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Effects of nano-chelated micronutrients and seaweed on nutrients uptake and chemical traits of quinoa (*Chenopodium quinoa* Willd.)

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ABSTRACT
The experiment was conducted in the fields of northern Nasiriya City, Iraq, in 2020 to study the effect of adding four concentrations (0, 1, 2, and 3 kg ha^{-1}) of chelate micronutrients fertilizer manufactured according to nanotechnology containing iron, zinc, manganese and boron with three concentrations (0, 1 and 2 kg ha^{-1}) of seaweed fertilizer containing 46% organic matter and 4% amino acids on nutrients uptake of NPK and chemical properties of quinoa, *Chenopodium quinoa* Willd. Randomized complete block design with three replications was used in the experiment. The results showed the best significant response once using the F_3 treatment (nano-chelated fertilizers containing nitrogen, phosphorous and potassium absorbed in the grains) with an increase of 12.86, 127.27 and 98.64% respectively compared to other treatments. In addition, F_3 treatment was recorded highest value (protein 17.01, ash 4.56 and fiber 2.23%), while F_2 exhibited superior values (fat 5.54 % and moisture 8.63%). Moreover, the results showed that S_2 treatment (seaweed) at 3 kg ha^{-1} was superior in most of the studied traits except for moisture and carbohydrates which was higher in the control treatment (9.06 and 68.14%) respectively.

Keywords: Nano-Fertilizer, Seaweed, NPK, Organic Matter, Quinoa.
Article type: Research Article.

INTRODUCTION
Quinoa, *Chenopodium quinoa* Willd. is a herbaceous plant native to the slopes of Pacific Ocean in South America belonging to the Amaranthaceae family. Quinoa grains have good nutritional value that can be used as human food or animal feed, exhibiting different colors such as white, pale yellow, orange, red, black and brown (Pearsall 1992). Quinoa is a rich source of many minerals, vitamins, oils, antioxidants, and high-quality protein that contains abundant amounts of sulfur-rich amino acids (Al-Naggar *et al.* 2017; Kurenkova *et al.* 2021). One of the main problems in dry and semi-arid areas are the suffering from the decreased organic matter and low soil fertility, consequently the declining in yield and production due to the effects of environmental conditions and soil factors, which lead to a deficiency in the absorption of micro- and some macro-nutrients by agricultural crops (Al-Juthery *et al.* 2018).The high degree of soil interaction and the soil content of carbonate minerals play a major role in the decrease in the availability of micronutrients present in the soil or those added to the soil in the form of mineral fertilizers. Iraqi soils are among the most soils that suffer from low concentrations of micronutrients as a result of their transformation into forms that are not ready for uptake by plants (Ali and Al-Juthery 2017; Rakhimova *et al.* 2021; Al-Dulaimy *et al.* 2022; Kamali Omidi *et al.* 2022). Nanotechnology has been widely used in many fields, including agriculture. Nanotechnology has the ability to develop the efficiency of slow-release nutrients, which can solve the problem or part of it, since it has a high surface area due to the small particles that range between 1-100 nanometers (Ditta & Arshad 2015). This technology is promising in improving agricultural processes through

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the composition of nano-fertilizer, which has unique properties such as high solubility and controlled release with effective concentration, low toxicity and ease of delivery of nutrients to the target sites (Rai *et al.* 2015). Quinoa is one of the crops which do not receive enough attention in Iraq in comparison with its importance. So, this study was conducted to find out the effect of micronutrients manufactured according to nanotechnology and seaweed fertilizer on the uptake of NPK and some chemical properties in quinoa grains.

MATERIALS AND METHODS

The experiment was conducted in the fields of northern Nasiriya City, in 2020 in the clay loam soil to study the effect of adding chelated fertilizers (given a variable F) manufactured according to nanotechnology that contain micro nutrients (Fe 8% , Zn 6%, Mn 4%, and B 2%) at four levels (0, 1, 2 and 3 kg ha^{-1}), which were dissolved in 400 L ha^{-1} water and seaweed fertilizer (given a variable S) containing 46% organic matter and 4% amino acids at three levels (0, 1 and 2 kg ha^{-1}). Samples were taken from the soil before planting from different locations, then samples were mixed well to obtain a composite sample followed by analyzing their chemical and physical properties (Table 1).

Table 1. Some chemical and physical properties of the soil before planting.

Traits		Value	Unit
pH		7.91	
EC		4.31	Ds m^{-1}
O.M		5.95	g. kg^{-1}
Available Nitrogen		22	mg kg^{-1}
Available Phosphorus		10	mg kg^{-1}
Available Potassium		154	mg kg^{-1}
Calcium carbonate		197	g kg^{-1}
Texture	Sand	271	g kg^{-1}
	Silt	398	g kg^{-1}
	Clay	331	g kg^{-1}

Nano-fertilizer and seaweed fertilizer were added in two batches: the first after one month and the second after two months of planting according to the manufacturer's recommendation (Fanavar Nano-Pazhohesh Markazi Company, Iran). Twelve treatments with three replications were tested in this experiment on randomized complete block design (RCBD). After harvest, nitrogen in cereal was estimated using a Microkjeldal device, phosphorous using a spectrophotometer, and potassium using flame photometer according to Haynes (1980). The total protein content was calculated from the nitrogen content using the following equation: protein (%) = N% × 6.25 according to Tomov *et al.* (2009). Fiber rate in cereals was measured using the standard method proven in AOCS (1971). The ash rate (%) was estimated according to the standard method No. 0.1-0.8 (AACC 1998). Fat rate (%) was estimated using the Soxhlet apparatus according to AOAC (1970). The moisture content was estimated according to the method described in (A.O.A.C., 2000). Carbohydrates rate (%) was estimated by calculating the difference after subtracting the rates (%) of protein, ash, fat, fiber and moisture from 100%.

Statistical analyses

Data were analyzed statistically by analysis of variance (ANOVA) using Genstat program, the significant differences among the means were tested using the Least Significant Difference (LSD) at a probability level of 0.05.

RESULTS AND DISCUSSION

The results in Table 2 showed significant differences between the mean treatments containing nano-micronutrients: F_3 excelled by giving the highest percentage (2.72 % nitrogen, 0.50 % phosphorous and 1.47% potassium absorbed in the grains) amounting with an increase of 12.86, 127.27 and 98.64% respectively, compared to the control treatment. This may be due to the effectiveness of micro-nutrients manufactured according to nanotechnology which play an important role in physiological and biochemical processes in plants leading to an increased NPK nutrient uptake and their transmission to grains. Jhanzab *et al.*(2015) and Dimkpa *et al.* (2018) reported that addition of nano-micro fertilizers led to a significant increase in NPK concentration in wheat grains. Moreover, adding seaweed, exhibited significant differences in the NPK values in the grains between the means of treatments. The treatment S_2 exhibited the higher average percentage of nitrogen 2.79 %, phosphorous 0.52 % and potassium 1.46% in the grains, with an increase of 15.76, 100 and 73.80% respectively, compared to the control treatment and with a significant difference from S_1. This may be attributed to the addition of seaweed fertilizer which stimulated the growth of roots, especially the transverse elongation through activating cell division, which increased the contact between root hairs and soil solution. In addition, it is an important source of many essential nutrients leading to an increase in their uptake and accumulation in the plant (Hasan *et al.* 2021). Also, the results in Table 2 showed that no significant differences were found in the binary interaction between nano-micronutrient fertilizers and seaweed in the average rate (%) of nitrogen uptake in the grains, while the interaction between the added fertilizers led to a significant increase in the phosphorous and potassium rates (%) in grains. So that, the highest rate was observed in transaction S_2F_3 which was 0.63 and 1.71%, respectively.

Table 2. Effects of nano-micronutrient fertilizers and Seaweed on NPK uptake in quinoa seeds.

nano- micro nutrients (kg ha^{-1})			
Treatment	**%**		
	N	**P**	**K**
F_0	2.41	0.22	0.74
F_1	2.65	0.39	1.20
F_2	2.71	0.46	1.38
F_3	**2.72**	**0.50**	**1.47**
$LSD_{0.05}$	0.125	0.031	0.044
Seaweed (kg ha^{-1})			
S_0	2.41	0.26	0.84
S_1	2.68	0.40	1.28
S_2	**2.79**	**0.52**	**1.46**
$LSD_{0.05}$	0.108	0.027	0.038
Interactions (S × F)			
S_0F_0	2.23	0.17	0.56
S_0F_1	2.38	0.18	0.63
S_0F_2	2.51	0.35	0.98
S_0F_3	2.52	0.35	1.20
S_1F_0	2.50	0.21	0.77
S_1F_1	2.71	0.43	1.37
S_1F_2	2.75	0.45	1.47
S_1F_3	2.76	0.51	1.51
S_2F_0	2.51	0.28	0.88
S_2F_1	2.86	0.57	1.60
S_2F_2	2.89	0.59	1.67
S_2F_3	**2.89**	**0.63**	**1.71**
$LSD_{0.05}$	NS	0.054	**0.077**

The results in Table 3 showed that the percentages of chemical properties in grains were significantly affected by the increased levels of nano-micronutrients. So that, F_3 recorded the highest rates of 17.01% protein, 4.56% ash and 2.23% fibers, while F_2 exhibited the highest significant value of 5.54% fat and 8.63% moisture. Meanwhile, the comparison treatment recorded the highest average of carbohydrates in grains reaching 68.14%. This may be due to nano-micronutrients especially iron which can provide a greater surface area for the various biological reactions in the plant. This elevates the rate of photosynthesis which encourages the upraised cell divisions, followed by increased growth of the plant, reflecting in the chemical properties of the plant (Benzon *et al.* 2015). This result agreed with Heidari et al. (2020) who explained that addition of nano-fertilizers led to an increase in the yield and its components in the quinoa plant. The results in Table 3 showed a significant differences between the mean of the seaweed addition treatments, S_2 was superior in most of the chemical properties of quinoa grains, i.e., 17.41 % protein, 5.41% ash, 2.47 % fiber and 5.90% fat, with a significant difference from S_1, while the comparison treatment recorded the lowest values for these traits amounting to 15.05, 2.57, 1.54 and 3.63% respectively. This may be due to that the seaweed fertilizer contributed significantly to the increased absorption of nutrients necessary for plant growth, which was reflected in the increased percentage of protein, ash, fiber and fat in the grains. This is in agreement with González *et al.* (2020). In the cases of moisture and carbohydrates in quinoa grains , the comparison treatment recorded the highest values (9.06 and 68.14%) respectively. This result is consistent with the findings of Soliman *et al.* (2019), who reported that the comparison treatment achieved the highest carbohydrates. The results in Table 3 showed no significant differences as a result of the interaction between nano-micronutrient fertilizers and seaweed in all the studied chemical characteristics except for the moisture rate (%) in the grains, S_0F_0 displayed the highest value (10.20%).

Table 3. Effect of nano-micronutrient fertilizers and Seaweed on seed chemical traits of quinoa plant.

Treatment	nano- micro nutrients kg ha^{-1} %					
	Protein	Ash	fiber	fat	Moisture	Carbohydrite
F_0	15.06	3.62	1.89	3.51	8.34	**67.57**
F_1	16.56	3.93	2.03	4.83	8.34	64.29
F_2	16.96	4.34	2.14	**5.54**	**8.63**	62.38
F_3	**17.01**	**4.56**	**2.23**	5.38	8.15	62.65
$LSD_{0.05}$	0.779	0.406	0.226	0.549	NS	1.310
Seaweed kg ha^{-1}						
S_0	15.05	2.57	1.54	3.63	**9.06**	**68.14**
S_1	16.74	4.35	2.20	4.90	8.03	63.76
S_2	**17.41**	**5.41**	**2.47**	**5.90**	8.00	60.78
$LSD_{0.05}$	0.674	0.352	0.195	0.476	0.334	1.135
Interactions (S × F)						
S_0F_0	13.91	1.96	1.21	2.81	**10.20**	69.89
S_0F_1	14.87	2.30	1.48	3.12	9.56	68.66
S_0F_2	15.68	2.83	1.65	4.42	8.63	66.79
S_0F_3	15.73	3.20	1.82	4.17	7.86	67.21
S_1F_0	15.61	3.86	2.06	3.59	7.30	67.57
S_1F_1	16.96	4.26	2.16	5.21	7.43	63.97
S_1F_2	17.16	4.56	2.26	5.51	9.10	61.40
S_1F_3	17.22	4.73	2.33	5.32	8.30	62.09
S_2F_0	15.66	5.03	1.89	4.12	7.53	65.26
S_2F_1	17.87	5.23	2.03	6.15	8.03	60.24
S_2F_2	18.04	5.63	2.14	6.70	8.16	58.95
S_2F_3	18.07	5.76	2.23	6.66	8.30	58.67
$LSD_{0.05}$	NS	NS	NS	NS	0.669	NS

CONCLUSION

The results revealed that adding micro-nutrients manufactured according to nanotechnology had a positive effect in increased absorption of nutrients, as well as stimulating growth, which was reflected in the qualitative characteristics of the plant compared to control treatment. Also, the addition of 2 kg ha^{-1} of seaweed played an important role in the increased uptake of NPK nutrients as well as improving the qualitative characteristics of the grains.

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