Effect of foliar spraying with roselle extract and proline acid on the growth and yield of okra *Abelmoschus esculenus* L. grown under salt stress conditions

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Abstract

The study was conducted at the Agricultural Research Station of the College of Agriculture, University of Basrah, in the Karmat Ali area during the spring of 2023. To study the effect of foliar spraying with Roselle extract (0, 10 and 20 g L^{-1}) and with different concentrations of proline acid (0, 100 and 200 mg L^{-1})and the interaction between them on the growth and specific yield of okra plants, Al-Khanisriya variety. The results showed that spraying with 10 g L^{-1} of Roselle extract caused a significant increase in plant height, number of branches, number of leaves, leaf area and fresh and dry weights of the plant. Spraying with 100 mg L^{-1} of proline acid caused a significant increase in weight, number of branches, number of leaves, leaf area, fresh and dry weights of the plant, carotene content of the leaves, and fruit length. The interaction between the two factors showed a significant effect on most of the studied traits, as plants sprayed with 10 g L^{-1} of Roselle extract and 100 mg L^{-1} of proline acid gave the highest values of plant height, number of branches, number of leaves, leaf area and fresh and dry weights of the plant, which reached (48.0 cm, 9.0 branches, 51.0 leaves, 76.9 dm 233.0 gm,45.70 g) respectively.

Keywords: Okra plant; foliar spray; Roselle extract; proline acid; vegetative growth; specific yield.

Introduction

Okra (*Abelmoschus esculenus* L.Monch) is an important summer vegetable crop in Iraq and the world. It belongs to the Malvaceae family. Its green pods are eaten cooked and have a high nutritional value, as every 100 grams of it contains 81.6 grams of water, 2.1 grams of protein, 8.2 grams of carbohydrates, 1.7 grams of fiber, 0.2 grams of fat, 84 mg of calcium, 90 mg of phosphorus, 1.2 mg of iron, 185 micrograms of carotene, 0.08 mg of riboflavin, 47 mg of ascorbic acid, 0.4 mg of thiamine, 0.6 mg of niacin and provides 36 calories [1]. The cultivated area in Iraq for the year 2020 amounted to 64,000 dunums with a productivity of 93,700 tons. With a production rate of 1.461 tons per dunum [2]. Many studies have shown that the use of plant extracts has an encouraging effect on the growth and yield of the plant because

they are natural materials that contain the necessary nutrients that enhance plant growth, improve quality, increase yield, and contribute to reducing dependence on chemical fertilizers and pesticides. They also have great benefits in sustainable agriculture as they maintain environmental health [3]. Among these extracts is the extract of the *Hibiscus sabdariffa* L. (Roselle) plant, which is of great importance because its angiosperm leaves contain many active compounds, including glycosides, coumarins, and organic acids such as malic, citric, hexic, and ascorbic acid, and di- and polyphenols. These compounds play a major role in stimulating vital processes such as photosynthesis, respiration, and chlorophyll formation, encouraging cell division and tissue growth, regulating and activating plant hormones, and increasing the production of carbohydrates to be transported in turn from their manufacturing sites to their production sites [4]. It also contains high amounts of the element Potassium [5] works to reduce the effect of irrigation water salinity on plant growth [6].

[7] noted that spraying sweet pepper plants with a Roselle extract at a concentration of (10.5) g L^{-1} in addition to the comparison treatment caused both concentrations to significantly increase plant height, number of branches and fruit weight for both seasons, while the concentration of 4 g L^{-1} caused a significant increase in leaf area in the first season and fruit length in the second season. [8] obtained that when broad bean plants were sprayed with two concentrations of Roselle extract (10.5) g L^{-1} in addition to the comparison treatment, the concentration of 10 g L-1 significantly exceeded the increase in plant height, leaf area, fresh and dry weights of the plant, leaf chlorophyll content of Spad and pod weight of the plant. [9] indicated that spraying tomato plants with Roselle extract at two concentrations (4.2) g L^{-1} in addition to the comparison treatment significantly exceeded both concentrations in leaf area, dry weight of the vegetative group and leaf chlorophyll content. Spad compared to the control treatment and for both seasons of the experiment, [10] showed that spraying eggplant plants with the extract of 2 g L^{-1} of Roselle caused a significant increase in plant height, leaf area, fruit weight, and the percentage of total dissolved solids in it compared to the control treatment.

One of the means that can lead to improving growth and production is the plant's resistance to various environmental stresses such as salt, heat and drought stress by using some organic compounds, including proline acid, which is an amino acid that performs important vital functions and reduces the negative impact of environmental stresses because it is an osmotic buffer that allows plant cells to absorb water from the growth medium, increasing their size and maintaining the stability of membranes and proteins and improving free radicals, cell elongation and opening of stomata, and thus increasing the process of photosynthesis [11,12]. (Dawood *et al* (2014) obtained when spraying proline acid on fava bean plants *Vicia Faba* at concentrations of (50, 25, 0) millimoles. The concentration of 25 millimoles caused a significant increase in plant height, number of leaves, fresh and dry weight of the plant, and leaf content of chlorophyll b, a and carotene compared to the other two concentrations. [14] noted when spraying fava bean plants At different concentrations of proline (100, 50.0) mg

$L^{-1,}$ both concentrations caused a significant increase in plant height, number of leaves, fresh and dry weights of leaves, total chlorophyll content (Spad), pod length and width, and weight of 100 fresh seeds compared to the control treatment for both seasons of the experiment. [15]indicated that spraying okra plants with proline at a concentration of 2.5 mmol led to a significant increase in stem length, fresh and dry weights of the vegetative group, number of leaves, and their chlorophyll content (Spad) compared to the control treatment. [16] concluded that when okra plants were sprayed with different concentrations of proline (80, 40.0) mg L^{-1}, the concentration of 80 mg L^{-1} significantly increased the number of branches, leaf area, and plant yield compared to the control treatment. Due to the lack of studies on the effect of foliar spraying and proline acid under the conditions of Basra city, which suffers from many environmental stresses, this study was conducted.

Materials and Methods

The experiment was carried out in the fields of the Agricultural Research Station belonging to the College of Agriculture, University of Basrah, in the Karmat Ali area during the agricultural season 2023 in a sandy mixture of soil (Table 1). The land was plowed perpendicularly, smoothed, leveled, fertilized with animal manure, and decomposed cow waste. It was divided into three holes with a length of 27 m and a distance of 80 cm between them. Okra seeds of the Khnaisriya variety were planted on 3/1/2023 using 3 seeds in the hole and with a distance of 25 cm between one hole and another. After germination was complete, they were thinned to one plant. Each hole was considered a single sector, and 9 foliar fertilization treatments were distributed randomly. The length of the experimental unit was 3 m, containing 12 plants. The treatments included foliar spraying with the extract of the Roselle (0, 10, 20) g L^{-1} and with different concentrations of proline acid (0,100,200) mg L^{-1} and the interaction between them in the growth and specific yield of okra plants of the variety. The spraying was done three times, the first one after one month of full germination and with a two-week interval between each spray, with the addition of Tween 20 as a spreading agent. The following vegetative growth indicators were studied: plant height and stem diameter (cm), number of branches and number of leaves, fresh and dry weight of the vegetative mass (g), leaf area (dm2) according to the method described by [17]. Total chlorophyll pigment in green leaves was estimated according to the method described by [18] and carotene pigment according to [19]. The fruit weight (g), length and diameter of the fruit (cm), and the percentage of total dissolved solids in it were measured according to what was mentioned in [20] The results were analyzed statistically according to the design followed, complete randomized sectors with three replicates and according to the statistical program Genstat and compared Arithmetic means of the coefficients according to the least significant difference (LSD) test at a significance level of 0.05 [21].

Table (1): Some chemical and physical characteristics of the study soil

Attribute		Value	Unit
pH		7.7	
ECE		5.22	ds m-¹
Available Phosphorus		38.8	mg kg-¹
Total Nitrogen		0.23	g kg-¹
Ready Potassium		101.20	mg kg-¹
solube positive ions	Calcium	16.5	millimoles l-¹
	Magnesium	11	
	Sodium	21.3	
	Bicarbonates	13.6	
	Sulfates	18.5	
	Chlorides	28.0	
Soil separators	Sand	593	G kg-1
	Silt	271.5	
	Clay	135.5	
Soil texture		sandy loam	

Results and Discussion

Table (2) shows that the spray treatments with the extract of Roselle had a significant effect on all the characteristics under study, as the concentration of 10 g L^{-1} was significantly superior compared to the comparison treatment and the concentration of 20 g L^{-1} in increasing the plant height by (9.26, 7.54)%, the number of branches (55.82, 96.33)%, the number of leaves (52.44, 45.33)%, and the leaf area (34.01, 15.98)%, respectively, while the concentration of 20 g L^{-1} was significantly superior in increasing the stem diameter compared to the comparison treatment and the concentration of 10 g L^{-1} by an increase of (5.18, 10.93)%, and in turn the concentration of 10 g L^{-1} was significantly superior compared to the comparison treatment by an increase of 5.46%. The significant increase in spraying with the extract of Roselle when using the appropriate concentration may be attributed to the mineral elements and growth regulators it contains. And on reducing and non-reducing sugars, which play a role in activating enzymes specific to various growth activities, including photosynthesis, and thus increasing the production of nutrients in the leaves, which is positively reflected in increasing vegetative growth indicators [4] These results are consistent with what was obtained by [7,8,9,15].

The same table shows that spraying with proline acid had a significant effect on all the studied traits except for the stem, as the concentration of 100 mg L^{-1} was significantly higher than the comparison treatment, and the concentration of 200 mg L^{-1} in increasing the number of branches by an increased rate of (39.84, 63.36) % and leaf area by (24.75, 77.46) %, respectively. While the opposite happened for the trait of plant height, as the concentration of 200 mg L^{-1} caused a significant decrease compared to the comparison treatment by a decrease rate of 5.22%, and the spraying treatment with the concentration of 100 mg L^{-1} did not differ significantly from them. The significant increase when spraying with the appropriate concentration of proline

acid is due to its positive role in improving the process of photosynthesis and respiration and delaying wilting and aging of the plant [22], and this result is consistent with what was obtained by [16] in okra. As for the interaction between the two study factors, it showed a significant effect on all the traits under study, as the plants sprayed with 10 gm L^{-1} of Roselle extract and 100 mg L^{-1} of proline acid gave the highest values for plant height, number of branches, number of leaves, and leaf area, which amounted to (48.0 cm, 9.0 branches, 51.0 leaves, 76.9 dm, respectively).

Table (2): The effect of foliar spraying with Roselle extract, proline acid, and their interaction on some vegetative growth indicators of okra plants.

Treatments			Plant height cm	Stem diameter cm	Number of branche	Number of leaves	Leaves area dm^2
Average effect of Roselle extract gL^{-1}		0	42.67	1.28	3.00	23.78	39.4
		10	45.89	1.35	5.89	34.56	45.7
		20	42.00	1.42	3.78	22.67	34.1
LSD 0.05			1.47	0.05	0.44	3.63	5.7
Proline acid effect extract mg.L		0	44.68	1.36	3.33	23.67	28.4
		100	43.33	1.37	5.44	33.11	50.4
		200	42.44	1.33	3.89	24.22	40.4
LSD 0.05			1.47	N.S	0.44	3.63	5.7
The effect of the interaction between Roselle and proline	0	0	41.67	1.18	1.67	15.67	14.0
		100	41.67	1.38	2.67	24.67	40.0
		200	44.67	1.29	4.67	31.00	46.1
	10	0	45.67	1.37	4.67	32.67	27.4
		100	48.00	1.37	9.00	51.00	76.9
		200	44.00	1.33	4.00	20.00	32.7
	20	0	47.00	1.53	3.67	22.67	43.7
		100	40.33	1.37	4.67	23.67	34.2
		200	38.67	1.37	4.67	21.67	24.4
LSD 0.05			2.55	0.08	3.00	6.29	10.0

The plants sprayed with the extract of Roselle at a concentration of 10 g L^{-1} and not sprayed with proline gave the largest stem diameter of 1.53 cm, while the lowest values for stem diameter, number of branches, number of leaves and leaf area in plants not sprayed with both compounds reached (1.18 cm, 1.67 branches, 15.67 leaves, 14.0 dm^2), respectively, while the lowest plant height reached 38.67 cm and was in plants sprayed with the extract of Roselle at a concentration of 20 g L^{-1} and proline at a concentration of 200 mg L^{-1}. Table (3) shows that foliar spraying with the extract of Roselle had a significant effect on the fresh and dry weights of the plant and did not significantly affect the leaf content of total chlorophyll and carotene pigments, as the concentration of 10 g L^{-1} caused a significant increase in the fresh and dry weights of the plant compared to the control treatment and the concentration of 20 g L^{-1} and an increased rate of (40.22, 37.19) % and (28.50, 33.34) %, respectively. The significant increase may be attributed to the role of the extract in increasing plant height, stem di-

ameter, number of branches and leaves, and leaf area (Table 2), which was positively reflected in increasing the fresh and dry weights of the plant. These results are consistent with [8,9].

The same table shows that spraying with proline acid had a significant effect on all the studied traits except for the total chlorophyll content of the leaves, as the concentration of 100 mg L^{-1} caused a significant increase in the fresh weight of the plant compared to the control treatment, with an increase rate of 16.22%. The concentration of 200 mg L^{-1} did not differ significantly from them. Both concentrations of 100 and 200 mg L^{-1} caused a significant increase in the dry weight of the plant compared to the control treatment, with an increase rate of (22.22, 22.38)%, respectively. As for the content of the leaves of carotene pigment, the concentration of 100 mg L^{-1} significantly exceeded the control treatment and the concentration of 200 mg L^{-1}, with an increase rate of (13.97, 27.07)%, respectively. The increase may be attributed to the role of proline acid in increasing the number of leaves and branches and leaf area (Table 2), which was positively reflected in the increase in the fresh and dry weights for plants.

Table (3): The effect of foliar spraying with Roselle extract, proline acid, and their interaction on Fresh and dry weights of plants and leaf content of photosynthesis.

Treatments			Fresh weight of plant (g)	Dry weight of plant (g)	Total chlorophyl in leaves mg.g-1	Carotene in leaves mg 100 g^{-1} fresh
Average effect of Roselle extract gL^{-1}		0	139.0	26.54	6.23	0.1209
		10	190.7	35.39	5.05	0.1060
		20	136.0	27.54	5.19	0.1122
LSD 0.05			18.9	3.18	N.S	N.S
Proline acid effect extract mgL^{-1}		0	144.2	25.96	5.23	0.1001
		100	167.6	31.77	6.07	0.1272
		200	154.8	31.73	5.17	0.1116
LSD 0.05			18.9	3.18	N.S	0.0150
The effect of the interaction between Roselle and proline	0	0	90.4	18.35	6.27	0.1067
		100	138.6	25.68	6.88	0.1310
		200	190.7	35.59	5.54	0.1250
	10	0	183.8	31.66	4.69	0.0930
		100	233.0	45.70	5.27	0.1257
		200	155.3	28.81	5.21	0.0993
	20	0	158.4	27.87	4.75	0.1007
		100	13104	23.93	6.07	0.1240
		200	118.3	30.81	4.77	0.1110
LSD 0.05			32.7	5.51	N.S	N.S

The increase in carotene pigment may be due to the role of proline acid in reducing the harmful effect of salinity and increased the leaf area and the content of carotene pigment in the leaves [11,12]. These results are consistent with [13,14,15]. As for the interaction between the two study factors, it showed a significant effect on the fresh and dry weights of the plant only, as the plants sprayed with the extract of Roselle at a concentration of 10 g L^{-1} and proline at a concentration of 100 mg L^{-1} gave the

highest values for these two traits, reaching (45.70, 233.0) g, respectively, while the plants not sprayed with both compounds gave the lowest values, reaching (18.35, 90.4) g, respectively.

Table (4) indicates that spraying with the extract of Roselle had a significant effect on the length and diameter of the pod, but did not significantly affect the weight of the pod and the percentage of total dissolved solids in the pods, as the concentration of 10 g L^{-1} caused a significant decrease in the length of the pod compared to the comparison treatment, with a decrease rate of 6.86%. The concentration treatment of 20 g L^{-1} did not differ significantly from them, while both concentrations of 10 and 20 g L^{-1} caused a significant decrease in the diameter of the pod compared to the comparison treatment, with a decrease rate of (4.23, 3.38)%, respectively. The decrease may be attributed to the role of the extract in increasing the vegetative group (Table 3.2) as a result of increasing the elongation and division of cells, increasing the efficiency of the photosynthesis process, increasing the manufacture of food materials and their transfer from their manufacturing sites to their storage sites, and increasing the number of pods. Due to the increased competition between them, this led to a decrease in their length and diameter. It appears from the same table that the spraying treatments with proline acid had a significant effect on all characteristics. Under the study, the concentration of 200 mg L^{-1} caused a significant increase in the pod weight compared to the control treatment and the concentration of 100 mg L^{-1}, with an increased rate of (15.72, 6.55)%, respectively.

Table (4): The effect of foliar spraying with Roselle extract, proline acid, and their interaction on some components of the okra plant

Treatments			Pod weight	Pod length (cm)	Pod diameter (cm)	Total dissolve solids percentage of pods
Average effect of Roselle extract gL^{-1}		0	3.57	4.66	1.18	1.95
		10	3.56	4.34	1.14	2.13
		20	3.79	4.58	1.13	2.05
LSD 0.05			N.S	0.12	0.02	N.S
Proline acid effect extract mgL^{-1}		0	3.66	4.16	1.21	2.18
		100	3.37	4.82	1.11	1.92
		200	3.90	4.60	1.12	2.03
LSD 0.05			0.23	012	0.02	0.19
The effect of the interaction between Roselle and proline	0	0	3.41	4.10	1.26	2.10
		100	3.35	5.15	1.14	1.76
		200	3.97	4.73	1.15	2.00
	10	0	5.31	4.16	1.23	2.40
		100	2.99	4.40	1.04	1.90
		200	4.18	4.48	1.15	2.10
	20	0	4.06	4.22	1.16	2.06
		100	3.79	4.92	1.16	2.10
		200	3.54	4.60	1.06	2.00

LSD 0.05	0.41	0.21	0.04	N.S

While both concentrations caused a significant increase in pod length compared to the comparison treatment and an increase rate of (10.57, 15.86) %, respectively, while both concentrations caused a significant decrease in pod diameter compared to the comparison treatment and a decrease rate of (7.43, 8.26) %, respectively. The concentration of 100 mg L^{-1} caused a significant decrease in the percentage of total dissolved solids in pods compared to the comparison treatment and a decrease rate of 11.92%, and the concentration of 200 mg L^{-1} did not differ significantly from it. The significant increase in pod weight and length may be due to the role of proline in increasing vegetative growth (Table 3.2) and increasing carotene pigment, which was positively reflected in pod weight and length. This result is consistent with [14] in fava beans. As for the decrease in pod diameter and percentage of total dissolved solids in pods when spraying with proline, it may be due to its role in increased vegetative growth and increased number of pods, which caused a decrease due to competition between them for the nutrients manufactured in the leaves and their transfer to the pods.

As for the interaction between the two study factors, it showed a significant effect on the pod weight, length and diameter, as the plants sprayed with the extract of Roselle at a concentration of 10 g L^{-1} and not sprayed with proline gave the highest pod weight of 5.31 g, while the plants not sprayed with the extract of Roselle and sprayed with proline at a concentration of 100 mg L^{-1} gave the longest pod length of 5.15 cm, while the plants not sprayed with both compounds gave the largest pod diameter of 1.26 cm and the smallest pod length of 4.10 cm, while the plants sprayed with the extract of Roselle at a concentration of 10 g L^{-1} and with proline at a concentration of 100 mg L^{-1} gave the lowest pod weight and diameter of 2.99 g and 1.04 cm, consecutive.

Can conclude from this study that to reduce the environmental stresses that okra plants are exposed to during the spring season in Basrah Governorate and to increase the growth and yield of plants, they must be sprayed with 10 gL^{-1} of Roselle extract and 100 mgL^{-1} of proline.

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