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Response of the active ingredients of fenugreek plant to spraying with different forms of microelements and planting dates under El Tor conditions in South Sinai

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ABSTRACT

This study was conducted at South Sinai Research Station, El-Tor Branch, Desert Research Center; on fenugreek plants during two successive seasons 2019-2020 and 2020-2021 to study the effect of micronutrients and sowing date on the productivity of fenugreek plants that are cultivated in south Sinai. The experimental design was a split-plot that included 9 treatments, planting dates in the main plots, and different forms of microelements in the sub-main plots. The planting dates which included three dates (1st September, 1st October and 1st November), and the different forms of microelements included (control, EDTA form, and humic form) were applied in three equal doses in both seasons. Results showed the effect of planting dates and different forms of microelements and the interaction between them on growth parameters, yield, and production, fixed oil production, active ingredients, chemical constituents, where significant differences were seen, that led to a significant increase, and the best treatment was with planting on October 1st with humic form treatment.

Keywords: EDTA**,** humic*,* planting dates, microelements, *Trigonella foenum-graecum* L.

1. Introduction

Fenugreek is an annual herb that grows to a height of 30–60 cm and is smooth and herbaceous. The leaves are light green and 7–12 cm long, alternating, complex, trifoliolate, and alternating. The fruits are 2–10 cm long, slender, and pointed pods with 10–20 seeds that are straight or sickle-like. The seeds are 6-8 mm long, oblong or square in shape, green-olive or brownish in colour, and have a pungent, spicy aroma (Ecocrop, 2017; Alaoui, 2005).

Trigonella foenum-graecum, L. belong to family leguminosa. It contains different medicinal compounds such as alkaloids, glycosides, and phenols that make it suitable for many purposes, such as in the agricultural and pharmaceutical industries. It is an important source for the manufacture of many medicines, and alkaloids have therapeutic and vital effects, and N –Trigonelline Methyl nicotinic acid is one of the most important alkaloid compounds, Wang and Wylie-Rosett, (2008).

Sunita *et al*. (2011), noted that Trigonelline from fenugreek has biological properties to treat diabetes, Hamza *et al*., (2012), cholesterol, migraine, microbes, cancerous tumors, memory improvement, sedative, and protection of neurons (Ghule *et al*., 2012). The amounts of Trigonelline alkaloid in fenugreek seeds range from 0.25: to 0.64% according to the different varieties and environmental conditions surrounding the plant.

Planting dates affect the production and yield of all plants through a direct effect as a result of different withering conditions such as temperature, humidity, and light. There are several studies conducted on fenugreek plants to study the effect of planting dates on production. Halesh *et al*. (2000) sowing was carried out on 6 planting dates, which are 15th June, 1st, 15th July, 1st, 15th September, and 1st October, where the best significant increase was recorded when planting on 1st July, which gave the highest values in plant length 56.7 cm, a number of branches 10.08 and number of pods 15.43 each plant while the weight of seeds for each plant was 50.95 g, respectively. Also, Samima *et al*. (2016) referred to a study conducted on the different planting dates in Bengal by planting on five different

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dates 2nd, 9th, 16th, 23rd November, and 28th December, which gave the best planting date when planting on 16th November, which recorded the highest effect and increases Significant in both seed yield and its active ingredients. In another study in India, Sowmya *et al*. (2017) indicated that during the cultivation of fenugreek on four dates: 25th September 10th, 25th October, and 9th November, where the 10th October treatment recorded the maximum significant increase in plant height, number of branches, fresh and dry weight of each plant As well as the length, weight, and number of pods for each plant, the number of seeds, their weight/plant, and the seed yield/plant and acre. The study, which was conducted on four different dates, 1st, 15th March, and 1st, 15th April, indicated a significant increase in plant height and weight of 1000 seeds, length and number and weight of pods, the number of pods per plant when planting on 1st, 15th March and 1st, 15th April in Turkey (Erman Beyzi and Bilal Gürbüz, 2020). In Iran, fenugreek was planted on several different dates, 28th February, 19th March, and 19th, 29th April. The planting date was 28th February, the best significant effect on seed yield was 88.34 g per plant, while the number of pods was 25.8, 1000 seeds weighed 12 g. The number of pods was 25.8, while the least significant effect on seed yield for each plant was 22.3 g, the weight of 1000 seeds was 9.9 g, and the number of pods was 6.8 when planting on 29th April (Seghatoleslami and Ahmadi, 2010).

using microelements as foliar fertilizers by spraying on plants cannot be a substitute for adding fertilizers through the soil, but it can supplement or increase the effectiveness of the fertilizer added to the soil because the stimulating effect of growth achieved by foliar fertilizer is due to the direct processing of nutrients to the active centers of the vital processes of the plant. Rania (2020), Rania and Wafaa (2017), and Ibrahim *et al.,* (2019) black cumin indicated that the micro-elements have an active role in many vital processes in the plant, including activating the formation of various proteins and enzymes for the plant, stimulating the formation of chlorophyll, helping to transport carbohydrates and sugars, and regulating the osmotic effort of plant cells, and the zinc element enters in Synthesis of the amino acid tryptophan, which is an essential substance in the manufacture of the hormone indole acetic acid (AAI) which is important in the process of plant growth. Also, activate chlorophyll and stimulates the absorption of microelements from the soil. Several studies have confirmed the importance of foliar feeding in improving growth and yield in all crops, especially medicinal and aromatic plants.

The aim of the study was the effect of planting dates and some micronutrients (iron, manganese, and zinc) added in two chelated forms of chelated humic and chelated (EDTA) as a foliar application on fenugreek growth, yield, and active components under El Tor conditions in South Sinai

2. Materials and Methods

This research paper was conducted at South Sinai Research Station - El-Tor Branch of the desert research center, on the fenugreek plants during the two successive wintertime seasons 2019-2020 and 2020-2021 to study the effect of the response of the active ingredients of (*Trigonella foenum-graecum*) fenugreek plant to planting dates and spraying with different forms of microelements under el tor conditions in south Sinai. Sowing was done on three dates, 1st September, 1st October and 1st November 2020 and 2021 during the first and second seasons, respectively, fenugreek seeds were sown in plots of 5 x 3 (m^2). The distance between the rows is 50 cm, space between the ridges is 30 cm between them. After full germination (30 days after sowing) the plants were thinned to one plant per hill, feddan (4200 m^2) containing 28000 plants. Regular agricultural treatments of fenugreek plants were practiced. Fenugreek plants were fertilized with different fertilizers at a rate of 20 m^3 compost, 150 kg calcium superphosphate (15.5% P_2O_5), 75 kg potassium sulfate (50% K_2O), and 150 kg ammonium nitrate (33% N) per feddan. Compost and calcium superphosphate were used during soil preparation. While ammonium nitrate and potassium sulfate in three equal doses and added to the soil after 30, 50, and 75 days of planting. A drip irrigation system was used in this experiment. The experimental design was a split-plot that included 9 treatments, planting dates in the main plots, and different forms of microelements in the sub-main plots. The planting dates which included 3 dates (1st September, 1st October and 1st November), and the different forms of microelements included (control, EDTA form, and humic form) were applied in three equal doses in both seasons (Ibrahim *et al*., (2019). The differences between the means of the treatments were considered by using statistix[9] analytical software (1985). Plants were sprayed with microelements forms three times three weeks intervals. All other agricultural practices needed by the plants were performed.

The following data were recorded:
1. 1st September
2. 1st October
3. 1st November
4. 1st September + EDTA form
5. 1st September + humic form
6. 1st October + EDTA form
7. 1st October + humic form
8. 1st November + EDTA form
9. 1st November + humic form

2.1. Measurements

2.1.1. Growth parameters

Plant samples were taken randomly on the growth at the age of 160 days (during the vegetative stage) in both seasons, and the following data were recorded: plant height (cm), number of branches per plant, and number of pods per plant.

2.1.2. Yield and production

At harvest dateseason15th and 18th May in the first and second seasons, respectively, the following data were recorded: seed weight per plant (g) and seed yield per feddan (kg).

2.1.3. Fixed oil production

Fixed oil percentage in the dry seeds was determined according to Moorthy *et al.* (2010), the fixed oil content per plant and feddan.

2.1.4. Active ingredients in Fenugreek seeds:

I. Trigonelline content: The alkaloids trigonelline was estimated in the seeds by the method of Rania (2020) on *Trigonella foenum-graecum*, L. plants then, the trigonelline content per plant was recorded.
II. Mucilage content: Mucilage percentage in seeds powdered dry matter was conducted according to the method of Anderson (1949). The mucilage content per plant was calculated by multiplying the mucilage percentage in the seed weight per plant.
III. Seed protein content ($g.g^{-1}$ DW) according to Naguib, (1969).

2.3. Chemical constituents:

1.1. The microelements (Zn + Mn and Fe) in the dried seeds of fenugreek were determined in the digested samples by atomic absorption by Chaman and Pratt (1961).
1.2. Carbohydrates percentage: Total carbohydrate percentage in fenugreek seeds was determined according to Dubios *et al*. (1956).

3. Results and Discussion

3.1. Effect of planting dates

Results of Table (1) show that there are significant differences in growth parameters according to different planting dates. 1st October treatment excelled in the average plant height (cm) 45.34 and 46.61 cm, the number of branches/plant 11.78 and 15.22, and the number of pods/plant 24.50 and 26.33 on all other transactions during the first and second seasons, respectively.

As for the effect of sowing dates on yield and production, it was a significant effect, especially sowing on 1st October, which gave the highest value of seed weight per plant and per plant (g) 25.40 and 26.47 g and seed yield per plant and feddan (kg) 711.10 and 741.14 kg during the first and second seasons, respectively, while the values decreased when planting on 1st September, which recorded the lowest values of seed weight per plant and per plant (g) 17.53 and 19.23 g and seed yield per plant and feddan (kg) 490.77 and 538.53 kg during the first and second seasons, respectively (Table 1).

Resume of the results in the same Table, there is a significant effect as a result of the difference in planting dates on fixed oil production, as 1st October agriculture outperformed the rest of the other dates in giving the highest value for fixed oil percentage 5.45% and 6.15% and oil yield per plant 1.48

g, 1.73 g and oil yield per feddan (kg) 41.33 kg and 48.53 kg during the first and second seasons, respectively.

Table 1: Effect of planting dates on growth parameters, yield and production, fixed oil production, active ingredients, and chemical constituents of *Trigonella foenum-graecum*, L. during the two seasons of 2020 and 2021.

	Growth parameters					
	Plant height (cm)		**Number of branches**		**Number of pods/plant**	
	Season1	**Season2**	**Season1**	**Season2**	**Season1**	**Season2**
1st September	32.64	34.05	9.89	12.78	15.67	18.70
1st October	45.34	46.61	11.78	15.22	24.50	26.33
1st November	42.49	43.95	11.22	14.44	21.20	23.54
LSD at 0.05	0.60	0.47	0.40	0.40	0.56	0.83
	Yield and production					
	Seed weight per plant (g)				**Seed yield per feddan (kg)**	
	Season1		**Season2**		**Season1**	**Season2**
1st September	17.53		19.23		490.77	538.53
1st October	25.40		26.47		711.10	741.14
1st November	23.69		24.16		663.17	676.49
LSD at 0.05	1.13		0.45		31.77	12.57
	Fixed oil production					
	Fixed oil percentage		**Oil yield per plant**		**Oil yield per feddan (kg)**	
	Season1	**Season2**	**Season1**	**Season2**	**Season1**	**Season2**
1st September	2.13	2.24	0.41	0.45	11.35	12.65
1st October	5.45	6.15	1.48	1.73	41.33	48.53
1st November	4.97	5.33	1.18	1.30	33.15	36.26
LSD at 0.05	0.22	0.35	0.06	0.11	1.79	3.21
	Active ingredients					
	Mucilage percentage		**Trigonelline content (100 mg/g d.w.)**		**Protein percentage**	
	Season1	**Season2**	**Season1**	**Season2**	**Season1**	**Season2**
1st September	13.40	16.18	0.257	0.258	11.89	13.45
1st October	21.60	24.66	0.461	0.462	17.44	18.34
1st November	20.01	23.00	0.449	0.442	16.10	16.69
LSD at 0.05	0.67	1.26	0.012	0.018	0.96	0.59
	Chemical constituents							
	Total carbohydrates (%)		**Fe mg/kg**		**Mn mg/kg**		**Zn mg/kg**	
	Season1	**Season2**	**Season1**	**Season2**	**Season1**	**Season2**	**Season1**	**Season2**
1st September	15.89	16.88	659.00	730.00	26.51	28.65	35.24	37.66
1st October	24.18	25.31	1098.50	1189.80	41.17	43.08	46.46	49.20
1st November	22.57	23.66	980.40	1068.20	34.47	36.33	44.38	46.90
LSD at 0.05	0.86	1.15	64.07	24.03	0.68	0.51	1.52	0.70

Perhaps the reason for an increase in plant height (cm), number of branches/plant, and number of pods/plant when planting on 1st October is due to the sufficient period for vegetative growth and the suitability of the environmental conditions surrounding the plant, which means exposure to an appropriate period of lighting that led to an increase in photosynthesis and the resulting substances about it and its reflection on the increase in yield and production and fixed oil production. The increase in seed weight per plant and per plant (g), seed yield per plant and feddan (kg) fixed oil percentage, oil yield per plant, and oil yield per feddan (kg) is also attributed to the availability of suitable temperature and light intensity of the process photosynthesis during the period of fruiting growth, which led to an increase in which was reflected in an increase in the result of the appropriate vegetative growth period and the length of the photoperiod, which was reflected in an increase in all the traits under study.

Regarding the response of the active ingredients, Table (1) showed that there is a significant effect due to the difference in planting dates if the 1st October treatment achieved the highest values in mucilage percentage 21.60% and 24.66% and trigonelline content (mg/100 g DW) 0.461 mg and 0.462 mg and the protein percentage was 17.44% and 18.34% compared to the late date on 1st November, which gave less in the active ingredients mentioned above, reaching 20.01%, 0.449 mg and 16.10% during the first season, respectively, and 23.00%, 0.442 mg, and 16.69% during the season second, respectively.

Chemical constituents the results in Table (1) indicate that the different sowing dates had a significant effect on total carbohydrates (%), Fe mg/kg, Mn mg/kg, and Zn mg/kg if sowing beat on 1st October was recorded at 24.18%, 1098.50, 41.17, 46.46 during the first season, and 25.31%, 1189.80, 43.08, and 49.20 during the second season, respectively. While the early planting was recorded on 1st September during the first season 15.89 %, 659.00, 26.51 while during the second season it recorded 35.24 16.88 %, 730.00, 28.65 and 37.66, respectively. While the results in the late cultivation on 1st November on the indicators for the above-mentioned traits were (22.57 and 23.66%), (980.40 and 1068.20), (34.47 and 36.33) and (44.38 and 46.90) during the first and second seasons, respectively.

The reason for the increase inactive ingredients and chemical constituents are also attributed to the superiority of cultivation on 1st October compared to the other dates 1st September and 1st November due to the appropriate length of the growth period, which led to an increase in the duration and rate of photosynthesis and the manufacture of carbohydrates and their transfer to seeds, and thus an increase in the active substances and nutrients which are mucilage percentage, trigonelline content (100 mg/g d.w.), protein percentage, total carbohydrates (%), F e mg/kg, Mn mg/kg and Zn mg/kg.

Similar results were recorded by Rania (2016) on *Cyamopsis tetragonoloba*, L. and Elham and Rania (2015) on *Hibiscus sabdariffa*, L.

3.2. Effect of different forms of microelements

The results of Table (2) show that the use of different forms of microelements led to a significant increase in the growth parameters of fenugreek plants, as spraying humic form exceeded, recording the highest values of plant height (cm), number of branches/plant and number of pods/plant44.92 cm, 11.78 and 23.79 during the first season, respectively. While the same parameters were recorded at 46.56 cm, 15.22, and 26.27 during the second season, respectively, outperforming EDTA form and control.

As for yield and production, different forms of microelements had a significant effect on increasing seed weight per plant and per plant (g) and seed yield per plant and feddan (kg), reaching the highest values (25.45 g and 26.17 g) and (712.55 kg, 732.88 kg) during the first and second season, respectively, when spraying humic form, while the lowest value was obtained in control plants (18.65 g and 20.29 g) and (522.27 kg and 568.17 kg) during the first and second season, respectively.

Regarding the effect of different forms of microelements on fixed oil production, it had a significant effect on fixed oil percentage, oil yield per plant (g), and oil yield per feddan (kg) during the two seasons.

It was found that the maximum values were recorded when spraying with humic form, which was fixed oil percentages of 5.47% and 6.04%, oil yield per plant (g) 1.46 g and 1.66 g, and oil yield per feddan (kg) 40.81 kg and 46.81 kg during the first and second season, respectively

On the other hand, Table (2) indicates the presence of a significant effect on inactive ingredients such as fowls; mucilage percentage, Trigonelline content (mg/100 g d.w.), and protein percentage by treating the plant with different forms of microelements, the percentage increased significantly with humic form spray, which outperformed all treatments, as it recorded 21.81 % and 0.47 mg, 17.36 % during the first season, respectively, while it recorded 25.00 %, 0.48 mg, 18.17% during the second season, respectively. In comparison with the control plants.

results in Table (2) illustrate a clear significant increase in chemical constituents with different forms of microelements, as the humic form outperformed the treatment without spraying, as it was recorded in the first season: total carbohydrates (%), Fe mg/kg, Mn mg/kg and Zn mg/kg 24.44 %, 1077.40 mg, 38.74 mg, and 46.38 mg, respectively, while recorded the same parameters 25.63 %, 1170.80 mg, 40.76 mg, and 48.84 mg during the second season, respectively.

The reason for the significant increase in the characteristics of vegetative growth, yield, active substances, and chemical components as a result of spraying Humic acid loaded with microelements is that Humic acid is one of the natural chelating compounds that have a major role in facilitating the nutrients of the plant, as it is best used as a spray on the leaves of the plant, as these natural chelates have a significant impact in increasing the extent of utilization of the elements associated with them, especially if they are added as paper nutrients, and these natural compounds have great energy to bind or chelate iron more effectively than the industrial chelated compounds EDTA form.

Table 2: Effect of different forms of microelements on growth parameters, yield and production, fixed oil production, active ingredients, and chemical constituents of *Trigonella foenum-graecum*, L. during the two seasons of 2020 and 2021.

	Growth parameters					
	Plant height (cm)		**Number of branches**		**Number of pods/plant**	
	Season1	**Season2**	**Season1**	**Season2**	**Season1**	**Season2**
Control	34.21	35.42	10.11	12.89	16.52	19.51
humic form	44.92	46.56	11.78	15.22	23.79	26.27
EDTA form	41.34	42.63	11.00	14.33	21.05	22.78
LSD at 0.05	0.485	0.437	0.342	0.342	0.484	0.666
	Yield and production					
	Seed weight per plant (g)			**Seed yield per feddan (kg)**		
	Season1	Season2		Season1	Season2	
Control	18.65	20.29		522.27	568.17	
humic form	25.45	26.17		712.55	732.88	
EDTA form	22.51	23.40		630.21	655.12	
LSD at 0.05	0.644	0.539		18.024	15.085	
	Fixed oil production					
	Fixed oil percentage		**Oil yield per plant**		**Oil yield per feddan (kg)**	
	Season1	**Season2**	**Season1**	**Season2**	**Season1**	**Season2**
Control	2.65	2.87	0.54	0.62	15.23	17.30
humic form	5.47	6.04	1.46	1.66	40.81	46.59
EDTA form	4.43	4.82	1.06	1.20	29.79	33.55
LSD at 0.05	0.243	0.203	0.054	0.073	1.514	2.049
	Active ingredients					
	Mucilage percentage		**Trigonelline content (mg/100 g d. W.)**		**Protein percentage**	
	Season1	**Season2**	**Season1**	**Season2**	**Season1**	**Season2**
Control	14.45	17.18	0.29	0.29	12.69	14.03
humic form	21.81	25.00	0.47	0.48	17.36	18.17
EDTA form	18.74	21.65	0.40	0.40	15.39	16.29
LSD at 0.05	0.637	1.043	0.016	0.016	0.678	0.531

	Chemical constituents							
	Total carbohydrates (%)		**Fe mg/kg**		**Mn mg/kg**		**Zn mg/kg**	
	Season1	**Season2**	**Season1**	**Season2**	**Season1**	**Season2**	**Season1**	**Season2**
Control	16.93	17.90	724.20	806.40	28.11	30.09	36.823	39.77
humic form	24.44	25.63	1077.40	1170.80	38.74	40.76	46.382	48.84
EDTA form	21.28	22.33	936.20	1010.80	35.30	37.21	42.866	45.16
LSD at 0.05	0.725	0.943	35.747	32.813	0.587	0.528	1.131	0.873

The humic form is distinguished from the EDTA form in that the chelated food element is surrounded and coated with natural amino acids, which prevents the chelated element from being removed by washing before it is absorbed by the plant, and when it enters the plant, there is an ease in its separation and entry into the cell to activate its procprocessesno acids enter the cell in the vital processes of protein formation, turning into peptides - polypeptide - protein, without the plant expending huge amounts of energy ATP and large quantities of glucose molecules, which reflects the effect of chelating compounds on increasing the protein content in the plant and pods and seeds with an increase in yield and improvement in the quality of the yield.

These results contracted with those informed by Rania and Wafaa (2017) on *Ocimum basilicum* plants, Ibrahim, *et al.* (2019) on black cumin, and Rania (2020) on *Trigonella foenum-graecum*, L. plants.

3.3. Effect of interaction between different forms of microelements and planting dates

Table, 3 shows that, a significant increase in plant height (cm) as a result of the interaction between planting dates and different forms of microelements. The best interaction was recorded when planting on 1st October with spraying with humic form 51.78 cm and 53.24 cm, followed by spraying with EDTA form 49.90 cm and 50.96 cm during the first and second season, respectively, while the lowest interaction treatment was recorded when planting on1st September with no spraying with microelements forms 29.28 cm and 30.18 cm respectively during the first and second season.

Also, observed in the same table that there were no significant differences in the number of branches per plant, which scored 13.33 and 17.00, and the number of pods per plant, which scored 29.91

and 32.38 during the first and second season, respectively, when planting on 1st October with humic form spray compared with control.

Table 3: Effect of interaction between planting dates and different forms of microelements on growth parameters, yield and production, fixed oil production, active ingredients, and chemical constituents of *Trigonella foenum-graecum*, L. during the two seasons of 2020 and 2021.

	Growth parameters					
	Plant height (cm)		**Number of branches**		**Number of pods/plant**	
	Season1	**Season2**	**Season1**	**Season2**	**Season1**	**Season2**
1st September	29.28	30.18	9.33	11.67	13.68	16.93
1st September + EDTA form	32.22	33.49	10.00	13.00	15.42	18.45
1st September + humic form	36.43	38.47	10.33	13.67	17.91	20.71
1st October	34.34	35.61	10.00	13.00	16.79	19.56
1st October + EDTA form	49.90	50.96	12.00	15.67	26.79	27.04
1st October + humic form	51.78	53.24	13.33	17.00	29.91	32.38
1st November	39.02	40.46	11.00	14.00	19.09	22.05
1stNovember + EDTA form	41.91	43.44	11.00	14.33	20.94	22.86
1st November + humic form	46.55	47.95	11.67	15.00	23.57	25.71
LSD at 0.05	0.90	0.77	0.62	0.62	0.88	1.25
	Yield and production					
	Seed weight per plant (g)		**Seed yield per feddan (kg)**			
	Season1	**Season2**	**Season1**	**Season2**		
1st September	14.56	17.39	407.65	486.99		
1st September + EDTA form	17.58	19.03	492.10	532.91		
1st September + humic form	20.45	21.28	572.55	595.69		
1st October	18.85	20.28	527.70	567.91		
1st October + EDTA form	26.00	27.16	728.02	760.60		
1st October + humic form	31.34	31.96	877.57	894.91		
1st November	22.55	23.20	631.47	649.61		
1st November + EDTA form	23.95	23.99	670.52	671.84		
1st November + humic form	24.55	25.29	687.52	708.03		
LSD at 0.05	1.44	0.88	40.44	24.64		

results in Table (3) indicate that there were significant differences when the interaction between planting dates and different forms of microelements led to an increase in yield and production where the highest values of seed weight per plant and per plant (g) and seed yield per plant and feddan (kg) were recorded 31.34 g and 877.57 kg during the first season, respectively, and recorded 31.96 g and 894.91 kg during the second season, respectively, followed by the interaction treatment of cultivation on 1st October + spraying with EDTA form, where the same traits were recorded in the first season 26.00 g and 728.02 kg, while recorded in the second season 27.16 g and 760.60 kg, respectively. While, the lowest value was recorded when planting on 1st September with no spraying with microelements forms for the same characters: seed weight per plant and per plant (g) 14.56 g and 17.39 g during the first and second seasons; respectively, seed yield per plant and feddan (kg) 407.65 kg and 486.99 kg during the first and second season, respectively.

Results are shown in Table (4) that were significant differences in yield and production observed through the interaction between planting dates and different forms of microelements on the following characters: fixed oil percentage, oil yield per plant (g), and oil yield per feddan (kg), where the maximum values were recorded at planting in 1st October with humic form 7.154 %, 2.243 g, and 62.819 kg during the first season, respectively, while, gave 8.253%, 2.642 g, and 73.983 kg during the second season, respectively, for the same characteristics of the previous plant.

While the lowest values of fixed oil percentage were 0.841 % and 0.942 %, oil yield per plant (g) was 0.132 g and 0.168 g, and oil yield per feddan (kg) 3.692 kg and 4.699 kg during the first and second seasons, respectively, compared the control treatment.

On the other hand, institute the effect of interaction between planting dates and different forms of microelements on active ingredients, which led to an insignificant effect between the treatments, while there was a significant effect between the 1st October + humic form and 1st October + EDTA form treatment compared to the control treatment and the rest of the treatments.

1st October + humic form treatment recorded the highest values for the properties of the active ingredients, which are mucilage percentage, Trigonelline content (mg/100g d.w.), and protein

percentage, which recorded 26.56%, 29.38 mg, and 0.574 mg during the first season, respectively, while it recorded 30.33%, 30.45 mg, and 0.573 mg during the second season, respectively compared to control plants, which gave the lowest values of active ingredients for fenugreek.

Moreover, the interaction between planting dates and different forms of microelements had a significant effect on Fe mg/kg and Zn mg/kg, while the effect on total carbohydrates (%) and Mn mg/kg had a significant effect.

The treatment on 1st October +humic form recorded the highest values of chemical constituents as total carbohydrates (%), Fe mg/kg, Mn mg/kg, and Zn mg/kg 29.38%, 1322.80 mg, 49.19 mg, and 52.62 mg during the first season, respectively. While the second season recorded 30.85%, 1455.70 mg, 51.12 mg, and 55.11 mg, respectively; compared to the control plants.

The progressive response of *Trigonella foenum-graecum*, L. plants to the interaction between planting dates and different forms of microelements was in bringing together with those assimilated by Ibrahim, *et al*. (2019) black cumin and Rania (2020) *Trigonella foenum-graecum*, L. plants.

Table 4: Effect of interaction between planting dates and different forms of microelements on fixed oil production, active ingredients, and chemical constituents of *Trigonella foenum-graecum*, L. during the two seasons of 2020 and 2021.

	Fixed oil production					
	Fixed oil percentage		**Oil yield per plant**		**Oil yield per feddan (kg)**	
	Season1	**Season2**	**Season1**	**Season2**	**Season1**	**Season2**
1st September	0.841	0.942	0.132	0.168	3.692	4.699
1st September + EDTA form	1.978	2.044	0.350	0.391	9.791	10.954
1st September + humic form	3.586	3.737	0.734	0.796	20.551	22.293
1st October	4.214	4.523	0.952	1.050	26.651	29.403
1st October + EDTA form	5.032	5.339	1.205	1.282	33.748	35.881
1st October + humic form	5.679	6.143	1.394	1.554	39.046	43.504
1st November	2.905	3.132	0.548	0.635	15.342	17.792
1st November + EDTA form	6.291	7.072	1.637	1.922	45.841	53.816
1st November + humic form	7.154	8.253	2.243	2.642	62.819	73.983
LSD at 0.05	0.404	0.449	0.099	0.153	2.774	4.292
	Active ingredients					
	Mucilage percentage		**Trigonelline content (mg/100 g d.w.)**		**Protein percentage**	
	Season1	**Season2**	**Season1**	**Season2**	**Season1**	**Season2**
	10.507	13.440	10.430	11.938	0.180	0.174
1st September	12.768	15.856	11.453	13.557	0.233	0.231
1st September + humic form	16.930	19.243	13.795	14.857	0.360	0.367
1st October	18.240	20.548	15.035	15.773	0.393	0.403
1st October + EDTA form	19.843	23.016	16.249	16.477	0.443	0.449
1st October + humic form	21.931	25.429	17.016	17.810	0.489	0.494
1st November	14.614	17.558	12.599	14.371	0.282	0.281
1st November + EDTA form	23.616	26.080	18.461	18.834	0.529	0.528
1st November + humic form	26.555	30.326	21.268	21.827	0.574	0.573
LSD at 0.05	1.118	1.929	1.348	0.948	0.029	0.025
	Chemical constituents							
	Total carbohydrates (%)		**Fe mg/kg**		**Mn mg/kg**		**Zn mg/kg**	
	Season1	**Season2**	**Season1**	**Season2**	**Season1**	**Season2**	**Season1**	**Season2**
1st September	13.05	14.12	478.50	577.30	22.44	25.51	30.26	33.40
1st September + EDTA form	15.36	16.50	634.20	692.20	26.44	27.86	35.26	37.09
1st September + humic form	19.27	20.03	864.20	920.40	30.67	32.57	40.19	42.49
1st October	20.58	21.34	920.20	988.30	32.68	34.33	42.34	44.97
1st October + EDTA form	22.47	23.65	975.70	1080.00	34.37	36.08	44.45	46.81
1st October + humic form	24.66	26.00	1045.30	1136.20	36.35	38.58	46.34	48.92
1st November	17.16	18.23	774.00	853.60	29.21	30.42	37.87	40.92
1st November + EDTA form	26.00	26.84	1198.90	1260.10	45.11	47.70	48.88	51.58
1st November + humic form	29.38	30.85	1322.80	1455.70	49.19	51.12	52.62	55.11
LSD at 0.05	1.33	1.75	81.03	52.04	1.06	0.90	2.19	1.41

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