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Evaluation of Growth, Yield and Active Ingredients in Fenugreek Plants under Different Potassium Fertilizer Rates and Kaolin Application

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Authors' contributions

This work was carried out in collaboration among all authors. Author NSAS designed the study and wrote the protocol. Author RHIH wrote the first draft of the manuscript. Authors RHIH, MAA and MAIA managed the analyses of the study. Author MAIA performed the statistical analysis of the study searches. Author MAA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

A split-plot experiment based on randomized complete block design (RCBD) with three replications was planned at Experimental Farm, Agriculture Faculty, Zagazig University, Egypt during the two consecutive seasons of 2018/2019 and 2019/2020. Aiming to study the effect of different potassium fertilization rate (0.0, 24 and 48 K_2O kg/feddan) and different kaolin concentrations (0.0, 15, 30 and 45 g/l) as well as their combination treatments on growth parameters, yield components, fixed oil, and active ingredient. Results indicated that growth parameters (plant height, branch number/ plant and dry weight/plant), yield components (number of pods/plant, seed yield/ plant and /feddan) and

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chemical constituents (total chlorophyll, total nitrogen, potassium, total carbohydrates, mucilage and trigonelline content) were influenced by experimental factors. Furthermore, the highest rate of potassium fertilization recorded significant increase in these above parameters compared to control. In the same trend, the highest values in this concern of *Trigonella feonum-graecum* was observed with 30 or 45 g/l of kaolin compared to control. Moreover, applied 48 kg K_2O /feddan was more efficient than 24 kg and control when combined with kaolin at 30 or 45 g /l, in most cases. Generally, this combination treatments seems promising in enhancing fenugreek growth and productivity under Sharkia Governorate conditions.

Keywords: Fenugreek; potassium; kaolin; growth; yield; chlorophyll; trigonelline.

1. INTRODUCTION

Fenugreek (*Trigonella foenum-graecum* L.) is member of Fabaceae(Leguminosae) family, However, regard old civilizations history, fenugreek has many medicinal uses. Romans and Greek were found to utilize it as cattle fodder, while, Egyptians utilize fenugreek seeds for embalming their prestigious majestic dead bodies [1]. Leaves and seeds of fenugreek are consumed for different purposes in different countries such as making food, medicinal uses, controlling insects in grain storages, roasted grain as coffee-substitute (in Africa), and perfume industries around the world. Fenugreek can be a very useful legume crop for incorporation into short-term rotation and for fixation of nitrogen in soil and its fertility, for hay and silage for livestock feed and etc [2].

Potassium (K) in enzyme activation, plays a role to aid substrate binding by lowering energy barriers in transition states and/or the ground rather than being the agents of causing catalysis [3]. Minerals such as potassium (K) may affect the growth and active ingredients synthesis in medicinal plants and are used by plants to build many processes. This mineral affects the function and levels of enzymes involved in the carbohydrates biosynthesis [4].

Kaolin (Kl) is a nonabrasive at white color fine-grained and contains aluminum silicate mineral [Al_4 $Si_4O_{10}(OH)_8$] that has been sized and purified so that Kl acts as an anti-transpirant, also, reducing drought stress on plants and easily disperses in water [5]. Kaolin spray was get going to decreasing leaf temperature by improving leaf reflectivity and to reduce rate of transpiration in many plant species grown at abnormal conditions [6]. Kaolin enhancing plant growth and yield as well as improve the efficient use of water in cape gooseberry plants [7].

The most important aim of this study is maximizing fenugreek plants growth, yield and active ingredients by using different potassium fertilization rates combined with different kaolin concentrations represented as foliar spray under Sharkia Governorate conditions.

2. MATERIALS AND METHODS

The present study was carried out at the Experimental Farm, Fac. Agric. Zagazig Univ., Egypt, during the two consecutive seasons of 2018/2019 and 2019/2020 Different potassium fertilization rate (0.0, 24 and 48 kg K_2O/fed.), different kaolin concentrations (0.0, 15, 30 and 45 g/l) and their combinations were used to evaluated plant growth, yield components and some chemical constituents of fenugreek (*Trigonella foenum-graecum*, L.) plants. These treatments were arranged in a split-plot in randomized complete blocks design with 3 replicates. Potassium fertilization rates were randomly arranged in the main plots and kaolin concentrations were distributed randomly in the sub plots. The physical and chemical properties of the experimental soil site as average of the two tested seasons are shown in Table 1, according to Chapman and Pratt [8].

Seeds of fenugreek plants were obtained from Medicinal and Aromatic Plants Dept., Hort. Res. Inst., Agric. Res. Center, Dokki, Giza, Egypt. Seeds were sown on 16th and 22th October during first and second season, respectively. The experimental unit contains 6 rows each of 3-meter length and 60 cm width and the distance between plants within the row was 25 cm, where the area of each plot was (3× 3.6 m)10.80 square meter. After complete germination (at 20 days after sowing) fenugreek plants were thinned to two plants per hill (56,000 plants / feddan). Furthermore, kaolin concentrations were added as foliar application. The first application began after 30 days after planting and repeated every two weeks until 90 days from sowing date. The untreated plants (control) was sprayed with tap water.

Table 1. Physical and chemical properties of experimental soil (average of the two seasons)

Physical analysis										Soil texture	
Clay (%)		Silt (%)	Fine sand (%)			Coarse sand (%)					
56.36		9.26	17.62			16.76				Clay	
Chemical analysis											
pH	E.C.m.mohs/cm	Organic matter (%)	Soluble cations (mq./L)			Soluble anions (mq./L)			Available (ppm)		
			Mg^{++}	Ca^{++}	Na^{+}	Cl^{-}	HCO_3^{-}	SO_4^{--}	N	P	K
7.82	0.98	0.58	3.1	2.3	4.3	4.5	1.7	3.5	18	20	71

All fenugreek plants received normal agricultural practices whenever they needed. All plants were fertilized with 200 kg/fed., of ammonium sulphate (20.5% N) and 200 kg/fed. of calcium super phosphate (15.5% P_2O_5). P fertilizer was added during soil preparation as a soil dressing application, while, N and K (as potassium sulphate contained 48% K_2O) fertilizers were divided into three equal portions and were added to the soil after 35, 55 and 75 days from sowing.

2.1 Data Recorded

Growth parameter: Plant height (cm) and number of branches /plant as well as total plant dry weight (g) were recorded at 80 days after sowing by taken 3 guarded plants at random from each experimental unit (9 plants were taken for each treatment).

Seed yield components: At harvesting stage number of pods / plant and seed yield were determined per plant then total seed yield (kg/ feddan) were calculated during both seasons.

Chemical constituents: A sample of dry seeds were randomly taken from each treatment for chemical analysis. Fixed oil percentage of fenugreek seeds was extracted by using petroleum ether in a Soxhlet system HT apparatus according to the methods of AOAC [9] and oil yield per plant was calculated. Total chlorophyll content (SPAD unit) was determined in fenugreek leaves by using a hand Spad-502 meter at 80 days after sowing [10]. Total nitrogen (%) was determined in dry seeds according to the methods described by Chapman and Pratt [8], in addition, potassium percentage in fenugreek seeds was determined according to the method described by Chapman and Pratt [8]. Also, total carbohydrate (%) and mucilage percentage were determined according to the method described by AOAC [9]. The trigonelline content (mg / 100 gm) in seeds was determined according to the equation; trigonelline alkaloid= absorbance of test at 268 nm/Absorbance of standard, by Gorham [11].

2.2 Statistical Analysis

The statistical layout of this experiment was split-plot experiment in completely randomized block design. Where, potassium fertilization rates were randomly distributed in the main plots, and kaolin concentrations were randomly arranged in sub-plots. Each treatment was included three replicates. Data were analyzed according to Gomez and Gomez [12]. The means were compared using computer program of Statistix version 9 [13].

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

3.1.1 Effect of main factors

Data presented in Table 2 demonstrate that, increasing rates of potassium fertilization as well as kaolin concentrations gradually increased plant height, number of branches/ plant and dry weight/ plant of fenugreek in both seasons. Moreover, 48 kg of K_2O recorded the highest values in this connection compared to control and the other rates under study. It is well known that potassium as chemical fertilization could enhance plant growth (plant height, number of branches as well as plant dry weight) due to the role of potassium as an activator of many enzymes including those responsible for producing proteins and starch by changing the shape of the enzyme molecule - exposing chemical sites that allow chemical reactions to occur. Moreover, potassium helps to maintain the optimum pH level (7-8), which is important for these reactions to occur. It is also vital for producing of adenosine triphosphate (ATP), which is necessary for photosynthesis [14] and [15]. These results are in accordance with those stated by Mostafa [16] on *Stevia rebaudiana* plants. However, the highest concentration of kaolin gave a significant increase regard fenugreek growth parameter compared to control in the two tested seasons. In addition, Faralli [17]

found that the kaolin foliar application concentrations improved eggplant growth (stem length, branch number and plant fresh weight) compared to control. Kaolin particle film increased relative water content of tomato leaves and irrigation water use efficiency which reflected in increasing plant growth [18].

3.1.2 Effect of combination treatments

Results under discussion in Table 3 reveal that, increasing rates of potassium fertilization under each kaolin concentration gradually increased fenugreek growth parameters (plant height, number of branches/ plant and dry weight/ plant)during the first and second seasons. Generally, the comparison of the combined effect between potassium rates and kaolin concentrations indicated that the best values of growth parameters of fenugreek plants were related to potassium fertilization at 48 kg K_2O/ feddan accompanied with kaolin at 45 g/l concentration which followed by 24 kg K_2O/ feddan in combination with 45 g kaolin /l in both seasons. Moreover, as mentioned above, both potassium fertilization rates and kaolin concentrations (each alone) increased growth parameters of fenugreek plant, in turn; they together might maximize their effects leading to taller, more branches and highest dry weight/ plant. However, [19] indicated that foliar treatments of wheat plants with kaolin or K_2SO_4 led to an increase in growth parameters (plant height, number of leaves/plant and dry weight).

Table 2. Effect of potassium fertilization rate and kaolin concentration on plant height (cm), number of branches/plant anddry weight/plant (g) of fenugreek plant (at 80 days after sowing) during 2018/2019 and 2019/2020 seasons

Treatments	Plant height (cm)		Number of branches/plants		Dry weight/plant (g)	
	2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020
Potassium fertilization rate (K_2O kg/feddan)						
0.0	61.60	66.58	7.06	6.83	20.10	20.94
24	64.86	68.47	7.92	8.42	21.74	22.50
48	64.80	71.50	9.06	9.31	22.56	23.36
LSD at 5%	1.96	2.06	0.58	0.43	0.77	0.79
Kaolin concentration (g/l)						
0.0	60.70	62.85	6.22	6.59	19.77	20.36
15	63.41	67.41	7.63	7.74	21.17	21.64
30	65.67	71.44	8.44	8.78	21.99	22.70
45	69.37	73.70	9.74	9.63	22.93	24.18
LSD at 5%	1.16	1.60	0.30	0.27	0.57	0.38

Table 3. Influence of combinations between potassium fertilization rate and kaolin concentration on plant height (cm), number of branches/plant and dry weight/plant (g) of fenugreek plant (at 80 days after sowing) during 2018/2019 and 2019/2020 seasons

Treatments		Plant height (cm)		Number of branches/plants		Dry weight/plant (g)	
Potassium (K_2O kg/fed.)	Kaolin (g/l)	2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020
0.0	0.0	59.67	57.78	5.55	5.22	18.67	19.48
	15	60.89	66.44	7.22	6.78	19.89	20.44
	30	63.22	70.89	7.56	7.56	20.95	21.57
	45	63.00	71.22	7.89	7.78	20.90	21.68
24	0.0	60.33	63.55	6.56	7.11	20.18	20.72
	15	64.22	66.22	7.56	8.00	21.40	21.80
	30	63.67	70.00	8.11	8.66	22.15	22.86
	45	71.22	74.11	9.44	9.89	23.22	24.63
48	0.0	62.11	67.22	6.56	7.44	20.44	20.89
	15	65.11	69.56	8.11	8.44	22.22	22.67
	30	70.11	73.44	9.67	10.11	22.89	23.67
	45	73.89	75.78	11.89	11.22	24.66	26.22
LSD at 5%		2.60	3.12	0.72	0.59	1.14	0.93

3.2 Yield Components and Fixed oil Production

3.2.1 Effect of main factors

As shown in Tables 4 and 5 that, the two potassium fertilization rates under study significantly increased fenugreek yield components (number of pods/ plant, seed yield/plant and seed yield / feddan) and fixed oil production (fixed oil percentage and fixed oil yield/ plant) compared to control in both seasons. Fenugreek yield components as well as fixed oil yield per plant significantly increased with kaolin concentration compared to control. Furthermore, kaolin concentration at 45 g/l recorded higher increases in these parameters compared with the other treatments under study during the two seasons.

The same trend was noticed by Hassan et al. [20] on periwinkle plants. They found that potassium fertilizer at 50 kg K_2O/feddan significantly improved all growth characters and dry weight of *Catharanthus roseus* compared to control and the lowest level under study.

3.2.2 Effect of combination treatments

The data illustrated in Tables 6 and 7show that,the combination between 48 kg K_2O/ feddan and kaolin at 30 or 45 g/l produced the maximum seed yield per plant and feddan with significant difference between the other ones under study during both seasons. Furthermore, increasing concentration of kaolin under each potassium fertilization rate gradually increased fenugreek yield component number of pods/ plant, seed yield/plant and seed yield/feddan) and fixed oil

Table 4. Influence of potassium fertilization rate and kaolin concentration on number of pods/plant and seed yield/plant (g) and /feddan (kg)of fenugreek plant during 2018/2019 and 2019/2020 seasons

Treatments	Number of pods/plant		Seed yield/plant (g)		Seed yield/feddan (kg)	
	2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020
	Potassium fertilization rate (K_2O kg/feddan)					
0.0	16.92	18.25	6.71	6.78	375.99	390.74
24	25.69	27.31	8.28	8.44	463.68	472.87
48	27.64	28.94	8.71	8.98	487.48	502.88
LSD at 5%	**0.61**	**0.83**	**0.63**	**0.33**	**35.00**	**18.24**
	Kaolin concentration (g/l)					
0.0	20.55	21.33	6.95	6.75	388.95	378.12
15	22.81	24.30	7.72	7.97	432.51	446.07
30	24.22	25.59	8.07	8.55	451.80	478.92
45	26.07	28.11	8.86	9.27	496.28	518.87
LSD at 5%	**0.56**	**0.42**	**0.38**	**0.28**	**21.06**	**15.82**

Table 5. Influence of potassium fertilization rate and kaolin concentration on fixed oil percentage in seeds and seed oil yield/plant (ml) of fenugreek plant during 2018/2019 and 2019/2020 seasons

Treatments	Fixed oil (%)		Fixed oil yield /plant (ml)	
	2018/2019	2019/2020	2018/2019	2019/2020
	Potassium fertilization rate (K_2O kg/feddan)			
0.0	10.60	10.67	0.712	0.746
24	11.74	11.94	0.976	1.013
48	12.24	12.68	1.071	1.148
LSD at 5%	**0.14**	**0.20**	**0.077**	**0.038**
	Kaolin concentration (g/l)			
0.0	10.92	11.09	0.762	0.751
15	11.39	11.58	0.885	0.927
30	11.59	11.90	0.940	1.025
45	12.21	12.50	1.091	1.171
LSD at 5%	**0.07**	**0.24**	**0.043**	**0.036**

production (fixed oil percentage and fixed oil yield/ plant) during the two consecutive seasons. According to these results and from economic point of view it is better to fertilize fenugreek plants by 48 kg K_2O/ feddanand spray them with kaolin at 30 g/l to gain the maximum seed and fixed oil yield of fenugreek plants. Regarding potassium fertilization effect on yield and oil components, Helaly and Hegazy [21] reported that potassium fertilization level at 50 kg K_2O/fed. significantly increased herb dry yield/fed., volatile oil production (volatile oil percentage and volatile oil yield/plant) of lavender plant compared to control. While, regarding kaolin effect, Ibrahim and Selim [22] found thatmean fruit weight, total fruit yield/fed., marketable yield/fed. of squash plant significantly increased with increasing kaolin levels.

3.3 Chemical Constituents and Some Active Ingredients

3.3.1 Effect of main factors

Potassium fertilization rates (24 and 48 kg K_2O/fed.) significantly increased fenugreek total chlorophyll content (SPAD), total nitrogen (%), potassium (%), total carbohydrates (%), mucilage (%) and trigonelline content (mg/100 g as dry weight) compared to control in the two tested seasons(Tables 8 and 9). Generally, increasing K rates gradually increased the

Table 6. Influence of combinations between potassium fertilization rate and kaolin concentration on number of pods/plant and seed yield/plant (g) and /feddan (kg) of fenugreek plant during 2018/2019 and 2019/2020 seasons

Treatments		Number of pods/plant		Seed yield/plant (g)		Seed yield/feddan (kg)	
Potassium (K_2O kg/fed.)	Kaolin (g/l)	2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020
0.0	0.0	14.89	15.44	5.78	5.78	323.49	323.49
	15	16.56	18.11	6.25	7.01	350.19	392.37
	30	17.11	18.56	7.25	7.39	406.19	414.03
	45	19.11	20.89	7.57	7.73	424.11	433.07
24	0.0	23.00	24.22	7.43	7.26	416.08	406.56
	15	25.11	26.56	8.33	8.35	466.29	467.41
	30	26.78	27.78	8.35	8.73	467.79	489.07
	45	27.89	30.67	9.01	9.44	504.56	528.45
48	0.0	23.78	24.34	7.63	7.22	427.28	404.32
	15	26.78	28.22	8.59	8.54	481.04	478.43
	30	28.78	30.44	8.60	9.53	481.41	533.68
	45	30.22	32.78	10.00	10.63	560.19	595.09
LSD at 5%		1.04	1.03	0.83	0.53	46.69	29.68

Table 7. Influence of combinations between potassium fertilization rate and kaolin concentration on fixed oil percentage in seeds and seed oil yield/plant (ml) of fenugreek plant during 2018/2019 and 2019/2020 seasons

Treatments		Fixed oil (%)		Fixed oil yield /plant (ml)	
Potassium (K_2O kg/fed.)	Kaolin (g/l)	2018/2019	2019/2020	2018/2019	2019/2020
0.0	0.0	10.41	10.49	0.601	0.606
	15	10.64	10.60	0.665	0.743
	30	10.62	10.71	0.771	0.792
	45	10.72	10.88	0.812	0.842
24	0.0	11.11	11.26	0.825	0.818
	15	11.32	11.50	0.943	0.960
	30	11.71	12.03	0.978	1.051
	45	12.83	12.96	1.156	1.223
48	0.0	11.24	11.50	0.858	0.830
	15	12.20	12.64	1.048	1.080
	30	12.45	12.95	1.070	1.234
	45	13.08	13.65	1.307	1.450
LSD at 5 %		0.017	0.40	0.099	0.066

above-mentioned parameters in both seasons. Similarly, Ibrahim and Selim [21] demonstrated that total chlorophyll content and percentages of total carbohydrates as well as K in lavender leaves were increased by increasing potassium fertilization level. The best treatment in chemical constituents and active ingredients of fenugreek leaves and seeds was that 45 g/l kaolin compared to the other concentrations under study during both seasons. In the same time, increasing kaolin concentrations gradually increased the above-mentioned fenugreek parameters in the first and second seasons (Tables 8 and 9). Foliar spray with kaolin could lead to a decrease in the transpiration rate, which in turn maintained higher content of water in the tissues of the plant and hence might improve the plant metabolism, the physiological processes, photosynthetic rate, carbohydrate metabolism and, many other important factors that directly affect plant [23,24]. Moreover, [19] on wheat plants, suggested that kaolin as foliar spray increased photosynthetic pigments and carbohydrate constituents compared to control. In contrast, Noor et al. [25] on *Zinnia elegans* plants, noticed that increasing kaolin concentration decreased chlorophylls contents.

3.3.2 Effect of combination treatments

It is quite clear from the data in Tables 10 and 11 that, the combination between potassium fertilization and kaolin application increased total chlorophyll content in fenugreek leaves (SPAD unit) as well as total nitrogen, potassium and total carbohydrates percentages in fenugreek seeds as compared the control. Increased the combined potassium rate from 0.0, 24 to 48 kg K_2O/feddan resulted in significant increases in

Table 8. Influence of potassium fertilization rate and kaolin concentration on total chlorophyll content (SPAD) in leaves as well as total nitrogen (%) and potassium (%) in seeds of fenugreek plant during 2018/2019 and 2019/2020 seasons

Treatments	Total chlorophyll content (SPAD)		Total nitrogen (%)		Potassium (%)	
	2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020
	Potassium fertilization rate (K_2O kg/feddan)					
0.0	41.17	41.29	3.46	3.47	2.80	2.80
24	43.71	44.92	3.53	3.68	3.03	3.11
48	46.38	46.04	3.65	3.75	3.16	3.20
LSD at 5 %	0.31	0.80	0.03	0.07	0.06	0.01
	Kaolin concentration (g/l)					
0.0	41.72	41.83	3.36	3.44	2.82	2.82
15	43.11	43.22	3.51	3.62	2.93	3.00
30	44.33	44.67	3.61	3.71	3.10	3.14
45	45.83	46.61	3.70	3.76	3.14	3.19
LSD at 5 %	0.36	0.61	0.04	0.04	0.06	0.02

Table 9. Influence of potassium fertilization rate and kaolin concentration on total carbohydrates (%), mucilage (%) and trigonelline content (mg/100 g as dry weight) in seeds of fenugreek plant during 2018/2019 and 2019/2020 seasons

Treatments	Total carbohydrates (%)		Mucilage (%)		Trigonelline content (mg/100 g d. w.)	
	2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020
	Potassium fertilization rate (K_2O kg/feddan)					
0.0	37.04	37.78	29.84	28.87	0.378	0.384
24	38.97	39.68	30.51	30.85	0.406	0.407
48	39.11	39.71	31.27	31.75	0.420	0.453
LSD at 5 %	0.51	0.50	0.38	0.18	0.006	0.057
	Kaolin concentration (g/l)					
0.0	37.49	37.99	29.49	29.02	0.373	0.413
15	38.26	38.82	30.20	30.17	0.391	0.387
30	38.76	39.29	32.23	31.35	0.423	0.435
45	38.99	40.13	31.22	31.41	0.417	0.423
LSD at 5 %	0.50	0.40	0.39	0.43	0.007	N.S.

Table 10. Influence of combinations between potassium fertilization rate and kaolin concentration on total chlorophyll content (SPAD) in leaves as well as total nitrogen (%) and potassium (%) in seeds of fenugreek plant (at 80 days after sowing) during 2018/2019 and 2019/2020 seasons

Treatments		Total chlorophyll content (SPAD)		Total nitrogen (%)		Potassium (%)	
Potassium (K_2O kg/fed.)	Kaolin (g/l)	2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020
0.0	0.0	40.50	39.67	3.28	3.31	2.65	2.62
	15	40.67	41.17	3.48	3.49	2.80	2.74
	30	41.67	41.83	3.48	3.49	2.87	2.91
	45	41.83	42.50	3.59	3.56	2.88	2.94
24	0.0	42.67	43.00	3.31	3.45	2.79	2.77
	15	43.17	44.00	3.48	3.67	2.92	3.16
	30	43.67	45.00	3.60	3.77	3.19	3.22
	45	45.33	47.67	3.72	3.83	3.23	3.30
48	0.0	42.00	42.83	3.49	3.55	3.02	3.06
	15	45.50	44.50	3.57	3.71	3.09	3.11
	30	47.67	47.17	3.76	3.85	3.23	3.29
	45	50.33	49.67	3.78	3.90	3.30	3.34
LSD at 5 %		0.62	1.20	0.07	0.09	0.10	0.04

Table 11. Influence of combinations between potassium fertilization rate and kaolin concentration on total carbohydrates (%), mucilage (%) and trigonelline content (mg/100 g as dry weight) in seeds of fenugreek plant during 2018/2019 and 2019/2020 seasons

Treatments		Total carbohydrates (%)		Mucilage (%)		Trigonelline content (mg/100 g d. w.)	
Potassium (K_2O kg/fed.)	Kaolin (g/l)	2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020
0.0	0.0	36.70	36.97	28.85	28.02	0.361	0.370
	15	37.00	37.33	29.84	28.38	0.374	0.377
	30	37.00	38.17	30.24	29.32	0.380	0.385
	45	34.47	38.67	30.40	29.76	0.397	0.405
24	0.0	37.80	38.17	29.62	28.70	0.373	0.378
	15	38.97	39.43	30.16	31.00	0.391	0.387
	30	39.47	40.30	30.70	31.52	0.438	0.442
	45	39.63	40.83	31.54	32.17	0.421	0.421
48	0.0	37.97	38.83	30.00	30.34	0.384	0.490
	15	38.80	39.70	30.60	31.15	0.408	0.394
	30	39.80	39.40	32.75	33.21	0.453	0.479
	45	39.87	40.90	31.72	32.29	0.434	0.443
LSD at 5 %		0.91	0.77	0.70	0.67	0.012	0.095

abovementioned parameters under different concentrations of kaolin. In addition, the highest values in active ingredients of fenugreek seeds (mucilage percentage and trigonelline content) were observed under the effect of combination treatments between K fertilizer rate of (48 kg K_2O/feddan) and kaolin at 30 g/l in first and second season, with significant increase compared to control. MacRobbie [26] reported that K^+ accumulating in guard cells in large quantity mainly in vacuole leads to stomata opening. K+ is necessary to generate sufficient turgor for stomatal opening. In addition, kaolin can be used as a foliar anti-transpirant in a form of water emulsion; kaolin forms a thin film on leaves, which reduces the water escape from plant by decreasing transpiration losses, decreasing stomatal conductance and improving plant water status. It is considered as a safe substance for the environment [27]. Potassium is an essential element and its ability controls several physiological as well as biochemical processes in all plants, also, kaolin can ameliorate plant physiology and consequently lead to higher yield and active ingredients production [19].

4. CONCLUSION

From above obtained results, it is preferable to spray *Trigonella foenum-graecum* L. plants with kaolin at 45 g/l five times a season with high potassium fertilization level (48 kg K_2O/feddan) to enhance the fenugreek growth, seed and fixed oil yield per feddan, mucilage percentage, trigonelline content as well as chemical constituents of fenugreek plant under Sharkia Governorate conditions.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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