Effect of Spraying with Zeatin and Potassium Phosphite on Growth, yield and Tubers Quality of Potato during Summer Season

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ABSTRACT

This study was conducted during the summer seasons of 2022/2023 and 2023/2024 on a private vegetable farm in Basat Karim El-Din village, Sherbin district, Dakahlia Governorate, Egypt, with the aim of studying the effect of foliar spraying with each of the two Zeatin (ZT) and potassium phosphite (KPhi) at a concentration of (0, 1, 1.5, 2.5 ml/L for each of them individually or in combination with the aim of obtaining the highest productivity and best specifications for the quality of potato tubers of Cara variety. The most important results obtained were as follows: All concentrations of both zeatin and KPhi led to a significant increase in plant growth, leaf chemical components, productivity and quality of potato tubers compared to the control treatment (zero ZT or KPhi). However, spraying potato plants four times with zeatin and potassium phosphite at 2.5 ml/L each resulted in the best growth (plant height, number of leaves and stems, leaf area, dry weight of leaves/plant, total chlorophyll (SPAD) and catalase in the leaf), and improved crop characteristics (average tuber weight, average number of tubers/plant, yield/plant and total yield/fed.) and best tuber quality (N, P and K contents, dry matter percentage, TSS and starch contents). On the other hand the control treatment showed the highest levels of Malondialdehyde (MDA), a marker of oxidative stress.

Keywords: Potato- Zeatin-MKPi- CAT- Yield and tuber quality

INTRODUCTION

The potato (*Solanum tuberosum* L.) is a crucial crop for global food security and a major vegetable, with only rice, wheat, and maize having higher production. Maximizing potato yields requires good management, such as using certified seeds and planting with optimal soil moisture and temperature (Darwish et al., 2022). Potato is an important source of carbohydrates, resistant starch (Camire et al., 2009). It is also a source of antioxidants and glycoalkaloids, which can have beneficial effects such as inhibition of the growth of cancer cells (Friedman, 2015).

Zeatin is a cytokinin plant biostimulant that is important for the growth and development of plants. (Mok and Mok, 2001). Furthermore, it was demonstrated that the concentration of zeatin was higher than that of any other cytokinin Al-Hussein et al. (2006). In addition, zeatin biostimulant boosted antioxidant activity and total phenolics in comparison to the control (Ravanfar et al., 2020). Similarly, when applied to maize plants, zeatin biostimulant increased antioxidant activity (Yousaf et al., 2024).

Similarly, when applied to maize plants, zeatin biostimulant increased antioxidant activity (Yousaf et al., 2024). Potassium phosphite: KPhi is advised as a biostimulator to increase the yield, fresh and dry biomass. It also acts as a biostimulator to increase resistance to biotic stressors as well as to increase resistance to biotic stressors brought on by different plant pathogen species by enhancing plant defense responses (Omar et al., 2020). The application of potassium phosphite (KPhi) on plants provides efficient protection against a wide range of diseases (Rezende et al., 2020). Phi also act as a signal to induce plants to produce glucanase, chitinase, peroxidase (Scott et al., 2016). Also phosphite applied topically as a biostimulant has improved crop output and

nutritional value in a variety of plant species (Burra et al., 2014).

Treated plants with potassium phosphate KPhi produced the best results for enhancing growth , productivity and quality, (Cicore et al., 2011 on potato, Estrada-Ortiz et al., 2013 on strawberry, Constán-Aguilar, et al., 2014 on cucumber, Tambascio, et al., 2014 on potato, Habchy, 2016 on tomato, Ewais et al., 2020, Chalhoub, 2020 on potato, Omar et al., 2020 on squash, Baoyu et al., 2021 on potato and Bhavya et al., 2024 on *Vigna radiate*).

This research deals with studying the effect of foliar spraying with both zeatin and potassium phosphite at different concentrations, individually or in combination, with the aim of obtaining the highest productivity and best quality specifications of Cara potato tubers grown in the summer season.

MATERIALS AND METHODS

This study was conducted during the summer seasons of 2022/2023 and 2023/2024 on a private vegetable farm in Bosat Karm El-Din village, Sherbin district, Dakahlia Governorate, Egypt, with the aim of studying the effect of foliar spraying with each of the two Zeatin (ZT) and potassium phosphite (KPhi) at a concentration of (0, 1, 1.5, 2.5 ml/L for each of them individually or in combination with the aim of obtaining the highest productivity and best specifications for the quality of potato tubers of Cara variety.

Before the experiment began, soil samples were taken from the top 30 cm of the experimental field. These samples were then analyzed, and the results of this analysis, detailing the soil's characteristics, are shown in **Table (A),**depending on Sparks et al. (2020) and Dane and Topp (2020).

Table (A). Characters of the initial soil (average of both seasons).

Parameters	Values
Particle size distribution (%)	
Clay	80.5
Silt	11.8
Sand	7.7
Textural classis clay	
Organic matter,%	3.39
ECdSm^{-1}(soil paste extract)	3.50
pH(soilsuspension,1:2.5)	7.3
N,mgKg^{-1}	58.5
P,mgKg^{-1}	18.94
K,mgKg^{-1}	410.3

This experiment included 16 treatments which were the combinations between four concentrations of Zeatin (0, 1, 1.5, 2.5 ml/L) and four concentrations of potassium phosphite (0, 1, 1.5, 2.5 ml/L) . The experimental design was a split plot design ZT concentrations were arranged in the main plot, while KPhi concentrations were distributed in the sub plot with three replications

Zeatin and Potassium Phosphite (Di potassium phosphite, K_2HPO_4) were commercially sourced from the Egyptian market, and subsequently, the specific concentrations required for the study were prepared.

During the first and second seasons of this research, potato seeds were sown on January 8th and 10th , respectively, with a consistent 20 cm spacing. To prevent fungal

diseases, the seeds were treated with an antifungal agent prior to planting. Each experimental unit, covering 10.5m², consisted of 3 ridges that were 5 meters in length and 0.7 meters in width. The plants were sprayed with different concentrations of ZT and KPi four times, commencing 20 days post-planting and continuing, 20 day intervals (20, 40, 60 and 80 days after planting) using a manual atomizer in the morning in both seasons. In the meantime, the untreated plants (control) received a single application of water.

Data recorded:-

1. Plant growth: In both growing seasons, five plants were randomly selected from each experimental plot at 90 days after planting. On these selected plants, the following measurements were taken: plant height (cm), the number of leaves per plant, the number of stems per plant, area of leaves (m^2) and foliage dry weight (g).

2. **Leaf chemical constituents** : Leaf total chlorophyll (SPAD): At the same time 90 days after planting in both seasons, the photosynthetic capacity (SPAD), was assessed by the use of a spade meter through the measurement of chlorophyll material which was analyzed as described by Picazo et al. (2013) , Catalase CAT (in units /g/min) and Malondialdehyde MDA ($\mu mol.g^{-1}$ F.W) enzymes was measured as an indicator of oxidative stress using spectrophotometric techniques described by Mendes et al. (2009) and Alici and Arabaci (2016).

3. Tuber yield: At the time of harvest (110 days after planting) in both seasons, the following characteristics were measured, i.e., tuber weight (g), tubers number/plant, tuber weight / plant and tuber yield/fed. (ton).

4. Tuber quality: From each harvested plot, ten healthy potato tubers were randomly selected for quality analysis. The chemical composition of the tubers was also analyzed, including total nitrogen (%), following AOAC (2000) protocols, and phosphorus and potassium (%) according to Rangana (1977). Dry matter (%): After 100 g of the shredded mixture were dried at 105.0°C till their weight stayed constant, the dry matter (%) was computed. Total soluble solids (TSS) were measured as a percentage with a hand refractometer. Total sugars were expressed as a percentage of the dry weight according to the method described by Forsee (1938). Total carbohydrate content of these tubers was determined using the method detailed by Hodge and Hofreiter (1962). Starch content, expressed as a percentage, was calculated based on the dry matter percentage using formula:

Starch=17.55+0.891×(Dry matter %−24.18) according to (AOAC, 1980)**.**

Statistical analysis

The collected data were statistically analyzed using the CoStat software (version 6.303). The statistical methods described by Gomez and Gomez (1984) were followed for this analysis. To determine if there were significant differences between the treatment groups, the Least Significant Difference (LSD) test was applied, with a significance threshold set at 5%.

RESULTS AND DISCUSSION

1. Plant growth

Effect of Zeatin (ZT)

Data in **Table (1)** indicate that plant height, number of leaves/ plant , number of stems / plant , leaf area / plant and foliage dry weight significantly increased with increasing Zeatin (ZT) up to 2.5 ml/l in both seasons with no significant differences with ZT at 1.5 ml /l concerning foliage dry weight in both seasons. respectively of potato Cara cultivar at 90 days after planting during summer plantations.

Zeatin dramatically improved photosynthetic efficiency, growth performance, and antioxidant activity. Larger leaves, longer shoots, and higher biomass were the results of ZT treatment, which also increased the accumulation of osmolytes, whereas root length and biomass decreased (Yousaf et al.,2024).

These results are harmony with those obtained with El-Areiny et al. (2019), El-Anany (2020) and Abouelsaad, and Brengi (2022). They showed that spraying potato plants with Cytokinin Types significantly increased vegetative growth parameters .

Table (1). Effect of spraying with Zeatin (ZT) on plant growth of potato plants at 90 days after planting during summer 2022/2023 and 2023/2024 seasons.

Treatments	Plant height (cm)	Number of leaves/ plant	Number of stems/plant	Leaf area/ plant (m^2)	Foliage dry weight (g)
			2022/2023 season		
Control	53.50 c	19.50 d	3.75 d	0.347 d	16.23 c
1 ml/l	56.62 b	23.25 c	4.25 c	0.437 c	18.58 b
1.5 ml/l	58.78 a	26.25 b	4.75 b	0.472 b	19.62 a
2.5 ml/l	59.58 a	31.25 a	5.25 a	0.502 a	19.83 a
			2023/2024 season		
Control	53.98 d	19.75 d	3.87 d	0.350 d	17.19 c
1 ml/l	57.14 c	24.50 c	5.00 c	0.452 c	18.61 b
1.5 ml/l	59.05 b	27.25 b	5.50 b	0.477 b	19.34 ab
2.5 ml/l	59.76 a	31.25 a	6.00 a	0.512 a	20.03 a

Effect of potassium phosphate (KPhi)

The obtained results in **Table (2**) illustrate that spraying Cara plants during summer plantations with potassium phosphite (KPhi) at 2.5 ml/l gave the highest values of plant height , number of leaves/ plant, number of stems / plant , leaf area / plant and foliage dry weight in the 1st and 2nd seasons, respectively at 90 days after planting followed by spraying with KPhi at 1.5 ml/l in both seasons.

Table (2). Effect of spraying with potassium phosphite (KPhi) on plant growth of potato plants at 90 days after planting during summer seasons of 2022/2023 and 2023/2024

Treatments	Plant height (cm)	Number of leaves/ plant	Number of stems/plant	Leaf area/ plant (m^2)	Foliage dry weight (g)
			2022/2023 season		
Control)	53.99 c	17.75 d	3.75 d	0.357 d	16.98 c
1 ml/l	57.37 b	26.25 c	4.50 c	0.450 c	18.63 b
1.5 ml/l	58.24 ab	27.25 b	5.00 a	0.465 b	19.11 a
2.5 ml/l	58.88 a	29.00 a	4.75 b	0.487 a	19.54 a
			2023/2024 season		
Control	54.65 d	18.25 c	4.50 d	0.370 d	17.39 c
1 ml/l	57.74 c	27.25 b	4.87 c	0.450 c	18.62 b
1.5 ml/l	58.46 b	27.75 b	5.25 b	0.475 b	19.48 a
2.5 ml/l	59.07 a	29.50 a	5.75 a	0.497 a	19.68 a

Potassium phosphite (KPhi) is a new phosphorous and potassium fertilizer for increasing crop yield and disease resistance (Hanrahan et al., 2005). In addition, Shaaban et al. (2008) foliar application of monopotassium phosphate could increase K concentrations in plant tissues which leads to an improved nutrient balance.

Results are harmony with those obtained with Tambascio et al. (2014) on potato and Habchy (2016) on tomato and Baoyu et al. (2021) on potato . They indicated that plant height and leaf number and shoot dry weight

significantly increased when plants treated with KPhi as compared to control treatment.

Effect of the interaction:

The interaction between spraying with ZT at 2.5 ml/l and foliar spray with KPhi at 2.5 ml/l increased plant growth (plant height , number of leaves/ plant , number of stems / plant, leaf area / plant and foliage dry weight of potato at 90 days after planting in both seasons **(Table 3).**

Table (3). Effect of the interaction between spraying with ZT and KPhi on plant growth of potato plants at 90 days after planting at 90 days after planting during summer seasons of 2022/2023 and 2023/2024.

Treatments		Plant height (cm)	Number of leaves/plant	Number of stems/plant	Leaf area/ plant (m^2)	Dry weight of shoots (g/plant
Zeatin (ml/l)	**KPhi** (ml/l)			**2022/2023 season**		
Control	**Control**	50.85 i	16.00 o	3.00 d	0.280 l	13.69 i
	1 ml/l	54.96 f-h	19.00 l	4.00 c	0.340 j	15.96 h
	1.5 ml/l	53.61 h	21.00 j	5.00 b	0.350 j	17.12 g
	2.5 ml/l	54.61 gh	22.00 i	3.00 d	0.420 h	18.17 f
1 ml/l	**Control**	54.24 gh	17.00 n	4.00 c	0.320 k	16.55 gh
	1 ml/l	56.81 d-f	25.00 h	4.00 c	0.470 f	19.10 c-f
	1.5 ml/l	57.45 c-e	26.00 g	5.00 b	0.480 ef	19.19 b-e
	2.5 ml/l	57.98 cd	25.00 h	4.00 c	0.480 ef	19.50 a-e
1.5 ml/l	**Control**	55.11 f-h	18.00 m	3.00 d	0.380 i	18.77 ef
	1 ml/l	58.57 cd	28.00 e	5.00 b	0.490 de	19.65 a-e
	1.5 ml/l	60.45 ab	27.00 f	5.00 b	0.510 bc	19.98 a-c
	2.5 ml/l	61.01 a	32.00 d	6.00 a	0.510 bc	20.11 ab
2.5 ml/l	**Control**	55.79 e-g	20.00 k	5.00 b	0.450 g	18.94 d-f
	1 ml/l	59.14 bc	33.00 c	5.00 b	0.500 cd	19.82 a-d
	1.5 ml/l	61.45 a	35.00 b	5.00 b	0.520 b	20.17 a
	2.5 ml/l	61.95 a	37.00a	6.00 a	0.540 a	20.41 a
				2023/2024 season		
Control	**Control**	51.95 i	14.00 j	3.00 f	0.260 h	15.89 g
	1 ml/l	55.66 f	20.00 hi	3.50 e	0.350 g	16.16 g
	1.5 ml/l	53.91 h	22.00 fg	4.00 d	0.360 g	18.32 ef
	2.5 ml/l	54.41 gh	23.00 f	5.00 c	0.430 f	18.42 d-f
1 ml/l	**Control**	55.34 fg	19.00 i	5.00 c	0.350 g	16.48 g
	1 ml/l	57.10 e	26.00 e	5.00 c	0.480 de	18.89 c-f
	1.5 ml/l	57.85 de	27.00 de	5.00 c	0.490 cd	19.38 a-f
	2.5 ml/l	58.28 cd	26.00 e	5.00 c	0.490 cd	19.70 a-e
1.5 ml/l	**Control**	55.41 fg	19.00 i	4.00 d	0.410 f	18.07 f
	1 ml/l	58.97 c	29.00 c	5.00 c	0.460 e	19.41 a-f
	1.5 ml/l	60.55 b	28.00 cd	6.00 b	0.520 b	19.87 a-d
	2.5 ml/l	61.27 b	33.00 b	7.00 a	0.520 b	20.01 a-c
2.5 ml/l	**Control**	55.93 f	21.00 gh	6.00 b	0.460 e	19.14 b-f
	1 ml/l	59.24 c	34.00 b	6.00 b	0.510 bc	20.02 a-c
	1.5 ml/l	61.55 ab	34.00 b	6.00 b	0.530ab	20.37 ab
	2.5 ml/l	62.35 a	36.00a	6.00 b	0.550a	20.61 a

2. Total chlorophyll, catalase CAT enzyme and Malondialdehyde (MDA):

Effect of ZT:

Total chlorophyll and CAT in leaves at 90 days after planting increased with increasing ZT up to 2.5 ml/l , whereas MDA decreased with increasing ZT up to 2.5 ml/l in both seasons (Table 4).

Phytohormones also affect the delay in leaf senescence (Zhao et al., 2021). Furthermore, ZT treatment increased photosynthetic rates by improving cell membrane integrity (Wang et al., 2023).

Results are harmony with **El-Anany (2020)** found that potato plants sprayed with BAP like ZT had much greater levels of photosynthetic pigments (chlorophyll a, b, and carotenoids)

Effect of KPhi

Data in **Table (4)** show that spraying with KPhi at 2.5 ml/l significantly increased total chlorophyll and CAT in leaves at 90 days after planting, significantly increased MDA enzyme in leaves in the 1st and 2nd seasons, respectively.

The inhibitory effect observed using KPhi application may be due to a competitive behavior between the elements potassium and magnesium, which are essential components in chlorophyll cells (Roca et al., 2016). Results are harmony with Chalhoub (2020) on potato , who found that treated plants with KPhi produced the best results for enhancing total chlorophyll content in leaf .

Table (4). Effect of spraying with ZT and KPhi on total chlorophyll and some enzymes at 90 days after planting in leaves of potato plants summer 2022/2023 and 2023/2024 seasons.

Treatments	Total chlorophyll (SPAD)		Catalase enzyme CAT (unit.g^{-1}.min^{-1})		Malondialdehyde MDA (µmol.g^{-1} F.W)	
	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season
Effect of ZT spraying						
Control (water)	41.81 c	41.53 d	4.08 c	4.05 c	8.26 a	8.21 a
1 ml/l	43.87 b	43.74 c	4.05 c	3.90 d	8.45 a	8.33 a
1.5 ml/l	45.81 a	45.52 b	5.58 b	5.56 b	7.04 b	6.72 b
2.5 ml/l	46.16 a	46.36 a	5.84 a	5.78 a	6.19 c	5.98 c
Effect of kPhi spraying						
Control (water)	42.25 c	42.57 d	4.49 d	4.48 d	8.05 a	7.78 a
1 ml/l	43.99 b	43.63 c	4.70 c	4.69 c	7.59 b	7.48 b
1.5 ml/l	45.41 a	45.19 b	4.98 b	4.96 b	7.33 c	7.15 c
2.5 ml/l	45.98 a	45.77 a	5.38 a	5.15 a	6.96 d	6.83 d

Effect of the interaction:

As for total chlorophyll , the interaction between ZT at 2.5 ml/l and KPhi at 2.5 ml/l increased total chlorophyll in leaves with no significant differences with the interaction between ZT at 2.5 ml/l and KPhi at 1.5 ml/l in both seasons **(Table 5).**

Concerning CAT enzyme , the interaction between ZT at 2.5 ml/l and KPhi at 2.5 ml/l increased CAT in leaves.

Data show that control treatment without ZT and KPhi increased MDA in leaves at 90 days after planting in both seasons. the interaction between ZT at 2.5ml/l and KPhi at 2.5 ml/l gave the lowest values of MDA in both seasons.

Table (5). Effect of the interaction between spraying with ZT and KPhi on total chlorophyll and some enzymes at 90 days after planting in leaves of potato plants summer 2022/2023 and 2023/2024 seasons.

Treatments		Total chlorophyll (SPAD)		Catalase enzyme CAT (unit.g^{-1}.min^{-1})		Malondialdehyde MDA (µmol.g^{-1} F.W)	
ZT (ml/l)	**KPhi** (ml/l)	**2022/2023 season**	**2023/2024 season**	**2022/2023 season**	**2023/2024 season**	**2022/2023 season**	**2023/2024 season**
Control	**Control**	38.39 h	39.50 j	3.28 l	3.23 j	9.01a	8.86 a
	1 ml/l	41.71 g	40.82 i	3.83 i	3.89 g	8.35 bc	8.10 bc
	1.5 ml/l	43.01 f	42.57 gh	4.58 h	4.51 f	7.88 cd	8.02 bc
	2.5 ml/l	44.13 ef	43.24 fg	4.66 h	4.59 f	7.80 de	7.88 c
1 ml/l	**Control**	41.51 g	41.62 hi	3.56 k	3.45 i	8.77ab	8.57 ab
	1 ml/l	43.14 f	42.25 gh	3.65 jk	3.66 h	8.56ab	8.60 ab
	1.5 ml/l	45.01 de	45.16 cd	3.75 ij	3.80 gh	8.56ab	8.52 ab
	2.5 ml/l	45.83 a-d	45.94 b-d	5.25 g	4.69 f	7.91 cd	7.63 cd
1.5 ml/l	**Control**	44.22 ef	44.15 ef	5.27 g	5.37 e	7.49 de	6.92 ef
	1 ml/l	45.54 cd	45.15 d	5.59 ef	5.49 de	7.33 ef	7.10 de
	1.5 ml/l	46.64 a-c	46.15 bc	5.57 f	5.57 cd	6.94 f	6.53 f-h
	2.5 ml/l	46.84 ab	46.65 ab	5.91 b	5.84ab	6.43 g	6.35 gh
2.5 ml/l	**Control**	44.91 de	45.02 de	5.85 bc	5.90ab	6.95 f	6.77 e-g
	1 ml/l	45.59 b-d	46.30 b	5.76 cd	5.75 bc	6.15 gh	6.13 h
	1.5 ml/l	47.01 a	46.89 ab	6.04 a	5.98a	5.97 gh	5.54 i
	2.5 ml/l	47.14 a	47.25 a	5.71 de	5.49 de	5.71 h	5.49 i

3. Yield and its components:-

Effect of ZT:

Spraying with ZT at different concentrations significantly increased yield and it components compared to control in both seasons **(Table 6).** Foliar spray with ZT at 2.5 ml/l increased average tuber weight, average number of tuber / plant , tuber weight / plant and total yield /fed. in the 1st and 2nd seasons, respectively.

Another adenine type of cytokinins: 6-benzyl amino purine (BAP) and zeatin riboside promote tuber formation of potato by increasing glycolysis and ATP synthesis activity (Cheng et al., 2019).

These results agree with Roumeliotis *et al*. (2012), Njogu et al. (2015) , Kolachevskaya et al. (2015) all on potato they showed that spraying potato plants with different sources of cytokinin such as CPPU, BAP and ZT achieved the highest mean tuber fresh and the number of tubers per plant and yield. Also, Abouelsaad, and Brengi (2022) came the similar results for cytokinins on yield and its components of potato.

Effect of KPhi:

Average tuber weight, average number of tuber / plant , tuber weight / plant and total yield /fed. significantly increased with increasing KPhi concentrations up to 2.5 ml/l (table 6). Foliar spray with KPhi at 2.5 ml/l gave the highest values of average tuber weight, average number of tuber / plant, tuber weight / plant and total yield /fed. in the 1st and 2nd seasons, respectively. The benefits of KPhi on yield and explained that it can be added as a biostimulator to improve the yield and performance of various crop types by inducing defense responses in plants, stimulating plant metabolism, phytohormones, and secondary metabolites that are crucial for plant growth, and raising the P content of the entire plant (Lovatt and Mikkelsen, 2006). Also, Estrada-Ortiz et al. (2013) who found that Phi increased total yield, fruit weight and number of fruit of strawberry , these positive effect are due to activation the synthesis of antioxidant metabolites and internal hormonal and chemical changes by phi application. These results are consistent with those reported by Tambascio *et al*. (2014), Ewais et al . (2020) , Chalhoub

(2020) and Baoyu et al. (2021) all on potato. They showed that spraying with KPhi produced the highest values of average tuber weight, number of tuber / plant and total yield.

Effect of the interaction:

The interaction between ZT at 2.5 and KPI at 2.5 ml/l recorded maximum values of average tuber weight, average number of tuber / plant, tuber weight / plant and total yield /fed. in the 1st and 2nd seasons, respectively. From the foregoing results , it could be concluded that spraying potato plans Cv Cara during summer plantations with Zeatin at 2.5 ml/l and potassium phosphate at 2.5 ml/l increased plant growth (plant height, number of leaves/ plant, number of stems / plant , leaf area/ plant and shoot dry weight, total chlorophyll, , yield and its components, i.e., average number of tubers/ plant , average tuber weight, yield / plant and total yield /fed. **(Table 7)**

Table (6). Effect of spraying with ZT and KPhi on yield and its components of potato plants during summer seasons of 2022/2023 and 2023/2024

Treatments	Average tuber weight (g)		Average number of tuber/plant		Tuber weight/plant (g)		Total yield (ton/fed.)	
	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season
Effect of ZT spraying								
Control	140.34 d	140.03 d	4.08 d	4.16 d	571.95 d	582.86 d	11.400 d	11.504 d
1 ml/l	151.62 c	149.04 c	4.33 c	4.33 c	653.83 c	645.55 c	12.825 c	12.661 c
1.5 ml/l	155.96 b	154.96 b	4.50 b	4.58 b	700.35 b	709.87 b	13.782 b	13.981 b
2.5 ml/l	161.62 a	160.66 a	5.08 a	5.41 a	820.03 a	869.14 a	16.157 a	16.701 a
Effect of KPhi spraying								
Control	146.74 d	145.91 d	4.24 d	4.24 d	624.81 c	622.56 d	12.324 d	12.237 d
1 ml/l	151.29 c	150.76 c	4.49 c	4.49 c	679.55 b	680.37c	13.407 c	13.412 c
1.5 ml/l	154.42 b	153.08 b	4.58 b	4.75 b	707.72 ab	728.85 b	13.998 b	14.135 b
2.5 ml/l	157.08 a	154.94 a	4.66 a	5.00 a	734.08 a	775.63 a	14.436 a	15.064 a

Table (7). Effect of the interaction between spraying with ZT and KPhi on yield and its components of potato plants during summer seasons of 2022/2023 and 2023/2024.

Treatments		Average tuber weight (g)		Average number of tuber / plant		Tuber weight/plant (g)		Total yield (ton /fed.)	
ZT (ml/l)	KPhi (ml/l)	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season
Control	**Control**	137.21 i	135.21 j	3.33 e	3.66 g	456.21 g	494.10 g	9.091 k	9.582 i
	1 ml/l	139.52hi	140.25 i	4.33 d	4.00 f	601.87 f	560.00 f	12.007 j	11.185 h
	1.5 ml/l	141.41gh	144.46 h	4.33 d	4.33 e	610.53 f	623.52 e	12.201 j	12.270 g
	2.5 ml/l	143.22 g	140.21 i	4.33 d	4.67 d	619.19ef	653.80 e	12.303h-j	12.980 ef
1 ml/l	**Control**	144.33 g	142.17 i	4.33 d	4.00 f	623.52ef	568.00 f	12.263 ij	11.160 h
	1 ml/l	150.81 f	148.29g	4.33 d	4.33 e	649.50ef	640.84e	12.690f-h	12.517 fg
	1.5 ml/l	153.72 ef	150.23fg	4.33 d	4.33 e	662.49ef	649.50e	13.050 e-g	12.890 ef
	2.5 ml/l	157.62cd	155.46 d	4.33 d	4.67 d	679.81de	723.85 d	13.296 e	14.077 d
1.5 ml/l	**Control**	150.71f	152.15ef	4.33 d	4.33 e	649.50ef	658.16e	12.690 g-i	12.895 ef
	1 ml/l	154.52e	153.27de	4.33 d	4.33 e	666.82 ef	662.49e	13.136 ef	13.050e
	1.5 ml/l	158.33c	155.13d	4.67 c	4.67 d	737.86cd	723.85d	14.557d	14.377 d
	2.5 ml/l	160.27c	159.29c	4.67 c	5.00 c	747.20cd	795.00c	14.744 d	15.600 c
2.5 ml/l	**Control**	154.71de	154.12de	5.00 b	5.00 c	770.00bc	770.00cd	15.250 c	15.310 c
	1 ml/l	160.32 c	161.23bc	5.00 b	5.33 b	800.00bc	858.13 b	15.795 b	16.895 b
	1.5 ml/l	164.23 b	162.49 b	5.00 b	5.67 a	820.00 b	918.54 a	16.183 b	17.001 b
	2.5 ml/l	167.22 a	164.79 a	5.33 a	5.67 a	890.11 a	929.88 a	17.402 a	17.598 a

The stimulative effect of the interaction between ZT at 2.5 ml/l and KPi at 2.5 ml/l on total yield may be due to that this interaction treatment increased plant growth (Table, 3), total chlorophyll (Table 5), average tuber weight and number of tuber/plant and tuber weight/plant (Table, 7). Under different levels of ZT (0,1,1.5 and 2.5 ml/l) and spraying with KPi at 1, 1.5 and 2.5 ml/l were the best treatments for enhancing average tuber weight and number of tuber/plant , tuber weight/plant and total yield/fed., compared to control (0 KPi) under the same treatments of ZT in both seasons. From the foregoing results, it could be concluded that spraying potato plans cv. Cara during summer plantations with Zeatin at 2.5 ml/l and potassium phosphate at 2.5 ml/l increased plant growth, yield and its components, i.e., average number of tubers/plant, average tuber weight, yield/plant and total yield/fed.

4. Tuber quality:-

Effect of ZT:

Foliar spray of potato plants cv. Cara with ZT at 2.5 ml/l gave the highest values of N, P and K contents and dry matter, TSS, total sugars, total carbohydrates and starch contents in the 1st and 2nd seasons, respectively **(Tables 8 and 9)**

The results showed that treatment agreed with Abouelsaad and Brengi (2022) indicated that the application of CPPU and KN like ZT lead to produce more tuber starch and reduced sugar in potato tuber. However, the plants which treated with 40 ppm BAP had the greatest total protein content and ascorbic acid in tubers.

Effect of KPhi:

Contents of N, P and K , dry matter, TSS, total sugars, total carbohydrates and starch contents in tubers significantly increased with increasing foliar spray with KPhi up to 2.5 ml/l in both seasons **(Tables 8 and 10)**. These results support those of Habchy (2016) indicated that fruit quality of tomato were significantly improved with different rates of potassium phosphate 2, 3 and 3.5 g L were the best when treated plants , with 3.5 g /l produced the highest values. Also, Omar et al. (2020) showed that treated squash plants with KPhi at different rates gave the highest values of N, P and K% in fruit .

Effect of the interaction:

The interaction between ZT at 2.5 ml/l and KPhi at 2.5 ml/l significantly increased N, P and K contents and dry matter , TSS , total sugars , total carbohydrates and starch contents in tuber with no significant differences with the interaction between ZT at 2.5ml/l and KPhi at 1.5 ml/l in both seasons in most cases **(Tables 11 and 12).**

Conclusion: under the same conditions, it could be concluded that spraying potato plants cv. Cara which planting in summer seasons with zeatin and potassium phosphate at the concentration of 2.5 ml/l each for times (20,40,60 and 80 days after planting) was the best treatment for enhancing plant growth, leaf chemical components, productivity and quality of potato tubers.

Table (8). Effect of spraying with ZT and KPhi on N, P and K contents in tuber at harvesting time of potato plants during summer seasons of 2022/2023 and 2023/2024

Treatments	Nitrogen (%)		Phosphorus (%)		Potassium (%)	
	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season
Effect of ZT spraying						
Control (water)	2.32 c	2.37 c	0.348 d	0.352 b	2.32 d	2.38 d
1 ml/l	2.55 b	2.62 b	0.362 c	0.362 b	2.59 c	2.50 c
1.5 ml/l	2.75 a	2.69 b	0.389 b	0.389 a	2.75 b	2.69 b
2.5 ml/l	2.79 a	2.83 a	0.404 a	0.399 a	3.19 a	3.21 a
Effect of KPhi spraying						
Control (water)	2.42 c	2.37 c	0.356 d	0.356 c	2.43 c	2.49 c
1 ml/l	2.54 b	2.62 b	0.370 c	0.372 b	2.54 b	2.54 c
1.5 ml/l	2.70 a	2.73 ab	0.384 b	0.383 a	2.91 a	2.81 b
2.5 ml/l	2.74 a	2.79 a	0.393 a	0.391 a	2.97 a	2.94 a

Table (9). Effect of spraying with ZT on tuber quality at harvest time of potato plants during summer seasons of 2022/2023 and 2023/2024

Treatments	Dry matter (%)	TSS (%)	Total sugars (%)	Total carbohydrates (%)	Starch contents (%)
	2023/2024 season				
Control	16.25 d	6.31 c	4.66 c	23.51 d	13.38 d
1 ml/l	17.03 c	6.38 c	4.70 c	24.37 c	13.93 c
1.5 ml/l	19.03 b	6.80 b	5.68 b	25.53 b	15.66 b
2.5 ml/l	21.00 a	6.98 a	6.60 a	26.61 a	17.18 a
	2023/2024 season				
Control	16.50 d	6.29 b	4.56 d	23.30 d	13.51 c
1 ml/l	16.89 c	6.36 b	4.70 c	24.19 c	13.82 c
1.5 ml/l	19.45 b	6.75 a	5.63 b	25.53 b	15.87 b
2.5 ml/l	21.25 a	6.85 a	6.58 a	26.45 a	17.37 a

Table (10). Effect of spraying with KPhi on tuber quality at harvest time of potato plants during summer seasons of 2022/2023 and 2023/2024

Treatments	Dry matter (%)	TSS (%)	Total sugars (%)	Total carbohydrates (%)	Starch contents (%)
	2023/2024 season				
Control)	17.47 d	6.38 d	5.13 d	24.27 c	14.29 c
1 ml/l	18.17 c	6.56 c	5.35 c	24.90 b	14.91 b
1.5 ml/l	18.43 b	6.70 b	5.52 b	25.25 ab	15.18 b
2.5 ml/l	19.24 a	6.83 a	5.65 a	25.62 a	15.78 a
	2023/2024 season				
Control	17.76 d	6.31 c	5.09 c	23.95 c	14.52 d
1 ml/l	18.30 c	6.49 b	5.35 b	24.66 b	15.01 c
1.5 ml/l	18.79 b	6.68 a	5.44 b	25.17ab	15.34 b
2.5 ml/l	19.24 a	6.78 a	5.58a	25.68a	15.70 a

Table (11). Effect of the interaction between spraying with ZT and KPhi on N, P and K contents in tuber at harvesting time of potato plants during summer seasons of 2022/2023 and 2023/2024.

Treatments		Nitrogen (%)		Phosphorus (%)		Potassium (%)	
ZT (ml/l)	Kphi (ml/l)	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season
Control	Control	2.18 f	2.09 h	0.308 j	0.317 j	2.27 e	2.29 g
	1 ml/l	2.17 f	2.26 gh	0.341 i	0.347 i	2.31 e	2.37 g
	1.5 ml/l	2.44 e	2.53 d-f	0.373 e-g	0.371 e-h	2.35 e	2.40 fg
	2.5 ml/l	2.52 de	2.63 c-e	0.373 e-g	0.375 d-g	2.37 e	2.46 fg
1 ml/l	Control	2.36 ef	2.38 fg	0.353 hi	0.354 hi	2.37 e	2.33 g
	1 ml/l	2.54 de	2.61 c-e	0.356 g-i	0.357 g-i	2.46 e	2.41 fg
	1.5 ml/l	2.66 b-d	2.75 b-d	0.359 g-i	0.361 f-i	2.86 cd	2.71 e
	2.5 ml/l	2.66 b-d	2.76 a-d	0.380 d-f	0.378 c-f	2.67 d	2.57 ef
1.5 ml/l	Control	2.53 de	2.43 e-g	0.367 f-h	0.375 d-g	2.34 e	2.44 fg
	1 ml/l	2.68 b-d	2.76 a-d	0.390 c-e	0.388 b-e	2.42 e	2.38 g
	1.5 ml/l	2.88 a	2.77 a-c	0.395 a-d	0.393 a-d	2.98 c	2.73 de
	2.5 ml/l	2.92 a	2.81 a-c	0.406 a-c	0.403 ab	3.29 b	3.24 b
2.5 ml/l	Control	2.64 cd	2.60 c-f	0.398 a-d	0.381 c-f	2.76 d	2.91 cd
	1 ml/l	2.78 a-c	2.87 ab	0.395 b-d	0.397 a-c	2.98 c	3.03 c
	1.5 ml/l	2.85 ab	2.88 ab	0.410 ab	0.408 ab	3.47 ab	3.42 ab
	2.5 ml/l	2.89 a	2.99 a	0.413 a	0.411 a	3.56 a	3.51 a

Table (12). Effect of the interaction between spraying with ZT and KPhi on tuber quality at harvest time of potato plants during summer seasons of 2022/2023 and 2023/2024.

Treatments		Dry matter (%)	TSS (%)	Total sugars (%)	Total carbohydrates (%)	Starch contents (%)
ZT (ml/l)	Kphi (ml/l)	2023/2024 season				
Control	Control	15.07 j	6.01 j	4.36 k	22.17 h	12.36 h
	1 ml/l	16.52 hi	6.29 hi	4.68 i	23.32 g	13.52 fg
	1.5 ml/l	16.74 gh	6.39 gh	4.75 hi	24.03 fg	13.70 fg
	2.5 ml/l	16.70 gh	6.57 e-g	4.88 h	24.54 ef	13.97 f
1 ml/l	Control	16.01 i	6.12 ij	4.42 jk	24.08 fg	13.12 g
	1 ml/l	16.68 gh	6.33 h	4.58 ij	24.10 fg	13.65 fg
	1.5 ml/l	17.05 g	6.46 f-h	4.90 h	24.53 f	13.95 f
	2.5 ml/l	18.38 f	6.62 d-f	4.90 h	24.80 d-f	15.01 e
1.5 ml/l	Control	18.43 f	6.63 d-f	5.51 g	24.91 d-f	15.05 e
	1 ml/l	19.03 e	6.73 c-e	5.59 fg	25.53 c-e	15.54 de
	1.5 ml/l	18.96 e	6.85 bc	5.72 f	25.64 cd	15.98 d
	2.5 ml/l	19.71 d	7.02 ab	5.91 e	26.06 bc	16.08 cd
2.5 ml/l	Control	20.40 c	6.79 cd	6.24 d	25.92 bc	16.63 bc
	1 ml/l	20.47 bc	6.90 bc	6.55 c	26.65 ab	16.94 b
	1.5 ml/l	20.97 b	7.11 a	6.73 b	26.80 ab	17.09 b
	2.5 ml/l	22.19 a	7.14 a	6.91 a	27.09 a	18.06 a
		2023/2024 season				
Control	Control	15.70 j	6.04 i	4.25 g	21.81 i	12.87 k
	1 ml/l	16.41 i	6.19 hi	4.53 f	22.62 hi	13.44 i-k
	1.5 ml/l	16.56 i	6.43 fg	4.63 ef	23.94 f-h	13.56 ij
	2.5 ml/l	17.35 h	6.53 d-f	4.83 e	24.84 d-f	14.19 gh
1 ml/l	Control	15.86 j	6.11 hi	4.50 f	23.24 g-i	13.00 jk
	1 ml/l	16.55 i	6.29 gh	4.68 ef	24.23 e-g	13.55 ij
	1.5 ml/l	17.13 h	6.51 ef	4.80 e	24.68 ef	14.02 hi
	2.5 ml/l	18.02 g	6.56 d-f	4.85 e	24.62 e-g	14.72 fg
1.5 ml/l	Control	18.76 f	6.62 c-f	5.46 d	25.07 c-f	15.32 ef
	1 ml/l	19.42 e	6.68 c-e	5.57 d	25.34 b-f	15.84 de
	1.5 ml/l	20.11 d	6.75 cd	5.66 cd	25.48 b-e	16.40 cd
	2.5 ml/l	19.54 e	6.97 ab	5.83 c	26.25 a-d	15.94 d
2.5 ml/l	Control	20.73 c	6.48 e-g	6.18 b	25.70 a-e	16.90 bc
	1 ml/l	20.84 c	6.80 bc	6.64 a	26.48 a-c	17.24 b
	1.5 ml/l	21.38 b	7.06 a	6.69 a	26.60 ab	17.41 ab
	2.5 ml/l	22.05a	7.07 a	6.83 a	27.04 a	17.95 a

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الملخص العربى

تأثير الرش بالزياتين والبوتاسيوم فوسفيت على النمو والمحصول وجوده درنات البطاطس فى العروه الصيفيه

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شعبه بحوث الخضر – معهد بحوث البساتين- مركز البحوث الزراعيه- مصر

أجريت هذه الدراسه خلال موسمى صيف 2023/2022، 2024/2023 بمزرعه خضر خاصه بقريه بساط كريم الدين ، منطقه شربين ، محافظه الدقهليه مصر بهدف دراسة تأثير الرش الورقي بكل من الزياتين والبوتاسيوم فوسفيت بتركيز (0، 1، 1.5 ، 2.5 مللتير /لتر لكل منهما منفردا أو مجتمعة بهدف الحصول على أعلى انتاجيه وافضل مواصفات لجوده درنات البطاطس صنف كارا.

كانت أهم النتائج التي تم الحصول عليها كما يلي، أدت جميع تركيزات كل من الزياتين و البوتاسيوم فوسفيت زيادة معنوية في نمو النبات والمكونات الكيميائية للأوراق والإنتاجية وجودة درنات البطاطس مقارنة بمعامله الكونترول (بدون الزياتين وفوسفيت البوتاسيوم). ومع ذلك، فإن رش نباتات البطاطس أربع مرات بـ الزياتين والبوتاسيوم فوسفيت بتركيز 2.5 مل/لتر لكل منهما أدى للحصول على أفضل نمو (ارتفاع النباتات، وعدد الأوراق والسيقان ومساحة الورقة والوزن الجاف للأوراق/نبات، والكلوروفيل الكلي (SPAD) وإنزيم الكاتاليز في الورقة)، وتحسن فى صفات المحصول (متوسط وزن الدرنة، ومتوسط عدد الدرنات/نبات، والمحصول/نبات والمحصول الكلي/فدان) وأفضل جودة للدرنات (محتوى النيتروجين والفوسفور والبوتاسيوم، ونسبة المادة الجافة، ومحتوى المواد الصلبة العالقة والنشا). من ناحية أخرى، أظهرت معاملة الكونترول (بدون الزياتين وفوسفيت البوتاسيوم) أعلى مستويات من المالونديالدهيد (MDA)، وهو مؤشر للإجهاد التأكسدي.