Potato Yield and Quality as Affected by Foliar Application with Cytokinin and Salicylic Acid

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ABSTRACT: Potato (*Solanum tuberosum* L.) ranks fourth on the list of the most important food stable worldwide. It cultivates in Egypt in three cycles, of which is the summer cycle where the predominant high temperature stress which exert an adverse effect on the growth of the whole plant. Therefore, this study hypothesized that foliar application of cytokinin-phenylurea-derivative as (CPPU) and salicylic acid (SA) could be a crucial role in this context. Thus, two open field experiments were conducted during summer seasons of 2016 and 2017, in a private farm of sandy loam soil, at Abou Elmatamer city, Behiera Governorate, Egypt. Certified imported potato seeds of 'Cara' cv. were used after splitting-up. Cut seedy explants (*ca*. 40 g) contain one eye each were planted at 0.80 m wide and 0.17 m apart between hills, using four concentrations of the synthetic cytokinin CPPU (0.00, 0.04, 0.08, and 0.12 mM) and five concentrations of SA (0.00, 1.00, 2.00, 3.00, and 4.00 mM) were foliar applied separately and in combinations. Control plants were sprayed with distilled water. The effects of both variables and their combinations were investigated on the vegetative growth-related characters, yield and its components, tuber quality, leaves and tubers chemical composition. The obtained results declare, in general, that foliar application treatments of cytokinin as CPPU and salicylic acid (SA) alone or in combination to potato plants gave, significantly, the highest average values of both yield and quality compare to untreated plants. The combination between 0.12 mM CPPU plus 4.00 mM SA might be considered as an optimal treatment for the production of high yield and good quality of potato plants under the environmental conditions of Behiera Governorate and other similar regions.

Keywords: CPPU [N-(2-chloro-4-pyridyl) -N'- phenylurea], Salicylic acid (SA), Potato growth attributes, Potato chemical attributes, Cara cv.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is a herbaceous annual plant that grows up to 100 cm tall and produces tubers and belongs to the Solanaceae 'Nightshade' family of flowering plants. Also, it ranks as the world's fourth most important food crop, after maize, wheat, and rice (Spooner and Bamberg, 1994). In Egypt, the total cultivated area of potatoes reached 439,504 feddans which produced 5,029,022 tons (FAO, 2016). Potato has an important economic role in the Egyptian economy. Increasing the potato yield and quality are crucial factors for this important crop, especially during summer seasons, where the predominant high temperature stress which exert an adverse effect on the growth of the whole plant (Boyer, 1982). Therefore, this study hypothesized that foliar application of cytokinin phenylurea derivative as CPPU and salicylic acid (SA) could play a vital role in this context. Cytokinins are plant hormones (upon biosynthesized endogenously), and plant growth regulators (upon biosynthesized exogenously), briefly, promote cell division and differentiation. The number of chemicals compatible with the definition of cytokinins has grown to include a large array of natural and synthetic compounds, adenine and

phenylurea derivatives. The phenylureas constitute a group of synthetic cytokinins, some of which are highly active, e.g. CPPU [N-(2-chloro-4-pyridyl) - N'- phenylurea] (Takahashi *et al.,* 1978) and thidiazuron (Mok *et al*., 1982a), with cytokinin activity exceeding that of zeatin (Mok *et al*., 1982b; Mok *et al*., 1987; Shudo, 1994). Cytokinins (CKs) have long been suggested to play a prominent role in tuberization. They are predominantly used for microtuber induction *in vitro* (Hussey and Stacey, 1984; Ebida and El-Gamal, 1992; Ebida and Hu, 1993; Donnelly *et al.,* 2003) and promote tuberization when directly applied to isolated stolons cultured *in vitro* (Estrada *et al.,* 1986; Palmer and Smith, 1970). Attempts to induce tuber formation by applying CKs to the leaves, however, have produced ambiguous results as these treatments were unable to induce tuberization in andigena plants grown under non-inducing conditions. Rodrýguez-Falcon *et al*. (2006) suggest that CK may function to control tuber enlargement and growth. Increased cytokinin levels due to antisense suppression of the potato box gene, also result in increased starch accumulation and active cell division in specific regions of the meristem and the leaves (Rosin *et al.,* 2003). In case of *in situ* situation, foliar application of cytokinin brought about regulation a variety of plant functions as proliferation of vegetative (foliage) growth, re-juvenility of senescence leaves, breaking apical dominance (even true). Likewise, affect tuber initiation, and tuber yield (Palmer and Smith, 1969; Langille and Forsline, 1974; Staden and Dimalla, 1976).

Likewise, salicylic acid (SA) acts as an endogenous hormone-like plant growth regulator, which has abroad, but also had different roles on stress adjustment and appears to be an effective agent for the plant to overcome different stresses (Canakci and Munzuroglu, 2007; Amanullah *et al*., 2010; Vicente and Plasencia, 2011). Due to the limiting knowledge regarding manipulating the heat stress practiced on potato growth performance and its attributes during summer season plantation, the main objective behind this paper was to investigate the effectiveness of foliar application of both cytokinin as CPPU and salicylic acid (SA) on Potato (*Solanum tuberosum* L. Cara cv.) as foliar application and to overcome or alleviate the heat stress or over heat of summer temperature especially (from April to June) during potato plantation (vegetative growth, yield and quality of the produced tubers).

MATERIALS AND METHODS

Two field experiments were carried out during the summer seasons of 2016 and 2017, in a private farm, at Abou Elmatamer city, Behiera Governorate, Egypt, under open field conditions in sandy loam soil. Before planting, random soil samples of 0-30 cm depth from different places of the planting field were collected and analyzed for some important chemical and physical properties as given in Table (1). The experimental field was polughed and pulverized. Certified imported potato seeds of 'Cara' cultivar was used after splitting. Cut seedy explants were, approxemately, 40 g in weight and each seedy explant contained 1 eye planted on the 20th February during both seasons in dry soil then irrigated. Cutting seeds were planted at 0.80 m wide and 0.17 m apart between hills on one side of the ridge (30882 plant/fed.). The experimental plot consisted of two ridges with 8.00 m long and 0.80 m width; making an area of

12.80 m^2. Treatments were consisted of two independent variables as a foliar applicants, i.e.; four concentrations of the synthetic cytokinin CPPU { N-(2-chloro-4-pyridyl)-N'-phenyl urea} as control, 0.04, 0.08, 0.12 mM [MW= 247.68] and five concentrations of salicylic acid as control, 1.00, 2.00, 3.00, 4.00 mM [MW= 138.12] separately and in combinations. Control plants were sprayed with distilled water. Both conducted experiments were factorial experiments layout in a randomized complete block design (RCBD), with three replicates. Each replicate included 20 treatments which distributed randomly within each block. Potato plants were sprayed with the allocated or assigned treatments twice during the growing seasons, the first one at 55 days (*ca*. 12-15 leaves) after planting, then 15 days after the first one (*ca.* 25-30 leaves).

Table (1). Some physical and chemical properties of the experimental site during both seasons of the experimentation (2016 and 2017)

Soil properties	Season	
	2016	2017
Mechanical Analysis:		
Clay (%)	11.28	11.30
Silt (%)	18.00	17.70
Sand (%)	70.72	71.00
Textural class	Sandy loam	Sandy loam
Chemical Analysis:		
pH (1:2 water suspension)	7.60	7.70
EC at 25° C (dS/m)	3.70	3.60
Soluble cations in (1:5) soil: water extract (meq/l)		
Ca^{++}	3.40	3.50
Mg^{++}	7.82	7.75
K^{+}	0.96	0.95
Na^{+}	22.47	20.80
Soluble anions in (1:5) soil: water extract (meq/l)		
HCO_3^{-}	14.00	14.10
Cl^{-}	19.70	18.10
SO_4^{--}	0.68	0.80
$CaCO_3$ (%)	9.40	9.30
Available N (mg/kg soil)	82.66	85.50
Available P (mg/kg soil)	7.00	8.25
Available K (mg/kg soil)	357	360

-The physical and chemical analyses were carried out at Soil and Agricultural Chemistry Departement, The Faculty of Agricultur (Saba Basha), Alexanderia University, Egypt.

The recommended agricultural practices for commercial potato production were followed. 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 85 days from planting, number of main stems per plant, number of leaves per plant, plant height (cm) and plant fresh weight (g) characters were determined. Plant dry weight (g) was conducted in an electrical oven at 70˚ C till obtaining a constant weight, then determined (in gram).

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 (g), tubers dry weight (%), average of tuber yield per plant (g), total tubers yield per feddan (ton).

Tubers quality physical characters were determined through ten tubers which were, randomly, taken from each plot at harvesting (i.e. tuber length (cm), diameter (cm) and shape index) during both seasons of the study using a micrometer (caliper), when it laid down on a flat surface.

Quality chemical characters

Total soluble solids content (TSS %), it was estimated according to A.O.A.C. (1992). Total phenols (mg/g d.w.) were determined using the method described by Snell and Snell (1953) with Folin reagent. Starch, reducing, non-reducing and total sugars (% d.w.) were determined for each tubers' sample according to the method described by Malik and Singh (1980).

Leaves chemical composition where leaves chlorophyll content (a , b and total chlorophyll) was expressed as (mg/g f.w.) and N, P and K contents were determined. - 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 85 days from planting in both seasons. Then they were calculated using the formula of Arnon (1956). - N, P and K contents of leaves were determined at 85 days after planting 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). Tubers chemical composition, tuber nitrogen content (%) was determined colorimetrically by Nessler's method (Chapman and Pratt, 1978). Tuber phosphorus content (%) was determined calorimetrically as described by Singh *et al*. (2005). Tuber potassium content (%) was measured using flame photometer as described by Singh *et al*. (2005).

Statistical Analysis:

All obtained data of the present study were, statistically, analyzed according to the design used by the MSTAT-C computer software program (Bricker, 1991) and were tested by analysis of variance. The revised least significant difference test at 0.05 level of probability was used to compare the differences among the means of the various treatment combinations as illustrated by Duncan (1965) and Gomez and Gomez (1984).

RESULTS AND DISCUSSION

The results, generally, revealed that cytokinin phenylurea derivative (CPPU), salicylic acid (SA) and their combinations affected, more or less, significantly ($p \leq 0.05$), the traits of the study as on overall during both seasons of the study.

1. Vegetative growth characters

The results illustrating the effects of cytokinin (CPPU), salicylic acid (SA) and their combinations on vegetative growth characters of potato plants (number of stems/plant, number of leaves/plant, plant height, plant fresh and dry weights) during both seasons of the study, i. e., 2016 and 2017, are presented in Table (2). Concerning the main effect of CPPU, the gained results reflect, generally more or less, that there is a direct proportionate relationship between the tested concentrations of this cytokinin and the traits under the study during both seasons of the study as compared to the control plants. For instance, foliar application of CPPU at the highest level (i.e. 0.12 mM) recorded the highest average values of the tested traits (despite insignificance effect ($p > 0.05$) among treating concentrations compare to control plants) for number of stems/plant. However, the intermediate tested levels of CPPU declared, also, such significant differences either among them, more or less, as compared to the control treatment. Moreover, the increment percentages (as averages of both seasons) of the above-mentioned traits were about 33.83% for number of stems/plant, 33.86% for number of leaves/plant, 13.19% for plant height, 30.52% for plant fresh weight, and 27.24% for plant dry weight compare to the control plants during both seasons. The present results are in agreement with those obtained by El-Shraiy and Hegazi (2010). These results could be attributed to the multiple functions of cytokinins and their derivates as CPPU. Whereas, cytokinins enhance cell division and enlargement (Te-Chato and Lim, 2000). Also, Zhang and Chang (2010) reported that CPPU has the functions to promote cell division, cell enlargement and delay senescence. Increasing plant fresh and dry weights could be given rise due to increasing number of stems, number of leaves and plant height due to using CPPU treatments.

Table (2). Average values of some vegetative growth-related characters of potato plants cv. 'Cara' as affected by foliar application with cytokinin (CPPU), salicylic acid (SA) and their combinations during the summer seasons of 2016 and 2017

Treatments		No. of stems/plant		No. of leaves/plant		Plant height (cm)		Plant fresh weight (g)		Plant dry weight (g)	
		2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
CPPU (main effect)											
Control		2.89 d	3.17 b	74.33 d	77.67 d	54.43 c	59.69 c	196.11 d	198.61 c	34.79 d	36.47 d
0.04 mM (CPPU)		3.56 c	3.93 a	89.07 c	96.27 c	58.88 b	63.77 b	237.62 c	226.81 b	40.52 c	43.06 c
0.08 mM (CPPU)		3.69 b	4.16 a	95.20 b	101.13 b	60.97 ab	65.27 ab	247.76 b	250.52 a	42.92 b	44.60 b
0.12 mM (CPPU)		3.82 a	4.29 a	99.60 a	103.87 a	62.09 a	67.08 a	256.01 a	259.16 a	44.46 a	46.21 a
SA (main effect)											
Control		3.08 e	3.42 b	78.92 e	82.25 d	47.60 c	60.17 c	209.21 e	211.77 cd	36.87 d	38.57 e
1 mM (SA)		3.34 d	3.71 b	85.33 d	92.25 c	51.40 b	62.96 b	224.33 d	210.73 d	39.50 c	41.35 d
2 mM (SA)		3.43 c	3.86 ab	89.33 c	93.83 c	53.50 b	63.64 b	231.06 c	233.50 bc	40.36 b	42.20 c
3 mM (SA)		3.76 b	4.18 a	95.17 b	101.58 b	57.60 a	66.00 a	250.76 b	253.49 ab	43.12 a	44.95 b
4 mM (SA)		3.83 a	4.28 a	99.00 a	103.75 a	59.10 a	66.99 a	256.52 a	259.40 a	43.52 a	45.86 a
Combinations effects											
CPPU (mM)	SA (mM)										
Control	Control	2.73 m	2.83 h	74.00 hi	73.00 j	52.39 f	57.67 h	186.29 s	188.40 kl	33.36 m	34.74 s
	1	2.83 l	2.93 h	70.33 i	76.00 ij	54.72 ef	59.83 gh	189.72 r	194.27 j-l	34.14 lm	35.61 r
	2	2.87 l	3.30 gh	78.00 f-h	78.00 hi	54.82 ef	60.17 gh	196.37 q	197.77 i-l	34.66 kl	36.45 q
	3	2.98 k	3.37 f-h	73.00 hi	80.33 h	54.72 ef	60.33 gh	200.86 p	203.47 h-l	35.49 jk	37.33 p
	4	3.03 k	3.43 e-h	76.33 gh	81.00 h	55.52 ef	60.47 gh	207.28 o	209.17 g-k	36.29 ij	38.20 o
0.04	Control	3.15 j	3.57 d-h	76.67 gh	81.33 h	55.03 ef	60.67 gh	211.33 n	214.23 f-k	37.09 i	39.05 n
	1	3.39 h	3.67 f-h	78.67 f-h	93.33 f	56.85 e	62.00 fg	226.11 k	161.20 l	39.46 fg	41.56 k
	2	3.44 h	3.83 b-g	90.33 e	96.00 ef	57.74 de	62.33 e-g	232.52 j	235.30 c-j	40.17 f	42.37 j
	3	3.91 d	4.27 a-e	97.33 cd	104.00 bc	62.65 bc	66.83 b-d	255.73 f	258.50 a-e	43.32 d	45.71 g
	4	3.91 d	4.33 a-d	102.33 bc	106.67 b	62.12 bc	67.00 b-d	262.43 e	264.83 a-d	42.58 d	46.60 e
0.08	Control	3.16 j	3.63 c-h	81.33 fg	87.00 g	56.59 e	60.83 f-h	216.08 m	218.93 e-k	38.14 h	39.79 n
	1	3.51 g	4.03 a-g	98.00 cd	99.33 de	60.59 cd	64.00 d-f	236.08 i	238.50 b-i	41.30 e	43.22 i
	2	3.64 f	4.07 a-g	93.33 de	99.67 de	60.60 cd	65.50 c-e	244.10 h	246.40 a-h	42.52 d	44.12 h
	3	3.99 c	4.50 a-c	99.00 b-d	107.67 b	63.07 a-c	67.83 bc	268.46 d	271.50 a-c	45.93 b	47.54 d
	4	4.12 b	4.57 ab	104.33 b	112.00 a	64.01 ab	68.17 bc	274.09 c	277.27 a-c	46.70 b	48.35 c
0.12	Control	3.28 i	3.63 c-h	83.67 f	87.67 g	56.75 e	61.50 fg	223.15 l	225.50 d-k	38.88 h	40.69 l
	1	3.65 f	4.20 a-f	94.33 de	100.33 cd	62.24 bc	66.00 b-d	245.41 h	248.93 a-g	43.09 d	45.00 g
	2	3.75 e	4.23 a-f	95.67 de	101.67 cd	62.25 bc	66.57 b-d	251.23 g	254.53 a-f	44.08 c	45.85 f
	3	4.15 b	4.60 ab	111.33 a	114.33 a	63.11 a-c	69.00 b	278.00 b	280.50 ab	47.75 a	49.22 b
	4	4.24 a	4.80 a	113.00 a	115.33 a	66.11 a	72.33 a	282.26 a	286.33 a	48.53 a	50.29 a

- Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using the revised L.S.D. test at 0.05 level of probability.

In terms of the main effect of foliar application with salicylic acid on the given characteristics, results presented in Table (2) reflect similar performance as CPPU, where there is a direct proportionate relationship was obvious between both independent and dependent variables, and the obtained calculated averages were affected significantly ($p \leq 0.05$) by applied levels of salicylic acid, during both seasons of the study. For example, spraying SA at 4 mM; brought about the highest average values of the studied traits, compare to average values of control plant measurements. However, the other intermediate examined concentration of SA, showed also such significant differences either among themselves, more or less, and compare to the control treatments. However, the increment percentages of the above stated characteristics were *ca*. 24.77% for number of stems/hill, 25.80 % for no. of leaves/plant, 17.00 % for plant height, 22.55% for plant fresh weight, and 18.48% for plant dry weight compare to the control plants during both seasons.

The present results are in agreement with those obtained by Awad and Mansour (2007) who indicated that foliar spray of potato plants with salicylic acid at 100 ppm caused a significant increase in foliage fresh and dry weights plant^{-1}, as well as, number of main stems plant^{-1}. Also, Daneshmand *et al*. (2009) indicated that using 1 µM acetylsalicylic acid (ASA) increased potato shoot length and shoot dry weight under salt and drought stresses. Similarly, Sánchez-Rojo *et al*. (2011) reported that exogenous application of potato plants with salicylic acid at 0.001 mM concentration; resulted in significant increases in leaf area index and crop relative growth rate. Also, Flores-Lopez *et al*. (2016) reported that potato foliar application with SA at 10^{-8} and 10^{-10} M; led to significant increases in plant height and plant fresh weight. In the same context, AL-Jeboori *et al*. (2017) ascertained the previous results, where spraying potato plants with salicylic acid at 100 mg/l; resulted in highest significant values of plant height, number of leaves per plant, foliage dry weight and leaf area. The positive effects of SA on vegetative growth-related characters in the present study could be attributed to SA mode of action in regulating and modulating the physiological processes on growth and development of potato plants under the study *via* ion uptake and transport, photosynthetic rate, membrane permeability and transpiration (Bhupinder and Usha, 2003; Wang *et al*., 2006). Increasing plant fresh and dry weights could be given rise due to increasing number of stems, number of leaves and plant height owing to SA treatments.

Pertaining the interaction between both independent variable levels, average values in Table (2) disclosed significant differences ($p \leq 0.05$) among the averages of their interactions. In general, combination between CPPU at 0.12 mM and SA at 4 mM achieved, more or less, the highest average values of all the studied characters. However, the increment percentages of the studied items were 62.59% for no. stems/plant, 55.33% for no. of leaves/plant, 25.79% for plant height, 51.75% for plant fresh weight, and 45.11% for plant dry weight (as an average of each item during both seasons, compare to control plants).

2. Yield characters

Results presented in Table (3) expressed that foliar application of potato plant cv. 'Cara' with synthetic cytokinin as CPPU, salicylic acid (SA) and their combinations; affected significantly ($p \leq 0.05$) all tested characteristics of the potato cultivar during both seasons. Concerning the main effect of CPPU, results presented in Table (3) reflected, generally, that there is such a proportionate relationship between the tested concentrations of the cytokinin and the traits of the study during both seasons of the study as compared to the control plants. For instance, foliar application of CPPU at the highest level (i.e. 0.12 mM) recorded the highest average values of the all examined items except tuber fresh weight in the first season. compared to control plant measurements. However, the intermediate tested levels of CPPU**;** declared also such significant differences either among them, more or less, and clear significant differences compare to the control treatment. In terms of average values of tuber fresh weight character,

Table (3). Average values of some yield characters of potato plants cv. 'Cara' as affected by foliar application with cytokinin (CPPU), salicylic acid (SA) and their combinations during the summer seasons of 2016 and 2017

Treatments		No. of tubers/plant		Tuber fresh weight (g)		Tuber dry weight (%)		Total yield/plant (g)		Total yield/feddan (ton)	
		2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
CPPU (main effect)											
Control		5.73 c	5.33 c	75.16 c	83.01 b	15.96 d	16.96 d	430.67 d	442.44 d	13.30 d	13.66 d
0.04 mM (CPPU)		5.93 bc	6.13 b	91.33 a	89.48 ab	16.60 c	17.83 c	541.59 c	548.51 c	16.72 c	16.94 c
0.08 mM (CPPU)		6.13 b	6.20 b	91.47 a	92.36 a	16.93 b	18.03 b	560.71 b	572.63 b	17.32 b	17.68 b
0.12 mM (CPPU)		6.87 a	6.80 a	84.22 b	86.89 ab	17.07 a	18.20 a	578.59 a	590.85 a	17.87 a	18.25 a
SA (main effect)											
Control		4.75 e	5.17 e	82.99 a	78.02 c	16.25 e	17.25 e	394.20 e	403.36 e	12.17 e	12.46 e
1 mM (SA)		5.58 d	5.58 d	83.00 a	84.40 bc	16.49 d	17.58 d	463.14 d	470.95 d	14.30 d	14.54 d
2 mM (SA)		6.08 c	6.17 c	88.53 a	89.01 ab	16.62 c	17.68 c	538.26 c	549.19 c	16.62 c	16.96 c
3 mM (SA)		6.92 b	6.58 b	87.38 a	93.97 a	16.98 b	18.09 b	604.67 b	618.32 b	18.67 b	19.10 b
4 mM (SA)		7.50 a	7.08 a	85.06 a	91.97 a	16.86 a	18.19 a	637.95 a	651.14 a	19.70 a	20.10 a
Combinations effects											
CPPU (mM)	SA (mM)										
Control	Control	4.33 j	4.67 h	79.22 b-d	75.59 f	15.78 n	16.74 p	343.02 p	353.00 r	10.59 p	10.90 r
	1	5.00 h-j	5.00 gh	76.88 cd	79.09 d-f	15.83 mn	16.86 op	384.40 o	395.45 q	11.87 o	12.21 q
	2	5.67 f-h	5.33 f-h	78.83 b-d	86.29 b-f	15.97 lm	16.95 no	446.01 l	459.92 m	13.80 l	14.20 m
	3	6.67 c-e	5.67 e-g	71.15 d	86.23 b-f	16.04 kl	17.07 mn	474.57 k	488.92 k	14.65 k	15.10 k
	4	7.00 b-d	6.00 d-f	72.07 d	85.83 b-f	16.15 jk	17.17 lm	504.49 i	514.98 i	15.58 i	15.90 i
0.04	Control	4.33 j	5.00 gh	92.81 a	81.89 c-f	16.26 ij	17.29 l	401.87 n	409.45 p	12.41 n	12.64 p
	1	5.33 g-l	5.67 e-g	87.81 a-c	84.02 b-f	16.53 gh	17.59 jk	468.05 k	476.40 l	14.45 k	14.71 l
	2	6.00 e-g	6.33 c-e	90.48 ab	87.29 b-f	16.58 gh	17.69 j	542.88 h	552.54 h	16.76 h	17.06 h
	3	6.67 c-e	6.67 b-d	93.93 a	95.25 ab	17.07 cd	18.25 ef	626.51 e	635.31 e	19.35 e	19.62 e
	4	7.33 a-c	7.00 bc	89.35 ab	95.28 ab	16.55 gh	18.35 de	654.93 c	666.96 d	20.23 c	20.60 d
0.08	Control	4.67 ij	5.33 f-h	88.59 ab	78.94 d-f	16.54 gh	17.47 k	413.70 m	420.75 n	12.78 m	13.00 n
	1	5.67 f-h	5.67 e-g	86.75 a-c	87.67 a-e	16.68 fg	17.83 i	491.87 j	497.09 j	15.19 j	15.35 j
	2	6.00 e-g	6.33 c-e	96.14 a	92.94 a-c	16.78 ef	17.92 hi	576.84 g	588.31 g	17.81 g	18.10 g
	3	6.67 c-e	6.67 b-d	96.33 a	99.14 a	17.25 bc	18.40 cd	642.54 d	661.26 d	19.84 d	20.42 d
	4	7.67 ab	7.00 bc	88.47 a-c	99.73 a	17.41 ab	18.53 bc	678.56 b	698.11 b	20.95 b	21.56 b
0.12	Control	5.67 f-h	5.67 e-g	73.75 d	75.88 ef	16.44 hi	17.48 k	418.16 m	430.23 n	12.91 m	13.29 n
	1	6.33 d-f	6.00 d-f	78.91 b-d	85.78 b-f	16.91 de	18.03 gh	499.50 ij	514.68 i	15.43 ij	15.89 i
	2	6.67 c-e	6.67 b-d	87.89 a-c	89.72 a-d	17.15 c	18.14 fg	586.22 f	598.43 f	18.10 f	18.48 f
	3	7.67 ab	7.33 b	88.01 a-c	93.83 ab	17.35 ab	18.65 ab	675.04 b	687.77 c	20.85 b	21.24 c
	4	8.00 a	8.33 a	89.24 ab	86.82 b-f	17.53 a	18.72 a	713.92 a	723.21 a	22.05 a	22.33 a

Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using the revised L.S.D. test at 0.05 level of probability.

plants sprayed with CPPU at 0.04 or 0.08 mM during the first season and at 0.04 or 0.08 or 0.12 mM during the second one gave rise to the highest significant average values compared to control plants, but with insignificant differences between the above-mentioned levels. However, the intermediate tested levels of CPPU declared also such significant differences either among them, more or less, and compare to the control treatment. However, the increment percentages of the above-mentioned traits were about 23.80% for number of tubers/plant, 7.20% for tuber dry weight, 33.94% for total yield/plant, and 33.98% for total yield/feddan compare to their control plants during both seasons.

The present results are in agreement with those obtained by several authors (Romanov *et al*., 2000; Roumeliotis *et al*., 2012; Kolachevskaya *et al.,* 2015, 2017) who declare that cytokinins can hasten and improve potato tuberization. Also, Roosta *et al.* (2015) reported that plant dry weight and tuber yield of potato plants were increased due to fortifying of BAP into *in vitro* cultures.

The recorded results, also, in agreement with those of El-Shraiy and Hegazi (2010) who reported that the highest mean values of tubers fresh and dry weights, were obtained by CPPU at 20 ppm treatment, which led to an increase in yield values. In the same arrangement, Njogu *et al*. (2015) reported that increase the level of cytokinin as BA lead to, significant, increased, number of tubers per plant and yield (ton/ha), due to increase number of leaves/plants because of using CPPU concentration at 0.12 mM.

Pertaining of the main effect of foliar application of salicylic acid on the given characteristics, results presented in Table (3) reflected similar performance as CPPU too, during both seasons of the study upon foliar spray SA at 4 mM; gave the highest average values, compare to control plants' measurements.

Concerning the average value of tuber fresh weight character, plants treated with SA at all levels reflected insignificant effects ($p > 0.05$) compare to control plants during first season of the study. While during the second season, plants treated with SA at 2 or 3 or 4 mM; gave the highest significant mean values compare to control plants. However, the other intermediate examined concentrations of SA showed, also, such significant differences either among themselves, more or less, and compare to the control treatments. However, the increment percentages of the above stated characteristics were *ca*. 47.40% for number of tubers/plant, 4.60% for tuber dry weight, 61.59 % for total yield/plant, and 61.60% for total yield/feddan compare to the control plant as an average of both seasons. The present results are in agreement with those obtained by Awad and Mansour (2007) and Sánchez-Rojo *et al*. (2011). Similar findings were recorded by Hadi *et al*. (2014), Flores-Lopez *et al*. (2016) and AL-Jeboori *et al*. (2017). The obtained results could be attributed to the role of salicylic acid (SA) in enhancing the plant defense in potato against phytoplasma attack,

reduces infection symptoms, favors photosynthates translocation and improves the yield and quality of tubers (Lopez-Delgado *et al*., 2018).

Regarding the interaction between both variables of the present study, the results presented in Table (3), in general, illustrated that various tested combinations affected significantly ($p \leq 0.05$) the characters under the investigation, in such way, arranged ascendingly with increasing or raising the tested concentrations of both variables and especially the combination of 0.12 mM CPPU plus 4 mM SA, which, brought about; the highest significant average values of all studied traits during both seasons compare to control plant treatments. The intermediate average values ranged and varied significantly ($p \leq 0.05$) compare to control plants' average values, too. In the present study, increasing of potato tuber yield could be taken place due to foliar application of CPPU, SA, and their combinations might be attributed to the increase of vegetative growth parameters (i.e. no. of stems/plant, no. of leaves/plant, plant height, plant fresh and dry weights). Number of stems/plant is a very significant indicator of tuber number per plant (i.e. tuber yield). It is well-known that as stem number and tuber number/plant increased by approximately tuber 1 for each 1 increase in stem number in typical plants ranging from 2.4 to 5.2 stems/plant could achieve a noticeable increase in tuber yield.

3. Tuber quality characteristics

3.1 Tuber Physical characters

Average values exhibited in Table (4) reveal that potato tuber characteristics *viz*. tuber length, diameter and tuber shape index were affected significantly ($p \leq 0.05$) by the various treatments of CPPU, SA and their combinations during both seasons. Considering the CPPU as a main effect, the obtained results demonstrated that all treated plants showed the highest significant ($p \leq 0.05$) average values of tuber length, diameter and its shape index characters compared to control plants during both seasons, as CPPU concentration increased. Potato plants foliar applicated with the highest level of CPPU (0.12 mM); produced tubers with the highest significant length and diameter, during both seasons compared to control plants. In the case of tuber shape index the giving results reflected, to such extend, insignificant differences ($p > 0.05$) among the plants treated with both 0.08 and 0.12 mM CPPU concentrations and control plants (treated with distilled water). In this context, it is an acceptable finding where Wurr *et al*. (2001) found that at the time of harvesting the seed crop did not affect either the tuber shape nor number of ground stems without interaction with tuber size. Plants treated with 0.04 mM CPPU; achieved the lowest significant tuber shape index traits compare to other treatments during both seasons. The obtained results are in parallel with those reported by Roosta *et al.* (2015) and Liu and Xie (2001).

Table (4). Average values of some physical quality characters of potato tubers cv. 'Cara' as affected by foliar application with cytokinin (CPPU), salicylic acid (SA) and their combinations during the summer seasons of 2016 and 2017

Treatments		Tuber length (cm)		Tuber diameter (cm)		Tuber shape index	
		2016	2017	2016	2017	2016	2017
CPPU (main effect)							
Control		6.46 d	7.03 d	6.10 c	6.00 c	1.059 a	1.172 ab
0.04 mM (CPPU)		7.01 c	7.65 c	6.78 b	6.56 b	1.034 b	1.166 b
0.08 mM (CPPU)		7.33 b	7.96 b	6.86 b	6.66 b	1.069 a	1.195 a
0.12 mM (CPPU)		7.49 a	8.15 a	7.02 a	6.82 a	1.067 a	1.195 a
SA (main effect)							
Control		6.87 c	7.48 c	6.28 e	6.16 e	1.094 a	1.214 a
1 mM (SA)		6.83 c	7.42 c	6.57 d	6.39 d	1.040 b	1.161 c
2 mM (SA)		6.90 c	7.54 c	6.67 c	6.47 c	1.034 b	1.165 c
3 mM (SA)		7.21 b	7.85 b	6.92 b	6.70 b	1.042 b	1.172 c
4 mM (SA)		7.56 a	8.20 a	7.01 a	6.82 a	1.078 a	1.202 b
Combinations effects							
CPPU (mM)	SA (mM)						
Control	Control	6.33 k	6.84 m	5.74 k	6.21 k	1.103 d	1.101 b
	1	6.37 k	6.93 lm	5.96 j	6.49 k	1.069 b-d	1.068 bc
	2	6.39 k	7.01 k-m	6.14 i	6.67 ij	1.041 cd	1.051 c
	3	6.54 jk	7.14 j-l	6.28 hi	6.82 hi	1.041 cd	1.047 c
	4	6.65 ij	7.25 i-k	6.36 gh	6.92 gh	1.046 cd	1.048 c
0.04	Control	6.73 ij	7.34 h-j	6.39 gh	6.94 gh	1.053 cd	1.058 bc
	1	6.86 g-i	7.48 g-i	6.66 f	7.24 ef	1.030 cd	1.033 c
	2	6.95 f-h	7.58 gh	6.77 ef	7.33 e	1.027 cd	1.034 c
	3	7.25 c-e	7.88 d-f	7.00 cd	7.58 cd	1.036 cd	1.040 c
	4	7.29 cd	7.96 c-e	7.08 bc	7.70 bc	1.030 cd	1.034 c
0.08	Control	7.60 b	8.28 b	6.48 g	7.05 fg	1.173 a	1.174 a
	1	6.99 f-h	7.55 gh	6.77 ef	7.31 e	1.033 cd	1.033 c
	2	7.06 e-g	7.68 fg	6.76 ef	7.34 e	1.044 cd	1.046 c
	3	7.45 bc	8.09 b-d	7.17 i	7.77 bc	1.039 cd	1.041 c
	4	7.53 b	8.19 bc	7.10 bc	7.72 bc	1.061 b-d	1.061 bc
0.12	Control	6.80 hi	7.46 g-i	6.48 g	7.04 f-h	1.049 cd	1.060 bc
	1	7.09 d-f	7.69 e-g	6.90 de	7.46 de	1.028 d	1.031 c
	2	7.22 de	7.91 d-f	7.00 cd	7.62 cd	1.031 cd	1.038 c
	3	7.57 b	8.30 b	7.21 b	7.85 b	1.050 cd	1.057 bc
	4	8.77 a	9.40 a	7.49 a	8.17 a	1.171 a	1.151 a

-Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using the revised L.S.D. test at 0.05 level of probability.

Regarding the SA main effect, the tabulated results showed that foliar application of potato plants with SA at 4 mM; produced the highest significant averages values for tuber length, and tuber diameter compare to the other treatments during both seasons of the experimentation. The control plants gave the highest mean values for tuber shape index during both seasons, in addition to 4 mM SA during first season only. The finding ascertains, as reported earlier, the hypothesis of Wurr *et al*. (2001).

As for the interaction between various concentrations of both variables under the study, the results tabulated in Table (4) demonstrated that plants treated with 0.12 mM CPPU combined with 4 mM SA, showed the highest significant mean values for all characters (i.e. tuber length, diameter and shape index) compared to the other treatments during both seasons of the study. The intermediate average values ranged and varied significantly ($p \leq 0.05$) of the other combinations differed significantly ($p \leq 0.05$) from the control plants' average values, as general.

3.2 Tuber chemical characteristics

Results postulated in Table (5) exhibit that the potato tubers chemical quality determinations were affected significantly ($p \leq 0.05$) by the various tested treatments of the investigation. Pertaining CPPU as a main effect, there is a direct proportionate relationship between CPPU concentrations and the given traits and *vice versa*. The obtained results reported that potato plants treated with 0.12 mM as foliar application; gave the highest significant average values for tubers TSS (%), total phenols (mg/g d.w.), starch (% d.w.), reducing sugars (% d.w.), non-reducing sugars, and total sugars (% d.w.) compared to control plants measurements The intermediate tested levels of CPPU declared, also, such significant differences either among them, more or less, and compared to the control treatment.

Table (5). Averages values of some chemical quality determination of potato tubers cv. 'Cara' characteristics as affected by foliar application with cytokinin (CPPU), salicylic acid (SA) and their combinations during the summer seasons of 2016 and 2017

Treatments		TSS % (Brix)		Tubers total phenols (mg/g d.w.)		Starch (%)		Tubers sugars (% d.w)					
								Reducing sugars		Non-reducing sugars		Total sugars	
		2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
CPPU (main effect)													
Control		5.56 d	5.77 d	216.49 d	221.27 d	17.36 d	17.93 d	2.10 d	2.15 d	2.35 c	2.51 d	4.45 d	4.66 d
0.04 mM (CPPU)		6.15 c	6.34 c	246.90 c	254.63 c	18.33 c	19.13 c	2.58 c	2.64 c	2.93 b	3.03 c	5.51 c	5.67 c
0.08 mM (CPPU)		6.29 b	6.47 b	256.04 b	262.05 b	18.77 b	19.42 b	2.66 b	2.75 b	2.99 b	3.14 b	5.64 b	5.89 b
0.12 mM (CPPU)		6.36 a	6.59 a	263.20 a	269.99 a	19.20 a	19.66 a	2.82 a	2.87 a	3.11 a	3.24 a	5.93 a	6.11 a
SA (main effect)													
Control		5.77 a	5.95 e	225.98 e	231.46 e	17.89 d	18.31 e	2.22 e	2.30 e	2.54 d	2.66 e	4.76 e	4.96 e
1 mM (SA)		5.97 c	6.18 d	238.70 d	245.13 d	18.09 c	18.76 d	2.41 d	2.49 d	2.74 c	2.87 d	5.14 d	5.37 d
2 mM (SA)		6.04 b	6.23 c	242.43 c	248.65 c	18.34 b	18.95 c	2.53 c	2.56 c	2.82 b	2.95 c	5.35 c	5.51 c
3 mM (SA)		6.32 a	6.52 b	258.03 b	265.09 b	18.80 a	19.50 b	2.71 b	2.79 b	3.05 a	3.19 b	5.76 b	5.98 b
4 mM (SA)		6.35 a	6.59 a	263.15 a	269.58 a	18.97 a	19.66 a	2.83 a	2.87 a	3.07 a	3.23 a	5.91 a	6.10 a
Combinations effects													
CPPU (mM)	SA (mM)												
Control	Control	5.51 mn	5.62 t	209.00 p	213.80 s	17.10 m	17.65 n	1.96 m	2.03 m	2.19 l	2.38 p	4.14 p	4.42 s
	1	5.48 n	5.72 s	213.10 o	217.40 r	17.15 m	17.73 n	2.02 lm	2.10 l	2.30 k	2.45 o	4.32 o	4.56 r
	2	5.54 mn	5.76 r	217.43 n	221.43 q	17.39 l	17.95 m	2.08 kl	2.12 l	2.34 k	2.52 n	4.42 n	4.65 q
	3	5.57 m	5.84 q	219.30 n	224.63 p	17.56 k	18.08 lm	2.14 k	2.21 k	2.45 j	2.57 m	4.59 m	4.79 p
	4	5.68 l	5.90 p	223.60 m	229.07 o	17.62 k	18.23 l	2.30 j	2.27 j	2.47 j	2.61 m	4.77 l	4.89 o
0.04	Control	5.76 k	5.99 o	226.97 l	233.20 n	17.82 j	18.39 k	2.26 j	2.32 j	2.64 i	2.69 l	4.91 k	5.01 n
	1	5.97 i	6.20 l	239.10 j	245.67 k	18.17 h	18.82 i	2.46 h	2.50 h	2.80 h	2.89 i	5.26 i	5.39 k
	2	6.10 h	6.25 k	241.53 i	249.37 j	18.20 h	18.95 hi	2.54 g	2.59 g	2.87 g	2.95 h	5.41 h	5.55 j
	3	6.48 de	6.60 f	261.23 e	270.47 f	18.45 f	19.68 de	2.74 e	2.87 e	3.21 c	3.27 e	5.95 e	6.13 f
	4	6.45 e	6.69 e	265.67 d	274.43 e	19.02 c	19.83 d	2.91 c	2.93 d	3.11 de	3.33 d	6.02 d	6.26 e
0.08	Control	5.90 j	6.07 n	233.30 k	237.43 m	18.09 i	18.54 jk	2.29 j	2.38 i	2.69 i	2.76 k	4.98 j	5.14 m
	1	6.23 g	6.32 j	245.97 h	254.63 i	18.31 g	19.09 h	2.45 h	2.63 g	2.85 gh	2.98 h	5.30 i	5.61 j
	2	6.21 g	6.39 i	251.13 g	257.40 i	18.77 d	19.34 g	2.66 f	2.71 f	3.03 f	3.09 g	5.69 g	5.80 i
	3	6.60 bc	6.75 d	272.80 c	278.17 d	19.32 b	19.98 c	2.91 c	2.99 c	3.15 cd	3.41 c	6.07 d	6.40 d
	4	6.54 cd	6.80 c	277.00 b	282.60 c	19.34 b	20.13 bc	2.96 c	3.06 b	3.21 c	3.44 bc	6.17 c	6.50 c
0.12	Control	5.91 ij	6.13 m	234.63 k	241.40 l	18.55 e	18.67 j	2.37 i	2.45 h	2.63 i	2.82 j	5.00 j	5.26 l
	1	6.18 g	6.47 h	256.63 f	262.83 h	18.74 d	19.40 fg	2.69 ef	2.74 f	3.01 f	3.17 f	5.69 g	5.91 h
	2	6.30 f	6.54 g	259.63 e	266.40 g	18.98 c	19.54 ef	2.82 d	2.82 e	3.05 ef	3.22 e	5.87 f	6.04 g
	3	6.64 b	6.88 b	278.77 b	287.10 b	19.85 a	20.26 b	3.04 b	3.11 b	3.39 b	3.49 ab	6.43 b	6.60 b
	4	6.75 a	6.95 a	286.33 a	292.20 a	19.90 a	20.44 a	3.17 a	3.21 a	3.50 a	3.53 a	6.66 a	6.74 a

-Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using the revised L.S.D. test at 0.05 level of probability.

The obtained results are in parallel with those reported by (Rosin *et al*., 2003; El-Shraiy and Hegazi, 2010).

In terms of the main effect of foliar application of salicylic acid on the given characteristics, the gained results reflected similar performance as CPPU which exhibited an obvious a direct proportionate relationship between SA concentration and the given traits, whereas SA concentration increased; the average values of the studied traits increased and *vice versa*, and the obtained calculated averages were affected significantly ($p \leq 0.05$) by applied levels of salicylic acid, during both seasons of the study. Spraying SA at 4 mM; led to the highest average values for tubers TSS, total phenols, tuber starch content, tuber reducing, non-reducing, and total sugars during both seasons compare to average values of control plants' measurements. However, the intermediate tested levels of SA declared, also, such significant differences either among themselves, more or less, and compared to the control treatment. The obtained results are in parallel with those reported by (Sánchez-Rojo *et al*., 2011; Flores-Lopez *et al*., 2016).

Concerning interaction between both variables of the present study, the tabulated results reflected that as both independent variable concentrations increased; the given traits' average values increased significantly ($p \leq 0.05$) in a direct proportionate relationship, especially when potato plants were foliar treated with 0.12 mM CPPU in combination with 4 mM SA; gave rise to the highest significant average values for tuber content of TSS, total phenols, starch content, reducing, non-reducing, and total sugars compare to average values of control plants' measurements. However, the intermediate tested levels declared, also, such significant differences either among them, more or less, and compared to the control treatment.

In this respect, it is worthy to report that plant growth regulators (PGR_S) stimulate plants' life processes, thus improving the quality and volume of plant yields (Wierzbowska *et al*., 2015). In potato, PGR_S affect the yield of tubers, improve their biochemical parameters and enhance the potato's resistance to adverse environmental conditions or pathogens (Cerny *et al*., 2002; Sawicka *et al*., 2011).

4 Chemical analyses of leaves and tubers characters

4.1 Leaf chlorophyll contents

Pertaining the main effect of CPPU, the postulated results presented in Table (6) exhibited clearly that there is a direct proportionate relationship between CPPU concentrations and the defined traits and *vice versa*. However, the foliar application of potato plants with 0.12 mM CPPU showed significantly ($p \leq 0.05$) the highest average values concerning leaf chlorophyll contents (chlorophyll a, chlorophyll b, and total chlorophyll a+b) compare to the other tested CPPU levels and control treatment during both seasons. The intermediate tested levels of CPPU declared, also, such significant differences either among them, more or less, and compared to the control treatment. The

obtained results are in parallel with those reported by (El-Shraiy and Hegazi, 2010) and Lahijani *et al*. (2018).

With reference to the main effect of salicylic acid (SA), it exerted significant ($p \leq 0.05$) effect on the characteristics of the present study, in general. It is noticeable that there is a direct proportionate relationship between the foliar application of SA and the given traits. The highest level of SA (4 mM); led to the highest significant average values compare to the control (spraying with distilled water) plants. However, the intermediate tested levels showed, also, such significant differences either among them, more or less, and compared to the control treatment. These results are in harmony with those reported by Daneshmand *et al*. (2009); Hadi (2014); Flores-Lopez *et al*. (2016).

Table (6). Averages values of leaves chlorophyll and nutrient content of potato plants cv. 'Cara' as affected by foliar application with cytokinin (CPPU), salicylic acid (SA) and their combinations during the summer seasons of 2016 and 2017

Treatments		Leaves chlorophyll content (mg/g f.w.)						Nutrient contents of leaves (% d.w.)					
		Chlorophyll a		Chlorophyll b		Total chlorophyll (a + b)		N		P		K	
		2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
CPPU (main effect)													
Control		0.575 c	0.597 d	0.413 d	0.425 d	0.988 d	1.022 d	2.28 d	2.32 d	0.256 d	0.263 d	2.77 d	2.87 d
0.04 mM (CPPU)		0.633 b	0.659 c	0.457 c	0.473 c	1.090 c	1.132 c	2.80 c	2.88 c	0.310 c	0.317 c	3.34 c	3.40 c
0.08 mM (CPPU)		0.643 b	0.673 b	0.469 b	0.484 b	1.111 b	1.157 b	2.90 b	3.00 b	0.322 b	0.330 b	3.44 b	3.53 b
0.12 mM (CPPU)		0.661 a	0.686 a	0.479 a	0.494 a	1.140 a	1.180 a	3.01 a	3.10 a	0.332 a	0.342 a	3.56 a	3.65 a
SA (main effect)													
Control		0.599 c	0.616 e	0.426 e	0.439 e	1.025 e	1.055 e	2.43 e	2.50 e	0.273 d	0.280 e	2.97 e	3.05 e
1 mM (SA)		0.615 b	0.641 d	0.444 d	0.459 d	1.060 d	1.100 d	2.64 d	2.70 d	0.292 c	0.301 c	3.17 d	3.25 d
2 mM (SA)		0.621 b	0.648 c	0.451 c	0.464 c	1.072 c	1.112 c	2.70 c	2.78 c	0.299 b	0.307 d	3.22 c	3.31 c
3 mM (SA)		0.649 a	0.679 b	0.473 b	0.488 b	1.121 b	1.166 b	2.96 b	3.04 b	0.328 a	0.335 b	3.46 b	3.57 b
4 mM (SA)		0.656 a	0.685 a	0.478 a	0.494 a	1.134 a	1.180 a	3.01 a	3.10 a	0.332 a	0.341 a	3.56 a	3.64 a
Combinations effects													
CPPU (mM)	SA (mM)												
Control	Control	0.561 h	0.582 r	0.402 l	0.413 p	0.963 o	0.994 r	2.15 m	2.19 n	0.245 n	0.251 m	2.60 l	2.75 o
	1	0.565 h	0.591 q	0.406 kl	0.417 op	0.971 no	1.008 q	2.23 l	2.26 m	0.251 mn	0.258 l	2.67 l	2.81 n
	2	0.577 gh	0.595 q	0.412 k	0.423 o	0.989 mn	1.018 p	2.26 l	2.32 l	0.254 mn	0.260 l	2.76 k	2.86 n
	3	0.581 gh	0.606 p	0.422 j	0.432 n	1.003 lm	1.038 o	2.35 k	2.40 k	0.260 lm	0.269 k	2.86 j	2.93 m
	4	0.591 g	0.613 o	0.422 j	0.438 mn	1.014 kl	1.051 n	2.39 k	2.45 k	0.270 kl	0.276 j	2.96 i	3.00 l
0.04	Control	0.625 de	0.621 n	0.428 j	0.442 m	1.053 ij	1.063 m	2.48 j	2.54 j	0.278 jk	0.283 j	3.00 i	3.07 k
	1	0.618 e	0.643 k	0.445 h	0.460 k	1.064 hi	1.102 k	2.67 h	2.74 h	0.296 hi	0.303 h	3.22 g	3.25 hi
	2	0.617 e	0.652 j	0.452 gh	0.467 j	1.069 hi	1.119 j	2.71 gh	2.79 g	0.302 gh	0.309 gh	3.23 g	3.31 h
	3	0.647 cd	0.687 e	0.475 e	0.495 ef	1.122 de	1.182 f	3.06 d	3.13 d	0.332 de	0.342 d	3.57 d	3.65 d
	4	0.658 bc	0.694 d	0.483 d	0.501 de	1.141 d	1.195 e	3.08 d	3.18 d	0.341 cd	0.349 c	3.66 c	3.73 c
0.08	Control	0.595 fg	0.628 m	0.436 i	0.449 l	1.031 jk	1.077 l	2.49 j	2.58 j	0.282 jk	0.291 i	3.09 h	3.14 j
	1	0.632 de	0.659 i	0.454 e	0.475 i	1.086 gh	1.134 i	2.76 g	2.84 g	0.302 gh	0.314 g	3.34 f	3.40 g
	2	0.630 de	0.665 h	0.465 f	0.477 hi	1.094 fg	1.142 i	2.87 f	2.97 f	0.313 fg	0.324 f	3.36 f	3.47 f
	3	0.677 ab	0.704 c	0.491 c	0.504 d	1.168 c	1.208 d	3.14 c	3.28 c	0.361 ab	0.357 b	3.65 c	3.78 c
	4	0.679 ab	0.710 b	0.498 bc	0.512 c	1.177 bc	1.222 c	3.25 b	3.32 bc	0.352 bc	0.362 b	3.75 b	3.86 b
0.12	Control	0.614 ef	0.634 l	0.437 i	0.451 l	1.051 ij	1.085 l	2.58 i	2.67 i	0.287 ij	0.296 i	3.17 g	3.22 i
	1	0.646 cd	0.671 g	0.472 ef	0.483 gh	1.118 ef	1.154 h	2.88 f	2.97 f	0.319 ef	0.328 f	3.47 e	3.53 ef
	2	0.660 bc	0.681 f	0.474 e	0.489 fg	1.134 de	1.170 g	2.96 e	3.04 e	0.328 de	0.335 e	3.51 de	3.59 de
	3	0.690 a	0.719 a	0.503 ab	0.518 b	1.193 ab	1.238 b	3.27 b	3.37 b	0.360 ab	0.372 a	3.79 b	3.91 b
	4	0.696 a	0.724 a	0.509 a	0.527 a	1.205 a	1.251 a	3.34 a	3.44 a	0.366 a	0.377 a	3.88 a	3.98 a

-Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using the revised L.S.D. test at 0.05 level of probability.

This finding could be taken place due to the major role of SA in photosynthetic activity, ultra-structure of leaf organelles and photosynthetic rate (Wang *et al*., 2006). Likewise, this finding could be accounted for the role of SA in reducing the Na uptake of plants and/or increased the uptake of N, P, K, Ca, Mg and the other minerals as compared to control treatment under salt stress as reported by El-Tayeb (2005); Gunes *et al*. (2007); Szepesi *et al*. (2005); Yildirim *et al*. (2008).

As for interaction between both CPPU and SA tested concentration, the obtained average values exhibited similar trend as that denoted to previously stated, whereas the interaction among various combinations exerted significant ($p \leq 0.05$) effects on the tested characteristics, especially when the potato plants treated the combination between the 0.12 mM of CPPU and SA at 3 or 4 mM; gave rise to the highest average values for given traits. However, the intermediate tested levels demonstrated, also, such significant differences either among them, more or less, and compared to the control treatment.

4.2 Leaf N, P and K contents

Result outline in Table (6) exhibited that both variables of study (i.e. CPPU and SA concentrations) either individually or their combination showed significant ($p \leq 0.05$) effects on leaf nutrient content (N, P, and K) of potato plants during both seasons.

In relation to the main effect of CPPU levels, the presented averages declare that the given independent variable exerted significant ($p \leq 0.05$) effect on leaf nutrient contents (N, P, and K) of potato plants and the relationship between the tested concentrations of CPPU and the given traits was clear (progressive relationship), and *vice versa*. It is obvious that the potato plants treated with the highest CPPU concentration (0.12 mM) exhibited significant ($p \leq 0.05$) effect and resulted in the highest average values compare to other treatments during both seasons of the study, while control plants; recorded the lowest significant average values compare to other treatments during both seasons of the experiments. However, the intermediate tested levels, disclosed, also such significant differences either among them, more or less, and compared to the control treatment.

Pertaining main effect of SA concentration, there is a direct proportionate relationship between the tested levels and their corresponding traits. The highest concentration (4 mM SA) provided the highest significant leaf nutrient content of potato plants, and *vice versa* compare to other treatments during both seasons of the experimentation. On the other side, control plants recorded the lowest significant average values for the traits under the study. However, the intermediate tested levels expressed, also, such significant differences either among them, more or less, and compared to the control treatment. These results could be taken place due to the enhancing effect of SA on the availability and movement of nutrients could result in stimulating formation of different nutrients in the leaves (Raskin, 1992). In this concern, Grown (2012) reported such stimulatory effect of salicylic acid on concentrations of nutrition elements and yield components of sunflower

plants and attributed these findings to the effect of salicylic acid on many biochemical and physiological processes that were reflected on improving vegetative growth and active translocation of photosynthesis products from source to sink.

Concerning the combinations effects CPPU and SA concentrations, the obtained results tabulated in Table (6) reflected that as CPPU concentration increased, and SA at 4 mM, the average values increased significantly, especially when the combination was 0.12 mM CPPU combined with 4 mM of SA; which caused the highest significant average values for N leaves content and K compare to other treatments during both seasons of the experiments. While potato plants treated with CPPU at 0.12 mM in combination with either 3 or 4 mM; gave the highest significant P leaves content character compare to other treatments during both seasons of the experiments. On the contrary, the control plants showed the lowest average values for traits under the study. However, the intermediate tested levels showed, also, such significant differences either among them, more or less, and compared to the control treatment. This finding could be attributed to the synergistic mode of action of both variables under the study in accumulation of absorbed nutrients within leaf tissues.

4.3 Tubers N, P and K contents

Results outline in Table (7) showed that both CPPU and SA concentrations that sprayed as foliar application, either individually or their combination showed clearly significant ($p \leq 0.05$) effects on tubers' nutrient content (N, P, and K) of potato plants during both growing seasons of 2016 and 2017.

Concerning the main effect of CPPU levels, the obtained results declare that, in general, there is a significant ($p \leq 0.05$) effect and direct proportionate relationship between CPPU concentration and the nutrient contents of tubers (N, P, K). It is obvious clearly that the potato plants treated with the highest CPPU level (0.12 mM); recorded significantly ($p \leq 0.05$) the highest average values on dry weight basis compare to the other treatments during both seasons of the study. Whereas, control plants recorded the lowest significant average values However, the intermediate tested levels declared also such significant differences either among them, more or less, and compared to the control treatment.

In terms of main SA effect, the given results established similar performance as CPPU, where a direct proportionate was obvious and the obtained calculated averages were affected significantly ($p \leq 0.05$) by applied levels of salicylic acid, during both seasons of the study. For example, spraying SA at 4 mM; resulted in the highest average values for N, P and K tuber contents, compare to other treatments during both seasons of the experiments.

Table (7). Averages values of some chemical determination of potato tuber characteristics cv. 'Cara' as affected by foliar application with cytokinin (CPPU), salicylic acid (SA) and their combinations during the summer seasons of 2016 and 2017

Treatments		Nutrient contents of tubers (% d.w.)					
		N		P		K	
		2016	2017	2016	2017	2016	2017
CPPU (main effect)							
Control		1.46 d	1.56 d	0.254 d	0.262 d	2.56 d	2.68 d
0.04 mM (CPPU)		2.00 c	2.05 c	0.297 c	0.309 c	3.06 c	3.19 c
0.08 mM (CPPU)		2.05 b	2.16 b	0.309 b	0.321 b	3.15 b	3.31 b
0.12 mM (CPPU)		2.10 a	2.24 a	0.323 a	0.330 a	3.29 a	3.42 a
SA (main effect)							
Control		1.63 e	1.73 e	0.269 e	0.277 e	2.69 e	2.83 e
1 mM (SA)		1.82 d	1.90 d	0.286 d	0.294 d	2.91 d	3.05 d
2 mM (SA)		1.90 c	1.96 c	0.291 c	0.302 c	3.00 c	3.11 c
3 mM (SA)		2.04 b	2.18 b	0.312 b	0.324 b	3.17 b	3.36 b
4 mM (SA)		2.12 a	2.25 a	0.321 a	0.331 a	3.29 a	3.41 a
Combinations effects							
CPPU (mM)	SA (mM)						
Control	Control	1.33 l	1.46 n	0.243 i	0.253 m	2.42 n	2.57 o
	1	1.44 k	1.50 mn	0.247 i	0.254 m	2.51 m	2.62 no
	2	1.47 jk	1.56 lm	0.254 h	0.261 l	2.55 m	2.67 n
	3	1.53 ij	1.63 kl	0.259 h	0.267 l	2.60 l	2.75 m
	4	1.54 i	1.67 k	0.267 g	0.275 k	2.70 k	2.79 m
0.04	Control	1.65 h	1.75 j	0.273 g	0.281 j	2.75 j	2.86 l
	1	1.81 f	1.92 gh	0.288 f	0.293 h	2.92 h	3.03 j
	2	1.99 e	1.97 fg	0.290 f	0.303 g	3.05 g	3.13 i
	3	2.26 b	2.27 cd	0.315 d	0.330 d	3.18 f	3.43 e
	4	2.27 bc	2.32 bc	0.321 d	0.338 c	3.39 d	3.50 d
0.08	Control	1.79 fg	1.82 ij	0.274 g	0.287 i	2.75 j	2.92 k
	1	2.02 de	2.03 f	0.302 e	0.309 f	3.05 g	3.21 h
	2	2.07 d	2.11 e	0.300 e	0.316 e	3.15 f	3.26 gh
	3	2.17 c	2.36 b	0.327 c	0.343 c	3.35 d	3.56 cd
	4	2.22 bc	2.48 a	0.340 b	0.350 b	3.45 c	3.60 c
0.12	Control	1.75 g	1.88 hi	0.288 f	0.288 hi	2.85 i	2.98 jk
	1	2.01 de	2.14 e	0.306 e	0.319 e	3.15 f	3.32 fg
	2	2.07 d	2.22 d	0.320 d	0.326 d	3.26 e	3.36 f
	3	2.22 bc	2.47 a	0.347 a	0.355 ab	3.55 b	3.69 b
	4	2.43 a	2.52 a	0.354 a	0.361 a	3.63 a	3.76 a

-Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using the revised L.S.D. test at 0.05 level of probability.

On the other hand, control plants achieved the lowest significant average values for traits under the study. However, the intermediate tested levels declared, also, such significant differences either among them, more or less, and compared to the control treatment. In the same context, Awad and Mansour (2007) reported that foliar spraying of SA at 100 ppm increased, significantly, N, P and K contents in potato tubers.

Pertaining the combinations between CPPU and SA concentrations, the obtained results reflected that potato plants treated with 0.12 mM of CPPU combined with 4 mM of SA, led to the highest significant average values for N tubers content during the first season and K content during both seasons, compare to other treatments, while potato plants treated with CPPU at 0.12 mM

in combination with either 3 or 4 mM gave the highest significant mean values for N tubers content during the second season, and P tubers content character compare to other treatments during both seasons of the experiments. On the contrary, control plants showed the lowest mean values for traits under the study compare to other treatments during both seasons of the experiments. However, the intermediate tested levels declared also such significant differences either among them, more or less, and compared to the control treatment.This study recommends that foliar spraying of a combination of both CPPU and SA at 0.12mM and 4.00 mM respectively could enhance the productivity and quality of potato plants.

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الملخص العربي

محصول وجودة نباتات البطاطس متأثرة بالرش الورقي بالسيتوكينين وحمض السالسيلك

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تحتل البطاطس (Solanum *tuberosum* L.) المرتبة الرابعة في قائمة أهم الأغذية في العالم. تزرع البطاطس في مصر في ثلاث عروات، ولكن في عروة الصيف يكثر فيها الإجهاد المتمثل في درجة الحرارة المرتفعة والتي لها تأثير ضار على نمو النبات بأكمله. لذلك، افترضت هذه الدراسة أن الرش الورقي بالسيتوكينين (CPPU) وحمض الساليسيليك (SA) يمكن أن يكونا لهما دورًا حاسمًا في هذا السياق. لذلك، أجريت تجربتان حقليتان في الحقل المفتوح خلال فصلي الصيف لعامي ٢٠١٦ و٢٠١٧، في مزرعة خاصة ذات تربة لومية رملية، في مدينة أبو المطامير، محافظة البحيرة، مصر. ولقد تم استخدام تقاوي البطاطس المستوردة المعتمدة صنف 'كارا' بعد تقسيمها. كانت قطع التقاوي ذات وزن متماثل تقريباً (٤٠ جم) وتحتوي على عين واحدة زرعت في خطوط عرضها ٠.٨٠ مترا و٠.١٧ متر بين النباتات، مع أربعة تركيزات من السيتوكينين المخلق صناعياً (CPPU) بتركيزات (٠.٠٠، ٠.٠٤، ٠.٠٨، و٠.١٢ ملليمول) وخمسة تركيزات من حمض السالسيلك (٠.٠٠، ١.٠٠، ٢.٠٠، ٣.٠٠، و٤.٠٠ ملليمول) تم رشها منفردة أو في خليط. تم رش نباتات المشاهدة (الكنترول) بالماء المقطر. تم دراسة تأثير كل من المتغيرين المستقلين وتركيزاتها على صفات النمو الخضري والمحصول ومكوناته وجودة الدرنات والتركيب الكيميائي للأوراق والدرنات. وأوضحت النتائج المتحصل عليها، بشكل عام، أن معاملات الرش الورقي بالسيتوكينين (CPPU) بتركيز ٠.١٢ ملليمول وحمض الساليسيليك (SA) بتركيز ٤ ملليمول منفردين أو معاً في مزيج على نباتات البطاطس صنف 'كارا' قد أدت إلى الحصول، بشكل معنوي، على أعلى إنتاجية وجودة مقارنة بالنباتات غير المعاملة. ويمكن اعتبار التوليفة بين ٠.١٢ ملليمول سيتوكينين (CPPU) بالإضافة إلى ٤ ملليمول حمض سالسيلك (SA) المعاملة المثلى لإنتاج أعلى محصول وجودة لنباتات البطاطس تحت الظروف البيئية لمحافظة البحيرة والمناطق الأخرى المماثلة لها.