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The effect Folic acid and nano fertilizer compound NPK and irrigation with different levels of salinity on vegetation growth characteristics in *Lawsonia inermis* L

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Abstract

The experiment was conducted during the 2024-2025 season in the field of the College of Education, Al-Qurna - University of Basra, with the aim of knowing the effect of folic acid, nano-compound fertilizer (NPK), and irrigation with different levels of salinity on the vegetative growth characteristics of henna plant *Lawsonia inermis* L. The experiment included studying three factors, which are irrigation with different levels of salinity (2, 4 ,8) ds.m^{-1}, folic acid with three concentrations (0, 40 ,80) mg. L^{-1}, and spraying with nano-compound fertilizer (NPK) with three concentrations (0, 3,6) g. L^{-1} . The experiment was carried out using a split- plot design and according to the Randomized Complete Black design system (RCBD) was used with three replicates per treatment , and the Means treatmeant were compared by Least significant level at 0.05. The results showed that all irrigation concentrations at different levels of salinity led to a significant decrease in all vegetative growth characteristics (plant height, number of leaves, number of branches, leaf area, fresh weight, dry weight) compared to the control group, where the level of 8 dSm^{-1} (77.6 cm, 252.8,18, 3.17cm^{2}, 29.00 g.plant^{-1}, 45.72 g .plant^{-1}) gave). Spraying with folic acid and nano-compound fertilizer led to a significant superior in all the above-mentioned vegetative growth characteristics, where plants sprayed with folic acid concentration of 80 mg. L^{-1} and fertilizer concentration of 6 g. L^{-1} outperformed, respectively (107.1 cm, 390.59, 38.11, 5.06 cm^{2}, 56.46 g. plant^{-1}, 39.42 g. Plant^{-1}). For the mentioned characteristics with sequence.

Keywords: henna plant, folic acid, nano-compound fertilizer, irrigation at different levels of salinity.

I. INTRODUCTION

Henna *(Lawsonia inermis* L.) belongs to the Lythreceae family and is a shrub or small tree cultivated in many regions due to its medicinal, cosmetic and economic importance. It is widely cultivated in tropical, subtropical and semi-arid regions of Africa, South Asia and northern Australia (Muthumani *et al*., 2010). The plant is commonly cultivated for its roots, phloem, stems, leaves and seeds for medicinal uses. The plant contains proteins, carbohydrates and fatty acids as primary metabolites along with secondary metabolites such as tannins, quinines, terpenoids, coumarins, etc. The phytochemical constituents of L. *inermis* are responsible for its analgesic, anti-inflammatory, hepatoprotective and hypoglycemic properties. It also possesses antibacterial, antifungal, immunostimulant, antioxidant and cytotoxic activities (Sharma *et al*., 2016).

Salinity is considered the main factor responsible for the decline in crop productivity in many regions of the world, especially in arid and semi-arid areas (Mirza *et al.*, 2019). Salinity reduces the growth and productivity of non-halophytic plants by reducing water availability to the roots due to the osmotic effect of salt and the toxic effects of excessive salt accumulation within the plant (Abogadallah *et al*., 2010). The main factors caused by sodium chloride are the doubling of potassium uptake into cells (which is effective in closing stomata), which reduces photosynthetic activity, the generation of reactive oxygen radicals (ROS), and programmed cell death. Sodium and potassium compete for entry into

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cells, and stress blocks potassium entry into the cell. Ionic and osmotic stress cause metabolic effects in the plant, and the plant must reduce these stresses to maintain its growth (Shabala *et al*., 2017).

Folic acid is a type of vitamin B9 that participates in the synthesis of vital molecules such as nucleic acid. It plays an important role in amino acid metabolism and in scavenging free radicals (ROS) produced in plants during photosynthesis and respiration, and when plants are exposed to various types of stress (Fardet et al., 2008). Folic acid also participates in the synthesis of growth regulators such as auxins, polyamines, and ethylene through its important role in the biosynthesis of amino acids such as methionine, glycine, tryptophan, glutamic acid, and valsine (Stakhora et al., 2000). Folic acid is also indirectly responsible for the synthesis of chlorophyll, carotenoids, and alpha-tocopherol (vitamin H). The antioxidant properties of folate can be considered a key factor in explaining the enhancement of plant tolerance to various abiotic stresses and the prevention of oxidative damage (Hunang, 2018; Gliszne, 2007). Nano fertilizers are chemical compounds applied to enhance the growth of plants and fruits. They are manufactured according to the nanotechnology system on a specific scale ranging from (1-100 nanometers) (Boshion, 2017). They are manufactured to provide three main elements: N, P, and K. Nitrogen improves vegetative growth by participating in the synthesis of proteins and chlorophyll. Phosphorus works on root growth and enlargement of flowers and fruits, while potassium increases the growth of the stem and roots and also participates. This experiment was conducted to determine the effect of folic acid, nano-compound fertilizer NPK, and irrigation with different levels of salinity on the vegetative growth characteristics of henna plants and improve their growth and productivity.

II. Material and methods

The experiment was conducted during the 2024-2025 agricultural season at the University of Basra/College of Education, Al-Qurna, on the henna plant Lawsonia inermis L. A growth medium consisting of clay soil, river sand, and peat moss produced by the Dutch company Estonia was used in a 1:1:1 ratio. Table 1 shows the chemical and physical properties of the soil used. Henna plants were obtained from one of the Karmat Ali nurseries in Al-Hartha District, and were one and a half years old. They were identical in size and height. The plants were then transplanted into pots with a diameter of 24 cm and a weight of 6 kg per pot. A split-plot experiment was conducted, with salt concentrations placed in the plots. Salinity was the main factor, with three concentrations (2, 4, and 8) ds-1. Folic acid concentrations (0, 40, and 80) and nano-fertilizer (0, 3, and 6) were considered the main factor. Subplot, with three replicates, where the number of treatments was 3*3*3 and the total was 27 treatments, and the number of experimental units was 54 experimental units, and the total number of pots, each pot containing one plant, was 162 plants. The experiment was designed according to the Randomized Complete Black Design, then the results were analyzed using analysis of variance, and using the Revised Least Significant Difference Test (R.) to compare means at the probability level of 0.05 (Al-Rawi and Khalaf Allah, (1980)

Experimental measurement

Samples were collected after the experiment was completed.

1- Plant height: The plant height was measured from the point of contact with the soil to the highest point using a measuring tape. The length of all plants in the experimental units was measured, and the average was calculated for three replicates.

2- Number of leaves: The number of leaves per plant was calculated for all plants, and the average was calculated for three replicates.

3- Leaf area: According to the method mentioned by Morsi et al. (1968), the mature leaf was cut close to the growing tip, then the shape of the leaf was marked with a pen on a piece of paper. The leaf was then cut and weighed using a sensitive balance. The known area (3 x 3) was determined from the writing paper and weighed. The leaf area of the plant was then calculated by comparing the writing paper with the weight of the specified leaf area.

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4- Number of secondary branches: The number of lateral branches was calculated for all plants, and the average was calculated for three replicates.

5- Fresh weight. 6- Dry weight.

Table No. (1) shows the chemical and physical properties of field soil

character	Value
Acidity (PH)	**7.3**
Electrical conductivity EC	**11.5**
Organic matter	**25.7**
Total Nitrogen (g/kg)	**30.1**
Available Phosphorus (mg/kg)	**20.13**
Available potassium(mg/kg)	**62.87**
Soil Classifiers	
Clay	**40%**
Sand	**28%**
Silt	**32%**
Soil Texture	**Sand loam**

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III. Result and discussion

The results of the statistical analysis show that salinity levels, folic acid, and NPK levels, as well as their binary interactions and the triple interaction between salinity levels, folic acid concentrations, and NPK levels, had a significant effect on the studied traits (plant height, number of leaves per plant, leaf area, number of branches, fresh weight, and dry weight). From Tables (2, 3, 4, 5, 6, 7), it was noted that the salinity concentration in irrigation water brief to a significant decrease in the above traits. A concentration of 8 dS.m-1 produced the lowest mean for the traits (88 cm, 304.33 leaves.plant^{-1}, 28.85, 4.05 cm^2, 45.72 g/plant^{-1}, 29.00 g/plant^{-1}) for the above traits, respectively. Exposure of plants to different levels of salinity affects the growth and physiological functions of the plant. The reason for the decrease in growth is the reduction in the absorption of the necessary elements for the plant,(Farjani *et al* .,2003) which are potassium and calcium, and thus reduces the process of transporting it to the rest of the plant parts. This affects the indicators of vegetative growth, which reduces the process of photosynthesis. The reason for the decrease in plant height is the negative effect of the accumulation of toxic sodium,(Gonzalez et al .,2019). because it works. It inhibits photosynthesis and carbohydrate synthesis,(Kilic *et al* .,2016) thus affecting cell division and plant growth. (Gorelova *et al* .,2017., Gambonnet *et a*l .,2001., Jabrinet et al .,2021)The decrease in the number of branches, leaves, and leaf area also leads to a decrease in meristematic activity and cell elongation in the growing tip. It also affects the balance of plant hormones. Plants treated with 2ds. m^{-1} gave the highest rates of the above-mentioned traits (107.59 cm², 334.11 leaves/plant^{-1}, 4.30 cm², 50.54 g/plant^{-1}, 34.73 g/plant^{-1}). This is consistent with a study conducted on the *Oenanth javanice* plant (Kuma *al et*., 2021) and a study conducted on the *Calendula officialis* L (Bayate et al., 2023) and (Tchanifar, 2016) of four fig genotypes. Regarding folic acid concentrations, it is noted from the same tables that the 80 mg/L^{-1} treatment gave The highest rates of the studied traits were (107.19 cm, 377.52 leaves/plant^{-1}, 1.9 cm^2, 38.11 branches/plant^{-1}, 56.46 g/plant^{-1}, 35.31 g/plant^{-1}) respectively. Folic acid increases the rate of cell division, genome stability and growth. It acts as an antioxidant to reduce oxidative damage caused by salinity and drought by stimulating the glutathione-ascorbate cycle and reducing lipid peroxidation. The acid also participates in the activity of APX, G-POX, CAT, and SOD under saline conditions compared to plants not treated with saline. Folic acid increases proline synthesis, which helps plants acquire tolerance to stress (Burguies *et al*., 2007). FA binds to some essential elements, increases potassium and calcium absorption, restricts sodium uptake, and plays a role in protecting cytoplasmic enzymes from high levels of sodium and regulating osmotic potential under saline conditions. Acids play an important role in the biosynthesis of amino acids such as glycine, tryptophan, methionine, valine, and proline. This is consistent with a study conducted on *vicial fabal* L .bean plants (Al-Maliki *et al*., 2019) and a study conducted on L(Mossa *et al.*, 2021). While a concentration of 0 mg L-1 yielded the lowest rates, which were (83.59 cm², 235.0 leaves/plant^{-1}, 1.033 cm², 25.26 branches/plant^{-1}, 345.3 g/plant^{-1}, and 161.56 g/plant^{-1}), respectively.From the same tables, it was shown that the level of the nano-compound fertilizer NPK 6 g.L^{-1} gave the highest rates for the samples under study if they were (101.11 cm, 377.59 leaves. plant^{-1}, 5.05 cm2, 34.41 branches. plant^{-1}, 51.51 g. plant^{-1}, 39.43 g. plant^{-1}). As for the treatment of NPK fertilizer, it gave the lowest rates (89.26 cm, 235.0 leaves. plant^{-1}, 3.37 cm2, 27.48 branches. plant^{-1}, 23.36 g. plant^{-1}, 23.36 g. plant^{-1}) respectively. Nano-PK fertilizers play a crucial role in plant growth and development, as they provide abundant nutrients to the plant and release them slowly and steadily. This means that fertilizers work to further improve agricultural performance. Nitrogen is the nutrient responsible for plant growth (vegetative parts) and is an essential component of amino acids, proteins, and chlorophyll, which is a vital element for the metabolism process. Phosphorus plays a major role in energy transfer, root growth, and flower and fruit production. It is also an essential element for photosynthesis and respiration. Potassium is essential for overall plant health, as it regulates water absorption, helps resist diseases, and activates enzymes (Mandal *et al.*, 2009). This is consistent with a study conducted on citrus fruits by (Al-Tamimi *et al*., 2023), a study on *Abelmoschus esculentus* L(Aman *et al*., 2025), and a study on tomato (Krishi *et al.*, 2020).

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Table 2 Effect folic acid and nano fertilizer and irrigation different on salinity in hight plant cm

Folic acid(mg .L^{-1})	Nano fertilizer(g .L^{-1})	Salinity (ds.m-1)			Mean acid effect
		2	4	8	
0	0	92.00	80.00	72.00	83.59
	3	94.33	81.00	75.33	97.93
	6	95.67	82.00	79.33	107.19
40	0	92.33	84.00	76.67	Mean fertilizer effect
	3	117.67	98.33	93.67	89.26
	6	118.00	102.67	98.00	98.33
80	0	109.67	99.33	97.33	101.11
	3	118.33	103.11	99.00	Mean salinity effect
	6	130.33	106.67	100.67	107.59
L.S.D					93.11
					88.11
Folic acid	Nano fertilizer	Salinity			Folic acid ×fertilizer × salinity
1.305	1.305	1.305			5.536

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Table 3 Effect folic acids and nano fertilizer and irrigation different levels of salinty in number leaves

Folic acid(mg .L^{-1})	Nano fertilizer(g .L^{-1})	Salinity (ds.m-1)			Mean acid effect
		2	4	8	
0	0	189.33	186.00	174.00	234.33
	3	270.33	250.00	229.33	331.48
	6	289.33	267.00	253.33	390.59
40	0	258.00	237.00	229.00	Mean fertilizer effect
	3	385.67	372.00	359.00	235.00
	6	397.00	382.33	367.67	343.81
80	0	290.33	282.67	267.67	377.59
	3	432.33	402.67	392.67	Mean salinity effect
	6	494.67	481.33	471.00	334.11
L.S.D					317.96
					304.33
Folic acid	Nano fertilizer	Salinity			Folic acid ×fertilizer × salinity
1.279	1.279	1.279			3.838

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Table 4 Effect folic acid and nano fertilizer and irrigation different of salinity of leaf area cm^2

Folic acid(mg .L^{-1})	Nano fertilizer(g .L^{-1})	Salinity (ds.m-1)			mean acid effect
		2	4	8	
0	0	2.00	1.90	1.75	3.17
	3	3.95	3.78	3.65	4.29
	6	4.00	3.83	3.75	5.06
40	0	4.10	4.00	3.93	Mean fertilizer effect
	3	4.75	4.45	4.30	3.37
	6	4.55	4.35	4.20	4.28
80	0	4.90	4.81	4.72	5.05
	3	5.40	5.32	5.24	Mean salinity effect
	6	5.10	5.05	5.00	4.30
L.S.D					4.16
					4.05
Folic acid	Nano fertilizer	Salinity			Folic acid ×fertilizer × salinity
0.20	0.20	0.20			0.61

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Table 5 effect folic acid and nano fertilizer and irrigation different of salinity on number branch

Folic acid(mg .L^{-1})	Nano fertilizer(g .L^{-1})	Salinity (ds.m-1)			Mean acid effect
		2	4	8	
0	0	26.67	24.00	20.00	25.26
	3	27.33	25.33	24.33	30.07
	6	28.33	26.00	25.33	38.11
40	0	28.67	27.00	25.00	Mean fertilizer effect
	3	34.00	30.33	27.33	27.48
	6	35.00	32.67	30.33	31.56
80	0	33.33	32.00	30.67	34.41
	3	41.67	38.00	35.67	Mean salinity effect
	6	47.00	43.67	41.00	33.59
L.S.D					31.00
					28.85
Folic acid	Nano fertilizer	Salinity			Folic acid ×fertilizer × salinity
1.090	1.090	1.090			3.269

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Table 6 effect folic acid and nano fertilizer and irrigation different of salinity on fresh wieght

Folic acid(mg .L^{-1})	Nano fertilizer(g .L^{-1})	Salinity (ds.m-1)			Mean acid effect
		2	4	8	
0	0	40.00	39.53	37.00	40.78
	3	42.59	41.01	39.51	47.56
	6	45.41	42.00	40.05	56.46
40	0	47.00	45.31	42.00	Mean fertilizer effect
	3	49.13	46.78	43.09	45.40
	6	53.68	50.00	48.03	47.56
80	0	55.21	52.26	50.31	51.15
	3	58.90	55.07	52.00	Mean salinity effect
	6	63.00	61.91	59.53	50.54
L.S.D					48.20
					45.72
Folic acid	Nano fertilizer	Salinity			Folic acid ×fertilizer × salinity
0.49	0.49	0.49			1.19

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Table 7 effect folic acid and nano fertilizer and irrigation of salinity on dry wieght

Folic acid(mg .L^{-1})	Nano fertilizer(g .L^{-1})	Salinity (ds.m^{-1})			Mean acid effect
		2	4	8	
0	0	23.51	21.00	19.65	28.71
	3	25.00	23.12	20.43	31.56
	6	29.00	25.41	23.12	35.31
40	0	32.00	29.53	24.63	Mean fertilizer effect
	3	35.90	32.23	30.12	23.36
	6	39.66	36.58	34.62	32.80
80	0	38.33	36.60	33.12	39.43
	3	42.91	39.12	35.23	Mean salinity effect
	6	46.33	43.11	40.06	34.73
L.S.D					30.88
					29.00
Folic acid	Nano fertilizer	Salinity			Folic acid ×fertilizer × salinity
1.07	1.07	1.07			2.63

IV. Conclusions

From the above results, we conclude that increasing the salt concentration in irrigation water leads to a decrease in vegetative characteristics, while increasing the concentrations of folic acid and the level of nano-compound fertilizer NPK sprayed on plants leads to an increase in the studied characteristics and the role it plays in reducing the effect of salt concentrations.

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https://jam.utq.edu.iq/index.php/main *https://doi.org/10.54174/utjagr.v13i1.323*

V. References

Abogadallah, G. M. (2010). Insights into the significance of antioxidative defense under salt stress. Plant signaling & behavior, 5(4), 369-374.00:21

Alnusairi, G.S.; Mazrou, Y.S.; Qari, S.H.; Elkelish, A.A.; Soliman, M.H.; Eweis, M.; Abdelaal, K.; El-Samad, G.A.; Ibrahim, M.F.; ElNahhas, N. Exogenous nitric oxide reinforces photosynthetic efficiency, osmolyte, mineral uptake, antioxidant, expression of stress-responsive genes and ameliorates the effects of salinity stress in wheat. Plants 2021, 10, 1693. [CrossRef]

Al-Maliki, Azhar Ward Abboud and Jari, Awatif Nemah and Obaid, Faris Ibrahim. 2019. Effect of spraying with folic acid and cysteine on the growth and yield of green broad bean (Vicia faba L.) plant. Al-Muthanna Journal of Agricultural Sciences, Vol. 7, No. 4, pp. 22-28.

Al-Rawi, Khashe' Mahmoud and Abdul Aziz Khalaf Allah. 1980. Design and Analysis of Agricultural Tracts. University of Mosul. College of Agriculture and Forestry. Iraq.

Fardet, A., Rock, E., & Rémésy, C. (2008). Is the in vitro antioxidant potential of whole-grain cereals and cereal products well reflected in vivo?. Journal of Cereal Science, 48(2), 258-276.

Alnusairi, G.S.; Mazrou, Y.S.; Qari, S.H.; Elkelish, A.A.; Solimu M.H.; Eweis, M.; Abdelaal, K.; El-Samad, G.A.; Ibrahim, M.F.; ElNahhas, N. Exogenous nitric oxide reinforces photosynthetic efficiency, osmolyte, mineral uptake, antioxidant, expression of stress-responsive genes and ameliorates the effects of salinity stress in wheat. *Plants* **2021**, *10*, 1693. [CrossRef]

Ashraf, M.; Harris, J.C. Potential biochemical indicators of salinity tolerance in plants. Plant Sci. 2004, 166, 3–16. [Google Scholar] [CrossRef]

Cui, S.; Lv, X.; Li, W.; Li, Z.; Liu, H.; Gao, Y.; Huang, G. Folic acid modulates VPO1 DNA methylation levels and alleviates oxidative stress-induced apoptosis in vivo and in vitro. Redox Biol. 2018, 19, 81–91. [CrossRef]

Donkor Sarkodie C, Quainoo AK, Gustav M. Propagation of Henna (Lawsonia inermis) cuttings using nathelene acetic acid, indole .

Elkelish, A.A.; Soliman, M.H.; Alhaithloul, H.A.; El-Esawi, M.A. Selenium protects wheat seedlings against salt stress-mediated oxidative damage by up-regulating antioxidants and osmolytes metabolism. Plant Physiol. Biochem. 2019, 137, 144–153. [CrossRef] [PubMed

Ferjani, A.; Mustardy, L.; Sulpice, R.; Marin, K.; Suzuki, I.; Hagemann, M.; Murata, N. Glucosylglycerol, a compatible solute, sustains cell division under salt stress. Plant Physiol. 2003, 131, 1628–1637. [CrossRef]

Gambonnet, B.; Jabrin, S.; Ravanel, S.; Karan, M.; Douce, R.; Rébeillé, F. Folate distribution during higher plant development. *J. Sci. Food Agric.* **2001**, *81*, 835–841. [CrossRef]

ISSN Onlin:2708-9347, ISSN Print: 2708-9339 Volume 14, Issue 2 (2025) PP 640-652
https://jam.utq.edu.iq/index.php/main *https://doi.org/10.54174/utjagr.v13i1.323*

González, B.; Vera, P. Folate metabolism interferes with plant immunity through 1C methionine synthase-directed genome-wide DNA methylation enhancement. Mol. Plant 2019, 12, 1227–1242. [CrossRef] [PubMed]

Gorelova, V.; Ambach, L.; Rébeillé, F.; Stove, C.; Van Der Straeten, D. Folates in plants: Research advances and progress in crop biofortification. *Front. Chem.* **2017**, *5*, 21. [CrossRef]

Hernández, J.A. Salinity tolerance in plants: Trends and perspectives. Int. J. Mol. Sci. 2019, 20, 2408. [Google Scholar] [CrossRef] [PubMed] [Green Version]

Hussain, K.; Majeed, A.; Nawaz, K.; Khizar, H.B.; Nisar, M.F. Effect of different levels of salinity on growth and ion contents of black seeds (Nigella sativa L.). Curr. Res. J. Biol. Sci. 2009, 1, 135–138. [Google Scholar]

Jabrin, S.; Ravanel, S.; Gambonnet, B.; Douce, R.; Rébeillé, F. One-carbon metabolism in plants. Regulation of tetrahydrofolate synthesis during germination and seedling development. *Plant Physiol.* **2003**, *131*, 1431–1439. [CrossRef]

Kumar, A., Singh, S., Mukherjee, A., Rastogi, R. P., & Verma, J. P. (2021). Salt-tolerant plant growth-promoting Bacillus pumilus strain JPVS11 to enhance plant growth attributes of rice and improve soil health under salinity stress. Microbiological Research, 242, 126616 .

Muthumani P, Meera R, Sundaraganapathy Devi P, Mohamed Sheik Arabath S, Cholarja K. Biological evaluation of dried fruits of Lawsonia inermis. J Pharm Biomed Sci. 2010;1:1–5.

Nahhas, N.E.; Abdelaal, K.A.; AlKahtani, M.D.; Al Husnain, L.; AlGwaiz, H.I.; Hafez, Y.M.; Attia, K.A.; El-Esawi, M.A.; Ibrahim, M.F.; Elkelish, A. Biochar and jasmonic acid application attenuate antioxidative systems and improves growth, physiology, nutrient uptake and productivity of faba bean (*Vicia faba* L.) irrigated with saline water. *Plant Physiol. Biochem.* **2021**, *166*, 807–817. [CrossRef]

R.k Sharma et al (2016) int Jappl Sci Biotechnol vol 4 (1) :15-20 DoI:10.3126/ijasbt.v4il .14728.

Donkor Sarkodie C, Quainoo AK, Gustav M. Propagation of Henna (Lawsonia inermis) cuttings using nathelene acetic acid, indole . Elkelish, A.A.; Soliman, M.H.; Alhaithloul, H.A.; El-Esawi, M.A. Selenium protects wheat seedlings against salt stress-mediated oxidative damage by up-regulating antioxidants and osmolytes metabolism. Plant Physiol. Biochem. 2019, 137, 144–153. [CrossRef] [PubMed Hernández, J.A. Salinity tolerance in plants: Trends and perspectives. Int. J. Mol. Sci. 2019, 20, 2408. [Google Scholar] [CrossRef] [PubMed] [Green Version]

Hussain, K., Majeed, A., Nawaz, K., & Nisar, M. F. (2009). Effect of different levels of salinity on growth and ion contents of black seeds (Nigella sativa L.). Current Research Journal of Biological Sciences, 1(3), 135-138

Shabala, S. (2017). Signalling by potassium: another second messenger to add to the list?. Journal of experimental botany, 68(15), 4003-4007.05:55 Zarei, M., Azizi, M., Rahemi, M., & Tehranifar, A. (2016). Evaluation of NaCl salinity tolerance of four fig genotypes based on vegetative growth and ion content in leaves, shoots, and roots. HortScience, 51(11), 1427-1434. Zaki, . F., Ahmed, A. A., Singer, S. M., & El–Magd, M. M. A. (2009). Reducing the adverse effect of irrigation water

ISSN Onlin:2708-9347, ISSN Print: 2708-9339 Volume 14, Issue 2 (2025) PP 640-652

https://jam.utq.edu.iq/index.php/main *https://doi.org/10.54174/utjagr.v13i1.323*

salinity on the vegetative growth, green yield and quality of sweet fennel plants by organic manure. *Aust. J. Basic App. Sci*, *3*, 4449M

Shabala, S. (2017). Signalling by potassium: another second messenger to add to the list?. Journal of experimental botany, 68(15), 4003-4007.05:55 Zarei, M., Azizi, M., Rahemi, M., & Tehranifar, A. (2016). Evaluation of NaCl salinity tolerance of f

Soliman, M.H.; Abdulmajeed, A.M.; Alhaithloul, H.; Alharbi, B.M.; El-Esawi, M.A.; Hasanuzzaman, M.; Elkelish, A. Saponin biopriming positively stimulates antioxidants defense, osmolytes metabolism and ionic status to confer salt stress tolerance in soybean. *Acta Physiol. Plant.* **2020**, *42*, 114. [CrossRef

Stakhova, L.; Stakhov, L.; Ladygin, V. Effects of exogenous folic acid on the yield and amino acid content of the seed of *Pisum sativum* L. and *Hordeum vulgare* L. *Appl. Biochem. Microbiol.* **2000**, *36*, 85–89.

Ste˛pien´, P.; Kłbus, G. Water relations and photosynthesis in Cucumis sativus L. leaves under salt stress. Biol. Plant. 2006, 50, 610–616. [CrossRef]

Youssef, M.H.; Raafat, A.; El-Yazied, A.A.; Selim, S.; Azab, E.; Khojah, E.; El Nahhas, N.; Ibrahim, M.F. Exogenous Application of Alpha-Lipoic Acid Mitigates Salt-Induced Oxidative Damage in Sorghum Plants through Regulation Growth, Leaf Pigments, Ionic Homeostasis, Antioxidant Enzymes, and Expression of Salt Stress Responsive Genes. *Plants* **2021**, *10*, 2519. [CrossRef] [PubMed]

Youssef, M.H.; Raafat, A.; El-Yazied, A.A.; Selim, S.; Azab, E.; Khojah, E.; El Nahhas, N.; Özmen, S.; Tabur, S. Functions of folic acid (vitamin B9) against cytotoxic effects of salt stress in Hordeum vulgare L. Pak. J. Bot. 2020, 52, 17–22. [CrossRef]

Yu, Z.; Duan, X.; Luo, L.; Dai, S.; Ding, Z.; Xia, G. How plant hormones mediate salt stress responses. *Trends Plant Sci.* **2020**, *25*, 1117–1130. [CrossRef]

Zaki, M. F., Ahmed, A. A., Singer, S. M., & El–Magd, M. M. A. (2009). Reducing the adverse effect of irrigation water salinity on the vegetative growth, green yield and quality of sweet fennel plants by organic manure. Aust. J. Basic App. Sci, 3, 4449-4464.

Alleviating adverse effects of salt stress in pot marigold (Calendula officinalis L.) by foliar spray of silicon and nano-silicon under greenhouse and field conditions

Hassan Bayat1*, Basireh Shahraki1, Mohammad Hossein Aminifard1, 2 and Farhad Azarmi-Atajan, Alleviating adverse effects of salt stress in pot marigold (Calendula officinalis L.) by foliar spray of silicon and nano-silicon under greenhouse and field conditions