Pak. J. Bot., 57(5): DOI: http://dx.doi.org/10.30848/PJB2025-5(25)

COMPARING THE IMPACT OF DIFFERENT SOURCES AND LEVELS OF MANUFACTURED AND COMMERCIAL ORGANIC FERTILIZERS ON THE QUALITATIVE CHARACTERISTICS OF FENUGREEK (*TRIGONELLA FOENUM-GRAECUM* L.) SEEDS

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Abstract

A field study was conducted in Ramadi (about 110 kilometers west of Baghdad), Iraq (33° 25' 15" N, 043° 18' 26" E, with the aim of finding local alternatives to commercial organic fertilizers by recycling household and city waste at the lowest cost and applying them to fenugreek plants with the aim of increasing their nutrient content. The experiment consisted of two factors. The first factor involved applying sheep manure at three levels: 0, 6, or 8 Mg ha^{-1}. The second factor involved spraying commercial or manufactured organic acids at three concentrations: 0.5, 1, or 1.5 ml L^{-1}. The control treatment has been only sprayed with distilled water. The results showed that the second level of sheep manure (6 Mg ha^{-1}) gave the highest rate of micro and macro nutrient content in fenugreek seeds. The third level of commercial organic acid (1.5 ml L^{-1}) gave the highest content of nitrogen, phosphorus and zinc in the seeds, reaching 41.74 (gN kg^{-1}), (5.14gP kg^{-1}) and 32.3 (mgZn kg^{-1}), respectively. The commercial treatment of organic acids gave a value similar to the treatments of manufactured organic acids for potassium contents in seeds, which amounted to 10.42 (gK kg^{-1}) at the spray level (1.5 ml L^{-1}). The second level of commercial organic acid (1 ml/l) gave the highest magnesium content in seeds, reaching 2.41(gMg kg^{-1}). The third level of manufactured organic acid (1.5 ml/l) gave the highest percentage of iron in fenugreek seeds, which amounted to 578.7 (mgFe kg^{-1}). The highest manganese content was found in fenugreek seeds, which reached 33.0 (mg Mn kg^{-1}) when sprayed with the second level of manufactured acid (1 ml/l). The interaction between the second level of sheep manure and the third level (1.5 ml/l) of spraying with commercial organic acids gave the highest content of micro- and macronutrients in fenugreek seeds. The results of this study indicated that using organic acids and sheep manure could be a good way to improve the nutritional content of fenugreek seeds.

Key words: Organic fertilizer, Manufactured and commercial organic fertilizer, Quality characteristics, Fenugreek.

Introduction

The consumed food amount increased with the increase of the population worldwide, which is why, food waste amount had increased as well. Thus, it is safe to utilize that waste through recycling it and utilizing it as fertilizers improving the growth and production of the plant and eliminating its adverse impacts on environment. The trend has been towards the addition of organic fertilizers to reduce pollution and environmental damage caused by chemical fertilizers. The excessive use of non-organic fertilizers deteriorates the soil and the ecosystem, making the soil an unsuitable environment for cultivation. Chemical fertilizers are harmful directly or indirectly, as they contain heavy metals (arsenic and cadmium) that accumulate in plants and thus harm human health.(Jasim *et al*., 2014) and (Shah *et al*., 2007).

Recycled fertilizers are environmentally friendly and rich in nutrients, making them ideal for improving plant growth and production (Sanadi *et al*., 2019). An annual herb in legume family is fenugreek. Calcium, iron, potassium, phosphorus, and other minerals are the most significant elements found in its seeds, which also contain a range of proteins and vitamins that make up 25–36% of plant's dry weight (Ali *et al*., 2012). Considered a medicinal herb, fenugreek is frequently used as a spice. It contains an abundance of different active medicinal substances. Global pharmaceutical industry interest in natural therapeutic items, such as legume seeds, is increasing. Numerous health advantages of fenugreek have been demonstrated by scientific research, including its beneficial effects on anti-cancer, anti-diabetes, antioxidant, antimicrobial, anti-inflammatory, and antibacterial and antifungal properties, pharmacologic and medicinal actions of fenugreek are attributed to the variety of its constituents including steroids (diosgenin), alkaloids (trigonelline), flavonoids (luteolin), coumarins, aminoacids (hydroxyisoleucine), mucilage (galactomannan), volatile constituents, fixed oils and other substances (Adedapo, A. A *et al.*, 2014; Zandi *et al*., 2017; Pacheco *et al*., 2017; Al-Warshan *et al*., 2023).

Modern agricultural trends focus on reducing the use of chemical fertilizers and the trend towards using organic and biological fertilizers (Darzi *et al*., 2011). (Sharma *et al*., 2002) showed that organic farm waste improves the physical properties of the soil and increases the availability of nutrients in the soil. It also increases protein content, and this may be due to the availability of all essential nutrients found in organic matter. Organic fertilizers are rich in their content of nitrogen, phosphorus, potassium, and micronutrients (Pandey *et al*., 2007).

The effect of three types of fertilizers (integrated fertilizer, chemical fertilizer, and broiler chicken manure) was studied. The addition of chicken manure had a role in increasing the content of fenugreek seeds of all active compounds such as antioxidants and flavonoids (Salehi *et al*., 2019; Hadi & Mariod, 2022). It was proven that organic fertilizers improve the activity of antioxidants and biologically active compounds (Salehi *et al*., 2018). A field experiment has been carried out for testing the impact of various sources of organic and biological fertilizers on the biochemical characteristics of fenugreek. A considerable increase in the content of fenugreek of carbohydrates, protein, totals and soluble nitrogen, chlorophyll, carotene, and fatty acids was obtained with increasing levels of addition (Battah *et al.*, 2021. In the case of studying effects of poultry manure levels and spraying humic acid 2ml/l on fenugreek yield and growth, it has been noticed that the poultry manure (8/ton/ha) performance has been control treatment in the increase of those features (Jassim *et al*., 2016).

(Martnez-Alcantara *et al*., 2016) have manufactured liquid organic fertilizer that contains micro as well as macro nutrients (Zn, Mn, Cu, P, K, Fe, B) from mix of the animal manure and plant waste. The organic matter generally, and the organic acids particularly have been known due to their utilization in the improvement of fertility and biological soil traits (Canelas *et al*., 2015). They have as well improved their chemical as well as physical characteristics, thus leading to the improvement of the production and growth of the plants, therefore leading to the increase of micro and macro nutrient absorption. The humic acids work as well towards increasing nutrient availability in soil and increase the ability of the plant for osmotic stress and toxicity tolerance. A study was conducted for the purpose of evaluating humic acid application at of 2ml/l and 4ml/L concentration levels on the characteristics of growth and the active fenugreek compounds. Results have shown that 4ml/L concentration has been much better in all of the yield, growth characteristics, and content of the seeds of fenugreek of choline Trigonelline, Gentianine, Carpine (Majid *et al*., 2019. Fenugreek seed content of the protein and nitrogen have increased as well in the case where the organic farm manure has been added in an experiment field that has been carried out by (Lungariya *et al*., 2018). An important increase in qualitative characteristics has been obtained through the increase of the levels of application in the case where the fenugreek plants have been sprayed with the humic acid 0ppm, 50ppm, 100ppm, 200ppm, 300ppm, and 400ppm concentrations (Abdelhakem *et al*., 2021).

Results of field experimentation that has been carried out by (Abdelbaky *et al*., 2019) have shown a noticeable increase in all of the qualitative carbohydrate, phosphorus, potassium, protein, nitrogen, lysine, phenylalanine, arginine, and tryptophan traits in the case where the bean plants have been sprayed by the fulvic acid at 0g/L, 3g/L, 6g/L, and 9g/L concentration levels. Impacts of the topical application of fulvic acid to peas at 0, 0.50, and 1kg Fedan^{-1} has been researched. Findings have shown that the addition of an additional amount of the fulvic acid to application level have resulted in a significant increase of micro- and macro- nutrient amount in leaves and seeds (El-Battran *et al*., 2020). Study Aims:

The present paper is aimed to finding local alternatives to the commercial organic fertilizers through the recycling of the household and urban wastes at lowest costs and applying them to the fenugreek plants for the purpose of increasing their nutrient contents.

Material and Methods

Preparation of organic fertilizers: Two piles were made, one of sheep manure and the other of fruit and vegetable waste, each 1.5 meters high and 1 meter long. The moistening and turning process was carried out throughout the fermentation period of 90 days for fruit and vegetable waste, and 120 days for sheep manure. Some analyses were performed on these wastes after fermentation was completed (Table 1).

Table 1. Some characteristics of household and sheep manure after fermentation.

C/N	AV K (mg/kg)	AV P (mg/kg)	Total N %	pH	Ec (ds/m)	Type of waste
18.6	1.76	0.86	1.4	6.4	9.65	Household waste
17.1	1.3	0.7	1.8	6.4	7.7	Sheep manure

Extraction of humic acids: Potassium hydroxide was used to separate the humic acids (humic and fulvic) from fruit and vegetable waste according to the method used by (Schnitzer & Ghosh, 1982).

Soil preparation for planting: Fenugreek seeds were planted on October 25 in rows with a spacing of 30 cm between rows and 25 cm between plants. The area of each unit was 4 m^2. The drip irrigation system was used using fish tank water (aquaponics). The experiment has been carried out in a sandy loam soil in one of the agricultural fields affiliated to the College of Agriculture, University of Anbar, with the properties shown in (Table 2). The experiment was designed with the use of a randomized complete block design with three blocks, each block containing 21 experimental units. Sheep manure was added before planting at three levels:

A0 = 0 (no addition), A1 = 6 M ha^{-1}*, A2 = 8 M ha^{-1}.

* M ha^{-1} is Megagram hectare^{-1} = Tons per hectare^{-1}

Foliar spray treatments

- Control treatment: Sprayed with only distilled water, coded as (C).
- Commercial organic fertilizer treatments: Sprayed with commercial humic and fulvic acids at three levels: G1 = 0.5, G2 = 1, G3 = 1.5 ml liter^{-1}
- Manufactured organic fertilizer treatments: Sprayed with manufactured humic and fulvic acids at three levels: M1 = 0.5, M2 = 1, M3 = 1.5 ml liter^{-1}

Table 2. Some of the chemical and physical properties of the soil before planting.

$CaCO_3$ g.kg^{-1}	Bulck density g.cm^{-3}	available K mg.kg^{-1}	available P mg.kg^{-1}	Total N %	O.M%	pH	Ec ds.m^{-1}	Soil texture	Soil separates g kg^{-1}		
									Clay	Silt	Sand
110.58	1.48	86.62	8.824	0.056	0.890	7.23	2.88	Sandy loam	52	444	504

Dissolved positive and negative ions (milli-eq.L^{-1})

Ion	$SO4^{=}$	$HCO3^{-}$	$CO3^{=}$	Cl^{-}	K^{+}	Na^{+}	Mg^{++}	Ca^{++}
Concentration (meq./L)	8.2	2.8	Nil	4.88	0.69	1.92	12.4	11.4

C/N is The ratio of carbon to nitrogen, **AV** K is Available potassium, **AV** P is Available phosphorus, **Total N %** is Percentage of total nitrogen, **pH** is Hydrogen potential, **Ec** is Electrical conductivity, **O.M** is Organic Matter

The first application for manufactured and commercial organic acids was applied on December 31, the second application was applied on January 21, and the third application was applied on February 24. All applications were applied early in the morning to the point of complete wet. A 100% organic spreading agent was used to lowers the surface tension of the liquid, making it easier to spread. Crop management operations were carried out during the growing season, including hoeing and weeding. Harvest was carried out on 24 March.

Studied traits: Fenugreek seeds were dried after harvest, first by air drying and then in an oven at 65°C. They were then ground and digested using concentrated sulfuric and perchloric acids according to the method in (Gresser and Parson, 1979).

The nutrients in fenugreek seeds were estimated using the following methods:

Nitrogen was estimated using a micro-Kjeldahl apparatus according to the method in (Jackson, 1958)).

Phosphorus was estimated using the molybdate-ammonium-ascorbic acid method (John, 1970) and measured using a spectrophotometer at a wavelength of 620 nm according to the method in (Page *et al*., 1982).

Potassium was estimated using a flame photometer according to the method proposed by (Haynes,1980).

Micronutrients (zinc, iron, copper, and manganese) were estimated using atomic absorption instrument.

Results and Discussion

Macronutrients of fenugreek seeds

Nitrogen content of fenugreek seeds (g kg^{-1}): The study's results indicated that the nitrogen content of fenugreek seeds increased with increasing levels of sheep manure and commercial organic acids (Table 3). The third level of sheep manure gave the highest nitrogen content of 43.71 g kg^{-1}, compared to the lowest nitrogen content of 36.86 g kg^{-1} in the control treatment.

The application of commercial organic acids also resulted in the highest nitrogen content of 41.74 g kg^{-1} for G3 (1.5 ml L^{-1}), and the lowest nitrogen content in fenugreek seeds was 39.64 g kg^{-1}, found in the treatment (C) with only distilled water. The highest average nitrogen content of fenugreek seeds, 45.20 g kg^{-1}, was achieved by the fertilizer combination of A_2M_3. This increase is attributed to the effective role of organic fertilizers and organic acids in increasing the availability of nutrients to the plant, and their role as a source of these nutrients, including nitrogen. This is in agreement with what was mentioned by (Battah, 2021).

Phosphorus content of fenugreek seeds (g kg^{-1}): The phosphorus content of fenugreek seeds increased significantly with increasing levels of sheep manure and commercial organic acids (Table 4). The highest phosphorus content of 5.86 mg kg-1 was found in the treatment with the third level of in-ground addition of sheep manure, while the lowest phosphorus content of 3.42 mg kg-1 was found in the treatment with no sheep manure added. The application of commercial organic acids at the third level also gave a high phosphorus content of 5.14 mg kg-1, but the statistical analysis did not indicate a significant difference between the application treatments of manufactured and commercial organic acids.

The results showed that the third level of sheep manure application significantly increased the potassium content in fenugreek seeds, up to 10.63 g kg^{-1} (Table 5). The lowest potassium content, 9.30 g kg^{-1}, was recorded in the control treatment. The third level of spraying with either commercial or manufactured organic acids also resulted in a potassium content of 10.42 g kg^{-1}. While the lowest potassium content in fenugreek seeds when sprayed with distilled water only was 9.57 g kg^{-1} (Table 5). The statistical analysis results showed no significant interactions between sheep manure and spraying with commercial or manufactured organic acids. it means that the effect of one factor on the dependent variable is consistent across all levels or conditions of the other factor, i.e., both factors act in an independent manner, study results have suggested that sheep manure and spraying with organic acids impacts on fenugreek seed potassium contents are additive, which is an indication of the waus ffecting 2 factors could be combined for the purpose of producing greater potassium content increase compared to the each one of the factors separately.

Results of the study have been an indication of the fact that the 3rd ground application level of the sheep manure had resulted in a significant increase in fenugreek seeds' magnesium content, as high as 2.47g/kg. (Table 6.) The minimal content of magnesium, 2.2g/kg, has been found in the treatment of the controls. The 2nd commercial organic acid level had resulted as well in a 2.41g/kg content of magnesium, whereas lowest content of magnesium, 2.31g/kg, has been recorded in control treatment that sprayed by the distilled water alone. Lastly, study results have indicated that the 3rd sheep manure application level as well as the 2nd spraying level with the commercial organic acids could have a high effectiveness in the increase of the content of magnesium in the fenugreek seeds at 2.71g/kg.

Table 3. impact of different sources and levels of manufactured and commercial organic fertilizers on nitrogen content of fenugreek seeds (g kg^{-1}).

Sprayed organic extract	Sheep manure			Mean
	A_0	A_1	A_2	
C	35.10	41.10	42.71	39.64
G_1	36.50	42.71	43.50	40.90
G_2	36.91	43.30	43.16	41.12
G_3	37.90	43.10	44.20	41.74
M_1	36.10	41.70	43.60	40.47
M_2	37.90	42.90	43.60	41.47
M_3	37.60	42.10	45.20	41.64
Mean	36.86	42.42	43.71	
LSD 0.05	Sheep manure	organic extract	Interaction	
	0.002699	0.004123	0.007142	

Table 4. impact of different sources and levels of manufactured and commercial organic fertilizers on phosphorus content of fenugreek seeds (g kg^{-1}).

Sprayed organic extract	Sheep manure			Mean
	A_0	A_1	A_2	
C	3.30	5.17	5.56	4.68
G_1	3.42	5.41	5.79	4.87
G_2	3.48	5.65	5.97	5.04
G_3	3.55	5.76	6.11	5.14
M_1	3.36	5.29	5.69	4.78
M_2	3.37	5.62	5.89	4.96
M_3	3.46	5.55	6.02	5.01
Mean	3.42	5.49	5.86	
LSD 0.05	Sheep manure	organic extract	Interaction	
	0.007	0.011	0.019	

Table 5. impact of different sources and levels of manufactured and commercial organic fertilizers on potassium content of fenugreek seeds (g kg^{-1}).

Sprayed organic extract	Sheep manure			Mean
	A_0	A_1	A_2	
C	8.50	9.90	10.31	9.57
G_1	9.33	9.93	10.56	9.94
G_2	9.44	10.45	10.51	10.13
G_3	9.61	10.65	10.99	10.42
M_1	9.20	10.21	10.48	9.97
M_2	9.41	10.35	10.61	10.13
M_3	9.56	10.70	10.98	10.42
Mean	9.30	10.31	10.63	
LSD 0.05	Sheep manure	organic extract	Interaction	
	0.028	0.042	0.073	

Potassium content of fenugreek seeds, g kg^{-1}
Magnesium content of fenugreek seeds, g kg^{-1}

Table 6. impact of different sources and levels of manufactured and commercial organic fertilizers on magnesium content of fenugreek seeds (g kg^{-1}).

Sprayed organic extract	Sheep manure			Mean
	A_0	A_1	A_2	
C	2.23	2.27	2.43	2.31
G_1	2.17	2.35	2.58	2.36
G_2	2.18	2.42	2.62	2.41
G_3	2.16	2.30	2.71	2.39
M_1	2.14	2.11	2.36	2.20
M_2	2.19	2.17	2.31	2.22
M_3	2.37	2.23	2.30	2.30
Mean	2.20	2.26	2.47	
LSD 0.05	Sheep manure	organic extract	Interaction	
	0.005	0.008	0.013	

Micronutrients of fenugreek seeds,
Zinc content of fenugreek seeds mg kg^{-1}

Table 7. impact of different sources and levels of manufactured and commercial organic fertilizers on zinc content of fenugreek seeds (mg kg^{-1}).

Sprayed organic extract	Sheep manure			Mean
	A_0	A_1	A_2	
C	27.0	26.0	29.0	27.3
G_1	26.0	30.0	32.0	29.3
G_2	27.0	33.0	36.0	32.0
G_3	29.0	34.0	34.0	32.3
M_1	26.0	29.0	32.0	29.0
M_2	28.0	31.0	33.0	30.7
M_3	28.0	30.0	35.0	31.0
Mean	27.3	30.4	33.0	
LSD 0.05	Sheep manure	organic extract	Interaction	
	1.107	1.69	2.928	

Iron content of fenugreek seeds, mg kg^{-1}

Table 8. Impact of different sources and levels of manufactured and commercial organic fertilizers on iron content of fenugreek seeds (mg kg^{-1}).

Sprayed organic extract	Sheep manure			Mean
	A_0	A_1	A_2	
C	448.0	551.3	516.0	505.1
G_1	462.0	571.3	542.0	525.1
G_2	463.3	570.0	670.0	567.8
G_3	491.3	579.0	610.0	560.1
M_1	450.0	538.0	561.7	516.6
M_2	470.3	556.0	580.0	535.4
M_3	520.0	596.0	620.0	578.7
Mean	472.1	566.0	585.7	
LSD 0.05	Sheep manure	organic extract	Interaction	
	0.976	1.49	2.581	

Manganese content of fenugreek seeds, mg kg^{-1}

The results of the present study have been an indication of the fact that the 3rd ground application level of the sheep manure had resulted in a significant increase in fenugreek seeds' zinc content, as high as 33mg/kg (Table 7). The lowest content of zinc, which was 27.3mg/kg, has been recorded in control treatments.

The 3rd commercial organic acid level had resulted as well in 32.3mg/kg zinc content, on the other hand, it has not been that different from the spraying with the manufactured organic acids at 2nd and 3rd levels. None-the-less, sheep manure combination treatment (level 3) and commercial organic acids (level3) (A2 G2) had recorded maximum zinc content that was equal to 36mg/kg. which has suggested the fact that those 2 treatments could synergistically work for increasing fenugreek seeds' zinc content. The results of this study suggest that sheep manure and commercial or manufactured organic acids can be effective in increasing the zinc content in fenugreek seeds.

The results shows that the third level of ground application of sheep manure significantly exceeded in providing the highest iron content in fenugreek seeds, reaching 585.7 mg kg^{-1}, in comparison with the control treatment, which gave a content of 472.1 mg kg^{-1} (Table 8). Statistical analysis results also showed that the third level

of spraying with manufactured organic acids exceeded in providing the highest iron content in fenugreek seeds, reaching 578.7 mg kg^{-1}, in comparison with the control treatment, which gave a content of 505.1 mg kg^{-1}.

However, sheep manure combination treatment (level3) and commercial organic acids (level2) (A2 G2) have recorded maximum content of iron of 670mg/kg. Which has implied that those 2 treatments could synergistically work for the purpose of increasing the content of the iron in the fenugreek seeds. This study results have suggested that manufactured or commercial organic acids and sheep manure may be considered effective in the increase of fenugreek seeds' iron content.

Results have indicated a significant sheep manure application effect, with the 3rd ground application level of the sheep manure had been found significantly better compared to highest content of manganese in the fenugreek seeds, where it had reached 49.4mg/kg, while, control treatments had lowest content of manganese which had been equal to 11.7mg/kg.

Table 9. impact of different sources and levels of manufactured and commercial organic fertilizers on manganese content of fenugreek seeds (mg kg^{-1}).

Sprayed organic extract	Sheep manure			Mean
	A_0	A_1	A_2	
C	4.9	15.6	29.6	16.7
G_1	14.3	23.6	51.6	29.8
G_2	13.8	22.0	58.3	31.4
G_3	12.0	14.7	44.9	23.9
M_1	7.9	22.0	55.9	28.6
M_2	15.1	37.6	46.3	33.0
M_3	13.8	21.6	59.4	31.6
Mean	11.7	22.4	49.4	
LSD 0.05	Sheep manure	organic extract	Interaction	
	9.38	14.33	24.82	

Results of statistical analyses have shown significant effects of organic acid spraying. The maximum content of manganese in the seeds of fenugreek at 2nd spraying level with the manufactured organic acids has been 33mg/kg, (Table 9). whereas lowest content of manganese in rrhe seeds of fenugreek has been 16.7mg/kg at spraying with treatment that uses only distilled water.

Those results have been in agreement with earlier research that has been carried out by (Lunagariya *et al*., 2018), which had emphasized as well organic matter and organic acid spraying roles in the enhancement of the levels of nutrients in the fenugreek seeds, underscoring their importance as vital sources of nutrient and storage.

Statistical analysis results did not show a significant difference between the spraying treatments with commercial organic acids and the spraying treatments with manufactured organic acids for most of the studied traits.

Conclusion

Manufactured fertilizers showed promising results in improving some quality traits of fenugreek seeds. Additionally, statistical analysis did not reveal any significant differences between the effects of commercial and manufactured organic acids on most of the traits studied. Therefore, it is more advisable to recycle urban waste to produce organic acids for agricultural use instead of using expensive commercial acids.

Acknowledgement

The authors would like to acknowledge the contribution of the University of Anbar (www.uoanbar.edu.iq) via their prestigious academic staff in supporting this research with all required technical and academic support.

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(Received for publication 24 April 2024)