan, Egypt. The geographical coordinates of the site are 23°59′56″N, 32°51′36″E and average altitude of 85 m above sea level.

Before tubers planting, random soil samples (0 - 30 cm depth) from different places of the planting field were collected and some important chemical and physical properties were analyzed according to Page *et al*. (1982). These properties are showen in Table (1). The field experiments were done under open field condition in a sandy soil using the surface irrigation method and Nile River (located in the experimental area) is the source of irrigation water with pH about 7.4 and an average EC 0.66 dS m^{-1}.

The tubers of potato (*Solanum tubersum* L.); cv. Spunta were planted on the 15th of October for both seasons. Tubers were planted at 0.2 m apart between hills on one side of the ridge and 0.8 m width in dry soil then irrigated (Fed. = 26250 plants).

Table 1. Some physical and chemical properties of the experimental site during both seasons of the experiments (2019/2020 and 2020/2021)

Soil properties	Physical properties				Chemical properties					
	Clay (%)	Silt (%)	Sand (%)	Soil texture	OM (%)	pH	EC (dS m^{-1})	Available NPK (ppm)		
								N	P	K
2019	3.02	2.28	94.70	Sandy	0.09	8.25	0.25	125.31	8.00	175
2020	3.07	2.26	94.67		0.09	8.24	0.26	130.00	7.89	176

***The analyses were carried out at Soil Fertility Departement, Faculty of Agricultur (Saba Basha), Alexanderia University, Egypt.**

The experiment contained 9 treatments, which were distributed as:

T1: Control were sprayed with tap water.
T2: Soil application with 50 kg K_2O/feddan.
T3: Soil application with 100 kg K_2O/feddan.
T4: Soil application with 50 kg K_2O/feddan and foliar application with proline at 50 mg/l.
T5: Soil application with 50 kg K_2O/feddan and foliar application with proline at 100 mg/l.
T6: Soil application with 50 kg K_2O/feddan and foliar application with proline at 200 mg/l.
T7: Soil application with 100 kg K_2O/feddan and foliar application with proline at 50 mg/l.
T8: Soil application with 100 kg K_2O/feddan and foliar application with proline at 100 mg/l.
T9: Soil application with 100 kg K_2O/feddan and foliar application with proline at 200 mg/l.

The experimental layout was a randomized complete blocks design with three replications. Experimental plot area was 10.56 m^2 (66 plants).

Potato plants were sprayed with proline twice at 45 and 60 days after planting, during the growing seasons. All foliar sprayings were carried out to cover completely the whole plant foliage to run off, early in the morning.

Potassium dosages were applied equally in the form of potassium sulfate (50% K_2O), during soil preparation, at 45 and 60 days after tubers planting.

All other agro-management practices such as (fertilization, irrigation, weed control, pest and disease control) were performed whenever it was necessary as recommended in the commercial production of potato under the experimental site conditions.

Harvesting was accomplished after 120 days of planting during both years. Ten plants form each treatment in each replication were, randomly, selected and tagged for records of the growth and total yield as well as tubers quality parameters.

Growth attributes, records, after 75 days from planting, plant height, number of leaves per plant, number of main stems per plant, foliage fresh and dry weights characters were determined. foliage dry weight was conducted in an electrical oven at 70˚ C till obtaining a constant weight, then determined.

Yield and its component measurements

The following criteria were determined just after harvesting time (120 days from planting) using the average number of tubers of 10 plants. Number of tubers per plant, average of tuber fresh weight, average of tuber yield per plant, total tubers yield per feddan, marketable/feddan its diammeter more than 35 mm and unmarketable yield /feddan its diammeter less than 35 mm.

Chemical composition

- **Leaf contents of a, b and total chlorophyll (a+b):** The leaves pigments chlorophyll a, b and total chlorophyll (a+b) for the fourth top leaves of plant were estimated by spectrophotometer as described by Moran and Porath (1980) after 75 days from planting in both seasons. Then they were calculated using the formula of Arnon (1956).
- **N, P and K contents of leaves and tubers:** were determined at 75 days after planting for leaves and at 120 days after planting for tubers as follows: Total N content was determined colorimetrically according to Chapman and Pratt (1978), total P content was determined colorimetrically as described by Singh *et al*. (2005), total K content was determined photometrically using the flame photometer method Jackson (1973). Proline percentage in leaves according to A.O.A.C. (2005).
- **Chemical quality determination of potato tubers:**

The following criteria were determined just after harvesting time (120 days from planting) using the average number of tubers of 10 plants, Total soluble solids content (TSS %) was estimated in the juice of the fresh tubers using a hand refractometer according to A.O.A.C. (2005). Tubers' vitamin C was measured according to the method of Ranganna (1986). Total phenols were determined as described by Slinkard and Singleton (1977). Tuber dry matter (%) was determined. Total carbohydrates were estimated spectrophotometrically at 630 nm. according to Sadasivam and Manickam (1996). Starch, reducing, non-reducing and total sugars were determined according to the method described by Malik and Singh (1980). Total protein was calculated in the digested dry matter of tuber samples by multiplying the total nitrogen content by the factor of 6.25 as described by A.O.A.C. (2005).

Statistical Analysis :

The obtained data were analyzed using the CoStat Statistic Package computer software program (version 6.400). All data were statistical analysis accordance to the procedure out lined by Snedecore and Cochran (1989) and the treatment means were compared using the using Duncan's multiple range test at 0.05 level of probability as illustrated by Duncan (1955).

Meteorological data:

Meteorological data of the experimental site during time-course of the present study are illustrated in Table (2).

Table 2. The maximum, minimum and average air temperatures during the two winter seasons of 2019/2020 and 2020/2021.

weeks	Air temperature [°C]					
	2019/2020			2020/2021		
	Max.	Min.	x̄	Max.	Min.	x̄
11-20 Oct.	38.9	25.8	32.35	39.41	23.48	31.45
21 -31 Oct.	32.7	18.8	25.75	36.05	20.39	27.68
1- 10 Nov.	32.2	16.5	24.35	29.49	16.73	22.74
11- 20 Nov.	31.5	18.7	25.1	28.17	13.48	20.23
21 -30 Nov.	29.4	14.2	21.8	25.57	10.97	17.67
1-10 Dec.	25.7	11	18.35	27.23	12.05	18.75
11- 20 Dec.	24.9	9.9	17.4	27.20	12.48	19.28
21- 31 Dec.	22.5	7.7	15.1	26.27	11.38	18.08
1 – 10 Jan.	18.6	5.5	12.05	28.49	10.09	19.29
11-20 Jan.	22.6	8	15.3	24.11	8.82	16.47
21-31 Jan.	21.3	5.8	13.55	25.07	6.74	15.91
1-10 Feb.	23.2	7.5	15.35	28.32	11.17	19.75
11-20 Feb.	25.1	9	17.05	25.91	9.03	17.47

RESULTS AND DISCUSSION

Vegetative growth traits:

Results presented in Table (3) showed that there were significant differences between treatments in all studied vegetative growth characters during both seasons. All treatments using combined between potassium fertilization and proline foliar application at any levels were superior to control and potassium fertilization singly. The highest significant mean values for plant height, number of leaves per plant, number of main stems /plant, foliage fresh and dry weights were obtained when plants fertilized with 100 kg K_2O/feddan and foliar application with proline at 200 mg/l (T9). Meanwhile, intermediated mean values were recorded and distributed among other treatments. Ali *et al.* (2021) decided that increasing potassium application rates at 139 kg ha^{-1} and 183 kg ha^{-1} resulted in taller plants and increased total leaf area. The favorable effects of potassium fertilization on potato growth parameters are associated with various physiological processes such as translocation of assimilates and protein synthesis, osmotic regulation, ionic balance, and stomatal and enzymatic activity that immediately affect plant growth (Oosterhuis *et al.*, 2014; Bishwoyog and Swarnima, 2016; Naumann *et al.*, 2020).

Santos *et al.* (1996) reported that proline consider a source of nitrogen to improve plant growth. El-Helaly (2019) found that proline foliar application at 250 mg/l on potato plants gave highest plant height. Clausen *et al.* (2014), proline helps in increasing fresh weight in tomato under abiotic stress conditions. Kahlaoui *et al.* (2018) reported that spraying proline under stress condition improves tomato growth and productivity under commercial production. Also, Ismail and Helmy (2018) on broad bean found that spraying broad bean plants with 2 L potassium humate/feddan in addition 100 mg/l proline produced the highest values of plant height, No. of leaves/plant, total chlorophyll, leaves fresh and dry weight.

Table 3. Averages values of vegetative growth characters of potato plants as affected by potassium fertilization and proline foliar application during the seasons of 2019/2020 and 2020/2021.

Treatments	Plant height (cm)		No. of leaves/plant		No. of stems/plant		Foliage fresh weight(g)		Foliage dry weight(g)	
	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021
T1	73.17 g	73.40 h	90.80 g	88.00 g	2.67 c-e	3.00 b-d	388.77 h	422.74 i	47.35 i	51.50 i
T2	75.07 fg	75.00 gh	92.13 f	88.57 g	3.00 b-e	3.00 b-d	393.13 g	427.35 h	48.18 h	52.72 h
T3	76.57 ef	76.57 fg	93.17 f	90.03 fg	3.00 b-e	3.33 a-d	397.78 f	431.72 g	49.55 g	53.85 g
T4	77.20 de	78.00 ef	95.37 e	91.33 ef	3.33 a-d	3.67 a-c	400.68 f	435.80 f	50.74 f	55.14 f
T5	79.10 d	79.77 de	96.40 de	92.67 de	3.67 a-c	3.67 a-c	405.08 e	440.79 e	51.85 e	56.42 e
T6	81.80 c	81.67 cd	97.17 bc	93.60 cd	3.67 a-c	4.00 ab	409.40 d	444.96 d	52.94 d	57.57 d
T7	82.27 c	83.27 bc	97.87 bc	95.26 c	4.00 ab	4.00 ab	414.36 c	450.12 c	54.05 c	58.74 c
T8	84.25 b	85.36 b	98.95 b	97.20 b	4.00 ab	4.00 ab	418.63 b	454.70 b	55.14 b	60.12 b
T9	89.80 a	93.47 a	100.23 a	110.00 a	4.33 a	4.67 a	423.13 a	459.98 a	56.26 a	61.15 a

Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using Duncan's multiple range test at 0.05 level of probability.

From experiments conducted in growth chambers, it is known that growth is fastest in the temperature range of 20˚C - 25˚C (Marinus and Bodlaender, 1975; Van Dam *et al.*, 1996). Meteorological data (Table 2), showed that before tuber initiation (first 45 days from planting) increases in the temperature at day (32.94 and 31.74 ˚C during both seasons respectively) which causes stress in addition to dry weather and sandy soil. So, from results potassium soil application and proline foliar spray (especially at 100 kg K_2O and 200 mg/l proline) caused stress conditions alleviate stress and gave rise vegetative growth characters.

Yield and it's components characteristics:

Data illustrated in Table (4), showed that combination between different levels of potassium application and concentrations proline foliar application significantly affected on yield and its components during both seasons over the control and potassium fertilization singly. The highest mean values of all studied parameters (*i.e.* number of tubers per plant, average of tuber fresh weight, average of tuber yield per plant, total tubers yield per feddan, marketable and unmarketable yield/feddan recorded with plants treated by 100 kg K_2O/feddan and proline at 200 mg/l (T9). Meanwhile, intermediated mean values were recorded and distributed among other treatments. Several studies highlighted the importance of potassium fertilization to obtain high tuber yields (Mirdad, 2010; Abdel-Salam and Shams, 2012; Basha and Hassan, 2017). Scherer *et al.* (2011) conducted a long-term experiment studying the effect of potassium availability on various crops and suggested that potassium deprivation may result in a detrimental decline in potato tuber yield. These results were in accordance with those of Abd El-Latif *et al.* (2011) who claimed that increasing potassium fertilizer led to increase the yield of ptato. Trehan *et al*. (2009) concluded that potassium increases the size of tubers. So, it increases the yield by increasing the number and yield of large sized tubers. In the same context, Berisha *et al*. (2014) pointed out that potassium fertilizer rate, significantly, affected potato tuber yield. Also, Yakimenko and Naumova (2018) investigate the effect of K fertilization rates (0, 30, 60, 90, 120 and 150 kg K/ha) on potato tuber yield. They found that the tuber yield (kg/m^2) increased with increase in K rates.

These results might be attributed to T9 treatment gave the highest vegetative growth parameters as reported earlier (Table 3). The beneficial effects of potassium fertilization on potato yield parameters are associated with numerous physiological processes such as translocation of assimilates and protein synthesis, osmotic regulation, ionic balance, and stomatal and enzymatic activity that directly affect plant growth and consequently tuber

formation and yield (Oosterhuis *et al*., 2014; Bishwoyog and Swarnima, 2016; Naumann *et al*., 2020). It is known that optimal range for tuberization and tuber growth is 15˚C - 20˚C (Marinus and Bodlaender, 1975; Van Dam *et al*., 1996). From meteorological data (Table 2), at tuber initiation stage (from 45 days after planting till harvest) a difference between day and night temperatures were noticed (22.99, 8.05 and 26.58, 10.22˚C at day and night during both seasons respectively) which causes stress in addition to dry weather and sandy soil. So, from results potassium soil application and proline foliar spray (especially at 100 kg K_2O and 200 mg/l proline) led to alleviating stress conditions and gave rise yield and its component characters.

El-Helaly (2019) found that proline foliar application at 150 or 200 mg/l gave highest potato yield (ton/feddan). Also, Ismail and Helmy (2018) on broad bean found that spraying broad bean plants with 2 L potassium humate/feddan in addition 100 mg/l proline produced the highest values of length and wide of pod, green seeds number per pod, the weight of 100 green seeds. Potassium is involved in many aspects of the plant physiology (Youssef *et al*., 2007). It is considered as a major osmotic active cation in plant cell (Mehdi *et al.,* 2007), where it enhances water uptake and root permeability and acts as a guard cell controller, besides its role in increasing water use efficiency (Zekri and Obreza, 2009). It, also, plays an important role in yield and quality of the tuber due to its high movement in plant tissues (Mengel and Kirkby, 2012). Moreover, according to Wassie (2009), an appreciable increase in yield was noted in response to K application fertilizers, specifically from soils with below or very low critical K level.

Table 4. Averages values of yield characters of potato plants as affected by potassium fertilization and proline foliar application during the seasons of 2019/2020 and 2020/2021.

Treatments	Number of tubers/plant		Average tuber weight (g)		Yield/ plant (kg)		Total yield/feddan (ton)		Marketable yield/feddan (ton)		Unmarketable yield/feddan (ton)	
	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021
T1	4.84 c	4.96 c	116.24 g	111.35 e	562.60 g	552.30 i	14.768 g	14.498 i	13.499 f	13.277 g	1.269 a	1.221 a
T2	4.90 c	4.96 c	117.81 f	112.51 de	577.27 f	558.05 h	15.153 f	14.649 h	13.892 ef	13.476 fg	1.261 a	1.173 b
T3	4.92 c	5.00 c	118.31 f	112.63 de	582.09 f	563.15 g	15.280 f	14.783 g	14.039 ef	13.649 f	1.241 b	1.134 c
T4	4.93 c	5.07 c	120.58 e	115.06 cd	594.46 e	583.35 f	15.605 e	15.313 f	14.368 e	14.203 e	1.237 b	1.110 d
T5	5.14 b	5.29 b	121.21 e	116.42 c	623.02 d	615.86 d	16.354 d	16.166 d	15.117 d	15.068 cd	1.237 b	1.098 d
T6	5.16 b	5.21 b	126.45 d	116.50 c	652.48 c	606.97 e	17.128 c	15.933 e	15.907 c	14.863 d	1.221 c	1.070 e
T7	5.12 b	5.30 b	128.14 c	117.38 bc	656.08 c	622.11 c	17.222 c	16.330 c	16.084 b	15.280 c	1.138 d	1.050 ef
T8	5.12 b	5.44 a	132.28 b	119.97a b	677.27 b	652.64 b	17.778 b	17.132 b	16.664 b	16.090 b	1.114 e	1.042 fg
T9	5.32 a	5.56 a	134.15 a	121.38 a	713.68 a	674.87 a	18.734 a	17.715 a	17.672 a	16.693 a	1.062 f	1.022 g

- Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using Duncan's multiple range test at 0.05 level of probability.

Chemical composition

-Chemical composition of leaves

Data tabulated in Tables (5 and 6) indicated that plants treated with combination between soil application with potassium and foliar application with proline gave highest mean values of chlorophyll content (a, b and a + b), N, P and K% compared with plants treated with potassium fertilization only and control plants during both seasons. The highest mean values were obtained from plants treated by 100 kg potassium as soil application and 200 mg/l proline as foliar application (T9). Meanwhile, intermediated mean values were recorded and distributed among other treatments. Ali *et al*. (2021) decided that increasing potassium application rates at 139 kg ha^{-1} and 183 kg ha^{-1} increased chlorophyll content. Some investigation decided that potassium fertilization improve macro nutrient uptake (N, P, and K) in shoots (Mirdad, 2010; Abdel-Salam and Shams, 2012; Basha and Hassan, 2017). K % increase in leaves may be due to increases its availability by soil application at highest level (200 kg K_2O/feddan) (Oosterhuis *et al*., 2014; Naumann *et al*., 2020).

On the other side, percentage of leaves proline was decreased by potassium fertilization combined with proline foliar application. The highest proline percentage was obtained from control plants, while plants treated with 100 kg/feddan K_2O as soil application and 200 mg/l proline as foliar application gave the lowest proline percentage. This result may be due to that proline is accumulated at most in crops under stress condition. Increase of proline concentration in the vacuole inside the cell is a measure of how long the crop is under stress and how the crop is tolerant to that stress factor. Ismail and Helmy (2018) on broad bean found that spraying broad bean plants with 2 L potassium humate/feddan in addition 100 mg/l proline produced the highest values of total chlorophyll, N, P and K percentages in leaves.

Table 5. Averages values of leaf chlorophyll content of potato plants as affected by potassium fertilization and proline foliar application during the seasons of 2019/2020 and 2020/2021.

Treatments	Leaf chlorophyll content (mg/g, f.w.)					
	Chlorophyll a		Chlorophyll b		Total chlorophyll (a + b)	
	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021
T1	0.817 h	0.841 i	0.583 f	0.591 i	1.400 i	1.432 i
T2	0.830 g	0.851 h	0.593 e	0.600 h	1.423 h	1.451 h
T3	0.839 fg	0.864 g	0.597 e	0.609 g	1.436 g	1.473 g
T4	0.851 ef	0.872 f	0.612 d	0.619 f	1.463 f	1.491 f
T5	0.861 de	0.884 e	0.622 c	0.629 e	1.483 e	1.513 e
T6	0.872 cd	0.894 d	0.629 bc	0.636 d	1.501 d	1.53 d
T7	0.885 bc	0.906 c	0.636 b	0.647 c	1.521 c	1.553 c
T8	0.894 ab	0.919 b	0.648 a	0.660 b	1.542 b	1.579 b
T9	0.906 a	0.928 a	0.650 a	0.671 a	1.556 a	1.599 a

- Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using Duncan's multiple range test at 0.05 level of probability

Table 6. Averages values of leaf nutrient content of potato plants as affected by potassium fertilization and proline foliar application during the seasons of 2019/2020 and 2020/2021.

Treatments	Nutrient contents of leaf (% d.w.)							
	N		P		K		Proline	
	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021
T1	3.15 i	3.36 i	0.259 f	0.281 h	3.29 i	3.48 i	10.10 a	10.20 a
T2	3.28 h	3.45 h	0.265 f	0.291 g	3.42 h	3.60 h	9.80 b	9.50 b
T3	3.38 g	3.59 g	0.276 e	0.300 f	3.52 g	3.71 g	9.30 c	9.10 c
T4	3.50 f	3.71 f	0.283 e	0.312 e	3.63 f	3.83 f	8.70 d	8.30 d
T5	3.64 e	3.80 e	0.294 d	0.322 d	3.74 e	3.94 e	8.20 e	8.00 e
T6	3.73 d	3.91 d	0.303 c	0.333 c	3.84 d	4.06 d	7.60 f	7.70 f
T7	3.88 c	4.05 c	0.312 b	0.344 b	3.97 c	4.16 c	7.20 g	7.10 g
T8	3.98 b	4.16 b	0.321 a	0.354 a	4.07 b	4.30 b	6.80 h	6.60 h
T9	4.09 a	4.24 a	0.329 a	0.360 a	4.18 a	4.41 a	6.50 i	6.30 i

- Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using Duncan's multiple range test at 0.05 level of probability.

-Chemical composition of tubers

Results in Tables (7, 8 and 9) indicated that there were significant differences between treatments in total soluble solids content (TSS %), vitamin C /100 g, f.w., tuber dry matter (%), Starch, total protein, reducing, non-reducing and total sugars, tubers N, P and K content characters in both seasons. Plants treated with combination between soil application with potassium and foliar application with proline gave highest mean values of tubers chemical composition compared with plants treated with potassium fertilization separately and control plants during both seasons. The highest mean values of total soluble solids content (TSS %), vitamin C., tuber dry matter (%), Starch, total protein, reducing, non-reducing and total sugars (% d.w.), tubers N, P and K content characters were obtained from plants treated by 100 kg potassium as soil application and 200 mg/l proline as foliar application (T9) during both seasons. On contrary, tubers total phenols and NO_3-N tuber content characters increased significantly in control plants but decreased significantly with plants treated by 100 kg potassium as soil application and 200 mg/l proline as foliar application (T9) during both seasons. Meanwhile, intermediated mean values were recorded and distributed among other treatments. Potassium application rates are effective in regulating potato tuber quality, especially when considering the high requirements of the crop for this specific macronutrient (Farheen *et al*., 2018; Yakimenko and Naumova, 2018). Bishwoyog and Swarnima (2016) reported that potassium availability is associated with the activation of starch synthesis.

In addition, Yakimenko and Naumova (2018) investigated the effect of K fertilization rates (0, 30, 60, 90, 120 and 150 kg K/ha) on potato tuber quality. They found that tuber quality (dry matter, starch, sugar and ascorbic acid content) increased with increase in K rates.

Table 7. Averages values of chemical quality determination of potato plants as affected by potassium fertilization and proline foliar application during the seasons of 2019/2020 and 2020/2021.

Treatments	TSS%		Vitamin C (Ascorbic acid) mg/100 g		Total phenols mg/100g		Tuber dry matter (%)	
	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021
T1	7.44 h	7.69 i	20.40 i	20.38 i	241.60 a	266.43 a	13.64 g	16.66 g
T2	7.53 g	7.76 h	20.55 h	20.56 h	237.20 b	262.13 b	13.78 fg	16.94 fg
T3	7.62 f	7.84 g	20.67 g	20.71 g	233.63 bc	257.30 c	13.93 efg	17.13 f
T4	7.70 e	7.92 f	20.81 f	20.89 f	230.50 cd	253.53 d	14.05 def	17.35 ef
T5	7.80 d	8.02 e	20.94 e	21.05 e	227.20 de	248.27 e	14.22 cde	17.64 de
T6	7.88 c	8.10 d	21.06 d	21.21 d	224.87 e	244.70 f	14.33 bcd	17.86 cd
T7	7.94 c	8.16 c	21.19 c	21.37 c	224.47 e	239.53 g	14.48 abc	18.08 bc
T8	8.10 b	8.27 b	21.31 b	21.53 b	217.90 f	234.63 h	14.63 ab	18.32 ab
T9	8.21 a	8.35 a	21.45 a	21.73 a	214.40 fg	230.67 i	14.81 a	18.63 a

- Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using Duncan's multiple range test at 0.05 level of probability.

Table 8. Averages values of chemical quality determination of potato plants as affected by potassium fertilization and proline foliar application during the seasons of 2019/2020 and 2020/2021.

Treatments	Total carbohydrates %		Starch %		Total Protein %		Tuber sugars (% d.w.) Reducing sugars		Non-reducing sugars		Total sugars	
	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021
T1	26.93 g	28.16 h	20.21 gh	20.65 hi	11.44 h	12.06 i	2.59 g	2.61 fg	4.25 c-g	4.65 gh	6.84 fg	7.26 fg
T2	27.18 fg	28.46 g	20.28 g	20.85 gh	11.88 g	12.63 h	2.70 f	2.68 ef	4.26 c-g	4.71 fg	6.96 f	7.39 f
T3	27.42 ef	28.76 f	20.52 f	20.97 fg	12.38 f	13.25 g	2.75 f	2.81 de	4.31 c-f	4.73 f	7.06 ef	7.54 e
T4	27.67 de	28.85 ef	20.68 e	21.17 ef	12.94 e	13.75 f	2.83 e	2.84 d	4.38 b-e	4.79 e	7.21 de	7.63 de
T5	27.92 cd	29.02 e	20.83 d	21.34 de	13.31 d	14.25 e	2.91 d	2.90 cd	4.41 a-d	4.84 de	7.32 cd	7.74 cd
T6	28.16 c	29.25 d	20.97 d	21.55 cd	13.94 c	14.69 d	2.99 c	2.98 bc	4.46 a-d	4.89 cd	7.45 c	7.87 c
T7	28.44 b	29.56 c	21.14 c	21.73 bc	14.50 b	15.31 c	3.07 b	3.10 ab	4.48 abc	4.94 bc	7.55 bc	8.04 b
T8	28.72 a	30.12 b	21.32 b	21.87 ab	14.81 b	15.81 b	3.14 b	3.14 a	4.58 ab	4.97 ab	7.72 ab	8.11 ab
T9	28.94 a	30.44 a	21.50 a	22.12 a	15.38 a	16.44 a	3.25 a	3.16 a	4.62 a	5.03 a	7.87 a	8.19 a

Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using Duncan's multiple range test at 0.05 level of probability

Table 9. Averages values of chemical determination of potato tubers as affected by potassium fertilization and proline foliar application during the seasons of 2019/2020 and 2020/2021.

Treatments	Nutrient contents of tuber (% d.w.) N		P		K		NO_3-N (ppm)	
	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021
T1	1.83 h	1.93 i	0.188 h	0.204 g	2.27 i	2.40 h	38.06 a	40.14 a
T2	1.90 g	2.02 h	0.194 g	0.214 f	2.35 h	2.51 g	37.41 ab	39.44 ab
T3	1.98 f	2.12 g	0.201 f	0.222 e	2.43 g	2.55 g	36.77 bc	38.88 bc
T4	2.07 e	2.20 f	0.208 e	0.229 d	2.53 f	2.66 f	36.60 c	38.24 cd
T5	2.13 d	2.28 e	0.216 d	0.234 d	2.62 e	2.76 e	36.16 cd	37.65 de
T6	2.23 c	2.35 d	0.222 c	0.240 c	2.72 d	2.83 d	35.69 c	37.17 ef
T7	2.32 b	2.45 c	0.232 b	0.242 c	2.80 c	2.93 c	34.72 e	36.52 fg
T8	2.37 b	2.53 b	0.239 a	0.250 b	2.87 b	3.03 b	34.16 ef	35.97 gh
T9	2.46 a	2.63 a	0.241 a	0.260 a	2.98 a	3.14 a	33.66 fg	35.30 hi

-Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using Duncan's multiple range test at 0.05 level of probability.

Several investigations determined that potassium fertilization improve macro nutrient uptake (N, P, and K) in tubers (Mirdad, 2010; Abdel-Salam and Shams, 2012; Basha and Hassan, 2017). Increasing the availability of potassium in soil through increased application rates may have beneficial effects on protein content because potassium enhances nitrogen uptake from soil and up-regulates the synthesis of proteins and amino acids (Bishwoyog and Swarnima, 2016; Naumann *et al*., 2020). Therefore, it can be suggested that regulation of the potassium fertilization regime may improve specific quality parameters of potato tuber and can be a cost-effective cultivation practice aimed at increasing the added value of this important vegetable crop.

Proline plays an important role in cell osmotic adjustment, allowing the plant to absorb nutrients (Amini and Ehsanpour, 2005). El-Helaly (2019) found that proline foliar application at 150 or 200 mg/l on potato plants gave highest percentage of starch, dry matter, N, P and K tuber content. Spraying cucumber plants under saline stress conditions with proline improved the leaves minerals content (N, P and K) compared to the unsprayed plants (Youssef *et al*., 2018).

In addition, Ismail and Helmy (2018) on broad bean found that spraying broad bean plants with 2 L potassium humate/feddan in addition 100 mg/l proline produced the highest values of total carbohydrates and crude protein percentages in green pods.

CONCLUSION

From obtained results of this study, it could be recommended that soil application with 100 kg K_2O combined with proline foliar spraying at 200 mg/l enhance growth, yields and its components and chemical constituents of potato under the environmental conditions of this research.

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تأثير التسميد بالبوتاسيوم والرش بالبرولين على نمو ومحصول وجودة البطاطس النامية تحت ظروف المناطق الجافة

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أجريت تجربتان حقليتان خلال موسمي شتاء ٢٠٢٠/٢٠١٩ و٢٠٢١/٢٠٢٠ في المزرعة البحثية بكلية الزراعة والموارد الطبيعية، جامعة أسوان، أسوان، مصر. وكان الهدف الرئيسي من هذه الدراسة هو دراسة تأثير التسميد بالبوتاسيوم والرش بالبرولين على نمو ومحصول وجودة البطاطس النامية تحت ظروف المناطق الجافة .وقد تم استخدام تسع معاملات وهي (كنترول، إضافة البوتاسيوم للتربة عند مستويات ٥٠ و١٠٠ كجم K_2O / فدان منفردة أو مجتمعة مع ثلاثة مستويات من الرش بالبرولين (٥٠، ١٠٠ و٢٠٠ ملجم / لتر). وكان تصميم التجربة بنظام القطاعات الكاملة العشوائية في ثلاث مكررات. وبشكل عام أوضحت النتائج المتحصل عليها أن إضافة ١٠٠ كجم K_2O/فدان (٢٠٠ كجم سلفات بوتاسيوم) مع الرش بالبرولين بمعدل ٢٠٠ ملجم / لتر سجلت أعلى متوسط لقيم النمو الخضري، المحصول ،التركيب الكيميائي للأوراق والدرنات ويمكن اعتبارها المعاملة المثلى لإنتاج أعلي محصول ذو جودة عالية من نباتات البطاطس في ظل الظروف البيئية لمحافظة أسوان وغيرها من المناطق المماثلة.