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Impact Of Varying Humic Acid Concentrations on Optimizing Growth and Yield of White Roselle in Upper Egypt

تأثير تركيزات حمض الهيوميك المتفاوتة على تحسين نمو وإنتاجية الكركديه الأبيض في صعيد مصر

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Abstract:

White roselle is a newly variety introduced to Egypt with comparable pharmaceutical properties compared to the traditional red roselle verities. This study was conducted during 2022 and 2023 successive seasons with aim of investigating the effect of different humic acid (HA) concentrations (0, 1000, 2000 and 3000 ppm) on white roselle growth and yield properties. In this study, a high concentration of HA at 3000 ppm significantly enhanced the growth characteristics of white roselle. Plant height increased by 44-53%, stem diameter increased by 48-70%, the number of branches increased by 68-76%, shoot fresh weight increased by 68-141%, and shoot dry weight increased by 65-92%. Similarly, 3000 ppm HA resulted in substantial improvements in the fruit characteristics of white roselle, including an increase in the number of fruits by 35-48%, fresh calyx weight per plant and yield per feddan by 139-144%, and dry calyx weight per plant and yield per feddan by 141-188%. It is concluded that HA has significant positive effects not only on growth characteristics but also on the yield components of the newly introduced white roselle variety under Upper Egypt conditions. The highest values of growth characteristics and yield components were observed with 3000 ppm HA. This study recommends applying 3000 ppm HA for three times to improve the growth and yield of the white roselle variety under Upper Egypt conditions.

***Keywords*:** white roselle; humic acid; yield components; growth characteristics

ملخص:

الكركديه الأبيض هو صنف جديد تم إدخاله إلى مصر وله خصائص صيدلانية مماثلة لأصناف الكركديه الحمراء التقليدية. أجريت هذه الدراسة خلال موسمي ٢٠٢٢ و ٢٠٢٣ المتتاليين بهدف التحقق من تأثير تركيزات مختلفة من حمض الهيوميك (٠ و ١٠٠٠ و ٢٠٠٠ و ٣٠٠٠ جزء في المليون) على نمو الكركديه الأبيض وخصائص المحصول. في هذه الدراسة، أدى التركيز العالي من حمض الهيوميك عند ٣٠٠٠ جزء في المليون إلى تعزيز خصائص نمو الكركديه الأبيض بشكل كبير. زاد ارتفاع النبات بنسبة ٤٤-٥٣٪، وزاد قطر الساق بنسبة ٤٨-٧٠٪، وزاد عدد الفروع بنسبة ٦٨-٧٦٪، وزاد وزن البراعم الطازجة بنسبة ٦٨-١٤١٪، وزاد وزن البراعم الجافة

بنسبة ٦٥–٩٢٪. وبالمثل، أدى ٣٠٠٠ جزء في المليون من حمض الهيوميك إلى تحسينات كبيرة في خصائص ثمار الكركديه الأبيض، بما في ذلك زيادة في عدد الثمار بنسبة ٣٥–٤٨٪، ووزن الكأس الطازج للنبات ومحصول الفدان بنسبة ١٣٩–١٤٤٪، ووزن الكأس الجاف للنبات ومحصول الفدان بنسبة ١٤١–١٨٨٪. وخلص إلى أن حمض الهيوميك له تأثيرات إيجابية كبيرة ليس فقط على خصائص النمو ولكن أيضًا على مكونات المحصول لصنف الكركديه الأبيض تحت ظروف صعيد مصر. لوحظت أعلى قيم لخصائص النمو ومكونات المحصول مع ٣٠٠٠ جزء في المليون من حمض الهيوميك. وتوصي هذه الدراسة بتطبيق ٣٠٠٠ جزء في المليون من حمض الهيوميك لثلاث جرعات لتحسين نمو ومحصول صنف الكركديه الأبيض تحت ظروف صعيد مصر.

INTRODUCTION

Hibiscus sabdariffa L., commonly known as Roselle, is a plant species within the Malvaceae family. It is recognized by various names worldwide, including roselle, hibiscus, and red sorrel in English, and karkadeh in Arabic **[1],[2]**. It is an herbaceous shrub reaching heights of 1.5-2 meters, likely indigenous to tropical regions of Central and West Africa. *Hibiscus sabdariffa* L. is classified as a tropical and sub-tropical plant **[3]**.

Roselle serves a significant economic and subsistence role for rural farmers in developing nations. It is considered an ideal crop due to its adaptability for multi-cropping systems and its dual use as both food and fiber. In China, the seeds are valued for their oil content, and the plant is esteemed for its medicinal properties. Conversely, West African communities utilize the leaves and powdered seeds in culinary preparations. Furthermore, Roselle finds application in pharmaceutical and food sector **[4]**. The Roselle plant has been historically utilized in traditional medicine, as a natural coloring agent, and for the preparation of beverages **[5]**. Roselle is employed worldwide for various purposes, including the production of beverages such as bissap (Senegal), zobo or zoborodo (Nigeria), and Cranberry in Florida. It is also utilized in the preparation of liqueurs in Europe, soft drinks in West Africa, and alcoholic beverages in the United States **[6]**.

Recent studies have explored the antioxidant and antibacterial properties of different *Hibiscus sabdariffa* L. varieties, focusing on the white variety. Among five varieties, the white calyx exhibited the highest antioxidant and antibacterial capacities (ABAC), with inhibitory effects similar to chloramphenicol and 40% higher ABAC than red calyx varieties **[7]**. **Borrás-Linares *et al.* [8]** also found high ABAC in both white and red calyces, attributing the white variety's high ABAC to non-colored phenolic compounds like protocatechuic acid **[9]**. **Tahir *et al.* [10]** assessed the antioxidant properties of three red varieties and one white variety, finding that while the red varieties had superior antioxidant properties and aroma profiles, the white variety showed significant antioxidant potential, with the highest radical scavenging activity (RSA %) among all tested varieties. Other studies have noted that red calyx varieties contain anthocyanins, whereas white varieties have higher flavanol content. The phenolic acid profiles also differ, with white calyces having more p-hydroxybenzoic acid derivatives than red ones **[11],[12]**.

Organic fertilization is favored over mineral fertilizers to enhance crop quality, particularly for medicinal and aromatic varieties. Incorporating organic composts into soil significantly improves the growth, yield, and chemical composition of Roselle plants **[13]**. Organic acids and hormonal compounds also improve soil properties, boosting crop yield and quality **[14]**. Organic fertilizers, derived from carbon-containing organic sources, include mineral sources, animal waste, and plant-derived nutrients like humus, compost, and biosolids **[15]**. Using natural fertilizers such as humic acid enhances plant yield without environmental harm.

Humic acid (HA) is a water-soluble organic acid found in soil organic matter. As the principal component of humate substances, HA enhances plant development by improving nutrient absorption and promoting root growth **[16]**. It positively influences the root system by promoting lateral roots and root hairs, essential for nutrient uptake, and enhances soil properties, microbial activity, and structure **[17],[18]**. HA improves soil structure, stimulates microbial communities, and enhances nutrient assimilation **[19],[20]**.

Humic acid, as reported by **Bernoux and Cerri [21]**, is a complex macromolecular substance composed of aromatic and aliphatic hydrocarbons. It includes heterocyclic compounds containing nitrogen, oxygen, or sulfur. Humic acid is not a single compound but a mixture of various acids with carboxyl and phenolate groups, acting as dibasic or tribasic acids depending on their composition. Commercial humic acid products typically contain both humic and fulvic acids, with humic acid fractions characterized by large molecules with multiple charges on their surfaces.

HA plays a crucial role in regulating carbon cycles and catalyzing redox processes in ecosystems **[22],[23]**. Its redox-active functional groups facilitate microbial electron transfer onto Fe (III) **[24]**. HA contains essential nutrients, including hydrogen, oxygen, carbon, and nitrogen, which support plant growth **[25]**. Upon application, HA rapidly converts into accessible humic substances, enhancing plant development by increasing nutrient uptake from the soil **[26]**.

In light of these considerations, this experiment aimed to explore vegetative growth traits and productivity of the white roselle, newly introduced to Egypt, as influenced by application of different concentrations of humic acid under Upper Egypt conditions.

MATERIAL AND METHODS

This study was carried out during the 2022 and 2023 seasons at private farm in Esna, Luxor, Egypt. The aim of study was to investigate the effects of various humic acid (HA) concentrations on the growth and yield components of the white roselle variety, newly introduced to Egypt.

A. Plant materials and experimental site:

Seeds of white roselle variety were obtained from the National Research Centre, Cairo, Egypt. The experimental site was prepared as recommended before sowing the seeds. Plot size was 3 × 1.4 m comprising two rows. Roselle seeds were directly sown in soil at ٦٠ cm in a row, and ٧٠ cm between rows. The seeds were planted on 1st May in both seasons. After 30 days, the plants were thinned to one plant per hill (١٠ plants/plot) i.e. 10,000 plants/fed.

B. Experimental design:

The experiment was designed in a randomized complete block in a factorial design. The plots were comprehended four levels of HA (0, 1000, 2000 and 3000 ppm) replicated three times. HA was added to soil as potassium humates 75% with the different concentrations. HA was added three times starting 45 days after sowing and repeated with fifteen days interval for all sowing dates in both seasons.

C. Data recorded:

The plants were harvested in the middle of October for both seasons and the following data were recorded:

1) Vegetative growth characteristics

1. Plant height (cm): length of the main stem from soil surface to plant apex has been measured using a ruler.

2. Stem diameter (mm) was measured at the base above soil surface by 10 cm using a caliper.
3. Number of lateral branches per plant distributed on the main stem.
4. Fresh weight of shoots per plant (g) excluding fruits were recorded directly after harvesting during both seasons.
5. Dry weight of shoots per plant: the shoots were air dried in shade till constant weight was reached (almost one week).

2) Yield components

1. Fruits number per plant distributed on the main and lateral branches.
2. Calyx fresh weight per plant (g) was recorded after separating the calyxes from plants in fresh form.
3. Calyx dry weight per plant (g); calyxes were air dried in shade conditions for one week, and then weighed.
4. Calyx fresh weight per feddan (kg) was calculated by multiplying calyxes fresh weight per plant and plants number per feddan.
5. Calyx dry weight per feddan (kg) was calculated by multiplying calyxes dry weight per plant and plants number per feddan.

D. Statistical analysis:

The obtained data were subjected to statistical analysis using "F" Test **[27]** and the means were compared using a least significant difference (L.S.D.) test according to **[28].** Statistical analysis was performed using Microsoft Office 365 Excel program.

RESULTS

Data presented in Table (1) showed that vegetative characteristics differed greatly under different HA concentration compared to control, especially plant height and stem diameter. The tallest plants have been shown under high HA concentrations (2000 ppm and 3000 ppm) reaching approx. 126-128 cm compared to 83-89 cm under control conditions. Also, stem diameter increased from 16-17 mm under control to 25-29 mm under high HA concentrations (2000 ppm and 3000 ppm). Number of branches in the main stem also increased from approximately five branches under control treatment to reach nine branches per plant under 3000 ppm HA treatment.

TABLE 1. Effect of humic acid (HA) concentration on plant height (cm), stem diameter (mm), number of branches, plant fresh weight (g) and plant dry weight (g) of roselle plant.

Treatment	Plant height (cm)		Stem diameter (mm)		No. of branches		Shoot fresh weight (g)		Shoot dry weight (g)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Control	83.3	88.9	17.3	16.1	5.0	5.4	317.8	387.8	95.6	96.1
1000 ppm HA	113.9	110.0	24.2	23.0	7.0	6.9	593.1	500.0	149.4	147.8
2000 ppm HA	127.8	126.1	28.7	25.2	8.2	8.0	701.7	639.4	151.1	143.3
3000 ppm HA	127.6	128.3	25.7	27.3	8.8	8.8	766.1	653.3	183.9	158.9
F value	9.9	53.8	4.0	4.6	2.2	2.0	30.1	20.2	20.6	30.2
Probability	**	***	*	*	ns	ns	***	***	***	***

*, **, ** represent significant probability at level 0.05, 0.01 and 0.001, respectively, while ns represent non-significant.

In the same line, shoot fresh and dry weights greatly increased with increasing HA concentration (Table 1). The fresh shoot weights per plant were 317.8 and 387.8 g for untreated plants in the first and second season, respectively. These values increased to be 766.1 and 653.3 g for plants treated with HA at 3000 ppm in the 1st and 2nd seasons, respectively. Same like fresh weight, the dry shoot biomass was almost 96 g per plant for untreated plants in both seasons and reached 190 and 159 g after treatments with HA at 3000 ppm in the 1st and 2nd seasons, respectively.

Data presented in Table (2) showed that yield components differed greatly under different HA concentration compared to control, especially in the second season. Number of calyxes per plant was 155-122 under control and increased to 155-180 under high HA concentrations (3000 ppm). Also, calyxes fresh weight per plant increased from almost 200 g/plant under control to reach 477-488 g/plant under high HA concentrations (3000 ppm). The dry calyxes weight per plant also increased from 113.3 and 93.3 g/plant under control treatment to reach 273.3 and 268.3 g/plant under 3000 ppm HA treatment in the 1st and 2nd seasons, respectively.

TABLE 2: Effect of humic acid (HA) concentration on number of calyxes, calyxes fresh and dry weights per plant (g), and calyxes fresh and dry yield per feddan (kg) of roselle plant.

Treatment	No. of Calyxes		Calyxes FW per plant (g)		Calyxes DW per plant (g)		Calyxes FW per feddan (kg)		Calyxes DW per feddan (kg)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Control	115.6	122.2	199.4	200.0	37.8	31.1	1994	2000	377.7	311.0
1000 ppm HA	135.6	135.7	384.4	384.4	43.3	42.2	3844	3844	433.3	422.3
2000 ppm HA	145.6	142.8	403.9	407.8	88.9	83.3	4039	4078	889.0	833.3
3000 ppm HA	155.6	180.3	476.7	487.8	91.1	89.4	4767	4878	911.0	894.3
F value	14.1	15.4	20.9	60.1	30.1	40.5	20.9	60.1	30.1	40.5
Probability	**	**	***	***	***	***	***	***	***	***

* represent significant probability at level 0.05, while ns represent non-significant.

In the same line, calyxes fresh and dry yield per feddan greatly increased with increasing HA concentration (Table 2). The fresh yield/feddan were 1994 and 2000 kg/feddan for control treatment in the first and second seasons, respectively. These values increased to be 4767 and 4878 kg/feddan for HA at 3000 ppm treatment in the 1st and 2nd seasons, respectively. Same like fresh calyxes' yield, the dry calyxes' yield was 377.7 and 311.0 kg per feddan under control and reached 911.0 and 894.3 kg per feddan after treatment with HA at 3000 ppm in the 1st and 2nd seasons, respectively.

DISCUSSION

The growth and yield of crops are heavily influenced by growing conditions, and fertilization plays a pivotal role. Proper nutrition is essential for the growth and development of all crops, particularly medicinal plants that produce secondary metabolites **[29],[30],[31]**. Incorporating

natural plant biostimulants is crucial in sustainable horticulture production systems. Both natural and synthetic stimulants contribute to achieving sustainable, high-yield, and low-input crop production **[32],[33]**. A biostimulant, as defined by **du Jardin [34]**, is any substance or microorganism added to plants to enhance nutrient efficiency, abiotic stress resistance, and/or quality traits.

Potassium humate, derived from lignite, is extensively utilized to enhance soil fertility, nutrient uptake, crop yields, and agricultural product quality, making it a pollution-free organic fertilizer **[35]**. The presence of organic acids such as fulvic, cinnamic, salicylic, citric, oxalic, malic, succinic, acetic, and lactic acids in humic acid can improve plant growth, yield, and quality **[36]**. Potassium humate significantly impacts plant physiology by enhancing respiration, mineral element absorption, chlorophyll content, water metabolism, and the metabolism of sugars, nucleic acids, and proteins. It also improves drought resistance by reducing water evaporation and consumption. As a vital nutrient, potassium is crucial for plant growth and reproduction, second only to nitrogen **[37]**. Potassium humate has significant potential as a biostimulant for enhancing crop productivity **[38]**.

Recently, HA showed significant effects on bottle gourd growth and fruit characteristics such as plant height, number of leaves, fruit dry weight and its seeds dry weight. HA at high concentration (6000 ppm) showed high values of both growth and fruit characteristics, and it can be recommended to treat bottle gourd with HA at 6000 ppm to ensure significant improvement in both plant growth and fruit characteristics **[39]**. In this study, high HA concentration (2000 ppm) increased white roselle growth characteristics such as plant height by 44-53%, stem diameter by 48-70%, number of branches by 68-76%, shoot fresh weight 68-141%, and shoot dry weight by 65-92% approximately. In the same line, 2000 ppm HA led to significant increments of white roselle fruits characteristics including number of fruits by 35-48%, fresh calyxes weight per plant and yield per feddan by 139-144%, as well as dry calyxes dry weight per plant and yield per feddan by 141-188% approximately. The application of humic acid and potassium humate in agriculture demonstrates substantial benefits in enhancing plant growth, yield, quality, and resilience to environmental stresses, making them invaluable components in sustainable agricultural practices **[39]**.

CONCLUSION

It is concluded that HA has great significant positive effects not only on growth characteristics, but also on the yield components of the newly introduced white roselle variety under upper Egypt conditions. High HA concentration at 2000 ppm showed the highest values of growth characteristics and yield components. The results of this study showed the success of white roselle variety cultivation under Upper Egypt conditions, with the recommendation of applying 2000 ppm HA three times to improve the growth and yield of white roselle variety under Upper Egypt conditions.

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