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VICIA FABA L. ASSESSMENT FOR GROWTH AND PRODUCTIVITY TRAITS UNDER MAGNETIZED IRRIGATION WATER AND NANO-SEAWEED EXTRACT

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SUMMARY

The latest study aimed to assess the response of the broad bean to the magnetically-treated irrigation water and foliar application of nano-seaweed extract for growth and productivity traits. This experiment took place during the growing season of 2020–2021 under field conditions at Al-Najaf Governorate, Iraq. Turkish broad bean cultivar 'Luz-de-otono' was grown in a split-plot design by two factors with three replicates. The main plots received magnetized irrigation water with three diverse intensities (zero, 1000, and 2000 Gauss), while the nano-seaweed extract with three concentrations (0, 1, and 2 ml.L^{-1}) in the subplots. On average, the magnetization treatment at 2000 Gauss attained significant improvement in the growth and morphological traits (plant height, branch number per plant, leaf number, leaf area, and total leaf chlorophyll content) and yield traits (pod number, pod weight, plant yield, and total yield), compared with the control that gave the lowest values. Nano-seaweed foliar application at 2 ml.L^{-1} also revealed a significant increase and improvement in the same growth, morphological, and yield-related traits aforementioned, compared with the control treatment that gave the minimum values. Correspondingly, the interaction between both factors (magnetization intensity 2000 Gauss + Seaweed at 2 ml.L^{-1}) also showed significant effects and provided the highest averages of plant height (36.05 cm), branch number per plant (7.04 branch.plant^{-1}), leaf number (72.19 leaves.plant^{-1}), leaf area (3775.88 cm^2.plant^{-1}), and total leaf chlorophyll content (45.47 mg.100 g^{-1} FW) and yield traits: pod number (19.11 pods.plant^{-1}), pod weight (26.87 g), plant yield (513.49 g), and total yield (11.61 t.ha^{-1}), compared with the control treatment.

Keywords: Broad bean (*Vicia faba* L.), magnetized irrigation water, nano-seaweed extract, control, growth and morphological traits, yield-related variables

Key findings: Irrigation water at magnetization intensity (2000 Gauss) and the exogenous application of nano-seaweed extract at 2 ml.L^{-1} individually and in combination have significantly enhanced the growth and yield traits in broad beans (*Vicia faba* L.).

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INTRODUCTION

Broad bean (*Vicia faba* L.) is one of the chief legume crops and ranks fourth most important Fabaceae plant in the world. Cultivated for its fresh pods, green, and dry seeds, it contains rich nutrients, as every 100 gm of its seeds contains 73% water, 18% carbohydrates, 8%

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proteins, 2% fibers, 0.4% fats, and minerals like Fe (1.55 mg), Mg (1.55 mg), P (129 mg), K (332 mg), Vit C (3.7 mg), Vit B1 (0.133 mg), Vit B6 (0.104 mg), and Vit A (17 mg) (Boras *et al*., 2011). From a medical point of view, the bean plant can prevent constipation, and its iron content makes it useful for cholesterol reduction in the blood and for preventing anemia (Mustafa, 2010).

The world has witnessed a significant population growth that needs to provide food in that limited agricultural land, so the need to increase production per unit area. Further, exogenous application on the plant foliage positively impacts various physiological processes influencing growth and yield related-traits (Al-Sultani, 2020).

Once irrigation water passes through a pipe equipped with a magnetic device, water's chemical and physical properties, such as, salt solution capacity, density, and crystal deposition ratio, get altered, which has substantial advantages for soil properties and plant lifetime, growth, and production (Liu *et al*., 2019). In addition, the discovery of magnetized water to have several physical factors that impact plant growth and development improved the capacity for nutrient absorption and water uptake by the plant roots (Sadeghipour and Aghaei, 2013). Moreover, it reduced the use of chemical fertilizers, with harmful effects on human health and the environment (Al-Amin, 2018). According to Maheshwari and Grewal (2009), irrigation with magnetically treated water has a noticeable effect on plant productivity and some positive impact on plant growth and production.

Nanotechnology is one of the innovative techniques that has proven its efficiency in agriculture to resolve many problems. Moreover, nano-particles have potential applications in agricultural systems, such as, determining pollutants, pests, and plant diseases, especially, foliar and soil fertilization (Ghormade *et al*., 2011). Therefore, researchers use the nano-seaweed extract as a safer material. The seaweed extract foliar application helped enhance the efficiency of the metabolism processes of the leaves by increasing photosynthesis efficiency. Besides, seaweed extract contains cytokines, auxins, and many macro and micronutrients, as well as delays the plant senescence stage and prevents defoliation and flower and fruit abscission (Alali and Aljanabi, 2020). Spraying seaweed extract on plants showed significant improvements in the growth and yield attributing traits, i.e., plant height, branch number, shoot dry weight, fruit number per plant, plant yield, and total yield (Al-Zubaidi and Al-Hamzawi, 2016) on sweet pepper and (Al-Akaisi and Al-Sahaf, 2017) on okra plants. Similarly, Al-Asadi's (2020) findings revealed that foliar application of hornwort and Acadian seaweed extracts on the eggplant plants significantly increased plant height and total leaf number versus the control giving the lowest averages of vegetative parameters. Therefore, the present study aimed to determine the effects of magnetically-treated irrigation water and its role in reducing salt stress and foliar application of nano-seaweed extract for broad bean growth and productivity traits.

MATERIALS AND METHODS

This experiment proceeded during the growing season of 2020–2021 in the open field located in the desert area of Al-Haidariyah Sub-District, Al-Najaf Governorate, Iraq. Mixing several samples of the field soil prepared a sub-sample for analysis. In addition, the irrigation water underwent evaluation for the chemical and physical characteristics used from the experimental soil and the well water at the Department of Soil Science and Water Resources, College of Agriculture, University of Kufa, Iraq (Table 1).

The experimental field preparation included plowing, harrowing, leveling, and dividing into three lines 0.75 m apart, each line 20 m long. The Turkish bean cultivar 'Luz-de-otono' seeds produced by the Spanish Seed Company Fito Semillas, were planted at a distance of 30 cm, performing all the recommended field practices during the growing season. The experiment was laid out in a split-plot design with two factors with three replicates. The first factor included irrigation with magnetized water with different intensities (zero, 1000, and 2000 Gauss) served as main plots. The second factor comprised three concentrations of Super Fifty nano-seaweed extract (zero, 1, and 2 $ml.L^{-1}$) that was placed as subplots. The nano-seaweed extract consists of macro and micronutrients, i.e., organic N (3.43%), P_2O_5 (2.44%), K_2O (4.55%), Mg (0.68%), Ca (0.42%), Fe (150ppm), Mn (18ppm), B (4ppm), Zn (75ppm), and plant hormones auxin (0.027%) and cytokinin (0.021%). The nano-seaweed extract spraying ensued 30 days after planting and then at 15 days intervals (Al-Zurfi et al., 2021).

Table 1. Chemical and physical analysis of soil and well water properties of the experiment.

Soil Parameters	Unit	Values	
		Soil	Well Water
Soil Texture: Sandy			
Clay Silt Sand	g.kg^{-1} g.kg^{-1} g.kg^{-1}	120 182 698	
Cation Exchange Capacity (CEC) pH Electric Conductivity (EC) N P K Ca Na Organic Matter (OM)	Cmol.kg^{-1} --------- dS.m^{-1} mg. kg^{-1} mg. kg^{-1} Mml.L^{-1} ppm ppm %	3.95 7.56 3.95 4.12 3.74 0.59 1222.00 442.90 1.20	4.63 7.21 4.63 3.40 3.37 0.88 2132.20 662.30

Data record

At the end of the growing season, measurement of some growth and yield parameters in bean plants progressed as follows:

Growth and morphological traits

The plant height (cm), measured randomly in five plants using a metric tape from the soil surface to the highest point of the plant and then averaged. Counting the number of branches per plant continued in random plants and then averaged. The total number of leaves per plant randomly for five plants in each experimental unit was calculated and averaged. The leaf area (cm^2) calculation followed the method described by Sadik *et al*. (2011) using a scanner, with each image processed by Image J software. In the fresh green leaves, the total chlorophyll pigment (mg.100gm^{-1} FW) estimation used the method described by Goodwin (1976).

Yield components and total yield

The pod number per plant, counted randomly in five plants per experimental unit, got divided by the number of plants. For pod weight (g), the number of pods dividing the cumulative harvest of pods to take the average. For single plant yield (g), the number of plants dividing the total cumulative plant yield in each experimental unit to take the average. The total yield (t.ha^{-1}) calculation used the formula below:

$$\text{The total yield (t.ha}^{-1}) = \frac{10000\ m^2\ \ x\ \text{Experimental unit yield}}{\text{Experimental unit area}\ m^2}$$

Statistical analysis

Statistical analysis of the collected data used the two-way ANOVA according to the implemented design. The least significant difference (LSD) test was determined for mean comparisons at the level of 5% using the statistical program Statistix 10 (Analytical Software, Tallahassee, FL).

RESULTS

Growth and morphological traits

The results showed that the magnetically-treated irrigation water intensities revealed significant differences in bean plants ($P \leq 0.05$). At 2000 Gauss of magnetic water, growth and morphological traits, including plant height, branch number per plant, leaf number per plant, leaf area, and total chlorophyll concentration in leaves, have increased (30.92 cm, 5.88 branches.plant^{-1}, 67.57 leaves.plant^{-1}, 3205.54 cm^2.plant^{-1}, and 40.68 mg.100g^{-1} FW), respectively (Table 2). However, the non-magnetic water treatment (control) had the lowest values for these indicators (22.61 cm, 4.81 plant^{-1}, 39.01 leaves.plant^{-1}, 2293.64 cm^2.plant^{-1}, 34.68 mg.100g^{-1} FW), respectively.

The results further revealed that the nano-seaweed extract's different treatments also exhibited a significant difference in broad bean plants for growth and morphological traits ($P \leq 0.05$) (Table 2). Consequently, the nano-seaweed extract concentration at 2 ml.L^{-1} provided the highest values of the vegetative indicators, including plant height, branch number per plant, leaf number per plant, leaf

Table 2. Effect of nano-seaweed extract and magnetization of irrigation water on bean vegetative growth indicators.

Treatments			Plant height (cm)	Branches plant^{-1}	Leaves plant^{-1}	Leaf area (cm^2.plant^{-1})	Total chlorophyll (mg.100 g^{-1})
Magnetized irrigation water (Gauss)	0		22.61	4.81	39.01	2293.64	34.68
	1000		29.32	5.58	53.42	2676.88	37.30
	2000		30.92	5.88	67.57	3205.54	40.68
$LSD_{0.05}$			1.32	0.23	2.19	647.12	1.58
Nano-seaweed extract	0		23.19	3.56	46.59	2201.27	31.97
	1		27.96	6.24	53.30	2838.97	38.68
	2		31.72	6.47	60.11	3135.82	42.01
$LSD_{0.05}$			1.32	0.23	2.19	647.12	1.58
Magnetized irrigation water ×Nano-seaweed extract	0	0	20.33	3.28	31.45	1873.85	29.59
		1	22.41	5.43	38.73	2362.59	34.61
		2	25.10	5.72	46.86	2644.48	39.84
	1000	0	23.69	3.60	45.31	2191.33	32.06
		1	30.28	6.49	53.68	2852.21	39.12
		2	34.00	6.66	61.27	2987.10	40.73
	2000	0	25.54	3.81	63.02	2538.62	34.25
		1	31.18	6.80	67.50	3302.11	42.31
		2	36.05	7.04	72.19	3775.88	45.47
$LSD_{0.05}$			2.54	0.57	5.12	1277.65	2.63

area, and total leaf chlorophyll content, i.e., 31.72 cm, 6.47 branches.plant^{-1}, 60.11 leaves.plant^{-1}, 3135.82 cm^2.plant^{-1}, and 42.01 mg.100 g^{-1} FW, respectively. However, the control plants (sprayed with water only) provided the lowest values for the said traits, i.e., 23.19 cm, 3.56 branch.plant^{-1}, 46.59 leaves.plant^{-1}, 2201.27 cm^2.plant^{-1}, and 31.97 mg.100g^{-1} FW, consecutively.

Correspondingly, significant effects of the interaction between the treatments of the magnetized irrigation water and nano-seaweed extract foliar spray appeared for the vegetative traits ($P \leq 0.05$) (Table 2). The interaction of 2000 Gauss of magnetic water + 2 ml.L^{-1} of nano-seaweed extract provided the highest values for these traits (36.05 cm plant height, 7.04 branch.plant^{-1}, 72.19 leaves.plant^{-1}, 3775.88 cm^2.plant^{-1} leaf area, and 45.47 mg.100 g^{-1} FW total chlorophyll concentration in leaves). Contrarily, the control combination (non-magnetic water + water sprayed plants) resulted in the lowest values for growth and morphological traits (20.33 cm, 3.28 branch.plant^{-1}, 31.45 leaves.plant^{-1}, 1873.85 cm^2.plant^{-1}, and 29.59 mg.100 g^{-1} FW), respectively.

Yield contributing traits and total yield

The results revealed significant effects of magnetically-treated irrigation water and also differences among the magnetic water treatments for yield components and total yield in broad bean plants ($P \leq 0.05$) (Table 3). The irrigation water at magnetization intensity 2000 Gauss attained the highest values for the number of pods per plant, pod weight, pod yield per plant, and total yield (16.70 pods.plant^{-1}, 24.14 g.pod^{-1}, 407.50 g.plant^{-1}, and 8.77 t.ha^{-1}), sequentially. However, the control treatment (irrigation without magnetization) showed reduced values for the bean plant production traits (11.93 g.plant^{-1}, 20.39 g.pod^{-1}, 247.74 g.plant^{-1}, and 5.83 t.ha^{-1}), respectively.

Results also showed significant variations among the interactions of the three treatments of a nano-seaweed extract foliar application for the yield components and total pod yield (Table 3). The nano-seaweed extract at 2 ml.L^{-1} has significantly improved the pods per plant, pod weight, pod yield per plant, and total pod yield in the broad bean plants (16.83 pods.plant^{-1}, 24.96 g.pod^{-1}, 423.03 g.plant^{-1}, and 9.11 t.ha^{-1}), consecutively, compared with the control plants, which gave the lowest values for these traits (11.79 pods.plant^{-1}, 19.34 g.pod^{-1}, 231.20 g.plant^{-1}, and 4.90 t.ha^{-1}), respectively.

Furthermore, the interaction between both factors also significantly influenced bean plant production traits. With 2000 Gauss of magnetic water + 2 ml.L^{-1} of nano-seaweed extract foliar application, the yield traits, viz., pod number per plant, pod weight, single plant pod yield, and total pod yield gained significant enhancement by providing the maximum

Table 3. Effect of nano-seaweed extract and magnetization of irrigation water on bean yield indicators.

Treatments			Pods plant^{-1}	Pod weight (g)	Plant yield plant^{-1} (g)	Total yield (t. ha^{-1})
Magnetized irrigation water (Gauss)		0	11.93	20.39	247.74	5.83
		1000	14.35	22.35	325.79	6.94
		2000	16.70	24.14	407.50	8.77
LSD$_{0.05}$			1.03	1.19	20.31	0.22
Nano-seaweed extract (ml.L^{-1})		0	11.79	19.34	231.20	4.90
		1	14.35	22.57	357.60	7.52
		2	16.83	24.96	423.03	9.11
LSD $_{0.05}$			1.03	1.19	20.31	0.22
Magnetized irrigation water ×Nano-seaweed extract	0	0	9.66	17.23	166.44	4.28
		1	11.74	20.81	244.31	6.11
		2	14.38	23.12	332.47	7.09
	1000	0	11.49	19.45	223.49	4.86
		1	14.57	22.70	330.74	7.32
		2	17.00	24.89	423.13	8.63
	2000	0	14.23	21.34	303.67	5.57
		1	16.75	24.20	405.35	9.14
		2	19.11	26.87	513.49	11.61
LSD$_{0.05}$			1.79	1.95	50.18	0.78

values, i.e., 19.11 pods.plant^{-1}, 26.87 g.pod^{-1}, 513.49 g.plant^{-1}, and 11.61 t.ha^{-1}, respectively, compared with the minimum values in control plots (9.66 pods.plant^{-1}, 17.23 g.pod^{-1}, 166.44 g.plant^{-1}, and 4.28 t.ha^{-1}), respectively (Table 3).

DISCUSSION

Studying the importance of different intensities of magnetic irrigation water on broad bean plants transpired under various growth and yield indicators: plant height (cm), number of branches per plant, number of leaves per plant, leaf area (cm^2), total leaf chlorophyll content (mg.100 g^{-1} FW), pod number per plant, pod weight, single plant pod yield, and total pod yield. These parameters were influenced by both intensities (1000 and 2000 Gauss) of magnetically-treated irrigation water, with a maximum value recorded at 2000 Gauss compared with non-magnetic water treatment (control). Results related to the irrigation with magnetically-treated water realized a significant increase in the bean vegetative and morphological parameters. It may have come from the increase in the fluidity of water and its reduced viscosity due to magnetization effects and its rapid permeability within the plant cell membranes. The increase in water permeability within the plant cells caused an increase in the transfer of nutrients to the other plant parts, as well as, the flexibility of the cell walls and the elongation of cells (Ali-Noureddin and Al-Gawthari, 2017). Notably, the magnetic field intensity also plays a vital role in changing many of the physical and chemical properties of water, such as surface tension reduction, viscosity, and density, making it lighter and easier to absorb and penetrate the cell membranes of the plant root system (Al-Amin, 2018).

In addition, the significant improvement in bean yield traits may also have resulted from the significantly increased growth and morphological trait values. Further, the magnetically-treated irrigation water may have led to enhance the availability of nutrients in the soil for the crop plants; eventually, it improved and reflected positively an increase in the leaf area, photosynthesis rate, and the accumulation of carbohydrates which increased the branches and pod yield (Khabar, 2019). The magnetic field increases the absorption and transfer of macro and microelements, enhancing cell division and elongation, which helps synthesize carbohydrates, leading to an improved number and size of pods with increased green pods and the total yield (Al-Amin, 2018).

The effect of various concentrations of the nano-seaweed extract on the development of broad bean plants underwent investigation under five distinct growth parameters: plant height (cm), number of branches per plant, number of leaves per plant, leaf area (cm^2), and total leaf chlorophyll content (mg.100 g^{-1} FW). Both concentrations of nano-seaweed extracts increased shoot growth compared with the control. The improvement in vegetative growth resulted from the nutrients included in the composition of the nano-seaweed treatment. Nitrogen and phosphorus contribute to the composition of proteins, coenzymes, and nucleic acids (DNA and RNA), which increase photosynthesis rates (Al-Harmazi, 2011). Hence, increasing the ability of the plant to produce nutrients via the photosynthesis process reflected the growth traits positively (Al-Zuraidi and Al-Qabi, 2017; Wahab, 2020). Also, potassium plays an influential role as an osmotic regulator in the opening and closing of stomata, as reflected by the improved absorption of nutrients that activate photosynthesis and increase the vegetative indicators, such as, plant height, branches, leaves, shoot dry weight, and chlorophyll in leaves (Gleikh, 2020; Al-Mousawi, 2021).

Moreover, the nano-seaweed extract contains boron, which contributes to plant growth and development through its effects on most of the vital plant processes, including the transfer of sugars, formation of carbohydrates, development of the pollen tube, increased fertilization, and homeostasis stability of the cell (Naseem *et al*., 2019). The zinc in the nano-seaweed extract has crucial effects on the synthesis of the amino acid, Tryptophan, a precursor of auxin synthesis (indole acetic acid) that stimulates cell division and elongation, and meristematic cell division, then increases the leaf number, area, and yield traits (Al-Sahaf, 1989). The nano-seaweed extracts consist of macro and micronutrients, amino acids, vitamins, proteins, and organic compounds that play a relevant role in cellular metabolism and vital processes in treated plants, resulting in increased growth and crop production. Hence, these compositions provide the needed nutrients to transform vegetative buds into flowers and reduce competition between flowers, which increases yield-related traits (Al-Sahaf, 1989). Similarly, the presence of auxin and cytokinin growth regulators within the components of nano-particles of seaweed extracts supports plant growth and development by boosting cell division and elongation and the formation of leaf primordial, as well as, auxins enhance the production of flowers and pollen grains, which eventually increase the number of pods, size, and weight of pods, and the total yield (Nejatzadeh-Barandozi *et al*., 2014). Farming communities started exploiting nano-particles of seaweed formulations instead of synthetic chemical fertilizers to produce high-production value and chemical-free crops. These nanotechnology applications for fertilizers or growth stimulants require urgent promotion by farmers and producers to obtain nutritious food at an affordable cost throughout the year.

CONCLUSIONS

Based on the results, the study concluded that the magnetized irrigation water (2000 Gauss) reflected positive effects on growth and morphological traits with a significant improvement in the broad bean yield. Moreover, nano-seaweed extract foliar application at a concentration of 2 ml. L^{-1} also enhanced the growth and yield traits in bean plants. Similarly, the interaction between the above factors also showed an improvement in the vegetative and yield features of the broad bean.

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