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Effects of NPK and Nano-magnesium Fertilizers and their Interactions on the Chemical Characteristics of Fenugreek Plants

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ABSTRACT

This experiment was conducted in the nursery of Al-Diwaniyah Governorate/Iraq during the year 2021 to know the effect of Mg nano fertilizer and the balanced NPK compound foliar fertilizer (20-20-20) as well as to find out their interactions in improving the chemical properties of fenugreek plant. The nano-fertilizer was prepared in three levels 1, 2 and 3 g/l by dissolving the required amount of nano-Mg fertilizer in distilled water and completing the volume to one litre to get the above levels, according to the instructions of the Iranian Green Company, a manufacturer of nano-fertilizers. The foliar fertilizer prepared by the American company PRO-SOL and available in some agricultural offices in Baghdad was prepared in three levels, which were 1, 1.5 and 2 g/l of water. Nano-Mg did not give significant significance in phosphorus and potassium, while significant differences appeared in the rest of the elements represented by nitrogen, calcium, protein percentage, carbohydrates and fats. As for the balanced foliar fertilizer and the combination of nano-Mg and fertilizer, they showed significant indications in all of those mentioned elements.

Key words : Fenugreek plant, *Trigonella foenum-graecum* L., nano-magnesium, foliar fertilization, NPK

INTRODUCTION

Fenugreek, *Trigonella foenum-graecum* L., is widely used for its medicinal and nutritional properties all over the world, and it is a very important spice in Indian culture. There are about 260 species of this genus spread all over the world (Aasim, 2018). The genus name Trigonella means “tri-angled”, probably because of the triangular shape of the flowers, while the species name foenum-graecum means “Greek hay” (Aasim, 2018; Chaudhary *et al.*, 2018). Fenugreek is a dicotyledonous annual plant belonging to the sub-family Papilionodae, of the leguminous family Fabaceae (Aasim *et al.*, 2018).

The seeds and leaves of the fenugreek plant are primarily used for many nutritional and medicinal purposes. Leaves contain 89% water, 6% carbohydrates, 4% protein and less than 1% fat. The leaves are also rich in minerals, as the proportion of calcium is 40%, iron 15% and phosphorus is 7%. The seeds also contain 45-60% carbohydrates, 30% soluble fiber, 20% insoluble fiber, 20-30% protein and 5-10% oil (Meenakshi *et al.*, 2017). The seeds are a good source of calcium, magnesium, iron, phosphorus and vitamins (Kahandal *et al.*, 2017). One hundred g of fenugreek seeds contains approximately 65% of dietary fiber. Its protein is soluble at pH 11 (Khorshidian *et al.*, 2016). Several surveys show that fenugreek leaves are used as a food flavouring and that the seeds are used to preserve many foods (Sarwar *et al.*, 2020). Since the seeds are really hard to grind, their extract is used to flavour candy, vanilla, etc. (Sarwar *et al.*, 2020). In general, the addition of essential nutrients (elemental fertilization) is inevitable to improve crop yield and soil fertility (Li *et al.*, 2018). Therefore, careful control of fertilizers is one of the most basic requirements for sustainable agricultural development (Huang *et al.*, 2017). Intensive farming is practised which eventually leads to a vicious cycle of depleting soil fertility and deteriorating agricultural crops. It is estimated that approximately 40% of the world’s agricultural land has been seriously degraded, resulting in a severe loss of soil fertility due to these intensive agricultural practices (Kale and Gawade, 2016). In addition, the nutrient utilization efficiency of conventional fertilizers that are applied directly into the soil, or sprayed on the foliage, is largely dependent on the final concentration of the fertilizer reaching the target sites (Solanki *et al.*, 2015).

The use of water-soluble foliar fertilizers can

lead to increased vegetable production, thus achieving food security. The foliar nutrients are absorbed through the stomata and the epidermis. Hence, to obtain better results, it is important to apply foliar nutrients in the appropriate growth stage of the crop. These fertilizers are not a substitute for soil fertilizers, but they are a supplement especially when there is a lack of nutrients in the soil. Foliar feeding works as an effective method for managing nutrients in vegetables. To address the widespread shortage of nutrients that appear especially in the critical (first) stages of crop growth, foliar feeding can be successfully adopted (Krishnasree *et al.*, 2021).

MATERIALS AND METHODS

The nano-fertilizer was prepared in three levels 1, 2 and 3 g/l, by dissolving the required amount of nano-Mg fertilizer in distilled water and completing the volume to one litre for getting the above levels, according to the instructions of the Iranian Green Company, a manufacturer of nano-fertilizers.

The foliar fertilizer prepared by the American company PRO-SOL and available in some agricultural offices in Baghdad was prepared in three levels, which were 1, 1.5 and 2 g/l of water. A mixture of Mg nano-fertilizer and foliar fertilizer was prepared to study their interactions. This was done in three axes, the concentration of nano-Mg was fixed in each axle while changing the concentration of the foliar fertilizer in three levels. In the first axis, 1 g of nano-Mg was mixed with 1 g of foliar fertilizer, the second by mixing 1 g of nano-Mg with 1.5 g of foliar fertilizer, and the third by mixing 1 g of nano-Mg with 2 g of foliar fertilizer, and the required quantities were dissolved in distilled water to complete the volume to one litre to get above levels. In the second axis, the concentration of nano- Mg was fixed at 2 g and the concentration of the foliar fertilizer was changed with the same concentrations mentioned above (1, 1.5 and 2 g), and it was dissolved in distilled water. The same is the case in the third axis with an increase in the concentration of nano- Mg to 3 g.

Fenugreek seedlings were planted in pots after being prepared for planting. This was done by planting 10 in each pot on 3 September 2021. The first fertilization was carried out on 30 September 2021, by adding nano-Mg concentrations by spraying on the shoots of the plant using a one litre manual sprayer in the early morning; to ensure efficient absorption of the fertilizer by the plant (Al-Juthery *et al.*, 2018). The levels of the foliar fertilizer as well as the Mg nano-fertilizer mixture and the foliar fertilizer were added on the same date and in the same manner as above. The second treatment of the concentrations of nano-fertilizer, foliar fertilizer and their mixture was carried out on 15 October 2021 in the same way mentioned above.

Characters studied were vegetative growth characteristics including the percentage of nitrogen, phosphorus, potassium, calcium, protein, fat and carbohydrates. The laboratory experiment was carried out based on the complete randomized design (CRD), with the organization of two factors and their interactions and with three replicates for each treatment. Means were compared and the presence or absence of significant differences was observed using the Random least significant difference test (RLSD) at the level of significance of 0.05.

RESULTS AND DISCUSSION

The results of the current study showed significant differences in the treatments of fenugreek plants in the percentage of nitrogen when they were statistically analyzed in all concentrations when compared with the control treatment by using nano-Mg or balanced foliar fertilizer or both, as shown in Table 1. When using nano-Mg, the study showed that the highest average was 0.48%, at a concentration of 2 g/l in comparison with the plants treated with the lowest average, which amounted to 0.16%. The highest

Table 1. Effect of fertilizing with nano-Mg and NPK and their interactions on nitrogen percentage in fenugreek plants

Nano-Mg (g/l)	NPK				Average nano-Mg
	0	1	1.5	2	
0	0.07	0.14	0.15	0.29	0.16
1	0.13	0.49	0.21	0.28	0.27
2	0.35	0.90	0.42	0.28	0.48
3	0.22	0.420	0.29	0.14	0.26
Average NPK	0.19	0.48	0.26	0.24	
LSD (P≤0.05)	nano-Mg=0.027, NPK=0.027, interaction=0.033				

average was 0.48% in plants treated with a concentration of 1 g/l of balanced foliar fertilizer, when compared with control plants with an average of 0.19%. As for the bilateral interaction between the two factors of the study, the highest percentage of nitrogen was recorded at a concentration of 2 g/l of nano-Mg with 1 g/l of balanced foliar fertilizer with an average of 0.90% compared with the plants treated with a lower average of 0.07%.

One significant difference was observed when plants were treated with balanced foliar fertilizer at a concentration of 1 g/l with an average of 0.19%, compared to control plants with a lower average of 0.08. The results showed when studying the binary interaction between the two factors. The study revealed that there was only one significant significance at a concentration of 3 g/l of nano-Mg with 1 g/l of balanced foliar fertilizer with an average of 0.37%, compared to the plants treated with a lower average of 0.04% (Table 2).

Table 2. Effect of fertilizing with nano-Mg and NPK and their interactions on the percentage of phosphorus (%) in fenugreek plants

Nano-Mg (g/l)	NPK				Average nano-Mg
	0	1	1.5	2	
0	0.04	0.12	0.10	0.09	0.09
1	0.08	0.10	0.08	0.09	0.09
2	0.12	0.09	0.11	0.09	0.10
3	0.10	0.37	0.08	0.08	0.16
Average NPK	0.08	0.17	0.09	0.09	
LSD (P≤0.05)	nano-Mg=0.10, NPK=0.10, interaction=0.12				

Table 3 does not indicate a significant presence in the potassium percentage of fenugreek plant for all concentrations treated with nano-Mg, when compared with plants treated with the lowest average of 0.37%. However, the results indicated that there was one significant significance in the potassium percentage of fenugreek plants treated with balanced foliar fertilizer at a concentration of 1 g/l with an average of 0.48%, compared with the control plants with an average of 0.32%. As for the dual interaction between the two factors of the study, the results recorded significant differences in all concentrations, and the highest potassium percentage was recorded at a concentration of 2 g/l of nano-Mg with 1 g/l of balanced foliar fertilizer with an average of 0.49%, compared with the plants

Table 3. Effect of fertilizing with nano-Mg and NPK and their interactions on potassium percentage in fenugreek plants

Nano-Mg (g/l)	NPK				Average nano-Mg
	0	1	1.5	2	
0	0.04	0.61	0.44	0.39	0.37
1	0.41	0.43	0.32	0.38	0.38
2	0.39	0.49	0.40	0.36	0.41
3	0.46	0.40	0.37	0.31	0.38
Average NPK	0.32	0.48	0.38	0.36	
LSD (P≤0.05)	nano-Mg=0.11, NPK=0.11, interaction=0.13				

treated with the lowest average mean, which was 0.04%.

The results of the statistical analysis of the data did not show significant differences in the calcium ratio of fenugreek plants treated with nano-Mg except at a concentration of 2 g/l and an average of 0.46% when compared with the control plants with a lower average of 0.31%. All the concentrations of plants treated with balanced foliar fertilizer were significant, and the highest mean was in plants treated with a concentration of 2 g/l with an average of 0.53% compared with the control plants with an average of 0.25% (Table 4). The dual interaction between the two factors of the study also showed a significant effect similar to the effect of foliar fertilizer in terms of significant significance in all concentrations, and the highest percentage of calcium was recorded at a concentration of 1 g/l of nano-Mg with 2 g/l of balanced leaf fertilizer with an average of 0.80% compared to plants. The control treatment with the lowest mean amounted to 0.12%.

Table 4. Effect of nano-Mg fertilization and NPK and their interactions on calcium percentage in fenugreek plant

Nano-Mg (g/l)	NPK				Average nano-Mg
	0	1	1.5	2	
0	0.12	0.33	0.36	0.45	0.31
1	0.15	0.32	0.34	0.80	0.40
2	0.42	0.44	0.48	0.49	0.46
3	0.32	0.42	0.32	0.39	0.36
Average NPK	0.25	0.38	0.37	0.53	
LSD (P≤0.05)	nano-Mg=0.109, NPK=0.109, interaction=0.122				

The results of the statistical analysis of the data proved that there was a significant significance in the percentage of protein, and the highest average was 3.04% at a

concentration of 2 g/l, compared with the control treated plant with a minimum average of 1.01 (Table 5). As well all concentrations of fenugreek plants treated with balanced foliar fertilizer showed significant differences. The highest mean was reached in the plants treated with a concentration of 1 g/l with an average of 3.04%, compared to treated plants. The mean control was 1.20%. Similarly, the binary interaction between the two factors of the study showed a significant presence in all concentrations, and the highest percentage was recorded at the concentration of 2 g/l of nano-Mg with 1 g/l of balanced foliar fertilizer with an average of 5.62%, while the lowest average of the control treatment plants was 0.44%.

Table 5. The effect of fertilizing with nano-Mg and NPK and their interactions on the protein content (%) in fenugreek plants

Nano-Mg (g/l)	NPK				Average nano-Mg
	0	1	1.5	2	
0	0.44	0.87	0.94	1.81	1.01
1	0.81	3.06	1.31	1.75	1.73
2	2.19	5.62	2.62	1.75	3.04
3	1.37	2.62	1.81	0.87	1.67
Average NPK	1.20	3.04	1.67	1.54	
LSD (P≤0.05)	nano-Mg=0.15, NPK=0. 15, interaction=0.18				

The results of the current study showed that there were significant differences in the treatments of fenugreek plants in the percentage of carbohydrates when they were statistically analyzed in all concentrations when compared with the control treatment, using nano-Mg or balanced foliar fertilizer, and also indicated the presence of those differences in most of the concentrations of the interaction. The binary between the two factors of the study using nano-Mg showed that the highest average was 11.15% at a concentration of 2 g/l compared to the control plants with a lower average of 6.80% (Table 6). Likewise, in all concentrations of fenugreek plants treated with balanced foliar fertilizer, it was significant, and the highest mean was reached in plants treated with a concentration of 1 g/l with an average of 13.07% compared with plants treated in control with average 5.85%. As for the binary interaction between the two study factors, the highest percentage was recorded for carbohydrates at a concentration of 3 g/l of nano-Mg with 1 g/l of balanced foliar fertilizer averaging 10.46% compared to control plants with a lower average of 3.94%.

Table 6. Effect of nano-Mg and NPK and their interactions on carbohydrate percentage in Fenugreek plants

Nano-Mg (g/l)	NPK				Average nano-Mg
	0	1	1.5	2	
0	3.94	9.88	8.18	5.20	6.80
1	5.25	14.30	4.11	4.32	6.99
2	7.57	17.67	6.62	12.76	11.15
3	6.67	10.46	5.46	7.47	7.51
Average NPK	5.85	13.07	6.09	7.43	
LSD (P≤0.05)	nano-Mg=0.18, NPK=0.18, interaction=0.23				

The results of the statistical analysis of the data presented in Table 7 indicate that there was significant significance in the fat percentage of fenugreek plants for all concentrations treated with nano-Mg, where the highest average was 0.67% at a concentration of 2 g/l, compared with the plants treated with the lowest average of 0.54%. It also indicated that all concentrations of fenugreek plants treated with balanced foliar fertilizer were also significant, as the highest mean was reached in plants treated with a concentration of 1 g/l with an average of 0.66%, compared with control plants with an average of 0.56%. As for the binary interaction between the two factors of the study, the results also indicated that there were significant differences in all concentrations, the highest percentage of fat was recorded at the concentration of 2 g/l of nano-Mg and 1.5 g/l of balanced foliar fertilizer with an average of 0.79%, compared with the control treatment plants with the lowest average which amounted to 0.33%.

Table 7. Effect of nano-Mg and NPK and their interactions on fat (%) in fenugreek plants

Nano-Mg (g/l)	NPK				Average nano-Mg
	0	1	1.5	2	
0	0.33	0.63	0.47	0.76	0.54
1	0.77	0.61	0.57	0.53	0.62
2	0.65	0.74	0.79	0.52	0.67
3	0.50	0.67	0.61	0.66	0.61
Average NPK	0.56	0.66	0.61	0.61	
LSD (P≤0.05)	nano-Mg=0.03, NPK=0.03, interaction=0.04				

Mg nanoparticles did not give significant significance in phosphorus and potassium,

while significant differences appeared in the rest of the elements represented by nitrogen, calcium, protein, carbohydrates and fats. As for the balanced foliar fertilizer and the combination of nano- Mg and fertilizer, they showed significant indications in all those mentioned elements.

The results of this research are in agreement with the results of Salcido-Martinez *et al.* (2020) in *Phaseolus vulgaris* L., who found that the foliar application of Mg nanoparticles at 50 ppm led to the generation of the greatest amount of biomass and photosynthetic pigments, and it was found that a dose of 100 ppm led to improved production of pods and allowed to increase the activity of the nitrate reductase enzyme. The results also agreed with those of Ponce-García *et al.* (2019), who noted that foliar fertilization with Mg in green beans led to an increase in vegetative and root biomass, as well as the production of pods. The results of this study also agreed with those of Mahawar *et al.* (2018) as it was found that doses of 50 and 100 mg/l of MgO nanoparticles stimulated the performance of *Vigna radiata* L.

Mg affects many processes that modify the production and transport of carbohydrates in plants (Ceylan *et al.*, 2016). Carbohydrates (sugars) are transported over long distances from their sources of production in the leaves to the organs via the phloem, and this is strongly influenced by the availability of Mg (Ba *et al.,* 2020). The foliar feeding of water-soluble NPK fertilizer (19 : 19 : 19) after 30, 45 and 60 days after sowing reported that the protein content was significantly higher in cowpea seeds compared to the control (Singhal *et al.*, 2016). The optimum supply of nutrients to plants is the most important factor for increasing crop yield, and among all the essential plant nutrients are nitrogen, phosphorus and potassium. Macronutrients determine the growth and development of plants (Mensah *et al.*, 2020; Olegovich Bokov *et al.*, 2022).

CONCLUSION

In conclusion, nano-Mg did not give significant significance in phosphorus and potassium, while significant differences appeared in the rest of the elements represented by nitrogen, calcium, protein percentage, carbohydrates and fats. As for the balanced foliar fertilizer and the combination of nano-Mg and fertilizer, these nano-elements showed significant indications for those macro elements such as calcium.

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