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EFFECT OF ANTIOXIDANTS TO EQUALIZE SALINTY STRESS ON (*Moringa oleifera* L.) PLANT UNDER EL-ARISH AREA

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ABSTRACT

The present work aimed to study different effects of foliar application of humic acid, potassium silicat and prolin to alleviate salinity stress on growth, yield and active constituents of *Moringa oleifera* L. plant in El-Arish area. Field experiments were carried out at Faculty of Environmental Agricultural Sciences, Arish University, North Sinai, Egypt, during summer growing seasons of 2019/2020. This study included ten treatments**.** The experiment designed in Randomized Complete Design (RCD) in three replications. Moringa plants were treated with humic acid (1, 1.5 and 2 gl^{-1}), prolin (50,100 and 150 mgl^{-1}) and potassium silicat (200,400 and 600 mgl^{-1}) as well as control. Random sample of three plants was taken from each treatment after 90 days of sowing. Results showed positive effects for potassium silicat and prolin on all studied traits. The highest value for each of vegetative growth, minerals content, prolin accumulation and chlorophylls a and b was obtained with potassium silicat (200mgl^{-1}+4cm/l) and prolin (50mgl^{-1}+100mgl^{-1}).

INTRODUCTION

Moringa oleifera L. is a fast-growing, drought-resistant tree. That has been extensively known and used for its several benefits. It belongs to Moringaceae family. Moringaceae family is mono generic, that comprise single genus moringa, which that containing 10-14 species **(Anzano *et al.*, 2021)**. It is the most widely farmed plant in tropical and subtropical regions of Central Asia, America, and Africa (**Abdel-Wanis 2016).** It's also known as the horseradish tree because the roots taste like horseradish, the drumstick tree because the seedpods are long and slender, the miracle tree because of its therapeutic benefits, and the ben tree because it's high in behenic acid **(Shih *et al*., 2011).**

Leaves of *Moringa oleifera* L. have been found to be a good source of natural antioxidants like ascorbic acid, flavonoides, phenolics, and carotenoides, as well as a good supply of macro and micronutrients including, rich source β-carotene, protein, calcium, and potassium **(Siddhuraju and Becker, 2003)**. Moringa leaves have more vitamin A than carrots, more vitamin C than oranges, more calcium than milk, more potassium than bananas, and more iron than spinach **(Fahey, 2005)**. **Anzano *et al*. (2021)** recorded that, M. oleifera leaves have a high protein content, making them a good source of amino acids, M. *oleifera* leaves contain all of the necessary amino acids, accounting for more than half of the total amino acid content. **Stadtlander and Becker, (2017)** mentioned that the ability of M. *oleifera* seed powder to coagulate and flocculate suspended particles, including bacteria and other potential pathogens, is unquestionably one of the most important properties of the plant.

Salinity stress is one of the severe abiotic stresses which adversely affect plant growth

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and productivity in various regions, particularly in arid and semi-arid areas **(Hiji and Jerry, 2020)**. **Cui *et al*. (2021)** found that, drought and salt stress have a significant impact on plant growth and development by inducing multiple physiological and metabolic changes.

Silicon (Si) supply improved plant tolerance to salt stress and improved plant growth and productivity **(Souri *et al*., 2020).** Silicon works as a plant protectant and is essential for plant development and productivity, especially in stress condition **(Sawas and Ntatsi, 2015)** Si can improve K absorption and translocation in rice by up-regulating the expression of key genes, increasing K status and relieving salt stress **(Yan *et al*., 2021).**

The exogenous application of the amino acids is vital for cell growth stimulation and is also a well-known bio stimulant that improves plant growth, yield, and dramatically reduces abiotic stress damage **(Hiji and Jerry, 2020).** Proline, as a key role in plants under drought and salt stresses, not only serves as an osmoprotectant but also as an antioxidant in plants **(Cui *et al*., 2021)**.

Humic acid (HA) is a significant component of humic substances and might be employed as one of the main organic fertilizers **(Bakry *et al*., 2014).** It helps the plant adapt to salinity conditions and increases the absorption of elements in the soil **(Nayyef and Hammadi, 2021). Saidimoradi *et al.* (2019)** found that, humic acid reduced Na^+ and enhanced K^+ buildup during salinity treatment.

The aim of this study was to measure the potential roles of antioxidants foliar application (humic acid, potassium silicat and proline) on morphological, physiological, chemical parameters, yield quantity and quality of *Moringa oleifera* L. plants grown under salinity condition in El-Arish area.

MATERIALS AND METHODS

Field experiments were carried out during the two consecutive summer seasons of 2019 and 2020 at The Experimental Farm, Faculty of Environmental Agricultural Sciences, Arish University, North Sinai Governorate, Egypt. The study aim to evaluate different antioxidant types viz; humic acid, silicon, and proline at different rates on growth, yield, and active constituents of *Moringa oleifera* L. plant.

The experiment designed in Randomized Complete Design (RCD) in three replications. In the experiment, 10 treatments were under study; potassium humate was used as Humic source in three levels (200, 400 and 600 mgl^{-1}) and Potassium silicat as silicon source at three levels (0.5, 1 and 1.5 gl^{-1}) and prolin acid as amino acid at three levels (50,100 and 150mgl^{-1}) as well as control. Seeds of *Moringa oleifera* L. were genteelly obtained from The Egyptian Agriculture Research Centre in Dokki, Cairo, Egypt. Moringa seeds were sown on 14^{th} April in both seasons, the germination of seeds was about 90%. The field was properly ploughed, 3 days later it was split for lines, trenches on inside the lines were made to add compost at the rate of 15 ton fed^{-1}, then levelled the ground, installation of irrigation hoses and plots were prepared according to the plan of layout. Plants were transplanted after 21 days from sowing in both seasons around emitters of two dripper lines. plants were cultivated 50cm between rows, 30 cm between hills, one plant/hill, The experimental unite was 15 m length and 1.30 m wide. Total plot area was 39 m^2. The area around one dripper line (19.5 m^2). Drip irrigation system was used in both experiments. Foliar application treatments were applied at two successive times 45 and 80 days after transplanted. The normal agricultural practices were carried out as commonly followed in El-Arish region.

A random sample of three plants was taken from each treatment after 90 days after transplanted. Samples cleaned and dried in electric oven at 70°C, and ground in stainless steel mill. Dry powder was digested and analyzed for N, P and K. Irrigation water analysis is shown in Table 1, analyses were carried out according to **Jackson (1958).** Soil physical and chemical properties were done according to **Piper (1947)** in Table 2.

Data Recorded

The following data were recorded during both seasons.

Growth parameters

Plant height (cm), Root length (cm), Branch length (cm)/plant, Main stem diameter (cm)/plant, Branch number/ plant, Leaf number/plant, Fresh and dry weights of leaves, shoots and roots (g/ plant). were measured at 90 days of sowing.

Chemical Analysis

Chlorophyll content in leaves

The pigments were extracted by soaking 200 mg of fresh leaves in 5 ml of N, N-Dimethylformamide (DMF) in dark-colored glassware and stored at a temperature of 4˚C for 72 hours and then measured at the following wavelengths of 647, 480 and 664 using the spectrophotometry **Moran (1982)**.

Nitrogen content (%)

It was determined according to the method described by **Bremner and Mulvaney (1982)**.

Phosphorus content (%)

It was calorimetrically determined using the Spectrophotometer (Model 6300 and 6100 Jenway Co.) according to **Olsen and Sommers (1982)**.

Proline

Proline was determined according to the method described by **Bates *et al.* (1973)**.

Statistical Analysis

The obtained data were subjected to statistical analysis of variance according to **Snedecor and Cochran (1980**), and means separation was done according to **Duncan** (**1955**).

RESULTS AND DISCUSSION

Growth Parameters

Results in Table 3 indicate that there was a significant difference among treatments for all studied traits; *viz*., number of leaves/ plants, plant height, root length, branches length, stem diameter and number of branches/plant. In the first season, the highest value for each of root length (30 cm), stem diameters (15.8cm) and leaf number/plant (22.33) was obtained due to foliar application of 200mgl^{-1} potassium silicate (Sil). Results of root length, stem diameter and leaf number/plant in the second season were resemble with those of the first season. The highest values of branches length in both seasons were noted with application 50mgl^{-1} prolin . Potassium silicat of (600 mgl^{-1}) recorded the highest value of numbers of branches/plant.

These results are in concord with that reported by **Alkahtani *et al.* (2021)** who found that the use of Si as a foliar treatment reduced the prejudicial effects of drought, resulting in improved sugar beet plant health and increased root diameter and length. This increment is due to the positive role of Si as a valuable element in enhancing plant growth and development under a variety of stress, Si also helps to alleviate drought stress by increasing water storage capacity, improving soil enrichment, and controlling stomatal conductance and the photosynthetic process.

Fresh Weight

Results in Table 4 show significant differences among treatments for fresh weight traits of moringa plant. Fresh weight of leaves, branches and total fresh weight

Table 1. Chemical properties of irrigation water during the two successive seasons

pH	EC ($dS.m^{-1}$)	Soluble ions ($meq.l^{-1}$)							
		Cations				Anions			
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}	CO_3^{--}	SO_4^{--}
First season (2019)									
7.55	5.93	20.50	16.80	18.50	1.1	45.92	2.90	-	8.08
Second season (2020)									
7.60	6.00	20..95	17.00	18.80	3.2	46.75	2.97	-	10.28

Table 2. Physical and chemical properties of investigated soil during the two successive seasons

Properties	First season (2019)	Second season (2020)
Particles size distribution (%)		
Soil texture	Loamy sand	Loamy sand
Soluble ions $meq.l^{-1}$ (in 1:5 soil water extract)		
Ca^{+} ($meq.l^{-1}$)	3.90	3.90
Mg^{+} ($meq.l^{-1}$)	3.62	3.43
Na^{+} ($meq.l^{-1}$)	2.54	2.59
K^{+} ($meq.l^{-1}$)	0.44	0.28
CO_3^{-} ($meq.l^{-1}$)	-	-
HCO_3^{-} ($meq.l^{-1}$)	4.30	4.40
Cl^{-} ($meq.l^{-1}$)	4.70	4.35
SO_4 ($meq.l^{-1}$)	1.50	1.45
EC (dSm^{-1}) in 1:5 water extract.	1.05	1.02
pH (in1:2.5Soil water suspension extract)	8.10	8.13
Organic matter %	0.153	0.171
$CaCo_3$,%	**9.2**	**9.5**

According to **Piper (1947)**

Table 3. Effect of antioxidant application on growth parameters of (*Moringa oleifera* L.) plant during two successive seasons (2019 and 2020)

	Plant height (cm)	Root length (cm)/ plant	Branch length (cm)/plant	Stem diameter (cm)	Branch No./plant	No. of Leaves/ plant	Plant height (cm)	Root length (cm)	Branch Length (cm)/plant	Stem diameter (cm)	Branch No/ plant	No. of Leaves/ plant
			First season (2019)						Second season (2020)			
Control	90.0e	20.7cd	5.5e	12.0bcd	1.8e	16.0bc	73.5e	15.7b	6.4d	9.4e	1.5f	8.0b
Pro1	93.6e	20.6cd	40.5a	12.0bcd	8.7cd	10.0d	175.3b	30.8a	70.1a	20.1bcd	10.0cd	17.0a
Pro2	93.6e	24.9b	19.5d	11.3cd	15.3a	9.66d	183.3b	34.7a	28.5bc	19.8bcd	12.5abc	19.33a
Pro3	95.6e	22.5bc	23.0cd	13.6abc	7.0d	12.0cd	154.0c	27.9a	21.1c	18.1d	5.5e	15.66a
Si1	148.6b	30.0a	27.2bc	15.8a	9.5c	22.33a	205.0a	34.8a	23.9bc	22.7a	10.5cd	22.0a
Si2	156.3a	22.4bc	29.2b	14.4ab	12.8b	19.66ab	187.6b	31.8a	35.3b	19.8bcd	12.5abc	18.66a
Si3	137.6c	30.0a	25.5bc	15.6a	15.6a	19.66ab	204.6a	27.6a	23.3c	22.2ab	15.0a	21.0a
Hu1	118.1d	20.9bcd	28.5b	12.9abc	10.2c	10.00d	133.6d	29.3a	27.8bc	20.3abcd	14.0ab	15.66a
Hu2	113.5d	17.6d	18.7d	13.8abc	9.4c	13.33cd	175.1b	34.8a	24.2bc	19.3cd	8.5d	16.66a
Hu3	76.6f	13.3e	9.0e	9.8d	13.6ab	11.33cd	176.5b	31.6a	8.5d	21.0abc	11.5bc	17.0a
F. test	*	*	*	*	*	*	*	*	*	*	*	*

Values having the same alphabetical letter(s) did not significantly differ at 0.05 level of probability according to Duncan's multiple range test.

Pro1, Pro2, Pro3 are prolin of 50, 100 and150 mgl^{-1}; Hu1, Hu2 and Hu3 are humic of 1, 1.5 and 2 gl^{-1}; Si1, Si2 and Si3 are potassium silicat of 200, 400 and 600 mgl^{-1} respectively.

Table 4. Effect of antioxidant application on fresh weight of (*Moringa oleifera* L.) plant during two successive seasons (2019 and 2020)

	Fresh weight (g) of							
	Leaves /plant	Branches /plant	Roots /plant	Total	Leaves /plant	Branches /plant	Roots /plant	Total
	First season (2019)				Second season (2020)			
Control	21.83d	34.86cd	17.16c	73.8cd	33.50e	47.30d	42.90d	123.7d
Pro1	26.13d	52.80bcd	39.4abc	118.3cd	132.96abc	218.93abc	106.76bcd	458.6abc
Pro2	21.53d	44.90bcd	65.43a	131.8cd	138.16ab	207.86abc	190.33a	536.3ab
Pro3	13.23d	51.66bcd	51.2abc	116.1cd	107.6bcd	158.26c	74.20cd	340.0c
Si1	65.00ab	112.33a	62.66ab	228.6ab	158.66a	259.00a	156.33ab	574.0a
Si2	78.33a	101.00a	55.33abc	246.0a	95.66cd	159.33c	107.00bcd	362.0c
Si3	70.66a	97.66a	50.00abc	218.3ab	92.33d	241.66ab	138.33abc	472.3abc
Hu1	28.30cd	59.23bc	27.23abc	114.7cd	84.33d	179.43bc	125.13abc	388.9c
Hu2	48.63bc	68.96b	38.23abc	155.8bc	84.46d	177.13bc	118.26bc	379.8c
Hu3	17.90d	25.33d	21.86bc	65.1d	81.16d	172.06bc	173.00ab	426.2bc
F. test	*	*	*	*	*	*	*	*

Values having the same alphabetical letter(s) did not significantly differ at 0.05 level of probability according to Duncan's multiple range test.

increased with the application of potassium silicate (400 mgl^{-1}) in first season. Prolin application (100 mgl^{-1}) was the superior treatment for increasing fresh weight of roots in both seasons. Meanwhile, fresh weight of branches, leaves and total fresh weight/ plant recorded the highest value with application of potassium silicae (200 mgl^{-1}) in second season. These results are in a harmony with those found by **Alkahtani *et al.* (2021)** who propagated that application of proline leads to a significant increase in root length and diameter, as well as root and shoot fresh weights, when compared to drought-stressed untreated sugar beet plants in both seasons.

Dry Weight

Results in Table 5 indicat that potassium silicat (200 mgl^{-1}) application increased leaves, branches and total dry weight/plant in both seasons. Dry weight of leaves increased with application treatment of prolin (50 mgl^{-1}) in second season, compared with potassium silicat which increase dry weight of leaves without significantly differ among three levels (5, 1, and 1.5 gl^{-1}) in first season. These results are in harmony with those reported by **Hiji and Jerry (2020)** who found that, proline significantly increased plant growth more than other treatments and dry matter compared to the controls. This elevation is due to the role of prolin to protect cell membranes against ion toxicity and salt-induced oxidative stress, increased cellular growth, and thus increased the growth of cabbage plant.

Chemical Analysis

Chlorophyla a, b and total chlorophyle

Results in Table 6 indicat that total chlorophyle increase with application of potassium silicat (200 mgl^{-1}) and potassium silicat (400 mgl^{-1}) in both seasons. Meanwhile, potassium silicat application (400 mgl^{-1}) recoded the highest value of ch.b in both season as well as in ch.a in the second season. These results matched will with those reported by **Hiji and Jerry (2020)** who found that foliar application of proline at different rates significantly increased leaf photosynthetic pigment concentrations such as chlorophyll compared to the control plants, these increases in chlorophyll concentrations could be attributed to the more active scavenging of ROS by proline and other antioxidant compounds. The positive effect of proline on chlorophyll concentrations under salinity stress might also because of stabilizing photosynthetic reaction **(Abdelhamid *et al.*, 2013).** Proline foliar application increased total chlorophyll, which may be due to the role of proline in increasing the stomatal conductance and subsequently increasing the amount of carbon dioxide in the stomata space, thus increasing the rate of photosynthesis in the plant **(Sharkey *et al.*, 2007).** Moreover, proline protects the chloroplast structure by using the d-ditional energy of photosystem and inhibiting free radicals **(Moustakas *et al.*, 2011). Alkahtani *et al.* (2021)** reported that during two seasons, Si or proline, significantly raised Chl a and b in stressed sugar beet plants compared to untreated sugar beet plants.

Nitrogen, phosphors and Prolin contents of leaves

Results presented in Table 7 show the effect of antioxidant application levels on N, P and prolin. Results indicated that potassium silicate (400 mgl^{-1}) increased P percentage in leaves in both seasons. The highest values of prolin in leaves was obtained by applicationof prolin (100 mgl^{-1}) without significant differences with (200 mgl^{-1}) in the first seasons. Meanwhile, in the second season recorded the highest value with Application of potassium silicat potassium silicat (200 mgl^{-1}). Application of prolin (150 mgl^{-1}) recorded high values in N percentage in leaves in both seasons. These results are in agreement with that

Table 5. Effect of antioxidant application on dry weight of (*Moringa oleifera* L.) plant during two successive seasons (2019 and 2020)

	Dry weight (g) of							
	Leaves /plant	Branches /plant	Roots /plant	Total	Leaves /plant	Branches /plant	Roots /plant	Total
	First season (2019)				Second season (2020)			
Control	8.05c	9.0b	8.50	25.8c	8.50d	6.66c	8.65d	23.6c
Pro1	9.20bc	14.23ab	10.93	34.3abc	33.20a	55.90ab	28.36a-d	117.4ab
Pro2	8.46c	16.53ab	18.2	43.2abc	28.20abc	45.23b	50.90a	124.3ab
Pro3	6.76c	13.46ab	15.86	36.1abc	23.86bc	37.23b	20.00cd	81.1b
Si1	16.66a	20.80a	18.46	55.9a	31.23ab	73.43a	48.36ab	153.0a
Si2	16.56a	22.50a	14.46	53.5ab	21.33c	53.40ab	30.56a-d	105.3b
Si3	16.13a	19.5a	11.3	46.9abc	20.46c	60.86ab	39.36abc	120.7ab
Hu1	9.5bc	14.66ab	8.1	32.2bc	21.70c	50.46ab	27.63a-d	99.8b
Hu2	13.83ab	18.10ab	13.23	45.1abc	22.26c	61.46ab	31.20a-d	114.9ab
Hu3	6.36c	8.73b	15.13	30.2c	21.50c	60.33ab	23.00bcd	104.8 b
F.test	*	*	NS	*	*	*	*	*

Values having the same alphabetical letter(s) did not significantly differ at 0.05 level of probability according to Duncan's multiple range test**.** NS=not significant

Table 6. Effect of antioxidant application on chlorophyll a, b and total chlorophyll of (*Moringa oleifera* L.) plant during two successive seasons (2019 and 2020).

	Chl. a (mg/g fw)	Chl. b (mg/g fw)	Total (mg/g fw)	Chl. a (mg/g fw)	Chl. b (mg/g fw)	Total (mg/g fw)
	First season (2019)			Second season (2020)		
Control	82.57	155.20bcd	261.4ab	71.99bc	169.35ab	242.6ab
Pro1	91.10	164.47abcd	247.2bc	88.36a	160.56bc	248.9ab
Pro2	92.33	182.52ab	239.5bcd	68.19c	164.70bc	232.8ab
Pro3	87.33	178.30abcd	250.2b	83.41ab	140.00c	223.4b
Si1	83.60	181.44abc	272.6a	73.01bc	170.63ab	266.7a `
Si2	80.91	191.23a	276.3a	88.61a	193.70a	234.2ab
Si3	80.32	153.56cd	242.1bcd	78.04abc	159.14bc	237.1ab
Hu1	80.03	153.86bcd	223.8d	75.75bc	157.56bc	233.3ab
Hu2	75.88	152.20d	227.1cd	80.72ab	164.02bc	244.7ab
Hu3	74.78	165.56abcd	240.4bcd	80.05abc	153.17bc	233.2ab
F.test	NS	*	*	*	*	*

Values having the same alphabetical letter(s) did not significantly differ at 0.05 level of probability according to Duncan's multiple range test. NS=not significant

Table 7. Effect of antioxidant application on N and P (%) as well as Prolin of (*Moringa oleifera* L.) plant during two successive seasons (2019 and 2020)

	P (%)	N (%)	Prolin (g/100g)	P (%)	N (%)	Prolin (g/100g)
	First season (2019)			Second season (2020)		
Control	0.18d	2.01b	2.87de	0.26bc	2.87ab	2.52bcd
Pro1	0.25bc	4.24ab	2.92de	0.27abc	2.43b	3.1bc
Pro2	0.27ab	3.78ab	4.21a	0.28abc	2.37b	2.80bc
Pro3	0.23 bcd	4.52a	3.44bc	0.24bc	4.22a	3.37ab
Si1	0.20cd	2.11b	2.68e	0.19c	1.81b	4.03a
Si2	0.31a	2.15b	3.82ab	0.37a	2.21b	2.36cd
Si3	0.24bc	3.28ab	2.80de	0.27abc	3.71ab	2.78bc
Hu1	0.22bcd	1.6b	2.46e	0.30ab	2.31b	1.87d
Hu2	0.20cd	2.05b	2.93de	0.22bc	4.06ab	2.55bcd
Hu3	0.23bcd	2.09b	3.22cd	0.19bc	2.96ab	2.30cd
F. test	*	*	*	*	*	*

reported by **Abdelaal *et al.* (2020)** who reported that silicon application significantly increased the content of nitrogen (4.5% and 2.6%), phosphorus (0.33% and 0.25%) in stressed sweet pepper plants at both concentrations (1500 and 3000 ppm) of salinity.

Results showed that salinity stress or the application of proline, increased the aggregation of proline in the cabbage plants **(Hiji and Jerry, 2020)**. Aggregation of proline may be caused by the increase in proteolysis or by the reduction in protein synthesis or an increase in the content of the precursors of proline **(Borgo *et al.*, 2015).**

Conclusion

The present study concluded that (*Moringa oleifera* L.) could tolerate salt stress by using antioxidants foliar application (humic acid, potassium silicat and proline).

Results indicated that, potassium silicat recorded the highest value for each of plant high, root length, stem diameter, fresh weight of of leaves, branches, total fresh weight and No. leaves in both seasons also increased dry weight of branches and total dry weight/plant. Potassium silicat increased P percentage and prolin accumulation in plant.

Prolin application significantly increased branches length, dry weight of leaves, fresh weight of root, in the same time increase N percentage in leaves and prolin accumulation compared to control in the plants grown in the salinity conditions.

It can be concluded that Antioxidants foliar application increased Moringa salinity tolerance and enhanced the production of photosynthetic pigments of the tolerant *Moringa oleifera* L. even under salinity stress.

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الملخص العربي

تأثير مضادات الاكسدة في معادلة اجهاد الملوحة على نبات المورينجيا تحت ظروف منطقه العريش

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تهدف هذه الدراسة إلى تقييم التأثيرات المختلفة لإضافات حامض الهيوميك وسيليكات البوتاسيوم والبرولين (الورقية) للتخفيف من إجهاد الملوحة على النمو والمحصول والمكونات الفعالة لنبات (المورينجا أوليفيرا) في منطقة العريش. تم أجراء التجارب الحقلية بمزرعة كلية العلوم الزراعية البيئية، جامعة العريش، شمال سيناء، خلال الموسم الصيفي لعامي 2019، 2020. اشتملت هذه الدراسة على عشر معاملات، التجربة المصممة بالتصميم العشوائي الكامل (RCD) بثلاث مكررات. تمت معاملة نباتات المورينجا بحمض الهيوميك (1، 1.5، 2 جم/لتر)، البرولين (50، 100، 150 مجم / لتر) وسيليكات البوتاسيوم (200 و400 و600 مجم/لتر) والكنترول. تم أخذ عينة عشوائية من ثلاث نباتات من كل معاملة بعد 90 يومًا من الزراعة. أوضحت النتائج التأثير الإيجابي للبوتاسيوم سيليكات والبرولين على جميع الصفات المدروسة. تم الحصول على أعلى قيم للنمو الخضري ومحتوى المعادن (في الأوراق الجافة) وتراكم البرولين والكلوروفيل (الكلوروفيل) أ & ب باستخدام سيليكات البوتاسيوم (200 مجم/لتر + 400 مجم/لتر) والبرولين (50 مجم/لتر + 100 مجم/لتر) باستخدام فروق ذات دلالة إحصائية مقارنة بجميع المعاملات الأخرى. تم تسجيل هذه النتائج في كلا الموسمين.

الكلمات الاسترشادية: مورينجا اوليفيرا؛ حمض الهيوميك؛ برولين؛ سيلكات البوتاسيوم.

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