Response of Two Potato Varieties to Foliar Spray with CPPU and Cobalt

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Abstract

The experiment was conducted at the Research Station of the University of Anbar, College of Agriculture, in the Albuaitha area located on longitude E43.3265 and latitude N33.4537 for the spring season of 2023, with the aim of studying the effect of foliar spraying with the growth regulator CPPU and cobalt on two potato varieties, Rudolf and Albada. The experiment was conducted according to randomized complete block design (RCBD) with the split-split arrangement with three replications. The first factors are varieties, namely (Rudolf and Albada), coded as V1 and V2, allocated to the main plots, the second is CPPU spraying in three different concentrations (0, 3, and 6 mg. L^{-1}), symbolizes it B, and allocated to the sub-plots, and the third factor is cobalt spraying with three concentrations (0, 5, and 10 mg. L^{-1}), symbolizes it C, and allocated to sub-sub-plots. The outcome showed The Rudolf cultivar is superior in terms of plant height, leaf area, dry weight, and total yield, at 49.84 cm., 120.25 cm^2 $Plant^{-1}$, 58.86 g. $Plant^{-1}$, 54.06 tons. ha^{-1}) respectively. The Albada variety was superior in chlorophyll, achieving 22.569 mg 100 g^{-1} fresh weight). Whereas, for CPPU spraying, the third concentration achieved the highest value in plant height, leaf area, chlorophyll, vegetative dry weight, and total yield, at 49.75 cm. 119.74 cm^2. $Plant^{-1}$, 22.759 mg 100 g-1 fresh weight, 57.94 g. $Plant^{-1}$, and 61.55 tons. ha^{-1} respectively. Cobalt, however, in contrast, achieved the third concentration of 10 mg. L^{-1} in the same characteristics under study, the highest values reached (47.85 cm, 116.77 cm^2. $Plant^{-1}$, 22.692 mg 100 g^{-1} fresh weight, 55.37 g. $Plant^{-1}$, 56.81 tons. ha^{-1} respectively. Whereas, the three-way interaction, the Rudolf variety with the third level of CPPU and cobalt achieved plant height, leaf area, dry weight, and total yield at their highest value, which reached 57.26 cm. $Plant^{-1}$, 126.23 cm^2. Plant, 63.69 g. $Plant^{-1}$, 68.89 tons. ha^{-1}) and Albada with CPPU and cobalt at the second concentration gave the highest result of 26.940 mg 100 g-1 fresh weight for chlorophyll.

Keywords: CPPU, Cobalt, growth traits, yield.

استجابة صنفين من البطاطا للرش الورقي بالـ CPPU والكوبلت

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المستخلص

نفذت التجربة في المحطة البحثية التابعة لكلية الزراعة جامعة الانبار في منطقة البعيثة الواقعة على خط طول E43.3265 وخط عرض N33.4537 للموسم الربيعي 2023، بهدف دراسة تأثير الرش الورقي بمنظم النمو **CPPU** والكوبلت على صنفين من البطاطا رودلوف والبادا. طبقت التجربة حسب نظام القطع المنشقة – المنشقة (Split split system) ضمن تصميم القطاعات العشوائية الكاملة RCBD بثلاث عوامل الاول الاصناف اذ تم زراعة صنفين من البطاطا هما (رودلوف والبادا) رمزه V1 وV2 اما الثاني رش CPPU بثلاث تراكيز (0 و3 و6 ملغم. لتر$^{-1}$) رمزه B والثالث الرش بالكوبلت بثلاث تراكيز (0 و5 و10ملغم. لتر$^{-1}$) رمزه C .أظهرت النتائج تفوق الصنف رودلوف في ارتفاع النبات والمساحة الورقية والوزن الجاف والحاصل الكلي اذ بلغت (49.84 سم.نبات$^{-1}$، 120.25 دسم^2.نبات، 58.86غم.نبات$^{-1}$، 54.06 طن.هـ$^{-1}$) بالتتابع .اما الصنف البادا كان متفوقا في الكلوروفيل اذ حقق(22.569 ملغم 100 غم$^{-1}$ وزن طري) اما رش CPPU اذ حقق التركيز الثالث اعلى قيمة في ارتفاع النبات والمساحة الورقية والكلوروفيل والوزن الجاف للمجموع الخضري والحاصل الكلي اذ بلغت 49.75 سم.نبات$^{-1}$، 119.74 دسم^2.نبات، 22.759 ملغم 100 غم$^{-1}$ وزن طري، 57.94غم.نبات$^{-1}$، 61.55 طن.هـ$^{-1}$بالتتابع اما الكوبلت إذ حقق التركيز الثالث 10 ملغم.لتر$^{-1}$ في نفس الصفات السابقة قيد الدراسة اعلى القيم بلغت47.85سم. نبات، 77 .116دسم.2نبات، 22.692 ملغم 100 غم$^{-1}$ وزن طري، 55.37 غم. نبات$^{-1}$، 56.81 طن. هـ$^{-1}$ ما التداخل الثلاثي حقق الصنف رودلوف مع المستوى الثالث من CPPUوالكوبلت اعلى قيمة في ارتفاع النبات والمساحة الورقية والوزن الجاف والحاصل الكلي اذ بلغت 57.26 سم. نبات$^{-1}$، 126.23 دسم^2.نبات، 63.69 غم. نبات$^{-1}$، 68.89 طن. هـ$^{-1}$واعطى البادا مع CPPU والكوبلت بالتركيز الثاني اعلى قيمة للكلوروفيل بلغت 26.940 دسم^2.نبات.

الكلمات المفتاحية: الـ CPPU، الكوبلت، صفات النمو، الحاصل

Introduction

Potato (*Solanum tuberosum* L.) is among the most productive food crops in terms of yield and protein quality per unit area and unit time, and it is one of the Solanaceae family.It is considered a crop with great potential for food security due to its ability to produce a high-quality product with high quality per unit input with a shorter crop cycle (Hassan,1999). The potato is a highly significant crop that is grown and consumed

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globally. (Batool, et al., 2020; Calıskan, et al., 2022). An estimated 359,071,407 tons of potatoes are produced annually worldwide on 16,494,810 hectares of land. (FAOSTAT, 2020). Even though potatoes are produced in vast amounts all over the world, non-biotic stressors Such as stress in plants, pests, climate change, and low production all contribute to productivity gaps.

It is one of the tuberous vegetable crops, ranking fourth in economic and consumption importance after wheat, corn, and rice. It is a primary crop in the dietary system of all world populations, being a rich source of proteins, starch, and amino acids. It serves as an affordable energy source and provides essential minerals in human nutrition. The area under cultivation in Iraq for 2021 came to a total of 24,120 hectares with a production rate of 27.98 Mega grams ha^{-1} (Central Bureau of Statistics, 2022).

Every year, many new varieties emerge worldwide, as varieties are considered one of the most important factors determining productivity (Taha, 2009). The production of varieties is generally governed by genetic and environmental interactions. Therefore, the genetic nature of the cultivated variety influences both the quantity and quality of the yield.

In order to enhance plant growth processes, various growth regulators have been employed, playing a crucial role in plant growth and yield increase (Al-Khafaji, 2014). One of these growth regulators is CPPU, also known as KT-30, which belongs to synthetic cytokinins. It exhibits effectiveness surpassing that of benzyl adenine by 10-100 times and plays a significant role in stimulating encouraging cell division and growth (Yu et al.,2001). Additionally, it works to break apical dominance and stimulate lateral bud growth (Trejo, 2023).

The cobalt-nutrient solutions are considered one of the methods used to overcome the inhibitory effects on the vegetative growth characteristics of plants. This is achieved by enhancing plant growth processes through promoting leaf growth and delaying plant aging. Cobalt inhibits the biosynthesis of ethylene, improving the movement of nutrients from the plant's roots to its green sections and vice versa (Gad & El-Metwally, 2015).

In order to understand the extent of the impact of different concentrations of foliar spraying with CPPU and cobalt, and the interaction between them, on the growth and productivity of two potato varieties, this study was conducted.

Materials and Methods

The experiment was carried out at the Albuaitha in the field. region within one of the fields of Anbar University College Agriculture at for the spring season of 2023. Potato tubers were planted for the (Rudolf) Elite variety, and imported by Nahar Al-Awrad Potato and Agricultural produced by the Dutch company IBM Supplies Trading Company, which has recently been adopted. Additionally, the (Albada) variety, a French type produced by the French company Solawest and imported by the Earth Spar Agriculture Company, was also planted. The planting took place on January 12, 2023, for the spring season, using raised bed with dimensions of (2.5 m × 0.75 cm), with a spacing of 25 cm between each plant and a depth of 10-12 cm. This was done in three replications, resulting in a total of 54 experimental units, with an average of 20 plants per experimental unit. Each unit had one raised bed, and the raised bed were 5 m long and 0.75 m wide, with a spacing of 60 cm between each bed. A drip irrigation system was installed based on the number of treatments. The experiment was conducted according to randomized complete block design (RCBD) with the split-split arrangement with three replications. The first factors is varieties allocated to the main plot, second factor is CPPU allocated to sub-plot, while.

The third factor Cobalt allocated to sub-sub-plots. After the emergence of all planted tubers (one month after planting), they were sprayed with CPPU at concentrations of (0, 3, and 6) milligrams per liter. Three days later, the second factor, cobalt, was sprayed at concentrations of (0, 5, and 10) milligrams per liter. The spraying was repeated after 15 days from each spray, with a total of 3 sprays for each factor. Crop managements operations were performed, and chemical fertilizer was added according to the following recommendations (120,240, 400) for phosphorus, nitrogen, and potassium (Al-Fadhli, 2006). The results were analyzed using the Genstat program, and the means were compared using the Least Significant Difference (L.S.D) at a 5% significance level (Al Mohammadi, & Fadel, 2012).

Measured traits:

Plant Height (cm): It was measured before uprooting when the plant reached maturity after (80) days of cultivation. This was done by measuring the tallest main stems of ten randomly selected plants from ground level to the apex. The average height was then calculated.

Leaf Area (dm^2): was measured using the Digimizer software on a computer. Ten randomly selected plants from each treatment were chosen, and the fourth leaf of each plant was measured before uprooting. The leaf area was calculated using the following equation

Leaf Area = Number of plant leaves × Leaf area (Sadik *et al*., 2011)

Chlorophyll content of leaves: in the leaves was estimated in milligrams per 100 grams of fresh weight by taking the fourth leaf from the apex of the plant (Al-Sahhaf, 1989). The leaves were washed with distilled

water to remove dust, then dried, cut into small pieces with small scissors, mixed well, and 0.2 grams of the sample were taken. It was mixed with acetone (80%), and after allowing time for chlorophyll to decompose, the absorption of light at wavelengths 663 and 645 nanometers were read using a Spectrophotometer. The total chlorophyll was calculated using the following equation: Total Chlorophyll = 20.2 D.645 + 8.02 D.663.

The total vegetative dry weight (g/plant): was measured two weeks before uprooting by harvesting the total vegetation of ten randomly selected plants from the soil contact area. They were air-dried until completely dry. Then, the dry weight of the plants was measured.

Total yield (ton/ha): It was calculated from the yield of the selected plants. The yield per experimental unit and the yield per hectare were then calculated according to the following equations:

Experimental Unit Yield = Yield per individual plant × Number of emerged plants

Total yield per hectare = Experimental Unit Yield × 10,000 m² / Experimental Unit Area

Results

Plant height (cm)

The results show that the study's parameters showed a positive behavior (Table 1). The Rudolf cultivar attained the maximum plant height, measuring 49.84 cm plant^{-1}, outperforming the Albada cultivar, which registered the minimum value at 41.38 cm plant^{-1}. As for foliar spray CPPU, the plant height increased with an increase in the level of CPPU foliar spray. Treatment B2 recorded the highest value at 49.75 cm plant^{-1}compared to Treatment B0, which recorded 41.11 cm plant^{-1}. In contrast, cobalt spray Treatment C2 recorded the highest value at 47.85 cm plant^{-1}, while Treatment C0 recorded the lowest value at 43.72 cm plant^{-1} There were no significant differences between the varieties and CPPU interactions. However, the interaction between varieties and Cobalt displayed notable variations, with Treatment V1C2 achieving the highest value at 52.40 cm plant^{-1}, and Treatment V2C0 recording the lowest value at 39.31 cm plant^{-1}.

The interaction between the study factors, CPPU and cobalt, also showed significant differences. Treatment B2C2 recorded the highest value at 52.86 cm plant^{-1}, while Treatment B0C0 recorded the lowest value at 38.65 cm plant^{-1}. The triple intervention showed significant superiority between the study factors, as treatment V1C2B2 achieved the highest average of 57.26 cm plant^{-1}, while treatment V2C0B0 recorded 33.80 cm plant-1 as the lowest value.

Table 1. The effect of varieties, CPPU foliar spray, cobalt, and their interactions on plant height (cm plant^{-1}).

Varieties V	CPPU B	Cobalt C C0	C1	C2	V*B
V1	B0	43.50	43.26	48.42	45.06
	B1	50.07	50.34	51.51	50.64
	B2	50.84	53.35	57.26	53.82
V2	B0	33.80	38.36	39.29	37.15
	B1	40.86	40.84	42.19	41.30
	B2	43.27	45.32	48.46	45.68
					Mean V
V*C	V1	48.14	48.98	52.40	49.84
	V2	39.31	41.51	43.31	41.38
					Mean B
B*C	B0	38.65	40.81	43.85	41.11
	B1	45.47	45.59	46.85	45.97
	B2	47.06	49.34	52.86	49.75
Mean C		43.72	45.25	47.85	
LSD 5%					
V*B*C	B*C	V*C	V*B	C	B	V
2.40**	1.00**	2.63*	N.S	0.60**	0.61**	3.18**

Leaf Area (dm² plant^{-1}):

The results in Table (2) showed the significant superiority of the coefficients under study. The Rudolf variety gave the highest average leaf area, reaching 120.25 dm2, outperforming the Albada variety, which recorded the lowest value at 109.87 dm² plant^{-1}. As for foliar spray with CPPU, leaf area increased with an increase in the level of CPPU foliar spray. Treatment B2 recorded the highest value at 119.74 dm² plant^{-1}compared to Treatment B0, which recorded 110.30 dm² plant^{-1}. While, cobalt spray Treatment C2 recorded the Highest rate

116.77 dm² plant^{-1}, while Treatment C0 obtained the lowest value at 113.75 dm² plant^{-1}. The interaction between varieties and CPPU showed significant differences, with Treatment V1B2 achieving the highest value at 123.83 dm² plant^{-1}, while Treatment V2B0 recorded the lowest value at 104.44 dm² plant^{-1}. The interaction between varieties and cobalt also demonstrated significant differences, with Treatment V1C2 achieving the highest value at 122.31 dm² plant^{-1}, while Treatment V2C0 recorded the lowest value at 108.34 dm² plant^{-1}. However, the interaction between the study factors CPPU and cobalt did not show significant differences between them. The three-way interaction between the study factors exhibited significant superiority, with Treatment V1C2B2 achieving the highest average at 126.23 dm² plant^{-1}, while Treatment V2C0B0 The lowest value was recorded 103.30 dm² plant^{-1}.

Table 2. The effect of varieties, CPPU foliar spray, cobalt, and their interactions on leaf area (dm^2 plant^{-1})

Varieties V	CPPU B	Cobalt C			V*B
		C0	C1	C2	
V1	B0	114.66	114.81	119.01	116.16
	B1	120.06	120.49	121.70	120.75
	B2	122.75	122.50	126.23	123.83
V2	B0	103.30	104.42	105.60	104.44
	B1	109.14	108.66	110.73	109.51
	B2	112.58	117.03	117.35	115.66
					Mean V
V*C	V1	119.16	119.27	122.31	120.25
	V2	108.34	110.04	111.23	109.87
					Mean B
B*C	B0	108.98	109.62	112.31	110.30
	B1	114.60	114.57	116.21	115.13
	B2	117.67	119.77	121.79	119.74
Mean C		113.75	114.65	116.77	
			LSD 5%		
V*B*C	B*C	V*C	V*B	C	B	V
2.03*	N.S	0.98*	1.49*	0.76**	1.26**	0.87**

Relative Chlorophyll Content in Leaves (mg/100g Fresh Weight):

The results indicate the significant superiority of the study treatments (Table 3). The Albada variety achieved the highest chlorophyll content at 22.569 (mg 100g^{-1} fresh weight), surpassing the Rudolf variety, which yielded the lowest value at 20.011 (mg 100g^{-1} fresh weight). Regarding foliar spray with CPPU, the chlorophyll content increased with an increase in the level of CPPU foliar spray. Treatment B2 recorded the highest value at 22.759 (mg 100g^{-1} fresh weight) compared to Treatment B0, which recorded 19.546 (mg 100g^{-1} fresh weight). While, cobalt spray Treatment C2 recorded the highest value at 22.692 (mg 100g^{-1} fresh weight), while Treatment C0 recorded the lowest value at 19.499 (mg 100g^{-1} fresh weight). The interaction between varieties and CPPU showed significant differences, with Treatment V2B2 achieving the highest value at 25.026 (mg 100g^{-1} fresh weight), while Treatment V1B0 recorded the lowest value at 19.397 (mg 100g^{-1} fresh weight). The interaction between varieties and cobalt also demonstrated significant differences, with Treatment V2B2 achieving the highest value at 22.942 (mg 100g^{-1} fresh weight), while Treatment V1B0 recorded the lowest value at 17.113 (mg 100g^{-1} fresh weight). However, the interaction between the study factors CPPU and cobalt did not show significant differences between them. The three-way interaction between the study factors exhibited significant superiority, with Treatment V2B2C1 achieving the highest value at 26.940 (mg 100g^{-1} fresh weight), while Treatment V1B0C0 recorded the lowest value at 15.423 (mg 100g^{-1} fresh weight).

Table 3. The effect of varieties, CPPU foliar spray, cobalt, and their interactions on Chlorophyll Content (mg 100 g^{-1} fresh weight)

Varieties V	CPPU B	Cobalt C			V*B
		C0	C1	C2	
V1	B0	15.423	20.683	22.083	19.397
	B1	17.203	20.447	22.777	20.142
	B2	18.713	20.303	22.463	20.493
V2	B0	19.207	18.520	21.357	19.694
	B1	20.780	23.173	25.003	22.986
	B2	25.670	26.940	22.467	25.026
					Mean V
V*C	V1	17.113	20.478	22.441	20.011
	V2	21.886	22.878	22.942	22.569
					Mean B
B*C	B0	17.315	19.602	21.720	19.546
	B1	18.992	21.810	23.890	21.564
	B2	22.192	23.622	22.465	22.759
Mean C		19.499	21.678	22.692	
LSD 5%					
V*B*C	B*C	V*C	V*B	C	B	V
0.84**	0.60**	0.48**	0.28**	0.40**	0.23**	0.25**

Vegetative Dry weight (g plant^{-1})

The findings demonstrated the Rudolf variety's superiority in terms of vegetative dry weight, with a value of 58.86 g plant-1, surpassing that of the Albada variety, which produced the lowest value of 49.68 g plant-1 (Table 4). As for foliar spraying with CPPU, the dry weight increased with the increase in the level of foliar spraying with CPPU. Treatment B2 recorded the highest value at 57.94 g plant^{-1} compared to Treatment B0, which recorded 50.56 g plant^{-1}. In relation to cobalt spraying, treatment C2 recorded the highest value of 55.37 g plant^{-1}.and treatment C0 recorded the lowest value of 53.55 g plant^{-1}. As for the interaction between varieties and CPPU, significant differences were recorded between them. Treatment V1B2 achieved the highest value at 62.34 g plant^{-1}, while Treatment V2B0 recorded the lowest value at 46.99 g plant^{-1}. The interaction between varieties and cobalt showed significant differences as well. Treatment V1C2 achieved the highest value at 60.45 g plant^{-1}, while Treatment V2C1 recorded the lowest value at 49.28 g plant^{-1}. The interaction between the study factors CPPU and cobalt did not achieve significant differences between them. There was a notable superiority in the three-way interaction between the research factors. with the first variety in Treatment V1B2C2 achieving the highest average, reaching 63.69 g plant^{-1}, while Treatment V2B0C0 recorded the lowest value at 46.65 g plant^{-1}.

Table 4. The effect of varieties, CPPU foliar spray, cobalt, and their interactions on vegetative dry weight (g plant^{-1})

Varieties V	CPPU B	Cobalt C			V*B
		C0	C1	C2	
V1	B0	53.30	52.65	56.42	54.12
	B1	58.40	60.75	61.23	60.13
	B2	61.16	62.17	63.69	62.34
V2	B0	46.65	46.85	47.47	46.99
	B1	48.85	47.57	49.14	48.52
	B2	52.93	53.42	54.25	53.53
					Mean V
V*C	V1	57.62	58.53	60.45	58.86
	V2	49.48	49.28	50.29	49.68
					Mean B
B*C	B0	49.98	49.75	51.95	50.56
	B1	53.63	54.16	55.18	54.32
	B2	57.05	57.80	58.97	57.94
Mean C		53.55	53.90	55.37	
LSD 5%					
V*B*C	B*C	V*C	V*B	C	B	V
1.66*	N.S	0.83*	1.19**	0.64**	0.99**	0.78**

Total yield (ton ha^{-1})

The results indicate that the Rudolf variety had the highest total yield, reaching 54.06 tons ha^{-1}, surpassing the Albada variety, which gave the lowest value of 48.34 tons ha^{-1} (Table 5). As for the foliar spray of CPPU, the total yield of the plant increased with increasing levels of CPPU spray. Treatment B2 recorded the highest value of 61.55 tons ha^{-1}, compared to treatment B0, which recorded 41.73 tons ha^{-1}. Treatment C2, which received the highest dose of cobalt, recorded the highest value of 56.81 tons ha^{-1}, while treatment C0, which received no cobalt, recorded the lowest value of 44.43 tons ha^{-1}. However, the interaction between varieties and CPPU did not show a significant difference between them. The interaction between varieties and cobalt showed a significant difference, with treatment V1C2 recording the highest value of 61.20 tons ha^{-1}, while treatment V2C0 recorded the lowest value of 42.79 tons ha^{-1}. The interaction between the two study factors, CPPU and cobalt, showed a significant difference, with treatment B2C2 recording the highest value of 65.11 tons ha^{-1}. while treatment B0C0 recorded the lowest value of 31.37 tons ha^{-1} The three-way interaction between the study factors showed a significant difference, with the first variety in treatment V1C2B2 recording the highest yield of 68.89 tons ha^{-1}, while treatment V2C0B0 recorded the lowest value of 29.61 tons ha^{-1}.

Table 5. The effect of varieties, CPPU foliar spray, cobalt, and their interactions on total yield (ton ha^{-1})

Varieties V	CPPU B	Cobalt C			V*B
		C0	C1	C2	
V1	B0	33.13	44.35	54.65	44.04
	B1	44.15	53.51	60.05	52.57
	B2	60.96	66.86	68.89	65.57
V2	B0	29.61	43.30	45.34	39.42
	B1	45.97	47.78	50.62	48.06
	B2	52.97	58.32	61.32	57.54
					Mean V
V*C	V1	49.08	54.91	61.20	54.06
	V2	42.79	49.80	52.42	48.34
					Mean B
B*C	B0	31.37	43.83	49.99	41.73
	B1	44.97	50.64	55.33	50.32
	B2	56.96	62.59	65.11	55.61
Mean C		44.43	52.35	56.81	
LSD 5%					
V*B*C	B*C	V*C	V*B	C	B	V
5.87*	4.60**	2.87*	N.S	1.84**	4.09**	3.47*

Discussion

The results of tables (1, 2, 3, 4, 5) indicated that the research parameters significantly affected the vegetative growth and yield characteristics. These results are attributed to the multiple functions of cytokinins and their derivatives, such as CPPU. The increase in plant height is attributed to the regulatory role of CPPU in promoting cell division and increasing cell size in the growth cycle (McNeilly, 2004). As for the increase in the number of main stems and leaf area, it can be traced back to the regulatory role of the cytokinin synthetic CPPU in transactions by stimulating the formation of woody tissues in buds and stems. This facilitates the transfer of nutrients that play a role in the formation of lateral buds and an increase in the number of branches (Abu Zeid, 2000; Bangerth and Gruber, 2000). The importance of CPPU is highlighted in encouraging the growth of lateral buds through the differentiation of the vascular communication zone between the lateral bud and the stem, which helps in the growth of a larger number of buds (Warner, 2001). The positive effect of cytokinins on the leaf area of the plant may be attributed to the positive cycle of cell elongation, division, and delayed aging. This leads to an increase in the area of a single leaf by promoting cell division and expansion (Lomin *et al*., 2020). reported (Zhang & Changl, 2010) CPPU possesses physiological functions of promoting cell division and expansion, breaking apical dominance and delaying senescence. The use of CPPU results in an increase in both

wet and dry plant weight, an increase in the number of stems and leaves, and an overall increase in plant height due to CPPU applications.

This is due to the increased chlorophyll content of the leaves the use of cytokinins, which leads to an increase in chlorophyll content in leaf tissues by reducing chlorophyll breakdown and delaying the aging process (Aremu et al., 2020). CPPU stimulates cell division, increases the growth of lateral branches, and enhances biological reactions within the cell. This activation works to stimulate RNA, protein, and chlorophyll synthesis, which consequently postpones aging and leaf loss. (AL-Taey, 2021). It also increases the production of nutrients, resulting in the development of a huge leaf area and notable vegetative growth. This beneficial effect is reflected in the crop's type and quantity. These results are consistent with (Zainaldeen & Rasool, 2018).

Foliar cobalt application significantly enhanced plant growth, and the reason can be attributed to the importance of cobalt in enhancing several growth processes. The addition of different levels of cobalt resulted in an increase in plant height, the number of main stems, leaf area, dry weight, and total yield. Low levels of cobalt led to maximum plant growth and productivity. These responses to low cobalt levels can be attributed to the activities of catalase and peroxidase enzymes, which were found to decrease with low cobalt concentrations and increase with higher levels. It is known that these enzymes stimulate respiration in plants, leading to optimal consumption of photosynthetic products and, consequently, a decrease in plant growth. Furthermore, the decrease in cobalt levels has a positive effect due to various metabolic and hormonal effects, while high levels lead to an increase in the activity of some enzymes such as peroxidase and catalase, resulting in increased catabolic processes instead of constructive enzyme activity (Shehata et al., 2008).

Alternatively, it could be explained by the function of cobalt, which suppresses the effects of ethylene, boosts the effectiveness of hormones that promote growth, like auxins cytokinins, , and gibberellins, and improves the availability and transport of nutrients. (Gad & Kandil, 2009). This has a positive impact on vegetative growth traits. Cobalt also works to reduce water loss from leaves through transpiration, preventing wilting and improving water consumption efficiency by creating water balance within plant cell tissues. This provides a favorable environment for plant growth. These results are consistent with findings from previous studies (Gad & Bekbayera, 2013; Kandil et al., 2013; Gad et al.2017; Ahmed et al., 2021, Al-Janabi & Aubied, 2021; Shraida & Almohammedi, 2021; Al-Dulaimi & Al-Janabi,2021; Al-Issawi & Al-Mohammedi, 2023; Musleh *et al*.,2023).

Conclusion

From this study, we conclude that the optimal level for adding CPPU is 6 mg L^{-1}, and cobalt at a concentration of 10 mg L^{-1} yielded the best results in terms of plant vegetative characteristics and overall yield. Foliar fertilization effectively meets the plant's needs rapidly, providing an economically viable outcome and reducing the cost of using soil fertilizers by directly spraying them onto the plant. We recommend conducting further studies with different levels to enhance the understanding of these effects.

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