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Impact of Nitrogen Fertilizer, Nano-Micronutrients and Their Interaction on the Growth Characteristics of Fenugreek (*Trigonella foenum-graecum* L.) Plants

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Abstract: A field experiment was conducted at the Experimental Farm, Hort. Dept., Fac. Agric., Zagazig University during the winter in 2023/2024. To improve the growth parameters of fenugreek plants, two main factors were examined. First, nitrogen fertilization rates (0.0, 30 and 60 kg N/feddan) were applied as soil drench at two doses. Second, nano-micronutrients named Megro NanoMix (0.0, 0.5 and 1.0 g/litter) were applied as foliar spraying three times per season. The obtained results showed that fertilized fenugreek plants with 60 kg N/feddan significantly enhanced plant height, number of branches per plant, stem diameter, root length, fresh and dry weights of herb per plant, and fresh weight of roots per plant compared with the control and the lowest rate under study. The highest values of plant height, stem diameter, herb fresh weight per plant, and dry weight of roots per plant were recorded with 1.0 g/l of nano-micronutrient fertilizer rate compared with the control. Spraying plants with any rate of nano-micronutrients insignificantly affected root length, herb dry weight, and root fresh weight per plant. In general, the best combination treatment for improving the growth parameters of *Trigonella foenum-graecum* plants was 60 kg N/feddan combined with 0.50 g/l of nano-micronutrient fertilizers.

Keywords: Fenugreek, nitrogen fertilizer, Nano-micronutrients, growth

1. Introduction:

The fabaceae (leguminosae) family includes the annual herb fenugreek (*Trigonella foenum-greecum* L.), which is widely found in Southwest Asia and the Mediterranean region. According to **Kołodziej and Zejdan (2000)** and **Kini and Rhadi (2012)**, fenugreek is used as fodder in some parts of Europe and Northern Africa and is farmed for its aromatic seeds in Western Europe and China. The seed is grown for its therapeutic properties as well as to be used as a vegetable and spice for people and livestock. In addition, a variety of compounds found in seeds, including fixed and volatile oils, protein, sugar, mucilage, alkaloids, and saponins, are suitable as raw materials for the manufacture of steroid hormones in the commercial sector. This plant has various applications in food, medicine, and spices. It can be used to treat colic flatulence in diarrhea, dysentery, and dyspepsia as well as

conditions including diabetes, enlargement of the liver and spleen, loss of appetite, and chronic cough. **Shalaby *et al*. (1999)** and **Babaa (2007)** suggested that fenugreek seeds contain a significant amount of diosgenin, a steroidal component that serves as a precursor in the manufacture of sex hormones and oral contraceptives.

Plant life uses nitrogen for various purposes. Protoplasmic enzymes are vital components that expedite the process of life by acting as biological catalysts. According to **Vopyan (1984)**, nitrogen can be found in a variety of organic molecules found in plant cells, including glycosides, alkaloids, and chlorophyll phosphatides. In this regard, **Mehta *et al.* (2012)** reported that fenugreek plant height at all growth stages, as well as seed, straw, and biological yields, were significantly higher when 20 kg N/ha was applied. In addition, **Mohammed and Abd Elrahman (2021)** reported that when fenugreek plants were fertilized with nitrogen, their height and branch count significantly increased. Moreover, plants fertilized with urea at 50 and 100 kg/feddan produced the highest total seed yield in comparison with the control.

Wang *et al*. (2010) stated that leaf feeding, or the foliar application of micronutrients, is a workable method for meeting a plant's nutritional needs. Plant nutrition management strategies based on nanotechnology are beginning to show promise (**Solanki *et al*., 2015** and **Ghorbanpour *et al*., 2017**). Nano-fertilizers are made by pulverizing fertilizer ingredients into tiny particles that are between 1 and 100 nm in size. Accordingly, compared with unsprayed plants, the maximum values of plant height, fresh and dry weights, and covering density of P. vaginatum, Swartz, were attained by applying nanomicronutrients at 0.50 and 1.00 g/l rates (**Abdelsadek, 2020**). Also, **Al-Saidi *et al.* (2022)** showed significantly excelled of fenugreek plants treated with (spraying nano-micro elements 2 g. L^{-1} + nano seaweed extract 2 ml L^{-1} + NPK nanoconcentration 2 g L^{-1} + adding NPK mineral fertilizer) and the highest averages were achieved in the vegetative growth traits compared with the control treatment.

The main goal of the current study was to investigate the effect of using different nitrogen fertilizers, nano-micronutrient rates, and their combination treatments on the growth parameters of *Trigonella foenum-graecum***.**

2. Materials and Methods

The current study was conducted in the winter of 2023/2024 at the Experimental Farm, Faculty of Agriculture, Zagazig University, Egypt. On October 15, fenugreek seeds were seeded. The seeds were obtained from the Research Center of Medicinal and Aromatic Plants in Dorky, Giza. After sowing the seeds, they were immediately watered. Table 1 displays the mechanical and chemical characteristics of the farm soil used in the experiment, as reported by **Chapman and Pratt (1978)**.

Table 1. Experimental soil mechanical and chemical properties

Mechanical analysis			**Soil texture**
Clay (%)	Silt (%)	Sand (%)	**Sandy**
17.10	8.34	74.56	

Chemical analysis

pH	**E.C. (dsm^{-1})**	**Soluble cations (m.mol/l)**					**Soluble anions (m.mol/l)**			**Available (ppm)**		
		Ca^{++}	Mg^{++}	Na^{+}	Zn^{++}	Mo^{++}	Cl^{-}	HCO_3^{-}	SO_4^{--}	N	P	K
7.88	0.58	1.75	0.89	0.63	1.06	1.40	2.99	1.13	0.77	114	65	53

Treatments and fertilizer sources

This study included nine treatments to determine the effects of varying concentrations of nano- and micronutrients (0.0, 0.50, and 1.00 g/l) and three nitrogen fertilizer rates (0.0, 30 and 60 kg N/feddan) as urea (46% N) on fenugreek (*Trigonella foenum-graecum* L.) growth parameters. Nitrogen fertilizer was divided into three equal portions and added to the soil at 30, 52, and 67 days after sowing. Commercially marketed as Magro NanoMix, nano-micronutrients were added as a foliar treatment and comprised the following minerals: Zn (6%), Fe (6%), and B (2%) Additionally, it contains citric acid (4%), which was purchased from Modern Agricide Company (MAC), Mn (5%) - Cu (1%), and Mo (0.1%). Fenugreek plants were foliar sprayed three times with different nano-micronutrient concentrations at 30, 45, and 60 days after sowing as well as after each cutting. These doses were repeated.

Experimental design and cultivation

Three replicates of the treatments were set up in a split plot design, with the concentrations of nano- and micronutrients dispersed in random patterns in the subplots and nitrogen fertilizer rates randomly distributed in the main plots. One row, spaced 80 cm apart and spanning six meters, comprised the 4.8 m2 (0.80 × 6 m) plot area. On one side of the ridge, the seeds were placed in hills with a 20-cm distance between each hill. The seedlings were trimmed to two plants per hill three weeks after seeding. A drip irrigation method was used in this study.

Data recorded

Plant height (cm), branch number /plant, stem diameter (cm), herb fresh and dry weights/plant (g), and root length and roots fresh and dry weights/plant (g) were recorded 75 days after the sowing date.

Statistical Analysis

The following calculation, the data were tabulated and analyzed using Statistix Version 9 (**Analytical Software, 2008**). The least significant differences (L.S.D.) at the 5% level were then examined to determine the significance between the means of the various treatments.

3. Results and Discussion

Effect of nitrogen fertilizer rates

Results presented in Table 2 show that fertilized fenugreek plants with 60 kg N/feddan significantly increased plant height and branch number per plant compared with the control. The highest values of stem diameter and root length were produced when fenugreek plants were fertilized with the highest rate of nitrogen (Table 3). Increasing nitrogen fertilizer rates gradually improved the fresh and dry weights of the herb, with significant differences between them (Table 4). The highest roots fresh weight values were achieved from plots fertilized with 60 kg N/feddan, while this rate gave the lowest values of dry roots weight per plant (Table 5). A prominent position for nitrogen is held in the plant metabolic system. Nitrogen is an essential component of proteins and is linked to all vital functions in plants. Consequently, nitrogen application is essential and cannot be avoided to increase crop productivity. Because of its ability to increase crop productivity, nitrogen is essential to agriculture (**Massignam *et al*., 2009**). In addition, **Nawar and Ibraheim (2014)** found that fertilizing pea plants with 75% and 100 % of the nitrogen recommended rate significantly enhanced the umber of leaves and branches/plant, stem length, and total dry weight of pea. Similar to this, **Abdelkader *et al*. (2009)** demonstrated that the treatment with 90 kg N/fad produced the highest values in plant growth when compared with the other treatments being studied. Increasing nitrogen rates generally resulted in increases in pea plant height, branch count, and total dry weight/plant.

Table 2. Impact of nitrogen fertilizer (A), nanomicronutrients (B), and their interaction treatments on plant height (cm) and number of branches per plant of fenugreek (*Trigonella foenum-graecum* L.) during the 2023/2024 season

Nitrogen fertilizer rate (kg N/feddan)	Nano- micronutrients (g/l)			Mean (A)
	0.0	0.5	1.0	
Plant height (cm)				
Control	29.67 e	33.67 d	37.00 cd	**33.44 B**
30	35.67 d	35.00 d	37.33 b-d	**36.00 B**
60	42.00 ab	40.67 a-c	42.67 a	**41.78 A**
Mean (B)	**35.78 B**	**36.44 B**	**29.00 A**	
Number of branches/plant				
Control	10.00 f	13.33 de	16.00 cd	**13.11 C**
30	18.33 bc	16.00 cd	12.67 ef	**15.67 B**
60	20.67 ab	22.00 a	16.00 cd	**19.56 A**
Mean (B)	**16.33 AB**	**17.11 A**	**14.89 B**	

Table 3. Impact of nitrogen fertilizer (A), nano-micronutrients (B), and their interaction treatments on stem diameter (cm) and root length (cm) of fenugreek (*Trigonella foenum-graecum* L.) plants during the 2023/2024 season

Nitrogen fertilizer rate (kg N/feddan)	Nano- micronutrients (g/l)			Mean (A)
	0.0	0.5	1.0	
Stem diameter (cm)				
Control	0.40 cd	0.38 d	0.51 ab	**0.43 C**
30	0.47 bc	0.48 b	0.47 bc	**0.47 B**
60	0.55 a	0.50 ab	0.57 a	**0.54 A**
Mean (B)	**0.47 AB**	**0.45 B**	**0.51 A**	
Root length (cm)				
Control	10.33 d	8.83 d	11.83 cd	**10.33 C**
30	10.00 d	17.00 b	13.83 bc	**13.61 B**
60	20.67 a	14.67 b	15.33 b	**16.89 A**
Mean (B)	**13.67 A**	**13.50 A**	**13.67 A**	

Table 4. Impact of nitrogen fertilizer (A), nano-micronutrients (B), and their interaction treatments on the fresh and dry weight (g) of fenugreek (*Trigonella foenum-graecum* L.) plants during the 2023/2024 season

Nitrogen fertilizer rate (kg N/feddan)	Nano- micronutrients (g/l)			Mean (A)
	0.0	0.5	1.0	
Herb fresh weight (g)				
Control	20.17 f	22.70 f	41.93 cd	**28.27 B**
30	38.83 d	26.83 ef	29.70 e	**31.79 B**
60	49.33 b	57.83 a	48.20 bc	**51.79 A**
Mean (B)	**36.11 B**	**35.79 B**	**39.94 A**	
Herb dry weight (g)				
Control	2.93 e	3.00 e	4.95 cd	**3.63 C**
30	5.97 bc	5.13 cd	4.23 d	**5.11 B**
60	7.07 ab	7.17 ab	7.30 a	**7.18 A**
Mean (B)	**5.32 A**	**5.10 A**	**5.49 A**	

Table 5. Impact of nitrogen fertilizer (A), nano-micronutrients (B), and their interaction treatments on roots fresh and dry weight (g) of fenugreek (*Trigonella foenum-graecum* L.) plants during 2023/2024 season

Nitrogen fertilizer rate (kg N/feddan)	Nano- micronutrients (g/l)			Mean (A)
	0.0	0.5	1.0	
Root fresh weight (g/plant)				
Control	1.00 e	0.83 e	2.10 a	**1.31 B**
30	1.13 de	1.43 cd	1.10 de	**1.22 B**
60	1.87 ab	1.60 bc	1.13 de	**1.53 A**
Mean (B)	**1.33 A**	**1.29 A**	**1.44 A**	
Root dry weight (g/plant)				
Control	0.43 cd	0.33 d	1.27a	**0.68 A**
30	0.43 cd	0.63 b	0.53 bc	**0.53 B**
60	0.43 cd	0.53 bc	0.50 b-d	**0.49 B**
Mean (B)	**0.43 B**	**0.50 B**	**0.77 A**	

Effect of nano-micronutrient fertilizer rates

Compared with the control, the results tabulated in Tables 2, 3, 4, and 5 shows a significant increase in plant height, stem diameter, herb fresh weight/plant, and root dry weights/plant when fenugreek plants were sprayed with nano-micronutrients three times per season. Additionally, the highest concentration of nano-micronutrients (1.0 g/l) provided the highest values of the previously indicated parameters when compared with the control. Spraying plants with any rate of nano-micronutrients insignificantly affected root length, herb dry weight, and root fresh weight per plant. Likewise, **Hediat (2012)** findings suggest that nano-fertilizers facilitate nutrient uptake by plants,

accelerating photosynthesis and the production of dry matter while enhancing vegetative growth. In this regard, **Swaefy *et al.* (2021)** reported that using ZnO nanoparticles produced high results with all studied morphological parameters (shoot length, number of branches/ plant, shoot fresh and dry weights, root length, root fresh and dry weights of roots) of fenugreek plants.

Effect of combination between nitrogen and nano-micronutrient fertilizer rate

Concerning the impact of the combination between nitrogen fertilizers and nano-micronutrients, all combinations between N-fertilizer and nano-micronutrients treatments significantly improved plant height and number of branches per plant (Table 2) stem diameter (Table 3), herb fresh and dry weights/area (Table 4), and roots fresh weight/plant (Table 5) of fenugreek plants compared with control (without nitrogen or nano-micronutrients fertilizers applied). The mixture of nitrogen fertilizer and spraying with nano-micronutrients at a rate of 1.0 g/l resulted in the highest values of plant growth parameters compared with the other combinations under study. One of the main growth factors thought to affect how plants develop is their macronutrient, especially nitrogen element and micronutrient contents (**Marschner, 1995**; **Reffaat and Balbaa, 2001**). Moreover, fennel plants treated with phosphorus fertilizer or/and nano micronutrients instigated critical increments in vegetative growth (plant height and branch number/plant as well as dry weight of herb/plant) as contrasted and untreated plants (**Abdelkader *et al*., 2019**).

Conclusion

When nitrogen fertilizer was applied at a high rate (60 kg N/feddan), fenugreek plants generally grew more. Additionally, the fenugreek plant's development was significantly enhanced by the foliar spray of nano-micronutrients at 1.0 g/l. In addition, compared to the other combination treatments, 60 kg N/feddan as a soil drench and 0.50 g/l of nano-micronutrients as a foliar spray significantly impacted the growth parameters of fenugreek plants in the Sharkia Governorate.

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