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Response of Soybean Plants Cv. Shaima to NPK Fertilizer and Locally Produced Nano-Iron

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Abstract: An assay was carried out in the Research Station, Agricultural Extension and Training Center in Diyala in the season 2023 to study the response of soybean plants cv. Shaima to NPK fertilizer and locally produced nano-iron. A factorial experiment in a complete randomized block design was used, included two factors; the first factor included chemical fertilizer NPK at three levels (no addition, half the fertilizer recommendation, full recommendation), and the second factor included nano-iron fertilizer at three levels (no addition, half the fertilizer recommendation, full recommendation). The treatment of the full recommendation of NPK fertilizer and nano-iron performed better in most of the traits represented with plant height, leaf area, number of pods, dry shoot weight, iron concentration in leaves, nitrogen, and potassium, which reached 58.9 cm, 33.1 dcm, 47.0, 34.1 g, 98.4 ppm, 5.2%, and 4.3%, respectively. The full recommendation of NPK resulted in an increase in the total yield, reaching 3.8 tons ha-1, compared to the control treatment of 3.0 tons ha-1.

Keywords: Soybean, NPK, nano-iron

Introduction

Soybeans are regarded as a significant food and industrial crop and they are considered oil crops because of their significance in the extraction of oil, also they are an important source of oil as well as nourishment for humans and animals **(Zhou et al., 2020).** More than 20% of the seeds' oil is thought to offer significant therapeutic advantages **(Kumar et al., 2010).** It is rich in minerals, dietary fiber, vitamins, omega-3 fatty acids, and all of the essential and necessary amino acids for human health **(Ain et al., 2022).** The leftover crushed grain can be used as a source of fuel as well and as fertilizer to enhance the soil or as an alternative animal feed **(Camacho et al., 2019).** Chemical fertilizers are necessary, beneficial and significant for crop production in spite of their certain adverse effects **(Pahalvi et al., 2021).** The plant needs for certain microelements are lower than those of major elements, but microelements like iron are necessary for certain crops **(Wang et al., 2021).** Iron is a necessary nutrient for microorganisms, which are competitive organisms in their consumption and their need for iron; as a result, the soil's iron balance will be unbalanced, and the majority of symptoms of iron deficiency will manifest on the leaves of legumes, particularly soybeans **(Brear et al., 2013).** Iron is a part of numerous essential enzymes in the electron transport chain, including cytochromes, also Iron is necessary for preserving the structure and functionality of chloroplasts in plants and is involved in the synthesis of chlorophyll **(Read et al., 2021).** Some soils have high iron content, but it is unavailable to plants, which has an impact on their various processes **(Al-huraby, 2022).** According to **Yadav et al. (2023),** the creation of nano-fertilizer necessitates a substantial amount of work and qualitative expertise, in addition to strong manufacturing capabilities and support from pertinent parties, in order to produce a highly successful product. In addition to using produced or semi-made chemical materials, sophisticated equipment, labs, scientific capabilities and researchers who have conducted a lot of trials and have a lot of experience **(Abobatta, 2023).** Research has demonstrated the value of nano-fertilization for crops because it quickly addresses plant nutritional deficiencies because the fertilizer's components have extremely small diameters that allow them to penetrate essential plant parts **(Nandhakumar et al., 2023).** Iraq's planted areas of this legume crop have decreased as a result of neglect leading to poor production, which does not satisfy local demand; therefore, the state imports from overseas. Therefore, the aim of the study is to know the response of soybean plants to chemical fertilization and locally produced nano-iron.

Materials and methods

Production of nano-iron

The co-precipitation approach with ferrous (II) sulphate ($FeSO_4$) was used to create the nano-iron particles α-Fe_2O_3. To achieve a 0.1 M concentration, 50 mL of deionized water was used to dissolve the precursor salt (1.39 g), and the pH was modified to 11 by adding KOH solution (0.5 M). After obtaining the black precipitate ($Fe(OH)_2$), it was washed with deionized water and 100% ethanol until its pH ranged from 7 to 8. After that, the black precipitate was dried for 16 hours at 80 degrees Celsius in an oven, and then iron oxide nanoparticles (α-Fe_2O_3 NPs) were produced by calcining $Fe(OH)_2$ in a furnace at 600K for six hours **(Hitkari et al., 2018).** Nano-iron's properties were displayed in Table (1).

Table 1. The properties of the produced nano-iron

No	Device name		Findings
1	Zeta potential	Zeta Potential (Mean)	0.1 mV
2	DLS	Scattering Light Intensity Average	197.3 nm
3	EDX	W t %	Fe=85.7،O=9.4
4	FESEM	Average(nm)	44.21 nm
5	XRD	D, nm Average	26.21 nm

The RCBD design was used to divide the land into three blocks. The block included nine experimental units, each measuring one square meter. Chemical fertilizers (NPK) with three levels (0, half recommendation, full recommendation) were included in a factorial experiment with two factors. The half recommendation represented levels of urea at 25 kg ha^{-1}, superphosphate at 100 kg ha^{-1}, and potassium sulphate at 100 kg ha^{-1}, while the full recommendation was twice half the recommendation. The second factor was also represented by three levels of nano-iron (0, half recommendation, full recommendation), where the half recommendation represented spraying nano-iron at a concentration of 100 ppm and the full recommendation was 200 ppm. The soil was analyzed in the labs of the College of Soil for Pure Sciences Department at the University of Diyala and the Iraqi Geological Survey Department after samples were collected from the field (Table 2). The soybean seeds cv. Shaima were sown on June 22, 2023, by using the drip irrigation system; three plants from each experimental unit were harvested during the flowering time (50%) to perform measurements. After the season concluded on September 24, 2023, the crop was harvested. The studied characteristics included the plant height, leaf area, number of pods, fresh shoot weight, fresh root weight, dry shoot weight, iron concentration in the leaves, nitrogen, potassium, phosphor, total yield. The SPSS software version 20 was used to analyze the data using the Tukey test at a 0.05 probability level.

Table 2. Soil properties analysis

Measurements	Value	Units
So_3	0.007	ppm
Zn	2.20	ppm
Fe_2O_3	0.304	ppm
CaCo3	29.00	%
Organic matter	.08	%
K	92.0	ppm
P	1.87	ppm
N	63	ppm
Ec	1715	µc cm^{-1}
Ph	8.30	-
Sand	42	%
Silt	38	%
Clay	20	%

Results and discussion

The results of Table 3 indicated significant differences in NPK levels affecting plant height, leaf area, number of pods, and dry shoot weight; the full recommendation outperformed the others in these characteristics, achieving maximum values of 56.7 cm for plant height, 31.3 dcm for leaf area, 46.1 for number of pods and 31.7 g for dry shoot weight. In contrast, the control treatment produced the lowest value, with respective values of 48.9 cm, 25.7 dcm, 41.6, and 25.5 g. With the highest rate in the preceding traits, 54.9 cm, 30.0 dcm, 44.3, and 31.1 g, the full recommendation of nano-iron performed noticeably better than the control treatment, which produced the lowest rate, 50.9 cm, 26.8 dcm, 43.2, and 25.5 g, respectively. The full recommendations for each of the aforementioned traits were significantly outperformed with the highest values, reaching 58.9 cm, 33.1 dcm, 47.0, and 34.1 g, in comparison to the control treatment, which reached 47.6 cm, 23.4 dcm, 41.8, and 24.2 g, respectively. This indicates that the interaction between the NPK and nano-iron had a significant impact on the value of the previous traits. While there were no significant differences between the levels of NPK and nano-iron in the traits of fresh shoot and root weight.

Table 3. Effect of chemical fertilization NPK and produced nano-iron on plant height, leaf area, number of pods, fresh shoot weight, fresh root weight and dry shoot weight of soybean plants

Plant height (cm)				
NPK	**Nano-iron**			Mean
	0	0.5	1	
0	47.6 e	47.5 e	51.5 d	48.9 C
0.5	51.3 d	54.1 c	54.4 c	53.3 B
1	53.7 c	57.5 ab	58.9 a	56.7 A
Mean	50.9 C	53.0 B	54.9 A	
Leaf area (dcm)				
0	23.4 e	25.4 de	28.2 bcd	25.7 C
0.5	27.2 cd	27.1 cd	28.5 bc	27.6 B
1	29.7 bc	31.0 ab	33.1 a	31.3 A
Mean	26.8 B	27.8 B	30.0 A	
Number of pods				
0	41.8 d	41.6 d	41.5 d	41.6 C
0.5	43.1 cd	46.1 ab	44.3 c	44.5 B
1	44.7 bc	46.5 ab	47.0 a	46.1 A
Mean	43.2 B	44.7 A	44.3 A	
Fresh shoot weight (g)				
0	450.0 a	461.0 a	478.0 a	463.0 A
0.5	473.0 a	482.0 a	500.0 a	485.0 A
1	491.0 a	501.0 a	531.0 a	507.6 A
Mean	471.3 A	481.3 A	503.0 A	
Fresh root weight (g)				
0	139.6 a	150.6 a	167.6 a	152.6 A
0.5	162.6 a	171.6 a	189.6 a	174.6 A
1	180.6 a	190.6 a	220.6 a	197.3 A
Mean	161.0 A	171.0 A	192.6 A	
Dry shoot weight (g)				
0	24.2 d	24.0 d	28.2 bc	25.5 C
0.5	25.3 cd	26.2 cd	31.1 ab	27.5 B
1	27.0 cd	33.9 a	34.1 a	31.7 A
Mean	25.5 C	28.0 B	31.1 A	

Iron concentration in leaves, nitrogen, and potassium were all significantly impacted by NPK levels, as indicated by Table 4's findings. The full recommendation performed better than the others in these traits, reaching maximum values of 97.4 ppm for iron concentration in leaves, 4.8% for nitrogen, and 4.0% for potassium. The control treatment, on the other hand, yielded the lowest value, with values of 94.2 ppm, 3.5%, and 2.8%.With the maximum rate of iron concentration in leaves (96.7 ppm) and nitrogen (4.7%), the full recommendation of nano-iron outperformed the control treatment, which achieved the lowest rates of 95.1 ppm and 3.7%. Whereas, the half-recommendation of nano-iron and control treatments recorded the highest rate of potassium trait, reaching 3.6% and 3.8%, respectively, in comparison to the full recommendation of 3.0%.With the maximum values of 98.4 ppm, 5.2%, and 4.3% for each of the previously listed traits, the full recommendations were greatly outperformed compared to the control treatment, which achieved 93.1 ppm, 2.9%, and 2.2%, respectively, and this suggests that the NPK-nano-iron interaction significantly affected the prior traits' value. There were no significant differences between the levels of NPK and nano-iron in the trait of phosphor, and there were no significant differences between the levels of nano-iron in the trait of total yield, but the full recommendation of NPK achieved the highest value in this trait, reaching 3.8 tons ha^{-1} compared to the control of 3.0 tons ha^{-1}.

Table 4. Effect of chemical fertilization NPK and produced nano-iron on iron concentration in leaves, Nitrogen, potassium, phosphor and total yield of soybean plants

Iron concentration in leaves (ppm)				
NPK	**Nano-iron**			Mean
	0	0.5	1	
0	93.1 d	94.2 cd	95.3 bcd	94.2 B
0.5	96.1 abc	96.3 abc	96.6 abc	96.3 A
1	96.3 abc	97.4 ab	98.4 a	97.4 A
Mean	95.1 B	96.0 AB	96.7 A	
Nitrogen (%)				
0	2.9 c	3.4 bc	4.2 abc	3.5 B
0.5	3.8 abc	4.6 ab	4.8 ab	4.4 A
1	4.3 abc	4.8 ab	5.2 a	4.8 A
Mean	3.7 B	4.3 AB	4.7 A	
Potassium (%)				
0	2.2 c	2.7 bc	3.5 abc	2.8 B
0.5	3.1 abc	3.9 ab	3.7 ab	3.5 A
1	3.6 ab	4.1 a	4.3 a	4.0 A
Mean	3.8 A	3.6 A	3.0 B	
Phosphor (%)				
0	0.28 a	0.30 a	0.34 a	0.31 A
0.5	0.32 a	0.36 a	0.39 a	0.36 A
1	0.35 a	0.37 a	0.41 a	0.38 A
Mean	0.32 A	0.35 A	0.38 A	
Total yield (tons ha^{-1})				
0	2.8 a	3.0 a	3.1 a	3.0 B
0.5	3.4 a	3.0 a	3.2 a	3.2 AB
1	3.9 a	3.5 a	4.2 a	3.8 A
Mean	3.4 A	3.2 A	3.5 A	

Through these findings, the addition of a full recommendation of NPK and nano-iron led to an increase in most of the studied traits. **Hossain et al. (2020)** showed the importance of using nano-iron for soybean crops. The quick transfer of iron compounds taken up from the leaves by the activity of the photosynthetic process could be the cause of the rise in iron concentration **(Lyu et al., 2017).** In addition to enhancing the photosynthetic process, the presence of iron in a readily available and active form also increases the concentration of iron in various parts of the plant **(Feng et al., 2022).** The iron and other fertilizer elements lead to support of chlorophyll present in the plant leaves, which transfer these nutritional elements to the other plant parts, which impact plant height **(Sudhakar et al., 2015).** Iron plays a critical role in many essential plant functions by directly contributing as a structural constituent of building materials or by triggering enzymatic reactions inside the plant. Also, iron is essential for the RNA representation of chloroplasts in leaves **(Casiraghi, 2016).** Iron can aid in the development of cytochromes, which are essential for respiration and photosynthesis because they receive and transport electrons. Iron shortage can cause deficiencies in these enzymatic pigments, which can impede photosynthesis and cause young leaves to turn yellow and burn on the tips and edges. Thus, iron fertilization is required to enhance vegetative growth traits and raise chlorophyll levels in fertilized plants **(Tombuloglu et al., 2019).** Important plant functions like bloom stimulation and number growth are regulated by the nutritional components, which also increase enzyme activity. Additionally, by attaining the largest percentage of pollen germination and prolonging the pollen tube, some nutritional components in the nutrient solution combination, such as iron, help to improve seed set **(Pandey, 2018).** Phosphorus plays a crucial role in both supplying the pods with the most nutrients and promoting the growth of the developing tops. Furthermore, the presence of nitrogen promotes the development of the plant's branches, which raises the proportion of pods produced by each plant **(Malhotra et al., 2018).**

Conclusion

It was discovered that all of the traits under investigation for soybean plants cv. Shaima were clearly improved by raising the concentration of NPK fertilizers and nano-iron, and that the full recommendations for each of them were the most effective in enhancing those traits.

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