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Article

Effect of Glutamic Acid Foliar Application Concentrations on Growth and Yield Traits of Two Genotypes of Roselle (*Hibiscus Sabdariffa* L.)

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ABSTRACT

A field experiment was conducted during the summer season of 2024 in the fields of a farmer in the Koldara area, affiliated with Altun Kupri sub-district in Dibis district, located in northern Kirkuk Governorate (35°44'45.5"E, 44°07'21.5"N), approximately 23 km north of Kirkuk city. The objective was to evaluate the response of two roselle genotypes—Local Egyptian and Red Heet—to four foliar application concentrations of glutamic acid (0, 50, 100, and 150 mg L^{-1}) on growth and yield traits. Statistical analysis showed the superiority of the Red Heet genotype in all growth and yield parameters. Foliar application of glutamic acid at 150 mg L^{-1} significantly enhanced most studied traits. The interaction of Red Heet with 150 mg L^{-1} gave the best results in terms of number of branches (32.95 branches $plant^{-1}$), dry weight of sepals leaves (73.28 g), number of capsules (129.95 capsules $plant^{-1}$), dry weight of capsules (256.77 g), number of seeds per capsule (25.77), and seed yield (949.11 kg ha^{-1}).

INTRODUCTION

Roselle (*Hibiscus sabdariffa* L.), a member of the *Malvaceae* family, is a summer annual plant of significant medicinal, nutritional, and industrial value. It is widely cultivated in hot regions such as Africa, Indonesia, and India [1]. Roselle grows rapidly, reaching heights of 2.5–3 meters, begins flowering in August, and continues until early October. It is known by various names across the Arab world and is commonly referred to in Iraq as "Karkadeh tea".

Roselle is used globally in the treatment of various organic and microbial diseases due to its effectiveness, affordability, and safety compared to chemically synthesized pharmaceutical drugs [2]. Its secondary uses are also significant; for instance, its red pigment is used industrially as a natural food coloring, as a refreshing beverage, or in the production of jams, food preservatives, and confectioneries [3].

Genotypic variation significantly affects plant growth, with some genotypes exhibiting superior

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morphological traits due to their efficiency in nutrient absorption and response to environmental conditions, ultimately improving both yield quantity and quality [4]. Glutamic acid functions as an osmotic regulator in guard cells and enhances stomatal opening and closure. It also contributes to chlorophyll synthesis and is a key component in photosynthetic carbon metabolism [5].

Foliar application of glutamic acid increases its concentration in plant tissues, thereby improving growth indicators [6]. Reported [7] that foliar spraying of black cumin with glutamic acid at concentrations of 50 and 100 mg L^{-1} significantly increased plant height, with a 20.57% increase when the concentration was raised from 0 to 100 mg L^{-1}.

Given the medical and nutritional importance of roselle, this study aimed to compare two genotypes in terms of productivity, determine the optimal concentration of glutamic acid for yield improvement, and identify the best interaction between genotype and glutamic acid concentration for enhancing vegetative growth and yield components.

MATERIALS AND METHODS

A field experiment was conducted during the summer agricultural season of 2024 in the fields of a farmer located in the Koldara area, affiliated with the Altun Kupri sub-district, Dibis district, in northern Kirkuk Governorate. The soil of the experimental site was classified as sandy loam, and the study aimed to investigate the effect of different concentrations of glutamic acid foliar application on the growth and yield traits of two roselle genotypes.

Table 1. Physicochemical properties of the soil at 30 cm depth.

Measurement unit	Unit
pH	7.65
Electrical conductivity (EC, $dS.m^{-1}$)	1.48
Available nitrogen ($mg.kg^{-1}$)	133.5
Available potassium ($mg.kg^{-1}$)	6.66
Available phosphorus ($mg.kg^{-1}$)	10.13
Sand (%)	54.20
Silt (%)	29.30
Clay (%)	16.50
Soil texture	Sandy loam

Experimental Design and Treatments

The experiment was laid out using a randomized complete block design (RCBD) with three replicates and two factors:

Factor A (Genotype):

1. Local Egyptian
2. Red Heet

Factor B (Glutamic Acid Foliar Spray Concentrations):

1. Control (sprayed with distilled water only)
2. 50 mg L^{-1}
3. 100 mg L^{-1}
4. 150 mg L^{-1}

Foliar applications were conducted at the 4-leaf stage when plant height reached approximately 10 cm, early in the morning to minimize evaporation losses.

Field Management

Standard soil preparation practices, including plowing, leveling, and smoothing, were performed before sowing. The field was divided into 24 experimental units (plots), each measuring 3 × 3 m². Seeds were sown on ridges spaced 75 cm apart, with 40 cm between planting hills. Three seeds were placed per hill and later thinned to one healthy seedling per hill once the plants reached 10–15 cm in height.

Fertilizers were applied as follows:

- Nitrogen fertilizer (urea 46% N) was applied at a rate of 120 kg N ha^{-1} in two splits: the first at sowing and the second 45 days post-emergence [8].
- Phosphorus fertilizer (triple superphosphate 46% P_2O_5) was applied once before sowing at a rate of 50 kg $P_2O_5.ha^{-1}$ [9].

Irrigation and other cultural practices were carried out as needed according to recommended agronomic guidelines [10].

Measured Traits and Methods of Measurement

The following traits were evaluated based on measurements taken from 10 central plants in each experimental unit, while border plants were excluded to minimize edge effects:

- Plant height (cm): Measured from the soil surface to the apical meristem (growing tip) using a measuring tape.
- Number of main branches per plant: Counted manually for each selected plant by recording all primary branches emerging from the main stem.
- Fresh weight of sepals leaves (g): Sepals leaves were harvested and immediately weighed using a precision digital scale to determine the fresh biomass per plant.
- Dry weight of sepals leaves (g): After fresh weight recording, sepals leaves were oven-dried at 70 °C for 72 hours until a constant weight was achieved, then weighed using an analytical balance.
- Number of capsules per plant: The total number of mature capsules per plant was counted manually from the 10 selected plants.
- Fresh weight of capsules (g): Capsules from each plant were freshly harvested and weighed using a digital balance to determine total fresh yield per plant.
- Dry weight of capsules (g): Capsules were oven-dried at 70 °C for 72 hours until constant weight, then weighed to determine dry yield per plant.
- Number of seeds per capsule: Ten capsules were randomly selected from each plant, and seeds were manually counted to determine the average number of seeds per capsule.
- Seed yield (kg ha^{-1}): Seeds obtained from each plot were weighed, then the yield was extrapolated to kilograms per hectare based on plot area using the following formula:

$$\textbf{Seed yield } (\textbf{kg.ha}^{-1}) = \frac{Seed\ weight\ per\ plot\ (kg) x\ 10000}{Plot\ area\ (m^2)}$$

A factorial experiment was conducted using a randomized complete block design (R.C.B.D.), and the means were compared using Duncan's Multiple Range Test (DMRT) at the 0.05 probability level [11].

RESULTS AND DISCUSSION

Plant Height

The results in Table (2) showed that the 'Red Heet' cultivar significantly outperformed, recording the highest value of 137.22 cm compared to the Egyptian cultivar which recorded the lowest mean value of 120.70 cm. This variation between the two cultivars is attributed to genetic differences and is

consistent with the findings of [12]. The same table data showed the superiority of foliar spraying with glutamic acid at a concentration of 150 mg L^{-1}, which achieved the highest value of 139.33 cm, while the control treatment recorded the lowest value of 108.95 cm. Foliar application of glutamic acid positively influenced the stimulation of meristematic tissue division, which was reflected in increased plant height [13]. Regarding the interaction effect, 'Red Heet' sprayed with 150 mg L^{-1} achieved the highest plant height of 150.13 cm, while the Egyptian cultivar sprayed with distilled water had the lowest mean of 101.90 cm.

Table 2. Effect of the means of the two cultivars, glutamic acid spray concentrations, and their interaction on plant height (cm)

Genotype	Control 0 mg L^{-1}	Foliar spray 50 mg L^{-1}	Foliar spray 100 mg L^{-1}	Foliar spray 150 mg L^{-1}	Genotype Mean
Red Heet	116.00 b	140.70 a	142.03 a	150.13 a	137.22 a
Local Egyptian	101.90 c	123.57 b	128.80 b	128.53 b	120.70 b
Foliar spray Mean	108.95 c	132.13 b	135.42 ab	139.33 a	**$\bar{x}$=128.95**

At 5% of DMRT ,means with the same litters for each factor and interaction do not differ significantly

Number of Main Branches (branches per plant)

Results in Table (3) indicated a significant superiority of 'Red Heet' with the highest value of 29.25 branches per plant compared to the Egyptian cultivar, which recorded the lowest mean of 25.33 branches per plant. Branching is a trait linked to the genetic makeup of the cultivar and can explain differences among cultivars [14]. These results agree with those of [15]. Foliar spraying with glutamic acid at 150 mg L^{-1} also resulted in the highest mean of 30.01 branches per plant, while the control treatment recorded the lowest mean of 25.15 branches per plant. This increase may be due to glutamic acid's role in stimulating physiological processes and improving carbon assimilation by increasing chlorophyll production and plant growth [16]. The interaction effect showed that 'Red Heet' sprayed with 150 mg L^{-1} had the highest number of branches (32.95 branches per plant), while the Egyptian cultivar sprayed with distilled water recorded the lowest value (24.09 branches per plant).

Table 3. Effect of the means of the two cultivars, glutamic acid spray concentrations, and their interaction on the number of branches per plant (branches/plant)

Genotype	Control 0 mg L^{-1}	Foliar spray 50 mg L^{-1}	Foliar spray 100 mg L^{-1}	Foliar spray 150 mg L^{-1}	Genotype Mean
Red Heet	26.22 e	27.81 c	30.01 b	32.95 a	29.25 a
Local Egyptian	24.09 g	24.58 g	25.59 e	27.07 c	25.33 b
Foliar spray Mean	25.15 d	26.20 c	27.80 b	30.01 a	**$\bar{x}$=27.29**

Fresh Weight of Sepals Leaves

Table (4) results showed significant superiority of 'Red Heet' with the highest value of 259.64 g per plant compared to the Egyptian cultivar that recorded the lowest mean of 209.87 g per plant. This superiority is likely due to 'Red Heet' excelling in plant height and branch number, which influenced this trait positively. These results align with [17]. Foliar spraying with 150 mg L^{-1} glutamic acid gave the highest mean of 280.68 g per plant, while the control treatment gave the lowest mean of 194.73 g per plant. This effect is attributed to glutamic acid's nitrogen content, which enhances the formation of a strong root system that promotes efficient nutrient uptake, leading to increased carbon metabolism and plant growth including sepals leaves. The interaction showed that 'Red Heet' sprayed with 150 mg L^{-1} achieved the highest mean of 294.29 g per plant, while the Egyptian cultivar sprayed with distilled water recorded the lowest mean of 172.65 g per plant.

Table 4. Effect of the means of the two cultivars, glutamic acid spray concentrations, and their interaction on the fresh weight of sepals leaves

Genotype	Control 0 mg L^{-1}	Foliar spray 50 mg L^{-1}	Foliar spray 100 mg L^{-1}	Foliar spray 150 mg L^{-1}	Genotype Mean
Red Heet	216.80 ab	256.48 ab	271.01 a	294.29 a	259.64 a
Local Egyptian	172.65 b	225.42 ab	173.97 b	267.43 a	209.87 b
Foliar spray Mean	194.73 b	240.95 ab	222.49 b	280.86 a	**$\bar{x}$=234.75**

Dry Weight of Sepals Leaves (g per plant)

Table (5) shows the significant superiority of 'Red Heet' with the highest value of 63.73 g per plant, while the Egyptian cultivar had the lowest mean of 53.06 g per plant. The differences may be due to the cultivars' capacities for nitrogen uptake, increasing the plant's dry weight. This agrees with [17]. Foliar spraying with 150 mg L^{-1} glutamic acid recorded the highest value of 66.45 g per plant, whereas the control treatment had the lowest value of 49.60 g per plant. This superiority can be attributed to glutamic acid's role in enhancing vital physiological processes such as respiration, carbon metabolism, energy production, and synthesis of proteins, vitamins, sugars, and other important compounds, which are transported to sinks, resulting in increased dry weight of sepals leaves [18]. The interaction showed 'Red Heet' sprayed with 150 mg L^{-1} had the highest dry weight (73.28 g per plant), while the Egyptian cultivar with the control treatment had the lowest (44.60 g per plant).

Table 5. Effect of the means of the two cultivars, glutamic acid spray concentrations, and their interaction on the dry weight of sepals leaves (g/plant)

Genotype	Control 0 mg L^{-1}	Foliar spray 50 mg L^{-1}	Foliar spray 100 mg L^{-1}	Foliar spray 150 mg L^{-1}	Genotype Mean
Red Heet	54.60 d	59.49 c	67.56 b	73.28 a	63.73 a
Local Egyptian	44.60 f	51.52 e	56.52 d	59.62 c	53.06 b
Foliar spray Mean	49.60 d	55.51 c	62.04 b	66.45 a	**$\bar{x}$=58.39**

Number of Pods per Plant

Table (6) indicated that 'Red Heet' significantly outperformed with 122.32 pods per plant compared to the Egyptian cultivar which recorded the lowest number of 101.90 pods per plant. This is due to the superior growth traits of 'Red Heet' which reflected positively on this trait. Foliar spraying with 150 mg L^{-1} glutamic acid achieved the highest mean of 121.95 pods per plant, while the control treatment recorded the lowest mean of 97.93 pods per plant. The effect is attributed to nitrogen's role in increasing vegetative branching and floral buds that bear the yield [19]. The interaction showed 'Red Heet' sprayed with 150 mg L^{-1} had the highest mean of 129.95 pods per plant, while the Egyptian cultivar sprayed with distilled water had the lowest (82.93 pods per plant).

Table 6. Effect of the means of the two cultivars, glutamic acid spray concentrations, and their interaction on the number of pods per plant (pods/plant)

Genotype	Control 0 mg L^{-1}	Foliar spray 50 mg L^{-1}	Foliar spray 100 mg L^{-1}	Foliar spray 150 mg L^{-1}	Genotype Mean
Red Heet	112.93 c	120.83 b	125.56 a	129.95 a	122. 32 a
Local Egyptian	82.93 e	100.18 d	110.52 c	113.95 c	101.90 b
Foliar spray Mean	97.93 d	110.51 c	118.04 b	121.95 a	**$\bar{x}$=112.10**

Fresh Weight of Pod (g per pod)

Table (7) revealed significant superiority of 'Red Heet' with the highest value of 609.98 g per pod compared to the Egyptian cultivar's lowest mean of 483.06 g per pod. This superiority may be linked to 'Red Heet' having higher branch and pod numbers (Tables 5 and 7), resulting in increased fresh pod

weight. Foliar spraying with 100 mg L^{-1} glutamic acid resulted in the highest value of 619.45 g per pod, while the control recorded the lowest of 480.27 g per pod. The enhancement is due to glutamic acid increasing nutrient levels in leaf tissues, improving vegetative growth and increasing the number of branches bearing pods. These results agree with [20]. Interaction showed 'Red Heet' sprayed with 100 mg L^{-1} had the highest fresh pod weight of 700.61 g, while the Egyptian cultivar with control treatment had the lowest of 441.60 g per pod.

Table 7. Effect of the means of the two cultivars, glutamic acid spray concentrations, and their interaction on the fresh weight of pods (g/pod)

Genotype	Control 0 mg L^{-1}	Foliar spray 50 mg L^{-1}	Foliar spray 100 mg L^{-1}	Foliar spray 150 mg L^{-1}	Genotype Mean
Red Heet	518.93 e	573.83 c	700.61 a	646.56 b	609.98 a
Local Egyptian	441.60 h	460.52 g	538.28 d	491.85 f	483.06 b
Foliar spray Mean	480.27 d	517.17 c	619.45 a	569.21 b	$\bar{x}$=546.52

Dry Weight of Pod (g per pod)

Table (8) shows that 'Red Heet' significantly outperformed with the highest value of 202.67 g per pod, compared to the Egyptian cultivar's lowest of 164.14 g per pod. Genetic factors affected by environmental conditions explain the differences. Foliar spraying with 100 mg L^{-1} glutamic acid recorded the highest mean of 219.09 g per pod, while the control treatment had the lowest mean of 155.29 g per pod. These results agree with [21]. The interaction showed 'Red Heet' sprayed with 100 mg L^{-1} had the highest dry pod weight of 256.77 g per pod, whereas the Egyptian cultivar with distilled water spray had the lowest at 144.19 g per pod.

Table 8. Effect of the means of the two cultivars, glutamic acid spray concentrations, and their interaction on the dry weight of pods (g/pod)

Genotype	Control 0 mg L^{-1}	Foliar spray 50 mg L^{-1}	Foliar spray 100 mg L^{-1}	Foliar spray 150 mg L^{-1}	Genotype Mean
Red Heet	166.40 d	187.81 c	256.77 a	199.68 b	202.67 a
Local Egyptian	144.19 f	158.00 e	181.41 d	172.94 c	164.14 b
Foliar spray Mean	155. 29 d	172.91 c	219.09 a	186.31 b	**$\bar{x}$=183.40**

Number of Seeds per Pod

Table (9) results indicated that 'Red Heet' significantly surpassed the Egyptian cultivar with an average of 29.33 seeds per pod compared to 22.53 seeds per pod in the Egyptian cultivar. This is attributed to the overall superior growth traits of 'Red Heet' which positively impacted yield traits including seed number per pod these results agree with [22]. Foliar spraying with 150 mg L^{-1} glutamic acid recorded the highest mean of 24.53 seeds per pod, while the control treatment recorded the lowest mean of 22.06 seeds per pod. Glutamic acid stimulated physiological processes during flowering, increasing pollen quantity and thus improving seed number per pod. These results agree with [7]. Interaction showed 'Red Heet' sprayed with 150 mg L^{-1} had the highest mean of 25.77 seeds per pod, while the Egyptian cultivar sprayed with distilled water had the lowest mean of 21.38 seeds per pod.

Table 9. Effect of the means of the two cultivars, glutamic acid spray concentrations, and their interaction on the number of seeds per pod (seeds/pod)

Genotype	Control 0 mg L^{-1}	Foliar spray 50 mg L^{-1}	Foliar spray 100 mg L^{-1}	Foliar spray 150 mg L^{-1}	Genotype Mean
Red Heet	708.11 e	773.46 c	850.33 b	949.11 a	820.25 a
Local Egyptian	645.19 g	672.33 f	695.28 e	741.41 d	688.55 b
Foliar spray Mean	676.65 d	722.90 c	772.81 b	845.26 a	$\bar{x}$=754.40

Seed Yield (kg ha^{-1})

Table (10) indicates that 'Red Heet' recorded the highest seed yield of 820.25 kg ha^{-1} compared to the Egyptian cultivar's lowest of 688.55 kg ha^{-1}. This is due to the superiority of 'Red Heet' in all yield components, which reflected in seed yield these results agree with [8]; Al-Mafarji et al., (2024). Foliar spraying with 150 mg L^{-1} glutamic acid achieved the highest mean seed yield of 845.26 kg ha^{-1}, while the control treatment recorded the lowest of 676.65 kg ha^{-1}. Interaction showed 'Red Heet' sprayed with 150 mg L^{-1} had the highest seed yield of 949.11 kg ha^{-1}, while the Egyptian cultivar with control spray had the lowest of 645.19 kg ha^{-1}.

Table 10. Effect of the means of the two cultivars, glutamic acid spray concentrations, and their interaction on seed yield (kg ha^{-1})

Genotype	Control 0 mg L^{-1}	Foliar spray 50 mg L^{-1}	Foliar spray 100 mg L^{-1}	Foliar spray 150 mg L^{-1}	Genotype Mean
Red Heet	216.80 ab	256.48 ab	271.01 a	294.29 a	259.64 a
Local Egyptian	172.65 b	225.42 ab	173.97 b	267.43 a	209.87 b
Foliar spray Mean	194.73 b	240.95 ab	222.49 b	280.86 a	$\bar{x}$=234.75

Evaluation of Genetic Genotypes, Foliar Application of Glutamic Acid, and Their Interaction on the Studied Traits of Roselle (*Hibiscus sabdariffa* L.) Plants

Analysis of variance (Table 10) revealed that cultivar effect was significant at $p \leq 0.01$ for all studied traits except fresh weight of sepals leaves, which was significant at $p \leq 0.05$. Glutamic acid concentration effect was significant at $p \leq 0.01$ for all traits except fresh weight of sepals leaves (significant at $p \leq 0.05$). The interaction between cultivar and glutamic acid was significant at $p \leq 0.01$ for all traits except dry weight of sepals leaves (significant at $p \leq 0.05$). Interaction was not significant for plant height, fresh weight of sepals leaves, and number of seeds per pod, indicating differential cultivar responses to glutamic acid concentrations. These results agree with [12; 23; 24; 25; 26; 27; 28].

Table 11. Analysis of variance represented by mean squares for the study factors on growth traits, yield, and its components.

S.O.V	d.f.	Plant height	Number of main branches per plant	Fresh weight of sepals leaves	Dry weight of sepals leaves	Number of capsules per plant	Fresh weight of capsules	Dry weight of capsules	Number of seeds per capsule	Seed yield
R	2	44.15	1.07	1070. 6	10.09	24.88	707.39	122.54	0.33	120.79
A	1	1731.8**	95.74**	13944.04*	700.9**	2572.8**	98676.6**	9173.5**	19.11**	104762.3**
B	3	1082.7**	25.30**	8532.10*	320.68**	648.32**	21454.4**	4251.6**	7.55**	31143.9**
A * B	3	30.19$^{N.S.}$	4.35 **	1842.9$^{N.S.}$	8.91 *	67.25**	2432.82**	952.35**	0.284$^{N.S.}$	5869.3**
Error	14	27.99	0.44	2115.89	83.2	6.37	103.60	14.66	0.38	129.59

ns: not significant; *: significant at $p \leq 0.05$; **: significant at $p \leq 0.01$.

CONCLUSIONS

It is concluded that the 'Red Heet' cultivar is well-suited to the environmental conditions of the region due to its superiority in all studied traits. Foliar spraying with glutamic acid at 150 mg L^{-1} significantly improved growth traits, yield, and its components. The best combination was the 'Red Heet' cultivar sprayed with 150 mg L^{-1} glutamic acid, which achieved the highest growth and yield characteristics. It is recommended to use 'Red Heet' cultivar with 150 mg L^{-1} glutamic acid for optimal results.

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