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INFLUENCE OF PHOSPHORUS FERTILIZER AND SPIRULINA EXTRACT ON GROWTH, YIELD AND ACTIVE INGREDIENTS OF TRIGONELLA FOENUM-GRAECUM PLANT

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ABSTRACT: A field experiment was established at the Experimental Farm, Fac. of Environ. Agric. Sci., Arish Univ. during the two seasons of 2021/2022 and 2022/2023 to assess the influence of various phosphorus levels (0.0, 30 and 45 kg P_2O_5/feddan), spirulina extract rates (0.0, 1.5, 3.0 and 4.5 ml/l) as well as their combinations on the productivity of fenugreek plants. The experiment layout was a split-plot design in three replicates. The obtained results were referred to that fertilized fenugreek plants with 45 kg P_2O_5 per feddan gave the tallest plants, more branches per plant and heaviest herb weight compared to the other levels under study. Furthermore, the highest seed yield per plant, seed yield per feddan, total chlorophyll content, trigonelline content, mucilage percentage and total protein content were achieved with high levels of phosphorus compared to control. In general, increasing spirulina extract rates gradually increased growth traits and yield components. It could be recommended with utilizing phosphorus fertilizer at 45 kg P_2O_5/feddan combined with 4.5 ml/l of spirulina extract to obtain the highest values of seed yield and active ingredients of Trigonella foenum-graecum plants.

Key words: Fenugreek, phosphorus, spirulina, growth, yield, chlorophyll, trigonelline

INTRODUCTION

Trigonella foenumgraecum L., the fenugreek plant, is an annual herb belonging to the Leguminosae family. It originated in the Mediterranean region and is grown extensively throughout several nations (**Shalaby and Zaki, 1999**). The plant's leaves, stems, twigs and seeds are utilized for both culinary and therapeutic purposes. The fenugreek plant's seeds and leaves are both very nutritious and medicinally valuable. Vitamins A and C, iron, calcium, lipids, mucilaginous fiber, proteins, carbohydrates, and other minerals are abundant in the seeds (**Billaud and Adrian, 2001** and **Babaa, 2007**). Consuming fenugreek can help with digestion, liver and spleen stimulation, erythrocyte insulin receptor stimulation, pancreatic function, blood purification, appetite enhancement, and constipation prevention (**Randhir *et al.*, 2004**). It is well known that fenugreek seeds have anti-diabetic, astringent, carminative, diuretic, and demulcent qualities. Trigonelline, diosgnin, sapogenins, nicotinic acid and choline are responsible for these qualities; being a legume, its roots are equipped to fix nitrogen for plants (**Singh *et al.*, 2019**).

The most crucial component of macronutrients is phosphorus (P). It plays a variety of functions in plant growth, development, and metabolism and is essential for growing tissues. Because it regulates several plant metabolic functions, it is frequently referred to as the "key to life." A plant develops more rapidly and becomes more resilient when it gets enough P. Plants stop and slow down when they lack P, although above-ground organ growth accelerates P. Because it promotes biological processes including nodulation, nitrogen fixation, and nutrient uptake in the soil and rhizosphere environment and lessens the

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detrimental effects of drought on plant physiological parameters, P is also essential for enhancing legume yield (**Kacar and Katkat, 2007; Yadav *et al*., 2014; Singh and Singh, 2016; Gezgin, 2018**). Furthermore, **Laftah and Alabdulla (2022)** reported that applied safflower plants by 120 kg P h^{-1} gave of the highest height, the stem diameter and the total number of main leaves and branches.

One effective way to lessen dependency on chemical fertilizers is to use natural materials as organic-fertilizer. Spirulina is a blue-green, photosynthetic microalga that is abundant in protein and has nutritional value (**Prisa, 2019**). The green-blue cyanobacteria *Spirulina platensis* is a microalgae that can enhance soil fertility, crop development and yield (**Yanni *et al*., 2020**), and environmental quality in sustainable agriculture (**Godlewska *et al*., 2019**). Beyond these uses, its usage as a bio-stimulant for plant growth and bio-fertilizer in agriculture has drawn more interest recently (**Anitha *et al*., 2016; El Sherif *et al*., 2020**). By strengthening the body's defenses against biotic and abiotic stressors, compounds made from spirulina can increase plant growth (**Arahou *et al*., 2023**).

Thus, the goal of the current study is to assess how phosphorus fertilizer and spirulina extract might enhance the development and yield of fenugreek plants.

MATERIALS AND METHODS

In this study, the effects of various phosphorus fertilizer levels (0.0, 30 and 45 kg P_2O_5/feddan), rates of *Spirulina platensis* algae extract (0.0, 1.5, 3.0 and 4.5 ml/l), and their combinations were examined in relation to the growth, yield and chemical constituents of the fenugreek plant (*Trigonella foenum-graecum* L). This experiment was done at the Experimental Farm, Fac. of Environ. Agric. Sci., Arish Univ. during the two seasons of 2021/2022 and 2022/2023.

Experimental Design

A split-plot design in three replications was utilized for the experiment. The main plot was phosphorus fertilizer levels (0.0, 30 and 45 kg P_2O_5/feddan) as soil application, while, *Spirulina platensis* algae extract (0.0, 1.5, 3.0 and 4.5 ml/l) rates as foliar application, were allocated to the sub-plots application three times at one month intervals.

Experimen Treatments

Phosphorus fertilizer source was calcium super phosphate (15 % P_2O_5) added to the soil at various levels under study during soil preparation. Nitrogen and potassium fertilizers were added to the soil as drench through three times after 30, 45 and 60 days from sowing date. The nitrogen fertilizer level was (50 kg N/ feddan) as ammonium sulfate (20.5 % N), whereas, potassium fertilizer level was (8 % K_2O/feddan) as potassium sulfate. The Agriculture Microbiology Department, Faculty of Agriculture, Zagazig University, Egypt, provided 52% of the *Spirulina platensis* algae extract. After one month from sowing date and two and three monthes, *Spirulina platensis* treatments were applied topically every month. Using Super Film as a spreading agent, the solution at two letters was administered to each experimental unit at a rate of one milliliter per liter. The untreated (control) fenugreek plants were sprayed with tap water that contained a spreading agent. All other cultural traditions were followed as normal.

Cultivation and Soil Analysis

After being irrigated in the both seasons, fenugreek seeds-which were acquired from the Research Centre of Medicinal and Aromatic Plants in Dokky, Giza-were sown on November 22, 2021 and November 18, 2022, respectively. Then, with a 25-cm space between hills, the seedlings were thinned to be two plants per hill (about 56000 plants/ feddan). The experimental area was 10.80 m^2 (3.00 × 3.60 m) with six rows, each three meters long and 60 centimeters apart of the ridge. As indicated in Table 1 by **Chapman and Pratt (1978)**, a randomized soil sample was collected prior to planting in order to conduct a traditional physical and chemical analysis.

Sampling and Data Collection

Growth traits

Fenugreek plant samples were taken at random in April 17th and 23rd in 1st and 2nd seasons, respectively, the following data were collected: Plant height (cm), number of branches per plant and total dry weight of plant (g).

Table 1. Experimental soil physical and chemical properties

Physical analysis			Soil texture
Clay (%)	Silt (%)	Sand (%)	Sandy
8.07	11.56	84.17	

Chemical analysis												
pH	E.C. (dsm^{-1})	Soluble cations (m.mol/l)					Soluble anions (m.mol/l)			Available (ppm)		
		Ca^{++}	Mg^{++}	Na^{+}	Zn^{++}	Mo^{++}	Cl^{-}	HCO_3^{-}	SO_4^{--}	N	P	K
7.79	1.62	2.05	0.99	0.72	1.15	1.38	3.07	1.20	0.78	118	72	47

Yield components: Number of pods per plant, seed yield per plant (g) and seed yield per feddan (kg) were recorded at harvest stage (26^{th} and 29^{th} of April during 1^{st} and 2^{nd} seasons, respectively).

Chemical analysis and active ingredients

The SPAD-502 meter was used to measure the degree of greenness (SPAD unit) of fresh fenugreek leaves (**Markwell *et al*., 1995**). Using the **Gorham (1986)** approach, the trigonelline percentage in the seeds was calculated. **Amer (1978)** method was used to determine the proportion of mucilage in seeds. Total nitrogen, total phosphorus and potassium percentages in the dried seeds of fenugreek were determined according to **Chapman and Pratt (1978)**. Total protein % in fenugreek seeds was determined by multiplying total nitrogen percentage by factor 6.25 to obtain the total protein percentage as reported by **Mariotti *et al*. (2008)**. The **Dubois *et al.* (1956)** method was used to calculate the total carbohydrate percentage in fenugreek seeds. Fixed oil % in the dried seeds was determined according to the method of **A.O.A.C. (1980)**.

Statistical Analysis

Data of the present study were statically analyzed and the differences between the means of the treatments were considered significant when they were more than the least significant differences (L.S.D) at the 5% by utilizing computer program of Statistix version 9 (**Analytical Software, 2008**).

RESULTS AND DISCUSSION

Growth Traits

Data recorded in Table 2 reveal that fenugreek plant height (cm) and branches number per plant and plant dry weight (g) were affected significantly by soil application of phosphorus fertilizer. In addition, the superior values in fenugreek growth traits were attained by 45 kg P_2O_5/feddan compared to the control and the lowest level under study. Each of plant height and number of branches and dry weight of plant in *Trigonella foenum-graecum* plant were gradually increased by increasing phosphorus levels from 30 to 45 kg P_2O_5/ feddan. Different types of phosphate fertilizers are given to the soil to address the P deficiency, primarily in the case of legumes, which have a higher capacity for phosphorus utilization than other crops (**Gentili *et al.*, 2006**; **Rotaru and Sinclair, 2009**). Likewise, **Abd-Elghany *et al.* (2017)** pointed out that application of phosphorus at 48 kg P_2O_5/feddan caused significant increase in all growth parameters of fenugreek over the other levels under study (0.0 and 32 P_2O_5 kg/ feddan). Also, **Talaviya and Patel (2025)** indicated that application of 100% of phosphorus fertilizer (40 kg P_2O_5 /ha) had significant effect on number of branches per fenugreek plant.

As shown in Tables 2 treating fenugreek plants with *Spirulina platensis* extract at any rate (1.5, 3.0 or 4.5 ml/l) significantly improved all recorded plant growth traits (plant height, branches number/plant, total plant weight) compared to control. In addition, the values of these yield components were positively correlated with the extract rate of *Spirulina platensis*. This result was

demonstrated during the two seasons. This impact may result from *Spirulina platensis*'s enhanced influence on anabolis, a metabolic mechanism that promotes higher vegetative development (total plant dry weight). In this concern, *Spirulina platensis* (5%) had a significant plant height and number of leaves among *Eruca sativa*, according to **Hassan *et al.* (2017)**. The number of shoots per explant of *Lavandula officinalis in-vitro* plantlets was also found to increase with 40 ml/l of *Spirulina platensis* aqueous extract (**El Sherif *et al.*, 2020**). Comparing the plant height, number of leaves, and seedling growth of *Triticum aestivum* to other treatments and the control, the optimal concentration of *Spirulina platensis* liquid extract was 2% (**Hamouda *et al.*, 2022**).

The obtained data in Table 2 show that significant differences in fenugreek vegetative growth traits (fenugreek height, branches number and total plant weight) among the combination treatments were noticed. The best combination treatment for increasing fenugreek growth traits were obtained by 45 kg P_2O_5 per feddan combined with *Spirulina* foliar spray at 4.5 ml/l followed by 45 kg P_2O_5 per feddan combined with *Spirulina* foliar spray at 3.0 ml/l in both seasons in comparison with the other combinations under study. In general, as mentioned above, both phosphorus fertilizer levels and spirulina extract rates (each alone) improved growth parameters of fenugreek plant, in turn; they together might maximize their influences leading to obtain taller plants, more branches and heaviest dry weight. However, **Abd-Elghany *et al.* (2017)** pointed out that application of phosphorus at 48 kg P_2O_5/feddan caused significant increase in all growth parameters of fenugreek. Also, **Al Dayel and El Sherif (2022)** reported that *Spirulina platensis* aqueous extract (SAE) boosted the *Curcuma longa* plant height and leaves dry weight per plant, with 2 g/l SAE having the most influence.

Table 2. Influence of phosphorus fertilizer level, spirulina extract rate and their combinations on plant growth traits of fenugreek plants

Treatments		Plant height (cm)		Number of branches / plant		Total dry weight of plant (g)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
Phosphorus fertilizer level (P_2O_5 kg/feddan)							
Control		50.47	54.15	7.84	7.69	22.53	22.36
30		55.41	59.40	8.47	9.09	23.62	24.82
45		59.92	63.37	9.73	10.64	25.53	26.53
LSD 5%		**1.96**	**2.06**	**0.64**	**0.41**	**0.77**	**0.79**
Spirulina extract rate (ml/l)							
Control		51.18	52.97	6.89	7.48	22.19	22.72
1.5		53.88	57.53	8.26	8.67	23.60	23.99
3.0		56.14	61.57	9.11	9.78	24.42	25.06
4.5		59.85	63.83	10.44	10.63	25.36	26.53
LSD 5%		**1.16**	**1.59**	**0.40**	**0.29**	**0.57**	**0.38**
Combination between phosphorus level and spirulina extract rate							
Control	**Control**	48.44	45.35	6.22	5.89	21.10	21.05
	1.5	49.66	54.01	7.89	7.55	22.32	22.01
	3.0	51.99	58.46	8.23	8.56	23.38	23.14
	4.5	51.77	58.79	9.00	8.78	23.33	23.25
30	**Control**	50.88	54.48	7.22	7.78	22.06	23.04
	1.5	54.77	57.15	8.11	8.67	23.28	24.12
	3.0	54.22	60.93	8.78	9.33	24.03	25.18
	4.5	61.77	65.04	9.77	10.56	25.10	26.95
45	**Control**	54.22	59.09	7.23	8.77	23.41	24.06
	1.5	57.22	61.43	8.78	9.77	25.19	25.84
	3.0	62.22	65.31	10.34	11.44	25.86	26.84
	4.5	66.00	67.65	12.56	12.55	27.63	29.39
LSD 5%		**2.60**	**3.12**	**0.86**	**0.60**	**1.14**	**0.96**

Yield Components

During the two tested seasons, phosphorus application at a rate of 45 kg P_2O_5 per feddan produced the greatest increase in the number of pods per plant, seed yield per plant, and per feddan of fenugreek when compared to the other phosphorus levels under investigation (Table 3). Meanwhile, as phosphorus rates increased, the aforementioned characteristics gradually increased as well. A few specific factors that have been linked to phosphorus include root development, increased stack and stem strength, improved flower formation and seed production, more uniform and earlier crop maturity, increased nitrogen fixing capacity of legumes, improved crop quality, and resistance to plant disease. Phosphorus is necessary for the general health and vigorousness of all plants (**Abadi *et al.*, 2015**). **Maaruf *et al.* (2021)** revealed that the 20 kg P_2O_5 /ha application gave highest values of pods number /plant and weight of seed/chickpea plant. Likewise, pods number per plant and seed yield affected by moderate level of phosphorus for high yield and product quality of *Cyamopsis tetragonoloba* plants (**Toghrekan *et al.*, 2023**).

Table 4 suggests that, in 2021/2022 and 2022/2023 seasons; utilizing *Spirulina platensis* extract significantly raised the *Trigonella foenum-graecum* pods number per plant, seed yield per plant and per feddan as compared to the control. Yield components of fenugreek increased as Spirulina platensis extract was used at 3.0 and 4.5 ml/l, respectively. Liquid organic fertilizers, such as spirulina extract, offer vital plant nutrients that will enhance soil fertility by increasing nutrient availability and facilitating effective plant uptake, which promotes crop development and productivity (**Pangaribuan *et al.*, 2017**). Furthermore, **Kumar and Mehta (2023)** reported that *Spirulina platensis* applied topically and *Spirulina*-coated seeds demonstrated higher fenugreek yield components than the control.

Table 3. Influence of phosphorus fertilizer level, spirulina extract rate and their combinations on yield components of fenugreek plants

Treatments		Number of pods / plant		Seed yield / plant (g)		Seed yield / feddan (kg)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
Phosphorus fertilizer level (P_2O_5 kg/feddan)							
Control		18.25	20.03	6.98	7.45	390.83	417.06
30		28.25	28.97	8.93	8.93	500.08	500.31
45		31.97	32.61	9.42	9.79	527.24	548.24
LSD 5%		**0.63**	**0.82**	**0.66**	**0.33**	**37.20**	**18.24**
Spirulina extract rate (ml/l)							
Control		23.18	23.66	7.48	7.34	418.63	411.16
1.5		25.59	26.63	8.25	8.56	462.19	479.11
3.0		27.00	28.07	8.60	9.14	481.48	511.96
4.5		28.85	30.44	9.44	9.86	528.58	551.91
LSD 5%		**0.56**	**0.44**	**0.37**	**0.28**	**20.80**	**15.82**
Combination between phosphorus level and spirulina extract rate							
Control	**Control**	16.22	17.11	6.01	6.25	336.37	349.81
	1.5	17.89	19.78	6.48	7.48	363.07	418.69
	3.0	18.44	20.66	7.48	7.86	419.07	440.35
	4.5	20.44	22.55	7.94	8.20	444.83	459.39
30	**Control**	25.22	25.89	8.08	7.75	452.48	434.00
	1.5	27.78	28.22	8.98	8.83	502.69	494.85
	3.0	29.44	30.44	9.00	9.22	504.19	516.51
	4.5	30.55	32.33	9.66	9.93	540.96	555.89
45	**Control**	28.11	28.00	8.34	8.03	467.04	449.68
	1.5	31.11	31.89	9.30	9.35	520.80	523.79
	3.0	33.11	34.11	9.31	10.34	521.17	579.04
	4.5	35.55	36.44	10.71	11.44	599.95	640.45
LSD 5%		**1.04**	**1.04**	**0.86**	**0.53**	**48.08**	**29.68**

Data listed in Table 3 show that the better combination treatment between phosphorus fertilizer levels and *Spirulina* extract rates were 45 kg P_2O_5 per feddan combined with Spirulina foliar spray at 4.5 ml/l which gave the highest values of number of pods per plant, seed yield per plant and per feddan of fenugreek compared to control and the other combinations under study. Under any phosphorus fertilizer level, increasing *Spirulina* extract rates gradually increase fenugreek yield components. Also, under any *Spirulina* extract rate, increasing phosphorus fertilizer levels gradually increase total yield per fenugreek plant. Moreover, **Tunçtürk (2011)** indicated that phosphorus fertilizer applications positively affected pods number per fenugreek plant and total seed yield per hectare. Also, **Seğmen and Özdamar Ünlü (2023)** reported that spirulina application recorded the highest values in terms of yield parameters of *Capsicum annuum* plants.

Chemical Analysis And Active Ingredients

Results under discussion in Tables (4, 5 and 6) demonstrate that total chlorophyll content, trigonelline content, mucilage percentage, NPK percentages as well as total protein, total carbohydrates and fixed oil percentages of fenugreek were significantly increased with 45 kg P2O5 kg/feddan compared to control in both seasons. Based on the aforementioned findings, it can be concluded that the higher fenugreek chemical constituents achieved by applying phosphorus fertilizer is directly related to the improvement in fenugreek plant growth and yield parameters (Tables 2 and 3), which led to increases in metabolites converted to active ingredients, which in turn increased the total fenugreek quality. Moreover, **Asgharipour and Bijani (2016)** found that phosphorus fertilizer resulted in a significant impact on macronutrients uptake and photosynthetic pigments concentration of fenugreek plants.

Table 4. Influence of phosphorus fertilizer level, spirulina extract rate and their combinations on total chlorophyll content (SPAD), trigonelline content and mucilage percentage of fenugreek plants

Treatments		Total chlorophyll content (SPAD)		Trigonelline content (mg/100 g)		Mucilage percentage	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
Phosphorus fertilizer level (P_2O_5 kg/feddan)							
Control		39.67	42.79	0.310	0.330	26.42	26.21
30		46.21	46.92	0.438	0.385	27.39	29.02
45		49.38	48.54	0.432	0.474	29.85	30.62
LSD 5%		**0.31**	**0.80**	**0.01**	**0.06**	**0.38**	**0.18**
Spirulina extract rate (ml/l)							
Control		43.06	43.83	0.365	0.394	26.84	27.14
1.5		44.44	45.22	0.383	0.369	27.55	28.30
3.0		45.67	46.67	0.415	0.417	28.58	29.48
4.5		47.17	48.61	0.409	0.405	28.57	29.53
LSD 5%		**0.36**	**0.61**	**0.01**	**N.S.**	**0.40**	**0.43**
Combination between phosphorus level and spirulina extract rate							
Control	**Control**	39.00	41.17	0.293	0.316	25.43	25.35
	1.5	39.17	42.67	0.306	0.323	26.42	25.72
	3.0	40.17	43.33	0.312	0.331	26.82	26.66
	4.5	40.33	44.00	0.329	0.351	26.98	27.10
30	**Control**	45.17	45.00	0.405	0.356	26.50	26.87
	1.5	45.67	46.00	0.423	0.365	27.04	29.17
	3.0	46.17	47.00	0.470	0.420	27.58	29.69
	4.5	47.83	49.67	0.453	0.399	28.42	30.34
45	**Control**	45.00	45.33	0.396	0.511	28.58	29.21
	1.5	48.50	47.00	0.420	0.419	29.18	30.02
	3.0	50.67	49.67	0.465	0.500	31.33	32.08
	4.5	53.33	52.17	0.446	0.464	30.30	31.16
LSD 5%		**0.62**	**1.20**	**0.02**	**0.10**	**0.70**	**0.67**

Data in Table 4 show that spirulina application recorded the highest values of total chlorophyll content (SPAD), trigonelline content and mucilage percentage of fenugreek compared with control during both seasons, in most cases. *Spirulina*-applied reflect a significant influence regarding nitrogen, phosphorus and potassium percentage compared to control in both seasons (Table 5). The best rate of *Spirulina* was 4.5 ml/l regard total protein, total carbohydrates and fixed oil percentages compared to the other ones under study (Table 6). In addition, the plant active ingredients were improved by the large improvements in total protein, total carbohydrate accumulation, total phenol levels, and antioxidant activity that spirulina liquid extracts brought about (**Hamouda *et al*., 2022**).

From data given in Tables 4, 5 and 6 it is clear that, the combination treatment between phosphorus fertilizer at 45 kg P_2O_5 kg/feddan level and *Spirulina* extract at 4.5 ml/l significantly improved total chlorophyll content, trigonelline content, mucilage percentage, NPK percentages as well as total protein, total carbohydrates and fixed oil percentages of fenugreek compared to control and the other rates under study. In addition, increasing *Spirulina* extract rate up to 3 ml/l under each phosphorus fertilizer level significantly increased chemical constituents and active ingredients of fenugreek. Moreover, as mentioned just before, both phosphorus fertilizer and *Spirulina* extract treatments (each alone) enhanced chemical constituents and active ingredients of fenugreek, in turn, they together might maximize their influences leading higher active ingredients production. In the same time, **Kaseem *et al*. (2025**) noticed that *Spirulina*-extract as foliar application gave the highest significant increase in total chlorophyll leaf content and potassium percentage of *Prunus persical* seedlings compared to control.

Table 5. Influence of phosphorus fertilizer level, spirulina extract rate and their combinations (P×S) on N, P and K percentages of fenugreek plants

Treatments		Total nitrogen (%)		Total phosphorus (%)		Potassium (%)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
Phosphorus fertilizer level (P_2O_5 kg/feddan)							
Control		3.428	3.449	0.266	0.341	2.418	2.816
30		3.502	3.657	0.360	0.390	3.050	3.133
45		3.630	3.740	0.443	0.453	3.170	3.209
LSD 5%		**0.026**	**0.066**	**0.018**	**0.009**	**0.055**	**0.011**
Spirulina extract rate (ml/l)							
Control		3.334	3.421	0.335	0.360	2.834	2.835
1.5		3.490	3.604	0.346	0.386	2.947	3.015
3.0		3.589	3.690	0.368	0.405	3.112	3.152
4.5		3.669	3.745	0.375	0.427	3.151	3.208
LSD 5%		**0.043**	**0.039**	**0.008**	**0.007**	**0.057**	**0.024**
Combination between phosphorus level and spirulina extract rate							
Control	**Control**	3.248	3.298	0.252	0.316	2.664	2.634
	1.5	3.450	3.467	0.260	0.344	2.806	2.749
	3.0	3.452	3.481	0.274	0.348	2.881	2.918
	4.5	3.562	3.548	0.277	0.358	2.906	2.963
30	**Control**	3.283	3.427	0.340	0.370	2.807	2.801
	1.5	3.462	3.649	0.345	0.381	2.937	3.177
	3.0	3.573	3.573	0.372	0.401	3.211	3.238
	4.5	3.691	3.800	0.382	0.407	3.245	3.315
45	**Control**	3.471	3.538	0.411	0.395	3.031	3.069
	1.5	3.556	3.697	0.433	0.434	3.100	3.120
	3.0	3.741	3.835	0.460	0.467	3.244	3.301
	4.5	3.754	3.888	0.467	0.516	3.303	3.346
LSD 5%		**0.070**	**0.088**	**0.022**	**0.014**	**0.101**	**0.038**

Table 6. Influence of phosphorus fertilizer level, spirulina extract rate and their combinations (P×S) on total protein, total carbohydrates and fixed oil percentages of fenugreek plants

Treatments		Total protein (%)		Total carbohydrates (%)		Fixed oil (%)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
Phosphorus fertilizer level (P_2O_5 kg/feddan)							
Control		21.43	21.55	25.72	25.64	10.13	10.49
30		21.89	22.86	29.21	29.46	11.42	11.71
45		22.69	23.37	28.94	30.07	12.02	12.57
LSD 5%		**0.16**	**0.41**	**0.51**	**0.50**	**0.14**	**0.20**
Spirulina extract rate (ml/l)							
Control		20.84	21.38	27.07	27.32	10.58	10.91
1.5		21.81	22.53	27.84	28.16	11.05	11.40
3.0		22.43	23.06	28.34	28.62	11.26	11.72
4.5		22.93	23.41	28.57	29.47	11.87	12.32
LSD 5%		**0.27**	**0.25**	**0.50**	**0.40**	**0.07**	**0.24**
Combination between phosphorus level and spirulina extract rate							
Control	**Control**	20.30	20.61	25.38	24.83	9.94	10.31
	1.5	21.57	21.67	25.68	25.19	10.17	10.42
	3.0	21.58	21.76	25.68	26.03	10.15	10.53
	4.5	22.27	22.18	26.15	26.53	10.25	10.70
30	**Control**	20.52	21.42	28.04	27.95	10.79	11.03
	1.5	21.64	22.81	29.21	29.21	11.00	11.27
	3.0	22.33	23.46	29.71	30.08	11.39	11.80
	4.5	23.07	23.75	29.87	30.61	12.51	12.73
45	**Control**	21.69	22.11	27.80	29.19	11.02	11.38
	1.5	22.23	23.11	28.63	30.06	11.98	12.52
	3.0	23.38	23.97	29.63	29.76	12.23	12.83
	4.5	23.46	24.30	29.70	31.26	12.86	13.53
LSD 5%		**0.44**	**0.55**	**0.91**	**0.77**	**0.17**	**0.40**

CONCLUSION

From above mentioned results, it is preferable to applied fenugreek (*Trigonella foenum-graecum*) plants with phosphorus fertilizer at 45 kg P_2O_5 kg/feddan as well as spraying with spirulina extract at 4.5 ml/l to achieve the better growth, seed yield and active ingredients of this serious medicinal plant.

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تأثير السماد الفوسفاتي ومستخلص السبيرولينا على نمو وإنتاجية والمواد الفعالة لنبات الحلبة

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أُجريت تجربة حقلية في المزرعة التجريبية، التابعة لكلية العلوم الزراعية البيئة ، جامعة العريش، خلال موسمي 2022/2021 و2023/2022 لتقييم تأثير مستويات الفسفور المختلفة (صفر، 30 و45 كجم فو2أ5/فدان)، ومعدلات مستخلص السبيرولينا (صفر، 1.5، 3.0 و4.5 مللي/لتر)، بالإضافة إلى معاملات التداخل بينهما، على نمو وإنتاجية نباتات الحلبة. كان تصميم التجربة القطع المنشقة مرة واحدة في ثلاث مكررات. أشارت النتائج المتحصل عليها إلى أن نباتات الحلبة المُسمدة بمستوى 45 كجم فو2أ5/فدان أعطت أطول النباتات، وعدد الأفرع الأكثر لكل نبات، ووزنًا أثقل للنبات مقارنةً بالمستويات الأخرى قيد الدراسة. علاوة على ذلك، تم الحصول على أعلى إنتاجية للبذور لكل نبات، وأعلى إنتاجية للفدان، وأعلى محتوى من الكلوروفيل الكلي، وأعلى محتوى من التريجونيلين، وأعلى نسبة من الزيت، وأعلى محتوى من البروتين الكلي عند استخدام مستويات عالية من الفسفور مقارنةً بالكنترول. وبشكل عام، أدت زيادة معدلات مستخلص السبيرولينا تدريجيًا إلى زيادة صفات النمو ومكونات المحصول والمواد الفعالة مقارنة بالكنترول. ويمكن التوصية باستخدام سماد الفوسفات بمستوى 45 كجم فو2أ5/فدان مع الرش الورقي بمعدل 4.5 مللي/لتر من مستخلص السبيرولينا للحصول على أعلى القيم من إنتاجية البذور والمكونات الفعالة لنباتات الحلبة.

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