J. Agric. & Env. Sci. (Damanhour University) 2022, 21 (3): 101-126
Print: ISSN 1687-1464 Online: 2735-5098

IMPACTS OF POTASSIUM, AUXIN AND CYTOKININS ON YIELD AND QUALITY OF POTATO CV. HERMES

Said M. Gabr, Alaa El-Den H. Roshdy, Sary H. Brengi, Ibrahim A. Abo El-Saad And Mostafa M. Abdel-Halim

Horticulture Department, Faculty of Agriculture, Damanhour University, Damanhour, El-Beheira, PO Box 59, Egypt

ABSTRACT

Two field experiments were conducted in the summer seasons of 2020 and 2021 to study the effect of potassium fertilization (0, 40, and 80 Kg K_2O fad^{-1}), foliar application of NAA (0, 5 and 10 ppm), and CKs as two types (BAP and TDZ at 0, 10 and 20 ppm) on yield and quality of potato tubers c.v. "Hermes". Generally, the examined levels of each studied factor were affected significantly on all yield and tubers quality traits, in both seasons. Also, the best level of each factor was 80 Kg K_2O fad^{-1}, 5 ppm for NAA and 10 ppm TDZ for CKs. According to the first order interaction between the pairs of three main factors, the best treatment combinations were 80 Kg K_2O+5 ppm NAA, 80 Kg K_2O+10 ppm TDZ, and 5 ppm NAA+ 10 ppm TDZ, in both seasons. Moreover, the second order interaction among the three studied factors was found to affect significantly all the studied characters with superiority of treatment combination of 80 Kg K_2O+5 ppm NAA+10 ppm TDZ, in both seasons. The treatment combination of 80 Kg K_2O+5 ppm NAA+10 ppm TDZ could be a recommended for increasing potato yield with keeping high quality of potato tubers.

***Keywords*:** potato, K, NAA, cytokinins, yield, tubers quality

INTRODUCTION

Potato (*Solanum tuberosum* L.) is the third most substantially produced and consumed tuber crop around the globe with 1.3 billion people consuming it as a staple food crop (more than 50 kg/person/year) **(Devaux *et al.*, 2020)**.Potato is considered the second vegetable crop in terms of area in Egypt after tomatoes; the cultivated area in 2021 was 501026 faddan produced approximately 5,811,901 tones, while the winter season

(2018/2019) was 299,185 faddan (Reports of Ministry of Agriculture and Land Reclamation, Egypt, 2021). The increasing of tubers yield in line with high tubers quality is a contentious concern for the researchers.

Potassium (K) is an important macronutrient for growth and development of the plant by inducing numerous biochemical and physiological processes, and also promotes synthesis of protein, carbohydrate metabolism, and activation of enzyme **(Ma *et al.* 2012; Hasanuzzaman *et al.* 2018; Naciri *et al.* 2021)**. It could summarize the physiological effects of potassium nutrition on potato plants in translocation of assimilates and protein synthesis, osmotic regulation, ionic balance, and stomatal and enzymatic activity that affect plant growth **(Oosterhuis *et al.*, 2014; Bishwoyog and Swarnima, 2016; Naumann *et al.*, 2020)**.

The 1-Naphtalene acetic acid (NAA) is an organic compound with formula of $C_{10}H_7CH_2CO_2H$. The synthetic plant hormone NAA is a member of auxin family, which is commonly used in horticultural crops. It is commonly used in relatively low concentration to elicit auxin responses in cell growth, cell division, fruit setting and rooting **(Sun and Hong, 2010)**. Many of previous research papers were declared that the foliar application of synthetic auxin such as NAA can increase plant growth, yield and its components, quality parameters and nutrition composition, fruit set and development in many vegetable crops **(Vafaee *et al.* 2020 on potato; Naz *et al.* 2020** on tomato**; Aashish *et al.* 2022** on chilli**; Ahmed *et al.* 2022** on pepper **and El-Areiny *et al.* 2022** on potato**)**.

Cytokinins (CKs) are classical plant hormones; they regulate many processes, such as cell division, shoot and root growth rates, chloroplasts development, leaf senescence, resistance to adverse factors, … etc. **(Kieber and Schaller, 2014)**. Exogenous application of synthetic CKs e.g., N-(2-chloro-4-pyridyl)-N'-phenylurea (CPPU), 6-binzylaminopurine (BAP) and thidiazuron (TDZ) was resulting in elevating many processes in treated plants related to vegetative growth, yield, quality, and nutrition

composition **(Al-muhamadi and Al- essawi 2015** on potato; **Ahmed *et al.* 2021** on potato; **Mijwel and Ridha 2021** on cauliflower; **Samy and El-Zohiri 2021** on garlic; **El-Areiny *et al.* 2022** on potato and **Kumari *et al.* 2022** on okra). Accordingly, the objectives of this study were to determine the optimal doses ofpotassium, naphthalene acetic acid and cytokinins and their interactions on yield and qualityof potato cultivar (Hermes)

MATERIALS AND METHODS

Two field experiments were carried out during the two successive summer seasons of 2020 and 2021. The experiments were performed in a private farm, at Abou Elmatamer (30.9118° N, 30.1719° E), El-Behiera Governorate, Egypt, under open field conditions. The aim of this study is to determine the effect of potassium, naphthalin acetic acid and cytokinins treatments as well as their interactions on yield and tuber and quality of potato plants, cultivar "Hermes".

The experimental site soil texture was classified as sandy clay loam with pH range of 7.6 - 7.8, potassium content range of 0.96 - 0.95 meq L^{-1}, and available potassium range of 327 - 330 meq L^{-1}, in the first and second seasons, respectively (Agric. Directorate Lab of Damanhur city, El-Behera Gov., Egypt).

Potato cultivation

The experimental field was polughed and pulverized. Then, the soil was ridged into rows 0.80 m in width and divided into plots. Certified imported potato seeds of "Hermes" cultivar was used after cutting. The used seed tubers were exported from Scotland. Potato seed tubers pieces were, approximately, 40 g in weight that containe at least 1 eye for each. Planting date was on the 19th of January in both seasons in dry soil and then irrigated. Potato seed tubers pieces were planted at 0.25 m apart between hills on one side of the ridge (about 20000 plant fad^{-1}).

The experimental treatments

Treatments consisted of three main factors. The first factor was the soil application of potassium fertilizer in three levels (0, 40, and 80 kg fad^{-1}), the second factor was the foliar application of naphthalene acetic acid (NAA) in three levels (0, 5, and 10 ppm), and the third factor was the foliar application of cytokinins (CKs) as 6- binzylaminopurine (BAP) and thidiazuron (TDZ) in three levels 0, 10, and 20 ppm. The NAA, BAP and TDZ were purchased from El-Gomhouria Company for Chemicals, Alexandria, Egypt.

The potassium fertilization, as well as the CKs foliar application, was applied twice after 45 and 65 days from planting, while the NAA foliar applications were applied once at 35 days. All precautions and precision followed during weighing, dissolving, spraying of the three independent factors. Foliar application of NAA, BAP and TDZ were done afternoon during both seasons, to avoid deteriorations caused by the effect of high temperatures and ambient atmosphere.

Experimental layout

The experimental layout was a randomized complete block design (RCBD), with three replicates in a split-split-plot system arrangement where the mineral potassium fertilizer levels were allocated in main plots and the synthetic auxin (naphthalene acetic acid) treatments were assigned as the sub-plots; whereas, the CKs (BAP and TDZ) were devoted in sub-sub-plots. Each replicate included 45 treatments. Each treatment contains five rows, 0.8 m in width and 3 m long with total area of 12 m^2. All treatment was distributed in the experimental units randomly. All other recommended agricultural practices for commercial potato production were followed. Harvesting was accomplished after 120 days of planting during both seasons.

Data Recorded

Yield and its components

At harvesting time (120 days from planting) the yield and its components characters were recorded for 10 plants from each treatment namely average tuber fresh weight (g), number of tubers $plant^{-1}$, average tuber yield $plant^{-1}$

(g), total tubers yield fad^{-1} (ton) that estimated by multiplying the tubers weight plot^{-1} by the factor of 350 (4200 m^2/12 m^2), then divided by 1000.

Tubers quality

Tuber specific gravity was determined by the method of **Dinesh et al. (2005)** and determined from the equation of **Smith (1977)** as follows:

$$SG = \frac{\text{Tuber weight in the air}}{\text{Tuber weight in the air} - \text{Tuber weight in the water}}$$

Vitamin C was measured by titration with iodide potassium according to the method of **Ranganna (1986)** and calculated as mg vitamin C /100 g, fresh weight.

Starch and reducing sugars (as dry weight basis), were determined for each tubers' sample according to the method described by **Malik and Singh (1980)**.

Statistical Analysis

All recorded data were statistically analyzed by CoStat computer software (COSTAT, 2005) version 6.4 from cohort software. The revised least significant difference test (RLSD) was applied at 0.05 confidence level to compare means of the different treatments by using the same program.

RESULTS AND DISCUSSIONS

Yield and its components

Effect of potassium

The main effect of potassium on the tuber weight, tubers No. plant^{-1}, yield plant^{-1}, and yield per faddan, of potato plants exhibited significant effect in all the studied characters compared to the control treatment, in both seasons (Table 1). However, the differences between potassium at either 40 or 80 kg K_2O fad^{-1} are not significant in tuber number, in the first season only. For instance, application of potassium at 80 kg K_2O fad^{-1}

recorded the highest average values of tuber weight, tubers No. plant^{-1}, yield plant^{-1}, and yield per faddan compared to the other treatments, in both seasons. However, the differences between potassium at either 40 or 80 kg K_2O fad^{-1} are not significant in tuber number, in the first season only. Also, the favorite treatment (80 kg K_2O fad^{-1}) the estimated percentages increase in tuber weight, tubers No. plant^{-1}, yield plant^{-1}, and yield fad^{-1} were (3.40 and 3.35 %), (21.35 and 20.18 %), (25.21 and 24.13%), and (25.19 and 24.17%) compared to the control treatment in the first and second season, respectively.

This effect could be return to low concentration of K availability and low organic matter % in soil before planting as mentioned before. These results are in harmony with results of many other researchers who found a significant role of K fertilization in increasing potato tubers yield and its components **(Trehan *et al.*, 2009; Abd El-Latif *et al.*, 2011; Berisha *et al.*, 2014; and Yakimenko and Naumova, 2018)**. This favorable role of K could be due to its involvement in many processes 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 soils with low K level.

Effect of naphthalene acetic acid (NAA)

Concerning the main effect of NAA, it is clear from results in Table (1) that there were significant differences between values of all yield parameters, in both seasons. The application of NAA with 5 ppm was the most effective treatment that to give the highest mean values of yield and its components, in both seasons. This treatment gave increment percentages over control estimated by 3.53%, 15.59%, 19.80%, and 19.82% for tuber weight, tubers No. plant^{-1}, yield plant^{-1}, and yield fad^{-1}, respectively as an average of both seasons. The present results are in contract with those

obtained by **Aboud and Abd-Alrahman (2020)** on potato who reported that spraying plants with 50 ppm of tryptophan increased No. of tubers per plant and total yield compared to control. Moreover, **Vafaee *et al*. (2020)** reported that the highest mean values fresh weight of tuber, and potato yield were obtained from the treatment containing NAA compared with control. Also, **Ahmed *et al.* (2022)** on pepper found that NAA at 10 or 20 ppm increased number of fruits/plant, fruit set %, fresh weight of fruit/ plant and total yield/fad. compared to control. The positive effect of NAA could be due to enhancing the source-sink relationship thus improved the yield **(Huang *et al.*, 2018)**.

Effect of cytokinins (CKs)

Regarding the main effect of cytokinin (BAP and TDZ) on tuber weight, tubers No. plant^{-1}, yield plant^{-1}, and yield fad^{-1}, results existing in Table 1 revealed that adding of cytokinin as (6-binzylaminopurine or thidiazuron) showed significant impacts in all the studied yield characters compared to the control treatment, in both seasons. Moreover, spraying of thidiazuron (TDZ) at 10.0 ppm recorded the highest average values of all the studied yield characters compared to the other treatments, in both seasons. Adding TDZ at 10.0 ppm showed a percentages increases in tuber weight, tubers No. plant^{-1}, yield plant^{-1}, and yield fad^{-1} were (10.67 and 10.27 %), (34.00 and 29.66 %), (48.10 and 42.97%), and (48.10 and 42.97 %) compared to the control treatment in the first and second season, respectively. The current results are in contract with those obtained by numerous authors (**Bhattaraia, 2017, Nuraini *et al.*, 2021 and Lahijani *et al.*, 2021**) who stated that cytokinins can hasten and improve potato tuberization. Also, **Njogu *et al*. (2015)** reported that increase the level of CKs, led to, significant, increase in number of tubers per plant and yield (ton/ha). Moreover, **El-Areiny *et al.* (2022)** indicated that soaking cut tuber explants of potato in 10 mg L^{-1} CPPU for 10 min before planting gave the highest average tuber weight, number of tuber and total yield ton fad^{-1} compared with untreated plants.

J. Agric. & Env. Sci. (Damanhour University) 2022, 21 (3): 101-126
Print: ISSN 1687-1464 Online: 2735-5098

Table 1. The main effect of potassium, NAA and CKs on yield characters of potato plants during the summer seasons of 2020 and 2021.

Treatments*		Tuber weight (g)		Tubers number		Yield plant^{-1} (g)		Total yield (Ton fad^{-1})	
		2020	2021	2020	2021	2020	2021	2020	2021
K (kg fad^{-1})	**0**	127.11c	128.23c	6.23b	6.64c	795.95c	854.73c	15.92c	17.09c
	40	128.82b	130.07b	7.22 a	7.58b	934.31b	989.49b	18.69b	19.79b
	80	131.42a	132.53a	7.56a	7.98a	996.58a	1060.96a	19.93a	21.22a
NAA (ppm)	**0**	127.11c	128.24c	6.47c	6.89c	826.13c	887.07c	16.52c	17.74c
	5	131.62a	132.73a	7.53a	7.91a	996.47a	1055.44a	19.93a	21.11a
	10	128.66b	129.89b	7.02b	7.41b	906.70b	965.11b	18.13b	19.30b
CKs (ppm) BAP	**0**	121.85e	123.23e	6.00d	6.54d	733.23d	807.62d	14.66d	16.15d
	10	127.74d	128.89d	6.66c	7.00c	853.74c	904.41c	17.07c	18.09c
	20	132.63b	133.70b	7.44b	7.78b	988.78b	1041.44b	19.78b	20.83b
CKs (ppm) TDZ	**10**	134.85a	135.89a	8.04a	8.48a	1085.59a	1154.70a	21.71a	23.09a
	20	128.33c	129.48c	6.85c	7.19c	881.07c	932.04c	17.62c	18.64c

*Values having a common alphabetical letter (s), do not significantly differ using the revised L.S.D. test

Potassium and NAA interaction

The interaction effect between potassium levels and auxin treatments on tuber weight, tubers No. plant^{-1}, yield plant^{-1}, and yield fad^{-1}, results were presented in Table (2). Significant differences among the averages of their interactions between both variables were clear. The combined treatment of potassium rate at 80 kg K fad^{-1} and NAA at 5 ppm gave the highest average values of tuber weight, tubers No. plant^{-1}, yield plant^{-1}, and yield fad^{-1} compared to other treatments in both seasons. **Reddy *et al.* (2003)** on pigeon pea, indicated that the foliar application of NAA at 20 ppm+ KNO_3 at 0.5% significantly increased seed yield over the control. Moreover, **Ghosh *et al.* (2022),** on *Capsicum,* indicated that spray of potassium nitrate at 1% and NAA at 60 ppm increased number of fruits per plant, average fruit weight, yield per plant, per square meter and per hectare compared to control. **Mahajan *et al.* (2022)** suggested that application of NAA at 50 ppm and KNO_3 at 0.4% increased the yield and its components characters compared with control.

Table 2. Effect of K and NAA interaction on yield characters of potato plants during the summer seaso of 2020 and 2021.

Treatments		Tuber weight (g)		Tubers number		Yield plant^{-1} (g)		Total yield (Ton fad^{-1})	
K_2O (kg fad^{-1})	NAA (ppm)	2020	2021	2020	2021	2020	2021	2020	2021
0	0	125.27f	126.53e	5.73f	6.20e	722.00g	787.87f	14.44g	15.76f
	5	129.27c	130.13c	6.60de	6.93cd	857.53def	906.47de	17.15def	18.13de
	10	126.33ef	127.53de	6.33e	6.67de	803.27f	853.20ef	16.07f	17.06ef
40	0	126.87de	128.00de	6.60de	7.00cd	840.07ef	898.53de	16.80ef	17.97de
	5	131.67b	132.93b	7.80ab	8.13ab	1030.53ab	1084.73ab	20.61ab	21.69ab
	10	127.93cd	129.27cd	7.27bc	7.60bc	932.33cd	985.20b.d	18.65cd	19.70b.d
80	0	129.20c	130.20c	7.07cd	7.47bc	916.33cde	974.80cd	18.33c.e	19.50cd
	5	133.93a	135.13a	8.20a	8.67a	1101.33a	1175.13a	22.03a	23.50a
	10	131.13b	132.27b	7.40bc	7.80b	972.07bc	1032.93bc	19.44bc	20.66bc

*Values having a common alphabetical letter (s), do not significantly differ using the revised L.S.D. test

Potassium and CKs interaction

The influence of K fertilizer and CKs interaction on potato yield and its components was presented in Table (3). In general, the interaction mean values showed a clear significant interaction effects between the two variables, in the both seasons. Also, the results illustrated that the highest significant mean values of aforementioned yield parameters were recorded when plants treated with potassium rate at 80 kg K fad^{-1} with TDZ foliar application at the rate of 10 ppm, in both seasons. However, the differences between the two combined treatments 80 kg K fad^{-1} and 10 ppm TDZ or 40 kg K fad^{-1} and 10 ppm TDZ were not significant in the first season for tubers number. Studies of **Badawy *et al.* (2019)** on garlic, indicated that active dry yeast extract 5g/l, potassium humate 4 kg fad^{-1}, and both of them increased bulb diameter, bulbing ratio, number of cloves per bulb and weight of 100 cloves and total yield compared with control. **Samy and El-Zohiri (2021)** indicated that the highest values of the average bulb weight, cloves weight /bulb, average clove weight and total yield kg fad^{-1}. were observed in the first and second seasons, respectively, when the optimum rate of potassium fertilizers (108 kg K_2O fad^{-1}) was combined with 2.5 ppm cytokinin.

J. Agric. & Env. Sci. (Damanhour University) 2022, 21 (3): 101-126
Print: ISSN 1687-1464 Online: 2735-5098

Table 3. Effect of K, and CKs interaction on yield characters of potato plants during the summer seasons of 2020 and 2021.

Treatments*			Tuber weight (g)		Tubers number		Yield plant^{-1} (g)		Total yield (Ton fad^{-1})	
K_2O (kg fad^{-1})	CKs (ppm)		2020	2021	2020	2021	2020	2021	2020	2021
0	BAP	0	118.89i	120.33i	5.11h	5.56i	608.11k	668.56j	12.16k	13.37j
		10	125.33g	126.56g	5.89g	6.22h	738.89j	788.22i	14.78j	15.76i
		20	131.11d	132.00d	6.78ef	7.11f	889.56gh	939.22gh	17.79gh	18.78gh
	TDZ	10	133.33bc	134.44bc	7.22d	7.67de	963.56e	1031.11de	19.27e	20.62de
		20	126.11fg	127.00fg	6.11g	6.44gh	771.22j	818.78i	15.42j	16.38i
40	BAP	0	121.89h	123.44 h	6.22g	6.67g	759.00j	823.56i	15.18j	16.47i
		10	127.44ef	128.44ef	6.78ef	7.11f	864.78hi	914.78h	17.30hi	18.30h
		20	132.11cd	133.22cd	7.67bc	8.00cd	1013.78d	1067.00d	20.28d	21.34d
	TDZ	10	134.33b	135.44b	8.33a	8.67b	1120.56b	1175.22b	22.41b	23.50b
		20	129.00e	130.33e	7.11de	7.44ef	918.11fg	970.78fg	18.36fg	19.42fg
80	BAP	0	124.56g	125.67g	6.67f	7.22f	831.11i	908.22h	16.62i	18.16h
		10	130.44d	131.67d	7.33cd	7.67de	957.56ef	1010.22ef	19.15ef	20.20ef
		20	134.67b	135.89b	7.89b	8.22c	1063.00c	1118.11c	21.26c	22.36c
	TDZ	10	136.89a	137.78a	8.56a	9.11a	1172.67a	1257.78a	23.45a	25.16a
		20	130.56d	131.67d	7.33cd	7.67de	958.56e	1010.44ef	19.17e	20.21ef

*Values having a common alphabetical letter (s), do not significantly differ using the revised L.S.D. test

Naphthalene acetic acid and CKs interaction

Concerning the interaction effect between NAA and CKs on tuber weight, tubers No. plant^{-1}, yield plant^{-1}, and yield fad^{-1}, results presented in Table (4). There were significant differences among their interaction means. The combination treatment of 5 ppm of NAA with 10 ppm of TDZ, reached the highest mean values of all studied characters in both seasons. The superiority of such combination could be due to their influence on the source-sink relationships, the auxins influence the carbohydrate mobilization of the leaves and stem apex that stimulates the translocation of assimilated compounds to sink organs; and the CKs elevate the power of the sink organs, because of the growth stimulation and usability of sucrose, besides favoring the extension of the leaf area and the photosynthetic activity of the source **(Albacete *et al.*, 2014)**. In the same contest, **Ahmed**

***et al.* (2021)** studied the effects of NAA auxin (0, 25, 50, and 100 mg L^{-1}) and cytokinin BA (0, 25, 50, and 100 mg L^{1}) as foliar application separately or in combinations on growth and yield of potato cv. Cara. Their results showed that foliar application of auxin (NAA) and the cytokinin as BA alone or in combination to potato plants gave, significantly, the highest average values of yield and its component. Moreover, **El-Areiny *et al.* (2022)** studied the effect of CPPU at 0.0, 5.0, 10.0 mg L^{-1} and NAA at 0, 5 and 10 mg L^{-1} on vegetative growth, yield and its components and quality of potato tubers as soaking before planting. Their results indicated that soaking cut tuber explants of potato in 10 mg L^{-1} CPPU mixed with 10 mg L^{-1} NAA for 10 min before planting gave the highest mean values of yield and its components compared with untreated plants.

Table 4. Effect of the first order interaction between NAA and CKs on some yield characters of potato plants during the summer seasons of 2020 and 2021.

Treatments*			Tuber weight(g)		Tubers number		Yield plant^{-1} (g)		Total yield (Ton fad^{-1})	
NAA (ppm)	CKs (ppm)		2020	2021	2020	2021	2020	2021	2020	2021
0	BAP	0	120.11k	121.56k	5.44 k	6.11j	655.11i	744.00i	13.10i	14.88i
		10	125.67 i	126.78i	6.00j	6.33ij	755.22h	804.11hi	15.10h	16.08hi
		20	130.67ef	131.56ef	7.00efg	7.33ef	915.44efg	965.33ef	18.31eg	19.31ef
	TDZ	10	133.00cd	133.89cd	7.56cd	8.00bcd	1005.56cd	1071.56bcd	20.11cd	21.43bcd
		20	126.11hi	127.44hi	6.33ij	6.67g-j	799.33h	850.33gh	15.99h	17.01gh
5	BAP	0	123.78j	125.00j	6.44hi	6.78f-i	799.89h	849.33gh	16.00h	16.99gh
		10	130.33f	131.44f	7.22def	7.56de	942.33ef	994.33def	18.85ef	19.89def
		20	135.33b	136.56b	8.00b	8.33b	1083.22b	1138.89b	21.66b	22.78b
	TDZ	10	138.00a	139.00a	8.67a	9.22a	1197.44a	1284.00a	23.95a	25.68a
		20	130.67ef	131.67ef	7.33de	7.67cde	959.44de	1010.67def	19.19de	20.21de
10	BAP	0	121.44k	122.89k	6.11ij	6.56hij	743.22h	807.00hi	14.86h	16.14hi
		10	127.22gh	128.44gh	6.78gh	7.11e-h	863.67g	914.78fg	17.27g	18.30fg
		20	131.89de	133.00de	7.33de	7.67cde	967.67de	1020.11cde	19.35de	20.40cde
	TDZ	10	133.56c	134.78c	7.89bc	8.22bc	1053.78bc	1108.56bc	21.08bc	22.17bc
		20	128.22g	129.33g	6.89fg	7.22efg	884.44fg	935.11efg	17.69fg	18.70efg

*Values having a common alphabetical letter (s), do not significantly differ using the revised L.S.D. test

Potassium, NAA and CKs interaction

The comparisons among the mean values of the various treatment combinations K, NAA, and CKs on yield characters showed significant effect for all the studied characters, in both seasons (Table 5). Also, the results clarified that fertilization of K at 80 kg of K_2O fad^{-1} and foliar application of NAA at 5 ppm combined with the TDZ at 10 ppm gave the highest significant mean values of yield and its components characters, in the both seasons. This significant improvement of this triple treatment can be due to the complementarity of the roles played by each of these three factors**. Habtam *et al.*, (2018)** concluded that K has been well documented in photosynthesis, increasing enzyme activity, improving synthesis of protein, carbohydrates and fats translocation of photosynthetic. Also, **Pavlista (2011), and Roumeliotis *et al.* (2012)** indicated that auxin play a key role in the formation and growth of potato tubers. Moreover, **Hussain and Khalaf (2007)** illustrated that CKs stimulates cell division and enlargement, as well as, the synthesis of protein, nucleic acid and chlorophyll.

Tuber quality characteristics

Effect of K

The main effect of K fertilization on the quality parameters, results existing in Table (6) confirmed that application of potassium significantly increased TSS, vitamin C., specific gravity, dry matter, starch and protein contents of potato tubers, compared to control treatment in both seasons. However, the reducing sugar significantly decreased, in both seasons. It is clear that addition of potassium at 80 kg K_2O fad^{-1}gave the highest mean values of TSS, vitamin C., specific gravity, dry matter, starch and protein contents of potato tubers, in both seasons, compared to the other treatments. At the favorite treatment 80 kg K_2O fad^{-1}, the estimated percentages increase in TSS, vitamin C., specific gravity, dry matter, starch and protein contents of potato tuber were (6.7 and 6.8%), (6.6 and 6.3%), (0.96 and 0.86%), (6.1 and 6.1%), (8.5 and 8.8%) and (13.7 and 13.8%) compared to the control treatment in the first and second season, respectively.

J. Agric. & Env. Sci. (Damanhour University) 2022, 21 (3): 101-126
Print: ISSN 1687-1464 Online: 2735-5098

Table 5. Effect of potassium, NAA and CKs interaction on yield characters of potato plants during the summer seasons of 2020 and 2021.

Treatments				Tuber weight (g)		Tubers number		Yield plant^{-1} (g)		Total yield (Ton fad^{-1})	
K	NAA	CKs		2020	2021	2020	2021	2020	2021	2020	2021
0	0	BAP	0	117.00s	119.00w	4.67j	5.33k	545.67v	634.67x	10.91v	12.69x
			10	123.33p	124.67rs	5.33ij	5.67jk	658.00uv	706.33v-x	13.16uv	14.13v-x
			20	129.33j	130.33m	6.33f-i	6.67g-i	819.33n-s	868.67o-t	16.39n-s	17.37o-t
		TDZ	10	132.33g	133.33hi	6.67e-h	7.33efg	882.33j-p	977.67h-n	17.65j-p	19.55h-n
			20	124.33o	125.33qr	5.67h-j	6.00ijk	704.67stu	752.00uvw	14.09stu	15.04u-w
	5	BAP	0	120.33q	121.33uv	5.33ij	5.67jk	642.00uv	687.33wx	12.84uv	13.75wx
			10	128.33k	129.33n	6.33f-i	6.67g-i	812.67n-s	862.33o-t	16.25n-s	17.25o-t
			20	133.67f	134.33fg	7.33c-f	7.67d-f	980.33e-k	1030.00g-k	19.61e-k	20.60g-k
		TDZ	10	135.33cd	136.33c	7.67cde	8.00c-e	1037.67c-g	1090.67d-g	20.75c-g	21.81d-g
			20	128.67jk	129.33n	6.33f-i	6.67g-i	815.00n-s	862.00o-t	16.30n-s	17.24o-t
	10	BAP	0	119.33r	120.67v	5.33ij	5.67jk	636.67uv	683.67wx	12.73uv	13.67wx
			10	124.33o	125.67pq	6.00ghi	6.33h-j	746.00q-u	796.00s-v	14.92q-u	15.92s-v
			20	130.33i	131.33l	6.67e-h	7.00f-h	869.00k-q	919.00l-q	17.38k-q	18.38l-q
		TDZ	10	132.33g	133.67ghi	7.33c-f	7.67d-f	970.67f-k	1025.00g-l	19.41f-k	20.50g-l
			20	125.33mn	126.33p	6.33f-i	6.67g-i	794.00o-t	842.33p-u	15.88o-t	16.85p-u
40	0	BAP	0	120.33q	121.67tu	5.67hij	6.33h-j	681.67tu	770.67t-w	13.63tu	15.41t-w
			10	125.33mn	126.00pq	6.00ghi	6.33h-j	752.00q-u	798.33r-v	15.04q-u	15.97r-v
			20	130.33i	131.33l	7.00d-g	7.33e-g	912.33g-o	963.33i-o	18.25g-o	19.27i-o
		TDZ	10	132.33g	133.33hi	7.67cde	8.00c-e	1014.67d-i	1066.67e-i	20.29d-i	21.33e-i
			20	126.00lm	127.67o	6.67e-h	7.00f-h	839.67l-r	893.67n-s	16.79l-r	17.87n-s
	5	BAP	0	124.67no	126.33p	6.67e-h	7.00f-h	831.00l-s	884.33n-s	16.62l-s	17.69n-s
			10	130.33i	131.33l	7.33c-f	7.67d-f	955.67f-m	1007.00gm	19.11f-m	20.14g-m
			20	134.67de	136.00cd	8.33a-c	8.67bc	1122.33b-d	1179.00cd	22.45bcd	23.58cd
		TDZ	10	138.00b	139.00b	9.00ab	9.33b	1241.67ab	1297.33b	24.83ab	25.95b
			20	130.67hi	132.00kl	7.67c-e	8.00c-e	1002.00d-j	1056.00f-j	20.04d-j	21.12f-j
	10	BAP	0	120.67q	122.33t	6.33f-i	6.67g-i	764.33p-u	815.67q-u	15.29p-u	16.31q-u
			10	126.67l	128.00o	7.00d-g	7.33e-g	886.67i-p	939.00k-p	17.73i-p	18.78k-p
			20	131.33h	132.33jk	7.67c-e	8.00c-e	1006.67d-j	1058.67f-i	20.13d-j	21.17f-i
		TDZ	10	132.67g	134.00gh	8.33a-c	8.67bc	1105.33cde	1161.67c-f	22.11c-e	23.23c-f
			20	128.33k	129.67mn	7.00d-g	7.33e-g	898.67h-o	951.00j-o	17.97h-o	19.02j-o
80	0	BAP	0	123.00p	124.00s	6.00g-i	6.67g-i	738.00r-u	826.67q-u	14.76r-u	16.53q-u
			10	128.33k	129.67mn	6.67e-h	7.00f-h	855.67k-r	907.67m-q	17.11k-r	18.15m-q
			20	132.33g	133.00ij	7.67c-e	8.00c-e	1014.67d-i	1064.00e-i	20.29d-i	21.28e-i
		TDZ	10	134.33ef	135.00ef	8.33a-c	8.67bc	1119.67bcd	1170.33cde	22.39b-d	23.41c-e
			20	128.00k	129.33n	6.67e-h	7.00f-h	853.67k-r	905.33m-r	17.07k-r	18.11m-r
	5	BAP	0	126.33l	127.33o	7.33c-f	7.67d-f	926.67g-n	976.33h-n	18.53gn	19.53h-n
			10	132.33g	133.67ghi	8.00b-d	8.33cd	1058.67c-f	1113.67c-g	21.17c-f	22.27c-g
			20	137.67b	139.33b	8.33a-c	8.67bc	1147.00bc	1207.67bc	22.94bc	24.15bc

	TDZ	**10**	140.67a	141.67a	9.33a	10.33a	1313.00a	1464.00a	26.26a	29.28a
		20	132.67g	133.67g-i	8.00b-d	8.33cd	1061.33c-f	1114.00c-g	21.23c-f	22.28c-g
10	BAP	**0**	124.33o	125.67pq	6.67e-h	7.33e-g	828.67m-s	921.67l-q	16.57m-s	18.43l-q
		10	130.67hi	131.67kl	7.33c-f	7.67d-f	958.33f-m	1009.33g.m	19.17f-m	20.19g-m
		20	134.00ef	135.33de	7.67c-e	8.00c-e	1027.33c-h	1082.67d-h	20.55c-h	21.65d-h
	TDZ	**10**	135.67c	136.67c	8.00b-d	8.33cd	1085.33c-f	1139.00c-f	21.71c-f	22.78c-f
		20	131.00hi	132.00kl	7.33c-f	7.67d-f	960.67f-l	1012.00g.m	19.21f-l	20.24g-m

*Values having a common alphabetical letter (s), do not significantly differ using the revised L.S.D. test

On the other hand, increasing K rate significantly decreased the reduced sugars content and the decrements were more pronounced at higher K rates. Meanwhile, the control treatments (0 kg K_2O fad^{-1}) gave the highest mean values for reducing sugars content on both seasons. The improvement of tubers quality characters expressed as specific gravity, vitamin C., and starch as affected by increasing of K levels may be attributed to the positive effect of potassium on translocation of assimilates **(Pervez *et al.*, 2013)**. Also, **Yakimenko and Naumova (2018)** and **Rather *et al.* (2021)** reported that the K fertilization was strongly related to increasing the potato tubers quality attributes. Moreover, **Gerendas *et al.* (2007)** indicated that higher doses of K lead to a lower amount of reducing sugars content.

Effect of NAA

Regarding the main effect of naphthalene acetic acid, it is clear from results in Table (6) all naphthalene acetic acid treatments significantly increased TSS, vitamin C., specific gravity, dry matter, starch and protein with different significant levels when compared to non-treated plants, in both seasons. The maximum significant increases in aforementioned tubers quality were recorded at NAA 5 ppm. The estimated percentages increases in TSS, vitamin C., specific gravity, dry matter, starch and protein at NAA 5 ppm were (3.08 and 3.07%), (1.99 and 2.10%), (0.67 and 0.67%), (4.19 and 4.12%), (4.94 and 4.98%) and (12.44 and 12.45%) as compared to control treatment in the first and second seasons, respectively. On the other hand, NAA 5 ppm decreased reducing sugar by (15.00 and 15.31%) in the first and second seasons, respectively compared to control. These results are in agreement**.** These results are in harmony with those of **kumar *et al.*, (2012), Vafaee *et al*. (2020),** and **El-Areiny *et al.* (2022)** who found a

significant positive effect of auxins application on quality parameters of potato tubers.

Effect of CKs

The results in Table (6) cleared that the two types of CKs (6-binzylaminopurine and TDZ) significantly affected all studied parameters of potato tubers quality, in both seasons. On other words; the highest values ((5.68 and 5.67%)) for TSS, (4.99 and 4.81%) for vitamin C, (1.44 and 1.44) for specific gravity, (5.48 and 5.41%) for dry matter, (12.87 and 12.81%) for starch and (38.89 and 38.57%) for protein, respectively during both seasons were realized when potato plants treated with thidiazuron **(**TDZ**)** at 10 ppm**.** On the other hand, TDZ at 10 ppm decreased the reducing sugar by (25.82 and 25.96%) in the first and second seasons, respectively compared to control. These findings were emphasizing the positive role of cytokinins in improving the potato tubers quality as reported by **El-Anany *et al*. (2020), Ahmed and Mengistu (2020),** and **Malek *et al.* (2021)**.

Potassium and NAA interaction

Concerning the interaction effects between potassium levels and NAA treatments on specific gravity, vitamin C, starch and reducing sugars of potato tubers, results presented in Table (7) revealed significant differences among the interaction means, in both seasons. Also, the treatment combination of 80 kg K fad^{-1} and NAA at 5 ppm was found to give the highest mean values of specific gravity and starch; whereas, the vitamin C content exhibit the best content under 80 kg K fad^{-1} with NAA at either 5 or 10 ppm, in both seasons of study.

On contrary, the combined treatment of zero kg K fad^{-1} with zero ppm NAA attained the highest mean value of reducing sugar, in both seasons. These finding pointed out the favorable effect of treated potato plants with K and NAA for enhancing the quality parameters of produced yield as published by **Khajehzadeh *et al.* (2018)** and **Mahajan *et al.* (2022)**.

J. Agric. & Env. Sci. (Damanhour University) 2022, 21 (3): 101-126
Print: ISSN 1687-1464 Online: 2735-5098

Table 6. The main effect of K, NAA and CKs on specific gravity, vitamin C, starch, and reducing sugars of potato tubers during the summer seasons of 2020 and 2021.

Treatments		Specific gravity (g/cm^3)		Vitamin C (mg/100gf.w.)		Starch (%)		Reducing sugar (%)	
		2020	2021	2020	2021	2020	2021	2020	2021
K ($kg\ fad^{-1}$)	0	1.043c	1.045c	18.23c	18.29c	15.10c	15.15c	2.08a	2.04a
	40	1.048b	1.049b	18.50b	18.55b	15.87b	15.95b	1.82b	1.78b
	80	1.053a	1.054a	19.44a	19.45a	16.39a	16.49a	1.64c	1.58c
NAA (ppm)	0	1.045c	1.046c	18.52c	18.56c	15.40c	15.47c	2.00a	1.96a
	5	1.052a	1.053a	18.89a	18.95a	16.16a	16.24a	1.70c	1.66c
	10	1.047b	1.049b	18.77b	18.78b	15.80b	15.89b	1.83b	1.78b
CKs (ppm) BAP	0	1.040e	1.041e	18.24e	18.30e	14.84e	14.91e	2.13a	2.08a
	10	1.047d	1.048d	18.56d	18.61d	15.42d	15.50d	1.92b	1.87b
	20	1.051b	1.052b	18.98b	19.05b	16.34b	16.42b	1.73d	1.68d
TDZ	10	1.055a	1.056a	19.15a	19.18a	16.75a	16.82a	1.58e	1.54e
	20	1.048c	1.049c	18.70c	18.68c	15.57c	15.66c	1.86c	1.82c

*Values having a common alphabetical letter (s), do not significantly differ using the revised L.S.D. test

Table 7. Effect K and NAA interaction on specific gravity, vitamin C., starch and reducing sugar of potato tubers during the summer seasons of 2020 and 2021.

Treatments		Specific gravity (g/cm^3)		Vitamin C (mg/100gf.w.)		Starch (%)		Reducing sugars (%)	
K_2O ($kg\ fad^{-1}$)	NAA (ppm)	2020	2021	2020	2021	2020	2021	2020	2021
0	0	1.041f	1.042f	18.10e	18.16e	14.74g	14.79g	2.21a	2.18a
	5	1.047d	1.048d	18.37cde	18.43c.e	15.42e	15.48e	1.95c	1.91c
	10	1.043ef	1.044ef	18.20de	18.25de	15.07f	15.13f	2.07b	2.02b
40	0	1.045de	1.046de	18.34cde	18.39de	15.54e	15.61e	1.97bc	1.93bc
	5	1.051bc	1.053b	18.68c	18.73c	16.21bc	16.30bc	1.67e	1.63e
	10	1.047d	1.048d	18.49cd	18.54cd	15.85d	15.94d	1.81d	1.76d
80	0	1.049c	1.051c	19.13b	19.14b	15.93cd	16.02cd	1.83d	1.77d
	5	1.057a	1.058a	19.63a	19.70a	16.86a	16.96a	1.48f	1.42f
	10	1.052b	1.053b	19.57a	19.50a	16.39b	16.50b	1.60e	1.55e

*Values having a common alphabetical letter (s), do not significantly differ using the revised L.S.D. test

Potassium and CKs interaction

Relating to the interaction effect between potassium levels and auxin treatments on TSS, vitamin c., specific gravity, dry matter, starch and protein in potato tubers, results presented in Table (8) revealed significant differences among the averages of their interactions between both variables. The combination between potassium at 80 kg K fad^{-1} and NAA at 5 ppm reached the highest average values of TSS, vitamin C., specific gravity, dry matter, starch and protein of potato plants, in both seasons compared to other treatments.

Table 8. Effect of the K and CKs interaction on specific gravity, vitamin C., starch and reducing sugar of potato tubers during the summer seasons of 2020 and 2021.

Treatments			Specific gravity (g/cm^3)		Vitamin C (mg/100gf.w.)		Starch (%)		Reducing sugar (%)	
K_2O (kg fad^{-1})	CKs (ppm)		2020	2021	2020	2021	2020	2021	2020	2021
0	BAP	0	1.035j	1.037i	17.93e	17.98e	14.38i	14.43j	2.36a	2.31a
		10	1.042h	1.043g	18.17de	18.23de	14.80hi	14.86ij	2.17b	2.13b
		20	1.046f	1.048f	18.35cde	18.41cde	15.49efg	15.55fgh	1.97d	1.94d
	TDZ	10	1.050e	1.052e	18.46cde	18.53b-e	15.85def	15.90d-g	1.80g	1.76e
		20	1.043h	1.044g	18.21de	18.26de	14.87ghi	14.93hij	2.08c	2.05c
40	BAP	0	1.040i	1.041h	18.16de	18.20de	14.85ghi	14.93hij	2.13bc	2.09bc
		10	1.046f	1.047f	18.43cde	18.48b-e	15.57ef	15.66efg	1.87ef	1.83e
		20	1.051e	1.052e	18.64b-e	18.70b-e	16.40cd	16.47cd	1.71h	1.67f
	TDZ	10	1.055bc	1.056bc	18.80bcd	18.85bcd	16.78bc	16.86bc	1.56i	1.51g
		20	1.049ef	1.050ef	18.67b-e	18.72b-e	15.83def	15.92d-g	1.79g	1.75e
80	BAP	0	1.044gh	1.045g	18.60b-e	18.67b-e	15.22fgh	15.31ghi	1.91de	1.83e
		10	1.052de	1.053de	19.07bc	19.13bc	15.89de	15.98def	1.72h	1.66f
		20	1.056b	1.057b	19.96a	20.03a	17.13ab	17.23ab	1.50i	1.44g
	TDZ	10	1.060a	1.061a	20.19a	20.17a	17.62a	17.72a	1.39j	1.34h
		20	1.054cd	1.055cd	19.40ab	19.24b	16.11de	16.22cde	1.67h	1.62f

*Values having a common alphabetical letter (s), do not significantly differ using the revised L.S.D. test

However, the differences between 80 kg K fad^{-1} and NAA at either 5 or 10 ppm were not significant in vitamin C during both seasons. Conversely, the combined treatment between zero kg K fad^{-1} and zero ppm NAA attained the highest mean value of reducing sugar, in both seasons compared to other treatments. Other research works revealed the favorable effect of combined

treatment of K with CKs application on the quality parameters **(AL-muhamadi and AL-Essawi, 2015 on potato and Samy and El-Zohiri, 2021 on garlic)**.

Naphthalene acetic acid and CKs interaction

In this context, the mean values listed in Table (9) revealed a clear significant interaction effect between NAA and CKs on all the studied tubers quality parameters, in both seasons. The combination between NAA at 5 ppm and TDZ at 10 ppm chronicled the highest average values of TSS, vitamin C., specific gravity, dry matter, starch and protein of potato plants, in both seasons compared to other treatments. However, the differences between (NAA at 5 ppm and TDZ at 10 ppm) or (NAA at 5 ppm and BAB at 20 ppm) were not significant in TSS and vitamin C during both seasons.

Table 9. Effect of the NAA and CKs interaction on specific gravity, vitamin C., starch and reducing sugar of potato tubers during the summer seasons of 2020 and 2021.

Treatments*			Specific gravity(g/cm^3)		Vitamin C (mg/100gf.w.)		Starch (%)		Reducing sugar (%)	
NAA (ppm)	CKs (ppm)		2020	2021	2020	2021	2020	2021	2020	2021
0	BAP	0	1.037i	1.039i	18.07h	18.12j	14.59k	14.65k	2.31a	2.25a
		10	1.044fg	1.046fg	18.39fg	18.45hi	15.03ij	15.10ij	2.07b	2.03b
		20	1.048def	1.049def	18.78de	18.85ef	15.98de	16.06de	1.89d	1.85d
	TDZ	10	1.051cd	1.052cd	18.93cd	18.90de	16.26cd	16.32cd	1.74f	1.70g
		20	1.045fg	1.046fg	18.44fg	18.49h	15.16hi	15.23hi	2.00c	1.97c
5	BAP	0	1.042gh	1.043gh	18.37fg	18.43hi	15.07ij	15.14ij	1.99c	1.94c
		10	1.050cde	1.051cde	18.72de	18.78efg	15.82ef	15.92ef	1.79e	1.74f
		20	1.055b	1.056b	19.20ab	19.25b	16.71b	16.78b	1.57g	1.52h
	TDZ	10	1.061a	1.062a	19.40a	19.47a	17.25a	17.33a	1.44h	1.39i
		20	1.051cd	1.052cd	18.78de	18.83ef	15.97de	16.06de	1.72f	1.68g
10	BAP	0	1.039hi	1.040hi	18.24gh	18.30ij	14.80jk	14.89jk	2.10b	2.04b
		10	1.046ef	1.047efg	18.56ef	18.61gh	15.40gh	15.47gh	1.90d	1.85d
		20	1.050cde	1.051cde	18.97b.d	19.04cd	16.32c	16.41c	1.72f	1.67g
	TDZ	10	1.053bc	1.054bc	19.12bc	19.18bc	16.74b	16.82b	1.57g	1.52h
		20	1.047def	1.049def	18.87cd	18.71fg	15.59fg	15.68fg	1.85d	1.81e

*Values having a common alphabetical letter (s), do not significantly differ using the revised L.S.D. test

On the other hand, the combined treatment between zero ppm NAA and zero ppm TDZ attained the highest mean value of reducing sugar, in both seasons compared to other treatments. These findings are agreed with those of **El-Areiny *et al.* (2022)** who reported a significant favorable effect of NAA and CKs combination on tubers quality traits of potato.

Effect of K, NAA and CKs interaction

The interaction effect among the three main factors of K, NAA and CKs was found to be significant for all potato tubers quality parameters (Table, 10), in both seasons. Among these treatment combinations, the application of 80 kg K_2O fad^{-1} with foliar application of 5 ppm of NAA and 10 ppm of TDZ gave the highest average values of TSS, vitamin c., specific gravity, dry matter, starch and protein in potato tubers in both seasons compared to other treatments. **El-Sayed *et al.* (2015)** on bell pepper and **Binnoubah *et al.* (2022)** on potato reported the ability of combined the application of K with some growth modulators for enhancing the quality parameters.

Table 10. Effect of the second order interaction between pot, NAA and CKs on tubers quality characters of potato plants during the summer seasons of 2020 and 2021.

Treatments*				Specific gravity (g/cm^3)		Vitamin C (mg/100gf.w.)		Starch (%)		Reducing sugar (%)	
K	NAA	CKs		2020	2021	2020	2021	2020	2021	2020	2021
0	0	BAP	0	1.034B	1.035y	17.87H	17.91z	14.27K	14.32L	2.55a	2.51a
			10	1.040wx	1.042t	18.00E	18.07xy	14.44I	14.48J	2.25d	2.22c
			20	1.044t	1.045r	18.25z	18.31tu	15.14C	15.20C	2.11g	2.07f
		TDZ	10	1.046qr	1.048no	18.31x	18.39q.t	15.38z	15.42x	1.94l	1.91l
			20	1.041v	1.042t	18.07C	18.12v.x	14.47H	14.52I	2.19ef	2.17d
	5	BAP	0	1.037z	1.038w	17.99F	18.06xy	14.53G	14.58H	2.21e	2.17d
			10	1.045s	1.046q	18.35v	18.41q-t	15.14C	15.20C	2.09g	2.04h
			20	1.050im	1.051lm	18.48r	18.53m.p	15.89q	15.94p	1.85no	1.82no
		TDZ	10	1.055e	1.056ef	18.65n	18.72ij	16.33m	16.39l	1.66v	1.62u
			20	1.047op	1.048no	18.38u	18.43p-s	15.22B	15.29z	1.96k	1.92kl
	10	BAP	0	1.035A	1.037x	17.93G	17.97yz	14.34J	14.41K	2.33b	2.26b
			10	1.041v	1.042t	18.15B	18.20u-w	14.84E	14.89F	2.18f	2.13e
			20	1.046qr	1.047pq	18.32w	18.38rst	15.43y	15.49w	1.96k	1.92kl
		TDZ	10	1.049m	1.051lm	18.42t	18.48o-r	15.83r	15.89q	1.79p	1.75q

			20	1.042u	1.043s	18.19A	18.23uv	14.92D	14.99D	2.09g	2.06g
			0	1.038y	1.039v	18.05D	18.09wx	14.57F	14.62G	2.30c	2.27b
		BAP	**10**	1.044t	1.045r	18.31x	18.36st	15.20B	15.27A	2.02i	1.99i
	0		**20**	1.047op	1.049n	18.44s	18.50n-q	16.16n	16.23mn	1.86n	1.82no
		TDZ	**10**	1.051jk	1.053i	18.55q	18.60k-n	16.43k	16.49j	1.69tu	1.65t
			20	1.044t	1.045r	18.35v	18.39q-t	15.35A	15.42 x	1.97jk	1.93jk
			0	1.042u	1.044s	18.27y	18.31tu	15.15C	15.22 B	1.98j	1.94j
		BAP	**10**	1.048n	1.050m	18.56q	18.62j-m	15.94p	16.07o	1.74r	1.70r
40	**5**		**20**	1.055e	1.057d	18.86l	18.92h	16.69h	16.75h	1.53z	1.50xy
		TDZ	**10**	1.061b	1.062b	19.10j	19.15g	17.15e	17.23e	1.42B	1.38B
			20	1.049m	1.051lm	18.61p	18.64jkl	16.13o	16.21n	1.69tu	1.65t
			0	1.040wx	1.041u	18.16B	18.21uv	14.85E	14.94E	2.09g	2.05gh
		BAP	**10**	1.045s	1.047pq	18.43t	18.47o-s	15.56v	15.64t	1.85no	1.80o
	10		**20**	1.050im	1.051lm	18.63o	18.68jk	16.34m	16.43k	1.73rs	1.68s
		TDZ	**10**	1.053h	1.054h	18.74m	18.80i	16.75g	16.85g	1.56y	1.51x
			20	1.046qr	1.048no	18.50r	18.56l-o	15.73t	15.82r	1.83o	1.78p
			0	1.041v	1.042t	18.31x	18.37rst	14.93D	15.00D	2.07h	1.98i
		BAP	**10**	1.049m	1.051im	18.86l	18.93h	15.46x	15.55v	1.92l	1.88m
	0		**20**	1.052hi	1.054h	19.65g	19.74d	16.64i	16.75h	1.71st	1.66t
		TDZ	**10**	1.054fg	1.056ef	19.92f	19.72d	16.96f	17.06f	1.58x	1.54w
			20	1.051jk	1.052ij	18.90k	18.96h	15.64u	15.74s	1.85no	1.82no
			0	1.048n	1.049n	18.86l	18.94h	15.53w	15.62u	1.76q	1.70r
		BAP	**10**	1.055e	1.056ef	19.24i	19.30f	16.40l	16.49j	1.56y	1.49y
80	**5**		**20**	1.060b	1.061b	20.25b	20.31b	17.54c	17.64c	1.32D	1.25D
		TDZ	**10**	1.067a	1.068a	20.46a	20.53a	18.26a	18.36a	1.24E	1.18E
			20	1.056d	1.057d	19.36h	19.42e	16.57j	16.67i	1.52z	1.46z
			0	1.043u	1.044s	18.65n	18.71ijk	15.21B	15.33y	1.89m	1.82no
		BAP	**10**	1.052hi	1.052ij	19.11j	19.16g	15.80s	15.89q	1.67uv	1.62u
	10		**20**	1.056d	1.057d	19.97d	20.05c	17.20d	17.30d	1.46A	1.40A
		TDZ	**10**	1.058c	1.059c	20.19c	20.25b	17.64b	17.73b	1.36C	1.31C
			20	1.054fg	1.055g	19.94e	19.33ef	16.13o	16.25m	1.64w	1.60v

*Values having a common alphabetical letter (s), do not significantly differ using the revised L.S.D. test

Conclusion

The obtained results showed, generally, that the combination between potassium (80 kg K_2O fad^{-1}) + NAA (5ppm) + TDZ (10 ppm) recorded the highest average values and might be considered as the best treatment for the production of high yield and good quality of potato plants under the environmental conditions of Behiera Governorate and other similar regions.

References

Aashish, K. C.; J. Kumar; V. J. Silas; H. Giri; H. Khadka and M. K. Yadav, (2022). Effect of foliar application of urea and naphthalene acetic acid (NAA) on growth and yield of chilli (*Capsicum annum* L.) var Pusa Jwala. Pharma Innov. J., 11(7): 1187-1198.

Abd El-Latif, K. M.; E. A. M. Osman; R. Abdullah, and N. Abd El-Kader (2011). Response of potato plants to potassium fertilizer rates and soil moisture deficit. Adv. Appl. Sci. Res., 2(2): 388-397.

Aboud, F. S., and H. A. Abd-Alrahman (2020). Effect of foliar spray with some growth stimulants on potato plants under different growing media. Plant Archives 20 (2): 9244-9252.

Ahmed, A. A.; A. A. Alkharpotly; A. A. Gabal and A. I. Abido(2021).Potato growth and yield as affected by foliar application with NAA auxin and 6-BA cytokinin. J. Plant Prod., Mansoura Univ., 12 (6):591 – 596.

Ahmed, I. H.; E. F. Ali; A. A. Gad; A. Bardisi; A. M. El-Tahan; O. A. Abd Esadek, and A. S. Gendy, (2022). Impact of plant growth regulators spray on fruit quantity and quality of pepper (*Capsicum annuum* L.) cultivars grown under plastic tunnels. Saudi J. Biol. Sci., 29(4): 2291-2298.

Ahmed, K., and F. G. Mengistu (2020). Quality components of potato tubers as affected by plant growth regulators. Int. J. Res Stud. Agri. Sci. (IJRSAS), 6(11): 21-27.

Albacete, A. A.; C. Martínez-Andújar and F. Pérez-Alfocea, (2014). Hormonal and metabolic regulation of source–sink relations under salinity and drought: from plant survival to crop yield stability. Biotechnol. Adv., 32(1): 12-30.

AL-muhamadi O. H. M. and A. kh. H. AL- essawi (2015).Effect of spraying with Growth Regulators and some nutrients in quality characters of Potato plants *Solanum tuberosum* L. Burren cv. Anbar J. Agric.Sci.,13(2):267-276.

Badawy, A.; M. M. A. Zahran and M. M. Hefzy, (2019). Effect of irrigation level and bio-stimulants on productivity and quality of garlic (*Allium sativum* L.) in calcareous soils. Fayoum J. Agric. Res. & Develop., 33(1): 90-101.

Berisha, D.; E. Susaj; N. Bardhi; L. Susaj; V. Havolli; S. Aliu; I. Rusinovci; B. Neziraj, and A. Osmanaj (2014). Effect of potassium fertilization rate on several vegetative and yield characters of potato (*Solanum tuberosum* L.), grown under two different agro-climatic regions of Kosovo. Int. Interdiscip. Res. J., 4: 62-69.

Bhattaraia, P. (2017). Effects of plant growth regulators on growth and yield of pre-basic seed potato production under glasshouse condition. SAARC J. Agric., 15(1): 149-160.

Binnoubah A. H. A.; Z. H. A. Saed and A. A. A. Hadia (2022). Response of growth and potato tubers yield to potassium fertilization and some bio- extracts. Middle East J. Agric. Res., 11(3): 781-789.

Bishwoyog, B., and K. Swarnima (2016). Effect of potassium on quality and yield of potato tubers— A Review. Int. J. Agric. Environ. Sci., 3(6): 7–12.

Cohort Software; Version 6.4; CoStat: Monterey, CA, USA, 2005.

Devaux, A.; J.P. Goffart; A. Petsakos; P. Kromann; M. Gatto; J. Okello and G. Hareau (2020). Global food security, contributions from sustainable potato agri-food systems. In The potato crop (pp. 3-35).

Dinesh, K., R. Ezekiel, B. Singh and I. Ahmed (2005). Conversion table for specific gravity, dry matter, and starch content from under water weight of potatoes grown in North India plains. Potato J., 32 (1-2):79-84.

El-Anany, A. M. A.; Y. M. M. Osman and M. M. Abd El-Aal (2020). Studies on improving potato growth, yield and quality. Ann. Agric. Sci., Moshtohor, 58(4): 963 – 976.

El-Areiny, A. A. R.; A. E Alkharpotly; A. A. A. Gabal and M. A. Aly, (2022). Potato tuber eye explant growth performance as affected by some growth regulators. J. of Plant Production, 13(9): 641-648.

El-Sayed, H. A.; S. M. Farid and R. E. El-Zehery, (2015). The effect of some soil treatment and foliar applications on the productivity and quality of pepper crop 1-vegetative growth, yield and chemical. J. Plant Prod., 6(4): 623-643.

Gerendas, J.; F. Heuser and B. Sattlemacher (2007). Influence of nitrogen and potassium supply on contents of acrylamide precusors in potato tubers and on acrylamide accumulation in fries. J. Plant Nutr., 30 (7):1499-1516.

Ghosh, T.; A. M. Sonkamble; S. R. Patil, and A. W. D. Kankal (2022). Effect of chemicals and plant growth regulator on yield and economics of capsicum under shade net conditions. Pharma Innov. J., 11(4): 1659-1660.

Habtam S.; N. Dechassa and Y. Alemayehu, (2018). Influence of phosphorus and potassium fertilizers on growth and yield of potato (*Solanum tuberosum* L.) at Assosa, Benishangul Gumuz Regional State, Western Ethiopia. J. Soil Sci. & Environ. Manag., 9 (6): 81-90.

Hasanuzzaman M.; M.H.M. Borhannuddin Bhuyan; K. Nahar; S. Hossain; J. Al Mahmud, S.H. Md; A.A. Chowdhury Masud; Moumita, and M. Fujita (2018).

Potassium: a vital regulator of plant responses and tolerance to abiotic stresses. Agronomy 8:31.

Huang, Y.; X. Zeng and H. Cao, (2018). Hormonal regulation of floret closure of rice (*Oryza sativa*). PLoS One, 13: e0198828.

Hussain, W. and L. Khalaf, (2007). Effect of foliar spraying with yeast solution on growth and yield of potato plant cv. desiree.

Khajehzadeh, S.; N. Moallemi, and M. H. Mortazavi, (2018). Effect of foliar application of puttassium sulphate and naphtalin acitic acid on yield and quality of 'Pearl Tangelo'mandarin. Res. Pomol., 3(2): 16-26.

Kieber J. J., and G.E. Schaller (2014). Cytokinins. Arabidopsis Book. 12, e0168.

Kumar, A.; B.P. Singh and H. Katiyar (2012). Effect of foliar application of plant growth regulators on potato tubers quality. Progress. Hort., 44(2): 299-303.

Kumari, S.; M. L. Meena; A. Saini, and S. Kumar, (2022). Effect of foliar application of plant growth regulators on yield and yield attributes of okra in western arid region of Rajasthan. Pharma Innov. J., 11(2): 1544-1546.

Lahijani, M. J. A.; M. Kafi; A. Nezami; J. Nabati and J. E. Erwin (2021). ABA and BAP improve the accumulation of carbohydrates and alter carbon allocation in potato plants at elevated CO_2. Physiol. Mol. Biol. Plants, 27(2):313-325.

Ma, T-L.; W-H. Wu, and Y. Wang (2012). Transcriptome analysis of rice root responses to potassium deficiency. BMC Plant Biol., 12:161.

Mahajan, S.; D.K. Rana, Hema and L. Raj, (2022). Effect of different concentration of nutrient and PGRs on physico-chemical quality and yield of mango (*Mangifera indica* L.) cv. Amrapalli under valley conditions of Garhwal hill. Pharma Innov. J., 11(5): 2194-2197.

Malek, S.; A. I. A. Ebido; G. Abdel-Nasser; M. M. Ziton and A. A. A. Gabel (2021).Yield and quality of potato as affected by foliar spraying of boron and cytokinin. J. Adv. Agric. Res. (JAAR) 26 (2):86-99.

Malik, C. P. and M. B. Singh (1980). Plant Enzymology and Histo-Enzymology-A text Manual, PP. 276- 277, Kalyani Publishers, New Delhi, India.

Mehdi, S. M.; M. Sarfraz, and M. Hafeez (2007). Response of rice advance line PB-95 to potassium application in saline sodic soil. Pak. J. Biol. Sci., 10: 2935-2939.

Mengel, K., and E. A. Kirkby (2012). Principles of plant nutrition. Springer Science and Business Media.

Mijwel A. K. and R. A. Ridha (2021). Effect of thidiazuron on growth and yield parameters of cauliflower *Brassica oleracea* var *botrytis* hybrids. Plant Cell Biotechnol. Mol. Biol., 22(5&6):8-14.

Naciri R.; M. Lahrir; C. Benadis et al (2021). Interactive effect of potassium and cadmium on growth, root morphology and chlorophyll a fluorescence in tomato plant. Sci. Rep., 11:5384.

Naumann, M.; M. Koch; H. Thiel; A. Gransee, and E. Pawelzik (2020). The importance of nutrient management for potato production part II: Plant Nutrition and Tuber Quality. Potato Res., 63: 121–137.

Naz, S.; S. A. H. Naqvi; B. Siddique; M. A. Zulfiqar and A. Rehman, (2020). Exogenous application of selected antioxidants and phyto development directors influenced the development, output and biochemical attributes of tomato (*Lycopersicum esculentum* Mill.). Pakistan J. Agric. Res., 33(4): 789-797.

Njogu, M. K.; G. K. Gathungu and P. M. Daniel (2015). Comparative effects of foliar application of gibberellic acid and benzylaminopurine on seed potato tuber sprouting and yield of resultant plants. American J. Agric. For., 3(5):192-201.

Nuraini, A.; P. S. Nugroho; W. Sutari; S. Mubarok, and J. S. Hamdani, (2021). Effects of cytokinin and paclobutrazol application time on growth and yield of G2 potato (*Solanum tuberosum* L.) Medians cultivar at medium altitude in Indonesia. Agric. Nat. Resour., 55(2), 171-176.

Oosterhuis, D.M.; D.A. Loka; E.M. Kawakami and W.T. Pettigrew (2014). The physiology of potassium in crop production. In Advances in Agronomy; Elsevier: Amsterdam, The Netherlands, 126: 203–233.

Pavlista, A. D. (2011). Growth regulators increased yield of Atlantic. Potato Am. J. Potato Res., 88(6): 479-484.

Pervez, M.A.; M.A. Choudhary; M.R. Shaheen and M.A. Noor, (2013). Determination of physio morphological characteristics of potato crop regulated by potassium management. Pak J. Agric. Sci., 50(4): 611- 615.

Ranganna, S. (1986). Handbook of Analysis and Quality Control for Fruit and Vegetable Products. Tata McGraw-Hill Publishing Company Ltd., New Delhi, India.1112 Pp.

Rather, M. A.; M. A. Chattoo; T. A. Bhat; F. Mushtaq; M. Rashid; M. Shah and A. Sultan (2021). Influence of different levels of sulphur and potassium and their interactions on different quality and storage parameters of potato. Int. J. Plant & Soil Sci., 33(3): 38-46.

Reddy, P. J.; K. L. N. Rao; C. N. Rao, and B. K. Mahalakshmi (2003). Effect of different chemicals on growth, yield and yield attributes of pigeonpea in vertisols. Ann. plant physiol., 17(2): 120-124.

Roumeliotis E.; B. Kloosterman; M. Oortwijn; W. Kohlen; H. J. Bouwmeester; R.G.F. Visser, and C.W.B. Bachem (2012). The effects of auxin and strigolactones on tuber initiation and stolon architecture in potato. J. Exp. Bot., 63(12): 4539-4548.

Samy, M., and M. S. El-Zohiri, (2021). Improving seed productivity of garlic by using nitrogen, potassium fertilization and some growth regulators. J. Plant Prod., 12(7): 805-812.

Smith, O. (1977). Potatoes: production, storing and processing. The AVI Publishing Company, Westport, Connecticut, USA. Second edition. pp. 222-302.

Sun, Y.L., and S.K. Hong (2010). Effects of plant growth regulators and L-glutamic acid on shoot organogenesis in the halophyte *Leymus chinensis* (Trin.). Plant Cell Tiss. Organ Cult., 100: 317-328.

Trehan, S. P.; S. K. Pandev, and S. K. Bansal (2009). Potassium nutrition of potato Crop –Indian Scenario.

Vafaee M.; A. Golchin; F. Moradi and A. Shariatzade (2020). The effect of growth hormones and mycorrhizal fungi on the yield of potato plant (Agria Cultivar). Iranian J. Soil & Water Res., 51(7): 1623-1635.

Wassie, H. (2009). On farm verification of potassium fertilize effect on the yield of Irish potato grown on acidic soils of Hagere-Selam, Southern Ethiopia. Ethiopian J. Nat. Resour., 11(2): 207-221.

Yakimenko, V. N., and N. B. Naumova (2018). Potato tuber yield and quality under different potassium application rates and forms in West Siberia. Agriculture (Pol'nohospodárstvo), 64: 128–136.

Youssef, Y. A. A.; M. Y. El-Maziny; S. A. Abdalla; M. E. Meleha, and A. A. Hassan (2007). Effect of water stress and potassium fertilization on yield quantity and quality of potato. Afri. Crop Sci. Conf. Proc., (8): 445- 455.

Zekri, M., and T. A. Obreza (2009). Plant nutrients for citrus trees. SL 200, UF/IFAS Extension Service, Inst. Food. Agric. Sci. Univ. Florida.

J. Agric. & Env. Sci. (Damanhour University) **2022, 21 (3): 101-126**
Print: ISSN 1687-1464 **Online: 2735-5098**

الملخص العربي

تأثير البوتاسيوم والأوكسين والسيتوكينينات على محصول و جودة درنات البطاطس صنف هيرميس

سعيد محمد جبر، علاء الدين حسين رشدي، ساري حسن برنجي، ابراهيم على ابوالسعد و مصطفى محمود عبدالحليم

قسم البساتين- كلية الزراعة- جامعة دمنهور

تم إجراء تجربتين حقليتين خلال موسمي الصيف 2020 و 2021 لدراسة تأثير التسميد بالبوتاسيوم (0 ، 40 ، 80 كجم للفدان K_2O) ، وتطبيق الرش الورقي بحمض النفثالين أستيك أسيد (0، 5، 10 جزء في المليون NAA) ، و نوعين من السيتوكينينات (BAP و TDZ عند 0 و 10 و 20 جزء في المليون) على المحصول ومكوناته وجودة درنات البطاطس صنف هيرميس. بشكل عام فإن المستويات التي تم فحصها لكل عامل تم إختياره قد أثرت معنوياً على كل صفات المحصول وجودة الدرنات في كلا الموسمين. أيضًا ، كان أفضل مستوى لكل عامل هو 80 كجم K_2O للفدان و 5 جزء في المليون لـ NAA و 10 جزء في المليون من TDZ لـ CKs. وفقًا للتداخل الأول بين أزواج ثلاثة عوامل رئيسية ، كانت أفضل التداخلات 80 كجم K_2O + 5جزء في المليون NAA ، و 80 كجم K_2O + 10 جزء في المليون TDZ ، و 5 جزء في المليون NAA + 10جزء في المليون TDZ ، في كلا الموسمين. علاوة على ذلك ، وجد أن التداخل من الدرجة الثانية بين العوامل الثلاثة المدروسة أثر معنويا على جميع الصفات المدروسة مع تفوق المعاملة 80 كجم K2O + 5 جزء في المليون NAA + 10 جزء في المليون من TDZ ، في كلا موسمي الدراسة. يمكن أن يوصى بهذا العلاج الثلاثي لزيادة محصول البطاطس مع الحفاظ على جودة عالية من درنات البطاطس.