

Effect of Cultivars, Irrigation Water Sources, Salicylic Acid and Nano Nitrogen on Growth and Chemical Content of *Hibiscus sabdariffa*

Hoor Yasser. Abd Al-Baqi ^{1*}, Khalid .A.S .Al-Hamdani ²

¹Department of Biology, College of Education for Pure science, Samarra University, Samarra, Iraq

² College of Agriculture, Samarra University, Samarra, Iraq

*Corresponding author's email: EDUHM250048@stu.uosamarra.edu.iq

[Email addresses of coauthors: Khalid.a.s@uosamarra.edu.iq](mailto:Khalid.a.s@uosamarra.edu.iq)

Abstract

The study aimed to evaluate the effects of different water source, and spraying with salicylic acid and nano-nitrogen on morphological and physiological characteristics of the Two genotype of Roselle, red and black. **Methods:** Two genetic variations of the genotype (red and black) were studied. Two types of water were used to determine stress treatment (well and river water), also, four treatments were used on *H. sabdariffa* plant including (No treatment, 40% salicylic acid, 80% salicylic acid, 2% nano-nitrogen, and 4% nano-nitrogen all were diluted in 3 liters of water). The effect of treatments on plant height, stem diameter, nitrogen, potassium, Phosphorus and carbohydrate contents *Hibiscus sabdariffa* L. **Results:** Results: The results showed that irrigation water source (W), foliar spray treatments (T), genotype (V), and their interactions significantly ($P \leq 0.05$) affected vegetative growth and leaf chemical composition of Roselle. These were found to be higher in the red genotype (V2) compared to the black genotype (V1) with regard to leaf nitrogen (1.89%), phosphorus (0.54%), potassium (1.87%) and carbohydrates (0.59%). Well water irrigation (W2) resulted in significantly higher values than river water (W1) for all the parameters measured such as plant height (186.84 cm), leaf N (1.98%), leaf P (0.52 %), leaf K (2.01 %), and leaf carbohydrate (0.56 %). 2% nano-nitrogen (T3) gave the highest plant height (218.58 cm) and stem diameter (2.24 cm) while 4% nano-nitrogen (T4) gave the highest leaf nitrogen (2.02%) and carbohydrate content (0.55%). 80% salicylic acid (T2) resulted in the highest K (1.92%) and also with T3 resulted in the highest phosphorus in leaves (0.51%). The best combination seemed to be the red genotype (V2), along with well water (W2) and the treatment of nano-nitrogen or salicylic acid (T3 and T4, respectively), with the highest plant height (241.00 cm) achieved by V2 $\times$ W2 $\times$ T3 and the highest leaf nitrogen (2.75%) and carbohydrate content (0.68%) by V2 $\times$ W2 $\times$ T4. The study overall suggests that better genotype, water quality and foliar nutrient application significantly improves plant growth and nutrient status.

Keywords: salicylic acid, Phosphorus, potassium, carbohydrate., nano-nitrogen.

Introduction

Hibiscus sabdariffa is ordinarily termed Roselle. It comes from the family Malvaceae emanating from countries in the tropics and subtropics and grown and utilized extensively in several countries in the world including Africa. The plant has been utilized for cold and hot beverages and, a popular drink is made from its calyx [1].

The seeds of the Roselle are characterized by their small size and flattened shape. They also contain good proportions of protein and fat, making them an important source of nutrients. These seeds are used as animal feed, in addition to being incorporated into some food industries and in the preparation of spices [2]. However, their most common use is in the production of beverages, as they can be roasted, ground, and used as a

coffee substitute. A vegetable oil extracted from these seeds is also used in the manufacture of cosmetics and skincare products due to its moisturizing and antioxidant properties [3].

Roselle is a rich source of bioactive molecules, which are compounds produced by plants and possess important pharmacological properties, such as antioxidant, anti-inflammatory, and anticancer properties[4]. Among the most prominent of these compounds are polyphenols, flavonoids, flavanols, and flavanols, both in their simple and polymerized forms, along with phytosterols, saponins, lectins, glycosides, essential oils, and anthocyanins [5].

Nutritionally, carbohydrates constitute the largest proportion of the plant's components, followed by crude fiber and then ash content. The plant also contains important minerals such as potassium, magnesium, iron, copper, and calcium, in addition to amino acids and vitamins like niacin and riboflavin [6]. Studies also indicate that extracts of

Material and Methods

Study design

This experiment was carried out in plastic pots and designed as split-split plot under Randomized Complete Block Design (RCBD) with three replications. Irrigation water sources (river water and well water) were laid out in the main plots, kajrat genotypes (red and black) in subplots, and the five different foliar spray treatments (control, 2 salicylic acid (SA) concentrations, 2 nano-nitrogen (nano-N) concentrations) were randomly assigned to the sub-subplots. Thus 20 treatment combinations were set up (2 irrigation water sources $\times$ 2 genotypes $\times$ 5 foliar). The treatment combinations were replicated three times, thus 60 experimental units and each experimental unit contained two seedlings. The foliar

Roselle possess anti-proliferative properties against cancer cells, such as leukemia, making them useful in preventive and therapeutic medicine [7].

Due to its numerous physiological roles in plant growth and development, salicylic acid has been added to the list of known plant hormones, such as Auxins, Gibberellins, and Cytokinins. It contributes to various physiological processes that enhance and complement vital plant functions and has diverse effects on tolerance to biological and salt stress[8].

Nanoferrites affect key plant morphological traits such as plant height and number of leaves, demonstrating their superiority in promoting vegetative growth and increasing crop yields compared to conventional fertilizers [9]. This is supported by evidence showing that nanoparticles enhance various growth characteristics by influencing gene expression, which regulates biological pathways that improve both vegetative and reproductive growth[10]

spraying process was carried out in the early morning in three batches, the first on 1/6/2025 after germination, the second after 21 days from the first spraying process, and the third spraying date was 21 days after the second spraying date according to the source [11].

Investigated factors

Factor 1: Two genetic variations of the genotype *Kajrat* (red and black) were studied. These variations are designated by the symbols (red = V1, black = V2).

Factor 2: Addition of salicylic acid and nano-nitrogen.

Treatment 1 (T0) (Control): No treatment.

Treatment 2 (T1): 40% salicylic acid diluted in 3 liters of water(T1 = 40 x 3 ml/L)

Treatment 3 (T2): 80% salicylic acid diluted in 3 liters of water(T2 = 80 x 3 ml/L)

Treatment 4 (T3): Spraying 2% nano-nitrogen diluted in 3 liters of water(T3 = 2 x 3 = 6 ml/L)

Treatment 5 (T4): Spraying 4% nano-nitrogen diluted in 3 liters of water. (T4 = 4 x 3 = 12 mm/L)

Factor3: Irrigation Water Source

Two types of water were used to determine stress treatment:

1. River water treatment, designated W1
2. Well water treatment, designated W2

The two irrigation water samples (river water and well water) were analyzed in the laboratories of the Department of Environment and Water at the College of Agriculture, Tikrit University. Table (1) shows the analysis of the two water samples.

Table (1) Chemical analysis of water samples (river water – well water)

Well water	River water	Chemical parameters
7.8	7.2	Ph
3.43	0.18	Ec
108	101	HCO ₃
5.42	1.29	So ₄
1.25	0.2	P
1.67	0.89	K
1.45	0.32	Ca
12.37	4.97	Na
6.42	2.12	Mg
2.21	1.42	CL

Studied parameters

The studied parameters included vegetative growth characteristics(plant height and stem diameter) and some biochemical traits(leaf nitrogen, potassium, phosphorous and carbohydrates).

Vegetative Growth Traits

Measurements of the vegetative growth traits below were taken before and after treatment.

Plant Height (cm)

The average plant height for each treatment was calculated using a measuring tape from the soil surface to the top of the plant before and after treatment, according to the equation:

Rate of Increase in Plant Height = Plant Height After Treatment – Plant Height Before Treatment

Stem Diameter (mm)

Stem diameter measurements were taken in the plants in each experimental unit before and after treatment using an electronic caliper (Vernier).

Determination of Leaf Mineral Content:

Newly grown and mature leaves were collected by their petioles. The collected leaves were washed with water to remove dirt, then thoroughly dried in a pneumatic oven at 70°C until a constant weight was reached. They were then ground using an electric grinder and passed through a sieve with a 2.0 mm opening. A wet digestion process was performed using sulfuric and perchloric acids, as described in Al-Sahaf [12]. The digestion process and chemical properties were measured at the Consulting Office of the College of Agriculture, Tikrit University. The elements were then determined as follows:

1- Nitrogen (N): Nitrogen was determined using a Microkjeldahl apparatus.

2- Phosphorus (P): Phosphorus was determined using ammonium molybdate and ascorbic acid with a UV-VIS Spectrophotometer, model 80D, at a wavelength of 662 nm.

3- Potassium (K%): Potassium was determined using a flame photometer, as mentioned in Al-Sahaf [12]

4- Carbohydrates in leaves (%):

The Joslyn method [13] was used to estimate the total carbohydrate content in the leaves. 0.2 g of the dry sample powder was ground with 10 ml of distilled water and centrifuged for 15 minutes at 3000 rpm. After one minute, the clear solution was collected in a volumetric flask, and 1 ml was taken. This was then brought up to 10 ml by adding distilled water. Another 1 ml of the diluted solution was taken and mixed with 1 ml of the previously prepared 5% phenol solution and 5 ml of concentrated sulfuric acid. The absorbance of the solutions was measured using a spectrophotometer at a wavelength of 460 nm, and the percentage of total carbohydrates was calculated using the following equation: Total Carbohydrate % = Dilutions × Concentration / Sample Weight × 100

Statistical Analysis

Data were analysed using a split-split plot design in a Randomized Complete Block Design (RCBD) with the aid of SAS software. Irrigation water source was the main-plot treatment, genotype the subplot treatment and foliar treatments the sub-subplot treatment. Duncan's Multiple Range Test (DMRT) was used to compare the means at 5% probability level ($P \leq 0.05$)

Results

As shown in the results presented in Table (1), the difference between the various genetic variations, irrigation water sources, treatments and their interactions

were significant for plant height. The mean plant height of black variation of kajrat (V2) was 185.25 cm, which was significantly higher than red variation (V1) of kajrat with mean plant height of 169.65 cm.

As far as irrigation water quality is concerned, the plant growth in the case of well water treatment (W2) was significantly greater than the river water treatment (W1) with mean plant height 186.84 cm against 168.05 cm for the latter. Plant height was also significantly different between the treatments. The plant height with 2% nano-nitrogen (T3) was 218.58 cm, which was the highest among the other treatments, 80% salicylic acid (T2) and 40% salicylic acid (T1), which were 193.42 and 189.08 cm, respectively. The control treatment (T0) recorded the lowest value (134.72 cm) while the other treatments recorded higher values

It was observed that the black variation (V2) that was treated with 2% nano-nitrogen (T3) had the greatest plant height of 222.17 cm, followed by the same variation treated with 80% salicylic acid (T2) which recorded 208.67 cm. The lowest value was recorded for the red variation (V1) under the control treatment (T0) with the value of 96.93 cm. This means that each treatment was effective with a different variation in terms of their genetics.

The interaction of irrigation water source and treatments ($W \times T$) indicated that well water (W2) and 2% nano-nitrogen treatment (T3) resulted in the highest plant height (231.67 cm) while the lowest plant height occurred in water from the river (W1) and the control treatment (T0) (79.43 cm). There were also significant differences for the triple interaction of genetic variation x irrigation water source x treatments ($V \times W \times T$). The black variation (V2) with well water (W2) and 2% nano-nitrogen (T3) gave the

maximum plant height (241.00 cm), followed by the same variation in 80% salicylic acid (T2) which had a height of 232.67 cm. The control treatment (T0), on

the other hand, had the lowest value (1.53 cm) under the red variation (V1) and with river water (W1).

Table 1. Effect of variety (V), irrigation water source (W), foliar spray treatments (T), and their interactions on plant height of Roselle

Types	Water source	Treatments					V x W
		T0	T1	T2	T3	T4	
Black(V1)	W ₁	157.33 d	187.33 cd	123.67a	189.00b-d	168.00d	165.07 b
	W ₂	187.67cd	166.33d	232.67a	241.00 a	43.49 f	174.23 b
Red (V2)	W ₁	1.53 g	178.00 d	226.33 ab	222.00 a-c	167.00 d	199.47a
	W ₂	192.33 b-d	224.67 a-c	191.00 b-d	222.33 a-c	167.00 d	199.47 a
Varity effect							
V x T	V ₁	172.50 c	176.83 bc	178.17 bc	215.00 a	105.75 d	169.65 b
	V ₂	96.93 d	201.33 cd	208.67 a	222.17 a	197.17 a-c	185.25 a
Water source							
W x T	W1	79.43 f	182.67 cd	175.00d	205.50 bc	195.67 b-d	168.05 a
	W2	190.00b-d	195.50 b-d	211.83 ab	231.67 bc	105.25 c	186.84a
Treatments effect		134.72 d	189.08 b	193.42 b	218.58 a	151.46 c	

The mean stem diameter of the black variation (V1) of Kajrat was significantly cm and 1.89 cm respectively. In terms of water source for irrigation, river water treatment (W1) had significantly higher mean stem diameter of 2.03 cm than well water treatment (W2) which had a mean stem diameter of 1.98 cm.

The treatments also had a significant effect on stem diameter. The spraying of 2% nano-nitrogen (T3) had the highest stem diameter value (2.24 cm) followed by 8% salicylic acid (T2) (2.16 cm) while the

greater than that of red variation (V2), which was 2.03 control treatment (T0) was 2.07 cm. The lowest stem diameter (1.82 cm) was observed with spraying 4% nano-nitrogen diluted in 3 liters of water (T4).

The interaction of genetic variation and treatments (V × T) indicated that the black variation (V1) had the maximum stem diameter of 2.53 cm followed closely by the same variation treated with 80% salicylic acid (T2) recording 2.49 cm stem diameter. The lowest value (1.75 cm) was

obtained for the red variation (V2) under 4% nano-nitrogen treatment (T4) as compared to the other treatments. The interaction effect of irrigation water source and treatments (W × T) showed that well water (W2) under 80% salicylic acid treatment (T2) gave the highest stem diameter of 2.43 cm whereas the lowest stem diameter (1.65 cm) was obtained with well water (W2) and under 4% nano-nitrogen treatment (T4).

The triple combination of genetic variation, irrigation water source and diameter (1.36 cm).

treatments (V × W × T) also had significant differences. The most stem diameter (3.13cm) was found in black variation (V1) irrigated with well water (W2) and treated with 80% salicylic acid (T2) followed by the black variation (V1) irrigated with river water (W1) and treated with 2% nano-nitrogen (T3) at 2.64cm. On the other hand, the black variation (V1), with well water (W2) and 4% nano-nitrogen treatment (T4) had the lowest stem

Table(2): Effect of variety (V), irrigation water source (W), foliar spray treatments (T), and their interactions on stem diameter of Roselle

Types	Water source	Treatments					V x W
		T0	T1	T2	T3	T4	
Black(V1)	W ₁	1.77 i	2.13 e	1.93 gh	2.64 b	2.44 c	2.18 b
	W ₂	2.34 d	1.95 g	3.13 a	2.34 d	1.36 k	2.23 a
Red (V2)	W ₁	1.97 g	1.51 j	1.87 h	2.04 f	1.55 j	1.79 d
	W ₂	2.19 e	2.17 e	1.72 i	1.93 gh	1.49 g	1.99 c
Varity effect							
V x T	V ₁	2.06 b	2.04 b	2.53 a	2.49 a	1.90 d	2.03 a
	V ₂	2.08 b	1.84 e	1.79 f	1.98 gh	1.75 g	1.89 b
Water source							
W x T	W1	1.87 g	1.82 h	1.89 g	2.49 a	1.90 d	2.03 a
	W2	2.27 c	2.06 e	2.43 a	2.14 d	1.65 i	1.98 b
Treatments effect		2.07 c	1.94 d	2.16 b	2.24 a	1.82 e	

The mean leaf nitrogen content of the red variation of kajrat (V2) was significantly higher than the black variation (V1) 1.89% and 1.49% respectively. In the case of

water source for irrigation, the mean nitrogen level of the well water treatment (W2) was significantly higher than the river water treatment (W1) (1.98% vs.

1.40%). The leaf N content was significantly influenced by the treatments. The spraying of 4% of nano-nitrogen (T4) showed the highest nitrogen content (2.02%) and the spraying of 2% of nano-nitrogen (T3) showed an average nitrogen content of (1.88%). The control treatment (T0) had the lowest value (1.40%).

The results of interaction of genetic variation and treatments ($V \times T$) indicated that the red variation (V2) treated with 4% (T4) nano-nitrogen had the highest leaf nitrogen content (2.19%), followed by the same variation treated with 2% (T3) nano-nitrogen (2.11%). On the other hand, the black variation (V1) had the smallest value (1.29%) in the control (T0) and 40% salicylic acid (T1) treatments. The interaction between irrigation water source and treatments ($W \times T$) showed that the well water (W2) when irrigated with 4% nano-nitrogen (T4) had the highest nitrogen concentration of 2.55%, followed

by the well water (W2) treated at 2% nano-nitrogen (T3) at 2.31%. The lowest value (1.17%) occurred with the river water (W1) in the control treatment (T0), however.

There were also significant differences under the triple interaction, that is, genetic variation $\times$ irrigation water source $\times$ treatments ($V \times W \times T$). The red variation (V2) under well water (W2) and 4% nano-nitrogen (T4) treatment had the highest leaf nitrogen content (2.75%), followed by the same variation under 2% nano-nitrogen (T3) treatment (2.51%). The lowest value (1.08%) was recorded in the black variation (V1) with river water (W1) for the control treatment (T0), as opposed to the other treatments. The results of this study show that the interaction of irrigation water quality, foliar application treatments and genotype significantly influences the N content of the leaves.

Table (3) Effect of variety (V), irrigation water source (W), foliar spray treatments (T), and their interactions on leaves nitrogen content of Roselle

Types	Water source	Treatments					V x W
		T0	T1	T2	T3	T4	
Black(V1)	W ₁	1.08 p	1.21 o	1.25 n	1.20 o	1.31 m	1.21 d
	W ₂	1.51 k	1.36 l	1.59 j	2.11 d	2.35 c	1.78 b
Red (V2)	W ₁	1.25 n	1.59 j	1.76 g	1.71 h	1.64 i	1.59 c
	W ₂	1.77 g	1.98 e	1.90 f	2.51 b	2.75 a	2.18 a
Varity effect							
V x T	V ₁	1.29 h	1.29 h	1.42 g	1.66 e	1.83 c	1.49 b
	V ₂	1.51 f	1.79 d	1.83 c	2.11 b	2.19 a	1.89 a
Water source							
W x T	W1	1.17 j	1.40 i	1.51 f	1.46 h	1.48 g	1.40 b
	W2	1.64 e	1.67 d	1.75 c	2.31 b	2.55 a	1.98 a
Treatments effect		1.40 e	1.54 d	1.63 c	1.88 b	2.02 a	

As seen from the results presented in Table (4), there were significant differences between the various treatments and in the interaction among them and the genetic variation and the irrigation water source in leaf phosphorus content. The average of phosphorus content in the red and black variation of Kajrat (V2 and V1, respectively) was 0.54% and 0.39%, respectively, which is significantly higher in the red variation. Well water treatment (W2) also yielded a higher level of phosphorus content (0.52%) as compared to river water treatment (W1) with a phosphorus content of 0.42%. The sprayings significantly affected the level of phosphorus content with 2% nano-nitrogen (T3) and 80% salicylic acid (T2) having the highest (0.51%) and the control

treatment (T0) having the lowest level (0.38%). The red variation (V2) under the treatment (T2) with 80% salicylic acid showed the highest value of phosphorus content (0.62%) while the lowest value (0.32%) was obtained for black variation (V1) under control treatment (T0).

The combination of water source and treatments showed the highest concentration of phosphorus in well water (W2) + T2 or T3 (0.53%), and the lowest concentration in river water W1T0 (0.28%). The triple interaction ($V \times W \times T$) revealed that the highest phosphorus (0.66%) value was obtained for red variation (V2), under well water (W2) and 80% salicylic acid treatment (T2), while the lowest (0.27%) was obtained under river water (W1), and the control (T0).

Table (4) Effect of variety (V), irrigation water source (W), foliar spray treatments (T), and their interactions on leaf phosphorus content of Roselle

Types	Water source	Treatments					V x W
		T0	T1	T2	T3	T4	
Black(V1)	W ₁	0.28 l	0.37 i-k	0.39 h-j	0.41 gh	0.39 hi	0.37 d
	W ₂	0.36 jk	0.38 h-j	0.40 g-i	0.46 f	0.44 fg	0.41 c
Red (V2)	W ₁	0.27 l	0.35 k	0.57 ed	0.58 c-e	0.55 e	0.46 b
	W ₂	0.61 bc	0.64 ab	0.66 a	0.60 cd	0.60 b-d	0.62 a
Variety effect							
V x T	V ₁	0.32 g	0.38 f	0.39 ef	0.44 d	0.42 de	0.39 b
	V ₂	0.44 d	0.49 c	0.62 a	0.59 b	0.58 b	0.54 a
Water source							
W x T	W1	0.28 f	0.36 e	0.48 cd	0.49 bc	0.47 d	0.42 b
	W2	0.48 cd	0.51 ab	0.53 a	0.53 a	0.52 ab	0.52 a
Treatments effect		0.38 d	0.43 c	0.51 ab	0.51 a	0.49 b	

From the results presented in Table (5) it was observed that significant differences

exist between the various genetic variations, irrigation water sources,

treatments and their interactions for potassium content in the leaves. The red variation (V2) of rosella had significantly higher potassium content (1.87%) than the black variation (V1) of kajrat which had a potassium content of 1.71%. As far as the potassium content of the irrigation water source is concerned, W2 (well water treatment) was significantly higher at 2.01% while W1 (river water treatment) was 1.57%. Potassium content was also significantly influenced by the treatments. The highest value 1.92% was observed in treatment T2 (80% salicylic acid), followed by treatment T1, T3 and T4 and the lowest value 1.42% in the control treatment T0.

The interaction between cultivar variation and treatments indicated that the highest

level of potassium content (2.03%) was obtained in the red variation (V2) and the lowest level was found in black variation (V1) with the control treatment (T0). Water source and treatments interaction showed that well water (W2) with T1 treatment had the highest concentration of potassium at 2.28%, while river water (W1) and the control treatment (T0) had the lowest level of 1.29%. The triple interaction treatment V2W2T1 gave the highest potassium percentage, reaching (2.45%), followed by T2 (2.40%). The black variation (V1) with river water (W1) under the control treatment (T0) recorded the lowest value (1.28%), while the highest value (1.34%) was obtained in the other treatments.

Table (5) Effect of variety (V), irrigation water source (W), foliar spray treatments (T), and their interactions on leaf potasium content of Roselle

Types	Water source	Treatments					V x W
		T0	T1	T2	T3	T4	
Black(V1)	W ₁	1.28 l	1.43 k	1.66 h	1.72 g	1.78 ef	1.57 c
	W ₂	1.44 k	2.07 c	2.08 c	1.82 de	1.87 ed	1.85 b
Red (V2)	W ₁	1.32 k	1.60 i	1.53 j	1.62 hi	1.73 fg	1.56 c
	W ₂	1.64 hi	2.45 a	2.40 a	2.29 b	1.91 b	2.17 a
Varity effect							
V x T	V ₁	1.36 g	1.75 e	1.87 c	1.77 e	1.82 a	1.71 b
	V ₂	1.48 f	2.03 a	1.97 b	1.96 b	1.91 c	1.87 a
Water source							
W x T	W1	1.29 h	1.52 g	1.59 f	1.67 e	1.75 d	1.57 b
	W2	1.54 g	2.28 a	2.24 a	2.06 b	1.98 c	2.01 a
Treatments effect		1.42 c	1.89 b	1.92 a	1.86 b	1.87 b	

The results in Table (6) indicated that the level of leaf carbohydrates due to cultivar variation, irrigation water sources, salicylic

acid and nano-nitrogen and their interaction was significantly different. This is because the red variation of kajrat (V2)

has significantly more carbohydrate content (0.59%) than the black variety (V1) which had a carbohydrate content of 0.42%. As regards water source, well water treatment (W2) had significantly higher content of carbohydrate (0.56%) than river water treatment (W1) had (0.45%). The result of treatment T4 (4% nano-nitrogen) was the highest (0.56%), followed by treatment T3 (2% nano-nitrogen) (0.55%) and treatment T0 (control) (0.43%).

The interaction treatment V2T4 resulted in highest value for carbohydrates (0.66%) and the V1T0 given the lowest value

(0.37%). The interaction between water source and treatments showed that well water (W2) and T3 and T4 had the highest values for carbohydrate content (0.59%), while river water (W1) and the control treatment (T0) had the lowest values for carbohydrate content (0.33%). Triple interaction ($V \times W \times T$) indicated that the highest value of carbohydrates content (0.68%) was observed in the red variation (V2) with the treatment (T4) and irrigated with well water (W2); the lowest value of carbohydrates content (0.33%) was observed in the black colour variation (V1) with the treatment (T0) and irrigated with river water (W1).

Table (6) Effect of variety (V), irrigation water source (W), foliar spray treatments (T), and their interactions on leaves carbohydrate content of Roselle

Types	Water source	Treatments					V x W
		T0	T1	T2	T3	T4	
Black(V1)	W ₁	0.33 j	0.36 h-j	0.39 fg	0.37 g-j	0.41 f-h	0.37 d
	W ₂	0.40 f-h	0.46 de	0.44 ef	0.53 c	0.51 cd	0.47 c
Red (V2)	W ₁	0.34 ij	0.43 e-g	0.59 b	0.64 ab	0.64 ab	0.53 b
	W ₂	0.64 ab	0.64 ab	0.63 ab	0.65 a	0.68 a	0.65 a
Varity effect							
V x T	V ₁	0.37 f	0.41 e	0.41 e	0.45 d	0.46 d	0.42 b
	V ₂	0.49 d	0.53 c	0.61 b	0.65 ab	0.66 a	0.59 a
Water source							
W x T	W1	0.33 f	0.39 e	0.49 d	0.51 cd	0.52 b-d	0.45 b
	W2	0.52 b-d	0.55 b	0.54 bc	0.59 a	0.59 a	0.56 a
Treatments effect		1.42 c	0.43 d	0.47 c	0.51 b	0.55 a	

Discussion

The results of the present study showed that foliar application treatments significantly affected the morphological and chemical characteristics of roselle The

present study agree with Ilodibia et al.,[14], Richardson et al., [15], Sanou et al.,[16] indicated that roselle genotypes may differ significantly in morphology, mineral composition, phytochemical

content, and physiological performance. The higher values of leaf nitrogen, phosphorus, potassium, and carbohydrate content recorded in the red genotype may be related to stronger vegetative growth, higher photosynthetic activity, and more efficient translocation of assimilates. Similar findings were reported by Richardson et al. [15], who found that nutrient accumulation in *H. sabdariffa* varied among genotypes and production systems. Another study by Sanou et al. [16] reported that genetic variation in roselle influences biochemical and phytochemical traits.

The results also showed that irrigation with well water improved most growth and chemical traits compared with river water. This may be due to differences in water quality, salinity level, pH, and dissolved ions [17].

Salinity stress is considered one of the major environmental factors limiting plant productivity. In roselle, salinity stress have been shown to reduce plant growth, chlorophyll content, and biochemical performance [18,19].

The improvement observed under well-water irrigation, which has lower salinity or more suitable ionic composition, plants can maintain better physiological balance, absorb nutrients more efficiently, and accumulate higher carbohydrate levels. This result agrees with Abou-Sreya et al. [19], who reported that roselle growth and physiological parameters are negatively affected by increasing salinity levels, while stress-mitigation treatments can improve plant performance.

Foliar application treatments, especially nano-nitrogen and salicylic acid, showed clear positive effects on vegetative growth and nutrient accumulation compared with the control treatment. Nano-fertilizers are known to increase nutrient availability,

reduce nutrient losses, and improve plant growth, and stress tolerance [20,21].

Nitrogen is an essential macronutrient involved in chlorophyll formation, protein synthesis, enzyme activation, and photosynthetic processes. Therefore, the increase in plant height, stem diameter, and leaf nitrogen content following nano-nitrogen application may be attributed to improved nitrogen availability and more efficient assimilation. Fertilization studies on roselle have confirmed that nitrogen application can significantly improve growth, yield, and nutrient uptake compared with untreated plants [18].

The increased carbohydrate content recorded in plants treated with nano-nitrogen and salicylic acid may be attributed to improved photosynthetic efficiency and better nutrient balance. Salicylic acid is involved in regulating several physiological processes [22,23]. Under stress conditions, salicylic acid can reduce oxidative damage by enhancing antioxidant enzyme activity and improving plant water status [23,24]. In roselle, salicylic acid has also been reported to improve physiological and phytochemical traits under water scarcity or stress conditions [25].

The combined of nano-nitrogen and salicylic acid, increase in N, P, and K contents likely contributed to higher carbohydrate synthesis and accumulation. This agrees with El-Saadony et al., [20], Suraimia et al., [18] that demonstrated the role of balanced nutrition and foliar treatments in improving plant metabolism

Conclusion

Interaction effects revealed that the treatment combinations of red variation (V2), well water (W2) and nano-nitrogen or salicylic acid produced the best performance on *Hibiscus sabdariffa* L. plant, whereas the treatment combinations of black variation (V1), river water (W1)

and control treatments resulted in the lowest performance overall. The study overall suggests that better genotype, water quality and foliar nutrient application significantly improves plant growth and nutrient status.

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