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Response of growth and yield of potato plants grown in desert areas to spraying with proline acid and chelated iron.

Omar A. Ibrahim[1] **Abdulla A. Abdulla[1]**
Yelderem AKHOUNDNEJAD[2] **Lubna Ali Almaliki[3]**
University of Basrah- College of Agriculture- Department of Horticulture and Landscape Design.
[2]Department of Horticulture, Faculty of Agriculture, Sirnak University, Şırnak, Türkiye.
[3]Basrah agricultural Directorate.
*Corresponding Author: omar.ibrahem@uobasrah.edu.iq.

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ABSTRACT

The experiment was conducted during the fall season of the 2023-2024 agricultural season in the tomato cultivation project using modern technologies affiliated to the Basrah Agriculture Directorate in Khor Al-Zubair. With the aim of studying the effect of foliar spraying with proline acid and chelated iron at three concentrations of each (0, 100, 200) mg L^{-1} and the interaction between them on the growth and yield of potato plants of the Prowin variety. The results showed a significant superiority of spraying with proline acid at a concentration of 200 mg L^{-1} in plant height, number of aerial stems, number of leaves, leaf area, number of tubers, marketable yield, total yield, percentage of dry matter, starch and specific gravity of tubers. Plants sprayed with chelated iron at a concentration of 200 ml L^{-1} gave a significant superiority in number of aerial stems, number of leaves, leaf area, marketable yield and total yield. The interaction between the two study factors showed a significant effect on all studied traits except for the percentage of total soluble solids. Plants sprayed with proline acid and chelated iron at a concentration of 200 ml L^{-1} each gave the best values for marketable yield and the total yield reached (22.25, 24.75) tons/ha with an increase rate of (91.15, 92.29) % compared to unsprayed plants, respectively.

Keywords: *potato plants; proline; chelated iron; desert areas*.

INTRODUCTION

Potatoes (*Solanum toberosum* L.) are among the most important vegetable crops in the world in terms of cultivated area and production due to their high nutritional value [1] The cultivated area in Iraq for the year 2020 amounted to about 96,500 dunums with a total productivity of 678,400 tons and a production rate of 6,994 tons/dunum^{-1} [2].

One means of increasing production and cultivated areas for the potato crop is to exploit desert areas in southern Iraq as new areas for crop production. These areas are suitable for growing the crop because of their light sandy soil. It is also possible to plant them at different planting dates than other areas of Iraq, namely late autumn at the end of December. In order to reduce the environmental stresses that plants are exposed to in these areas, including salt, heat and water stress, some antioxidants must be used, such as proline acid, which is an amino acid that performs important vital functions, including reducing the negative impact of environmental stresses because it is an osmotic acid that allows plant cells to absorb water from the growth medium, increasing their size, maintaining the stability of membranes and proteins, sweeping free radicals, elongating cells, opening stomata, and thus increasing the process of photosynthesis [3,4,5], It is a source of organic nitrogen that quickly penetrates the plant. It plays an important role in the formation of proteins, vitamins, chloroplasts, and mitochondria. It stimulates the process of photosynthesis, the formation of carbohydrates, and increases the effectiveness of enzymes that decompose organic compounds, thereby liberating their components from elements, which enhances their readiness. Additionally, it plays a role in increasing growth rates by encouraging cell division and expansion [6]. It facilitates the processes of aerobic respiration, producing energy that aids in recovery from osmotic stress [7].

[8] Noted that spraying potato plants with proline acid at a concentration of 400 mg L^{-1} led to a significant increase in plant height, number of aerial stems, leaf area, tuber weight, marketable yield and total yield compared to the control treatment for both seasons of the experiment. It resulted in a significant increase in the percentage of starch and total soluble solids in tubers during the first season only. In a study, it found that spraying potato plants with proline acid at different concentrations (0, 0.15, 0.2) g L^{-1}, the concentration of 0.2 g L^{-1} led to a significant increase in plant height and percentage of dry matter in tubers for both seasons of the experiment compared to the control treatment, while spraying did not significantly affect the percentage of total soluble solids in tubers [9].

[10] showed that spraying potato plants with proline acid at concentrations of (50, 100, 200) mg L^{-1} overlapping with the addition of potassium fertilizer at levels of (50, 100, 200) kg K2O $feddan^{-1}$ in addition to the comparison treatment showed that plants sprayed with proline acid at a concentration of 200 mg L^{-1} and fertilized with potassium fertilizer at a level of 200 kg K2O $feddan^{-1}$ were significantly superior in plant height, number of aerial stems, number of leaves, number of tubers, tuber weight, marketable yield, total yield, and percentage of total dissolved solids in tubers compared to the comparison treatment.

Spraying plants with microelements also contributes to increasing the growth and yield of the potato plant, including iron, which is essential for growth due to its participation in many vital activities such as photosynthesis, chlorophyll formation, and enzymatic reactions [11] in addition to its role in the process of protein formation due to its contribution to reducing nitrates and forming RNA [12].

[13] observed that spraying potato plants with different concentrations of iron (0, 100, 200) mg L^{-1} led to a significant increase in plant height and leaf area in both spring and autumn seasons and in the number of tubers in the spring season only, while the concentration of 100 mg L^{-1} led to a significant increase in the yield per plant and the percentage of starch in tubers for both seasons of the experiment and in the number of tubers for the autumn season only.

[14] obtained when adding chelated iron at three levels (0, 0.5, 1) kg ha^{-1} and by two methods of foliar and ground addition, the foliar addition was significantly superior in the indicators of vegetative growth and yield, which included plant height, number of aerial stems, number of leaves, tuber weight, number of tubers, marketable yield and total yield. The effect increased significantly with increasing addition level. [15] indicated that adding chelated iron Fe. EDDHA at a concentration of 6% Fe to potato plants grown in gypsum soils at three different levels (0, 2, 4) kg ha^{-1} of soil led to a significant increase in the number of tubers, tuber weight, marketable yield and total yield.

Due to the lack of previous studies on the effect of spraying with the amino acid proline and chelated iron under the conditions of desert areas in southern Iraq, specifically in the Al-Zubair District, this study was conducted.

Materials and Methods

The experiment was conducted in the tomato cultivation project, utilising modern technologies affiliated with the Basrah Agriculture Directorate - Khor Al-Zubair, during the fall season of 2023-2024, in a sandy mixed soil. Table 1 shows the physical and chemical properties of the field soil. The study aims to determine the effect of foliar spraying with proline acid and chelated iron, as well as their interaction, on the growth and yield of the potato plant, Borin variety.

The cultivation was carried out after preparing the land by plowing, smoothing, leveling and dividing it into three lines with a length of 22.5 m, the distance between them is 1.1 m, then covering it with black plastic mulching. The tubers were planted on 12/25/2023 at a distance of 25 cm and a depth of 15 cm according to [16]. The line was divided into 9 experimental units with a length of 2.5 m. The unit contains 10 plants, so the plant density is 32,000 plants per $hectare^{-1}$. All agricultural service operations followed to produce the crop in the desert areas of southern Iraq were carried out, including fertilization, irrigation with a drip irrigation system, export, compensation and harvesting from all experimental units in a similar manner. It was implemented as a factorial experiment according to the complete randomized block design (RCBD) with two factors: the first is spraying with the amino acid proline and the second is spraying with chelated iron at three concentrations for each (0, 100, 200) mg L^{-1}, so that the number of factorial treatments is 9 treatments consisting of Possible combinations between them and with three replicates to make the number of experimental units 27 units,

Spraying treatments started after three weeks of complete tuber germination and for three sprays for each with an interval of 15 days between them with the addition of the spreading material Tween 20 to the spray solutions as a spreading material. Experimental measurements were taken at the end of the season 30/3/2024. The vegetative growth characteristics included plant height (cm), number of aerial stems, number of leaves, and leaf area (dm2) according to the weight method described by [17]. The quantitative yield included the number of tubers, tuber weight, marketable yield and total yield (ton ha-1), and the qualitative yield included the percentage of dry matter in tubers, the percentage of starch in tubers, the percentage of total soluble solids in tubers according to what was mentioned in [18], and the specific density of tubers according to what Mentioned in [1], the results were statistically analyzed using the statistical program Genstat V.10.3 (2013). The arithmetic means were compared according to the least significant difference test (LSD) at a significance level of 0.05.

Table 1 Some physical and chemical properties of field soil for the two growing seasons

Soil Properties		2023
Electrical Conductivity EC (deciemens m-1)		7.40
Reaction Level pH		7.55
Dissolved ions (mmol L-1)	Na^{+}	30.0
	Ca^{++}	20.00
	Mg^{++}	10.5
	SO_4^{--}	23.14
	Cl^{-}	65.00
	HCO_3^{-}	2.8
Ready Nitrogen	mg kg-1	170

Ready Phosphorus		7.540
Ready Potassium		185.4
Ready Silicon	mg kg-1	1.952
Organic matter (g kg-1)		5.08
Sand		830
Silt		36
Clay		134
Soil texture		Loamy sand

Results and discussion

Table (2) shows that spraying potato plants with proline acid had a significant effect on all studied vegetative growth indicators, as the spray concentration of 200 mg L^{-1} caused a significant increase in plant height compared to the concentration of 100 mg L^{-1} by an increase of 10.22% and did not differ significantly from the comparison treatment, which in turn outperformed the spray treatment at the concentration of 100 mg L^{-1} by an increase of 7.95%.

Both concentrations of 100 and 200 mg L^{-1} significantly increased the number of aerial stems compared to the control treatment, with an increase rate of (34.26, 31.17) %, respectively. The concentration of 200 mg L^{-1} also caused a significant increase in the number of leaves and leaf area compared to the control treatment and the 100 mg L-1 concentration treatment, with increase rates of 23.72% and 27.20%, respectively, for the two traits. The significant superiority when spraying with the appropriate concentration of proline acid may be attributed to its role as an osmotic regulator for the plant and a promoter of cell division and expansion processes [6], by stimulating the process of photosynthesis and reflecting this in increased vegetative growth of the plant. These results are consistent with those obtained by [10, 9, 8].

The same table shows that spraying with chelated iron had a significant effect on the number of aerial stems, number of leaves and leaf area, as the concentration of 200 mg L^{-1} was significantly higher than the control treatment and the concentration treatment of 100 mg L^{-1}, with increase rates of (39.23, 20.09%) and (14.81, 16.69) % and (35.35, 35.97) % for these characteristics, respectively, while spraying with chelated iron did not show a significant effect on plant height. The significant superiority of spraying with chelated iron at the appropriate concentration is due to its important role in participating in many vital activities in the plant, such as photosynthesis and the formation of many compounds such as chlorophyll, cytochrome and ferredoxin, which are important in the process of photosynthesis [11], which leads to an increase in the rates of photosynthesis and then an increase in the manufacture and accumulation of materials manufactured for cell division, in addition to its role in increasing plant hormones such as auxins and gibberellins. [19] This was reflected in the increase in the number of aerial stems, leaves and leaf area in the potato plant.

These results are consistent with what was obtained by [14,20] in increasing the vegetative growth of the yellow corn plant *Zea mays* L. when sprayed with iron at a concentration of 100 mg L^{-1}. The interaction between the two study factors showed a significant effect on all the traits under study. The plants sprayed with proline at a concentration of 200 mg L-1 and with chelated iron at a concentration of 200 mg L^{-1} gave the highest values for plant height, number of aerial stems, number of leaves and leaf area, reaching (47.67 cm, 7.0, 59.0, 163.0) dm^2, respectively, while the plants not sprayed with both gave the lowest values for plant height and number of aerial stems, reaching (39.67 cm, 2.67) respectively, while plants sprayed with proline at a concentration of 100 mg L^{-1} and with chelated iron at a concentration of 200 mg L^{-1} gave the lowest values for the number of leaves and leaf area, reaching (23.67, 34.2)cm^2, respectively.

Table (2). effect of foliar spraying with proline and iron and the interaction between them on some vegetative growth indicators of potato plants

Treatments			Plant height (cm)	Number of aerial stems	Number of Leaves	Leaf area (dm^2)
Average effect of proline mg.L^{-1}		0	42.22	3.56	30.89	68.0
		100	39.11	4.78	34.33	66.2
		200	43.11	4.67	38.22	86.5
LSD 0.05			1.67	0.66	3.22	18.1
Average effect of iron element mg.l^{-1}		0	41.44	3.67	33.00	65.9
		100	40.78	4.22	32.56	65.6
		200	42.22	5.11	37.89	89.2
LSD 0.05			N.S	0.66	3.22	18.1
Interaction between proline and iron	0	0	39.67	2.67	27.67	54.8
		100	42.00	3.67	34.00	78.8
		200	45.00	4.33	31.00	70.2
	100	0	40.67	5.00	45.67	93.8
		100	42.67	5.33	33.67	70.7
		200	34.00	4.00	23.67	34.2

	0	44.00	3.33	27.67	49.1
200	100	37.67	3.67	28.00	47.2
	200	47.67	7.00	59.00	163.0
LSD 0.05		2.89	1.14	5.59	35.8

Table (3) shows that spraying with proline acid had a significant effect on the components of the quantitative yield of potato plants, except for the tuber weight, as the concentration of 200 mg L^{-1} caused a significant increase in the number of tubers per plant and the marketable yield compared to the comparison treatment and the spraying treatment with a concentration of 100 mg L^{-1}, with increase rates of (18.55, 8.49)% and (21.73, 16.83)% for both traits, respectively, while the spraying concentration of 200 mg L^{-1} and the comparison treatment caused a significant decrease in the unmarketable yield compared to the spraying treatment with a concentration of 100 mg L^{-1}, with decrease rates of (32.8, 35.2)%, respectively. Regarding the total yield, plants sprayed with proline acid at a concentration of 200 mg L-1 showed a significant increase, with a rate of 19.85%, while the spraying treatment with a concentration of 100 mg L^{-1} did not differ. 1 liter morally about them.

Table (3). The effect of foliar spraying with proline and iron and the interaction between them on some components of the quantitative yield of potato plants

Treatments			Number of tubers	Tuber weight (g)	Market yield t.ha-1	Unmarketable crop t.ha-1	Total yield t.ha-1
Average effect of proline mg.L^{-1}		0	7.22	68.9	14.08	1.62	15.71
		100	7.89	65.8	14.67	2.50	17.18
		200	8.56	70.8	17.14	1.68	18.83
LSD 0.05			0.78	N.S	2.24	0.31	2.05
Average effect of iron element mg. L^{-1}		0	7.67	67.4	14.73	1.93	16.66
		100	7.89	67.5	14.88	1.43	16.32
		200	8.11	70.4	16.29	2.44	18.73
LSD 0.05			N.S	N.S	1.24	0.31	2.05
Interaction between proline and iron	0	0	6.33	64.7	11.64	1.18	12.83
		100	7.67	79.9	17.13	1.63	18.77
		200	7.67	62.0	13.48	2.04	15.53
	100	0	9.00	62.5	16.45	3.00	19.46
		100	8.00	64.6	14.44	1.72	16.16
		200	6.67	70.2	13.13	2.77	15.91
	200	0	7.67	75.1	16.10	1.59	17.70
		100	8.00	58.1	13.08	0.96	14.04
		200	10.00	79.1	22.25	2.50	24.75
LSD 0.05			1.36	14.1	2.58	0.53	3.88

The moral superiority of proline acid when sprayed at the appropriate concentration in the components of the quantitative yield may be attributed to its effective role as a defense against environmental stresses, as it sweeps away free radicals and rids cells of their harmful effects, which maintains the photosynthesis process and prevents the oxidation of lipids in the cell membrane [7], in addition to its role in encouraging the process of cell division and expansion [6], which contributes to increasing the number of tubers of the plant, the marketable yield, and the total yield. These results are consistent with [10,8]. The same table shows that spraying with chelated iron had a significant effect on the marketable and non-marketable yield and the total yield, as the concentration of 200 mg L^{-1} caused a significant increase compared to the comparison treatment and the concentration of 100 mg L^{-1}, with increase rates of (10.59, 9.47) % and (13.02, 15.37) %, respectively. As for the non-marketable yield, it decreased significantly when spraying with the concentration of 100 mg L^{-1} compared to the comparison treatment and the concentration of 200 mg L^{-1}, with decrease rates of (25.90, 41.39) %, respectively.

The moral superiority of spraying with chelated iron at the appropriate concentration of 200 mg L^{-1} in the marketable yield and the total yield is due to the role of chelated iron in increasing vegetative growth indicators (Table 2) as a result of its participation in many vital processes in the plant, including the process of photosynthesis and increasing its products [1], which was positively reflected in increasing the yield. These results are consistent with what was obtained by 14,20,15].

The interaction between the two study factors showed a significant effect on all components of the studied quantitative yield, as plants sprayed with proline at a concentration of 200 mg L^{-1} and chelated iron at 200 mg L^{-1} gave the highest values in the number of tubers, marketable yield and total yield amounting to (10.0, 22.25 tons' ha^{-1}, 24.75 tons ha^{-1}) respectively. In contrast, plants not sprayed with proline and chelated iron at a concentration of 100 mg/L yielded the highest tuber weight, reaching 79.9 g. As for the yield not suitable for marketing, it appeared in plants sprayed with proline at a concentration of 100 mg L^{-1} and not sprayed with chelated iron, amounting to 3.0 tons ha^{-1}. As for the lowest values for the number of tubers, marketable yield and total yield, it appeared in plants not sprayed with both of them amounting to (6.33 tubers, 11.64 t ha^{-1}, 12.83) t ha^{-1} respectively, and the lowest tuber weight and unmarketable yield appeared in plants sprayed with proline at a concentration of 200 mg L^{-1} and chelated iron at a concentration of 100 mg L^{-1} (58.1 g, 0.96) t ha^{-1} respectively.

The results of Table 4 indicate that spraying with proline acid had a significant effect on the characteristics of the qualitative yield of potato tubers. Spraying with a concentration of 200 mg L^{-1} led to a significant increase in the percentage of dry matter, starch percentage and specific density of tubers compared to the control treatment and the concentration treatment of 100 mg L^{-1}, with increase rates of (20.79, 16.33)% and (30.14, 23.27)% for all characteristics, respectively, while the control treatment and the concentration of 200 mg L^{-1} were significantly superior compared to the concentration treatment of 100 mg L^{-1} in the percentage of total dissolved solids, with an increase rate of (13.24, 8.79)%, respectively.

The significant superiority in the qualitative characteristics of tubers when sprayed with the appropriate concentration of proline acid may be due to its role in increasing vegetative growth indicators (Table 2), which contributed to increasing the products of the photosynthesis process and the efficiency of their transfer and conversion to tubers, which was positively reflected in increasing these qualitative characteristics. These results are consistent with what was obtained by [9,8].

Table (4). Effect of foliar spraying with proline and iron and the interaction between them on some characteristics of the qualitative yield of potato plants

Treatments			Dry matter content of tubers %	Starch content in tubers %	Specific gravity in tubers	Total dissolved solids (TSS)%
Average effect of proline mg.L^{-1}		0	14.33	8.79	1.052	3.93
		100	14.88	9.28	1.054	3.41
		200	17.31	11.44	1.066	3.71
LSD 0.05			0.62	0.55	0.003	0.29
Average effect of iron element mg. L^{-1}		0	15.99	10.26	1.060	3.77
		100	15.05	9.42	1.055	3.54
		200	15.49	9.81	1.057	3.73
LSD 0.05			0.62	0.55	0.004	N.S
Interaction between proline and iron	0	0	15.23	9.58	1.056	3.96
		100	14.49	8.93	1.053	3.73
		200	13.28	7.85	1.047	4.10
	100	0	14.69	9.10	1.054	3.50
		100	14.76	9.17	1.054	3.13
		200	15.20	9.56	1.056	3.60
	200	0	18.06	12.10	1.069	3.86
		100	15.89	10.17	1.059	3.76
		200	17.98	12.03	1.068	3.50
LSD 0.05			1.08	0.96	0.05	N.S

The same table shows that spraying with chelated iron had a significant effect on the qualitative characteristics of tubers, except for the percentage of total dissolved solids, as the concentration of 100 mg L^{-1} caused a significant decrease in the percentage of dry matter and starch in tubers compared to the control treatment, with decrease rates of (5.87, 8.18) %, respectively. The spraying treatment with a concentration of 200 mg L^{-1} did not differ significantly from it. In contrast, both concentrations of 100 and 200 mg L-1 caused a significant decrease in the specific density of tubers compared to the control treatment, with decrease rates of 0.47% and 0.28%, respectively.

The significant decrease in the quality characteristics of tubers when sprayed with chelated iron may be due to the effect of plants on the decrease in the leaf area of the plant (Table 2), which reduced the efficiency of the photosynthesis process due to the low efficiency of the leaves in their use of light and the low ability of the plant to make maximum use of light energy and convert it into dry matter [21], and consequently the low production of starch, amino acids and proteins.

The interaction between the two study factors showed a significant effect on all qualitative characteristics of tubers except for the percentage of total dissolved solids. Plants sprayed with proline acid at a concentration of 100 mg L^{-1} and not sprayed with chelated iron gave the highest values for the percentage of dry matter, starch percentage and specific gravity of tubers, reaching (18.06%, 12.10%, 1.096), respectively, while plants not sprayed with proline and sprayed with chelated iron at a concentration of 200 mg L^{-1} gave the lowest values for these characteristics, reaching (13.28%, 7.55%, 1.047), respectively.

Conculotions

We conclude from this study that in order to achieve good growth and yield of potato plants of the Bruin variety planted in the desert areas of southern Iraq in the late autumn season at the end of December, it is necessary to spray the plants with proline acid at a concentration of 200 mg L^{-1} and chelated iron at a concentration of 200 mg L^{-1}, with three sprays each, the first after (3) weeks of complete germination and the other with an interval of 15 days between one spray and the next.

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أستجابة نمو وحاصل نباتات البطاطا المزروعة في المناطق الصحراوية للرش بحامض البرولين والحديد المخلبي.

عمر عامر ابراهيم[1] **عبد الله عبد العزيز عبد الله[1]**
يلدرم اكهوهوندرجم[2] **لبنى علي المالكي[3]**
[1]قسم البستنة وهندسة الحدائق ،كلية الزراعة ،جامعة البصرة،العراق
[2]قسم البستنة، كلية الزراعة، جامعة شرناق، شرناق، تركيا
[3] مديرية زراعة البصرة.

الخلاصة

اجريت التجربة خلال العروة الخريفية للموسم الزراعي *2023 - 2024* في مشروع زراعة الطماطه بالتقانات الحديثة التابع الى مديرية زراعة البصرة في خور الزبير بهدف دراسة تأثير الرش الورقي بحامض البرولين والحديد المخلبي بثلاثة تراكيز لكل منهما (*0*، *100*، *200*) ملغم لتر*-1* والتداخل بينهما في النمو والحاصل لنباتات البطاطا صنف بروين.

أظهرت النتائج تفوق معنوي للرش بحامض البرولين بتركيز *200* ملغم لتر*-1* في ارتفاع النبات وعدد السيقان الهوائية وعدد الاوراق والمساحة الورقية وعدد الدرنات والحاصل الصالح للتسويق والحاصل الكلي ونسبة المادة الجافة والنشا والكثافة النوعية للدرنات، واعطت النباتات المرشوشة بالحديد المخلبي بتركيز *200* مل لتر*-1* تفوقاً معنوياً في عدد السيقان الهوائية وعدد الاوراق والمساحة الورقية والحاصل الصالح للتسويق والحاصل الكلي.

أظهر التداخل بين عاملي الدراسة تأثيراً معنوياً في جميع الصفات المدروسة باستثناء النسبة المئوية للمواد الصبة الذائبة الكلية فأعطت النباتات المرشوشة بحامض البرولين والحديد المخلبي بتركيز *200* مل لتر*-1* لكل منهما افضل القيم للحاصل الصالح للتسويق والحاصل الكلي بلغ (*22.25*، *24.75*) طن هكتار وبنسبة زيادة (*91.15*، *92.29*) % مقارنة بالنباتات غير المرشوشة وعلى التوالي.

الكلمات المفتاحية: نباتات البطاطا، حامض البرولين، الحديد المخلبي، المناطق الصحراوية.