

Growth and productivity response to nitrogen, potassium and humic acid of fenugreek (*Trigonella foenum-graecum* L.) plant

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ABSTRACT

Growth, yield, fixed oil production and chemical constituents of fenugreek plants depend, among others, upon fertilization treatments. The present study was conducted at a privet farm in Mansoura, Dakahlia Governorate, Egypt, during the two winter consecutive seasons of 2014/2015 and 2015/2016 with an objective to evaluate the optimum rates of nitrogen and potassium (N×K) and level of humic acid for obtaining maximum growth and productivity of fenugreek plants. Four different rates of N×K (0, 50, 75 and 100 % of recommended rate) and three levels of humic acid (0, 1 and 2 l/fed.) were applied, thereby making twelve treatment interactions. The recommended rate of NK was 200: 50 kg/faddan of ammonium sulfate (20.5% N) and potassium sulphate (48.5% K₂O), respectively. The statistical layout of this experiment was split-plot experiment included 12 treatments were arranged in a randomized complete block design with three replicates. The obtained results indicated that NK fertilization rates at 75 and 100 % of recommended rate (RR) significantly increased plant growth parameters (plant height, number of branches and leaves /plant and dry weight/plant), yield components (number of pods/plant and seed yield/plant and /feddan), fixed oil production (fixed oil percentage, fixed oil yield/plant and /feddan) and chemical constituents (total N, P, K and carbohydrates percentages, total chlorophyll content as SPAD unit and trigonilline content as mg/100g of dry weight) without significant differences between them, in most cases, compared to control. Moreover, the highest values of above mentioned characters were registered by foliar spray of humic acid at 2 l/feddan with significant differences between the other levels under study. Generally, the better growth parameters, higher yield components, fixed oil production, chemical constituents of seeds and as well as trigonilline content in seeds could be obtained by spraying humic acid at 2 l/feddan level on fertilized fenugreek plants with NK at 75% of recommended rate.

Key words: Fenugreek, nitrogen and potassium fertilization, humic acid, growth, productivity

Introduction

Fenugreek (*Trigonella foenum-graecum*), belonging to family Leguminosae, is an important minor spice grown for its seeds as well as leaves. Seeds are used as a condiment for flavoring of foods and leaves as vegetable. It has also got medicinal value, hence used for treatment of diarrhea, dysentery, flatulence, enlargement of liver and diabetes, rickets, spleen and many others (Dutta *et al.*, 2011).

The macronutrients, N and K, are often classified as 'primary' macronutrients, because deficiencies of N and K are more common than the 'secondary' macronutrients, Ca, Mg and S. Most of the macronutrients represent 0.1 to 5%, or 100 to 5000 parts per million of dry plant tissue, whereas the micronutrients generally comparison less than 0.025 %, or 250 ppm of dry plant tissue (Wiedenhoeft, 2006). However, nitrogen is present in chlorophyll phosphatides, alkaloids, glycosides and many other organic substances of plant cell (Vopyan, 1984). Potassium could be a soil exchangeable ion and is actively absorbed by plant roots. It a serious element of the many soils and is ultimately derived from the weathering of soil parent materials like potassium-aluminum-silicates within the soil (Wiedenhoeft, 2006).

Humic acid is part of the humus compounds which plays an important role in balance plant nutrition by improving physical, chemical and biological properties of soil. Mikkelsen (2005) reported that humic acid has a high molecular weight and high complication ability. Sangeetha *et al.* (2006) reported that humic material have two direct and indirect effects on physiological and biochemical processes in plant and on chemical, physical and biological properties of soil.

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The most important aim of this study was to investigate the response of growth, yield and chemical constituents as well as trigonilline content of *Trigonella foenum-graecum* plant to NK fertilization rate and humic acid level treatments under Dakahlia Governorate conditions.

Materials and Methods

The present study was conducted at a privet farm in Mansoura, Dakahlia Governorate, Egypt, during the two winter consecutive seasons of 2014/2015 and 2015/2016 with an objective to evaluate the optimum rates of nitrogen and potassium (N×K) and humic acid level for obtaining maximum growth, yield components, fixed oil production and chemical constituents of fenugreek plants. Four different rates of N×K (0, 50, 75 and 100 % of recommended rate) and three levels of humic acid (0, 1 and 2 l/fed.) were applied, thereby making twelve treatment interactions. The recommended rate of NK was 200: 50 kg/faddan of ammonium sulfate (20.5% N) and potassium sulphate (48.5% K₂O), respectively. The statistical layout of this experiment was split-plot experiment included 12 treatments were arranged in a randomized complete block design with three replicates.

Seeds of fenugreek were obtained from Research Centre of Medicinal and Aromatic Plants, Dokky, Giza, Egypt and were sown on 20th and 25th October during the first and second seasons, respectively.

Nitrogen and potassium fertilization rates were distributed in the main plots, while humic acid levels were randomly arranged in the sub-plots. The experimental unit contains 6 rows each of 3 meter length and 60 cm width and the distance between hills within the row was 20 cm, where the area of each plot was 10.8 m². Plants were thinned after complete germination (20 days after sowing) leaving two plants / hill.

The mechanical and chemical properties of the used experimental farm soil are shown in Table 1, according to Chapman and Pratt, (1978).

Table 1: Physical and chemical properties of experimental farm soil (average of two seasons)

		Mechanical analysis						Soil texture					
		Clay (%)	Silt (%)		Coarse sand (%)			Loamy					
		43.50	35.10		21.40								
		Chemical analysis											
pH	E.C. (dsm ⁻¹)	Soluble cations (m.mol/l)						Soluble anions (m.mol/l)			Available (ppm)		
		Ca ⁺⁺	Mg ⁺⁺	Na ⁺	Fe	Zn ⁺⁺	Mo ⁺⁺	Cl ⁻	HCO ₃ ⁻	SO ₄ ⁻	N	P	K
7.80	0.68	3.70	2.10	0.30	2.40	1.70	1.68	3.55	1.98	0.85	160	72	76

Four nitrogen and potassium fertilization rates were applied as ammonium sulfate (20.5% N) and potassium sulphate (48.5% K₂O), respectively, and were divided into three equal portions to the soil after 30, 50 and 70 days from sowing. Moreover, three humic acid levels were applied as foliar spray into three equal portions after 30, 55 and 80 days from sowing. Phosphorus fertilizer at 200 kg/fed., of calcium super phosphate (15.5% P₂O₅) was added during soil preparation as a soil dressing application. However, all the plants received normal agricultural practices whenever they needed.

Data recorded:

Plant growth parameters:

Plant height (cm), number of branches and leaves /plant and total plant dry weight (g) were estimated at 90 days after sowing by taking 9 random guarded plants from each experimental unit.

Seed yield and its component:

At harvesting stage, number of pods and seed yield/plant was determined and then total seed yield (kg/ faddan) was calculated.

Fixed oil production:

Seed oil was extracted using petroleum ether in a soxhlet system HT apparatus according to the methods of A.O.A.C. (1984). Then, oil percentage and oil yield per plant and per faddan was calculated.

Plant chemical analysis:

A sample of dry seeds was randomly taken from each treatment for chemical analysis. Furthermore, total nitrogen, potassium and phosphorus percentages were determined in dry seeds according to the methods described by Chapman and Pratt (1978) and were multiplied by seed yield/plant to calculate its content (g/plant), whereas, total carbohydrate percentage was determined according to the method described by Dubois *et al.* (1956). Total chlorophyll content was determined in fenugreek leaves by using a hand Spad-502 meter at 80 days after sowing. The trigonilline content (mg/100 g) in seeds was determined according to the equation; trigonilline alkaloid= absorbance of test at 268 nm/Absorbance of standard, by Gorham (1986).

Statistical analysis:

The complete randomized block design (CRBD) in a split-plot design was used in this experiment with three replicates. Where, four NK fertilization rates were randomly arranged in the main plots and three humic acid levels were distributed randomly in the sub plots. Data were assessed by analysis of variance (ANOVA) according to Snedecor and Cochran (1980). The means were compared using computer program of Statistix version 9 (Analytical software, 2008). Significance was accepted by least significant difference (L.S.D) at 5% level.

Results and Discussion

Plant growth parameters:

Effect of nitrogen and potassium fertilization rates:

Data recorded in Table 2 reveal that the highest values of fenugreek plant height, number of branches and leaves per plant and total dry weight per plant were obtained from nitrogen and potassium rate at 100% of recommended rate compared to control and the other rates under study. This increase was significantly in both seasons. In addition, fenugreek growth parameters were gradually increased with increasing NK fertilization rates in the two seasons. Also, Dutta *et al.* (2011) on fenugreek plants reported that growth parameters viz., plant height and number of branches were significantly better in 15 to 20 per cent substitution of fertilizer nitrogen. Nurzyska-Wierdak *et al.* (2012) found that the increasing rates of nitrogen and potassium contributed to an increase in plant weight of garden rocket plants.

Effect of humic acid levels:

The data presented in Table 2 show that, all of humic acid levels significantly increased fenugreek plant height, branch and leaf number per plant and total dry weight per plant compared to control. Furthermore, humic acid at the level of (2 l/fed.) recorded higher increase in fenugreek growth parameters compared with the other one under study with significant differences with the treatment of (control and 1 l/fad.) during the two seasons. Similar results were stated by Mohammad (2009) on *Catharansus roseus*, Nasiri *et al.* (2015) on *Pelargonium graveolens* plant and Awad (2016) on *Carum carvi* plant .

Effect of interaction between NK fertilization and humic acid:

Data tabulated in Table 2 indicate that, under two humic acid levels (1 and 2 l/fed.) different rates of NK gave significant increases in fenugreek growth parameters compared to control in both seasons, in most cases. Moreover, interaction treatments of (75 and 100% of NK recommended rate) and (2 l/fed. of humic acid) gave the highest values of plant height, branch and leaf number per plant and total dry weight per plant compared to other interaction treatments in two seasons, in most cases.

Similar results were obtained by El-Bassiony *et al.* (2010) on snap bean and Ali *et al.* (2014) on *Tulipa agesneriana*. Moreover, as mentioned just before, both NK rates and humic levels treatments (each alone) increased growth parameters of fenugreek plant, in turn; they together might maximize their effects leading to taller, more branches and leaves and heaviest plants.

Table 2: Effect of nitrogen and potassium fertilization rate, humic acid level and their interactions on vegetative growth parameters of fenugreek plant during 2014/2015 and 2015/2016 seasons

NK fertilization rates (F)	Humic acid level (HI/Fed)							
	Control	1	2	Mean (F)	Control	1	2	Mean (F)
	2014/2015 season				2015/2016 season			
	Plant height (cm)							
Control	48.00	49.33	54.00	50.44	47.00	47.33	53.00	49.11
50% RR	48.00	48.67	53.67	50.11	50.00	51.00	56.33	52.44
75% RR	51.67	58.33	63.33	57.87	50.33	58.33	65.00	57.89
100% RR*	53.33	59.00	65.00	59.11	54.67	61.00	65.33	60.33
Mean (H)	50.25	53.83	59.00		50.50	54.42	59.92	
LSD at 5%	(F)= 1.73	(H)= 1.08	(F×H)= 2.47		(F)= 1.74	(H)= 1.34	(F×H)= 2.79	
	Number of branches / plant							
Control	4.33	5.33	6.63	5.44	5.00	5.67	7.33	6.00
50% RR	5.33	7.33	7.67	6.78	6.33	7.67	8.33	7.44
75% RR	6.67	7.67	8.67	7.67	7.33	7.67	9.67	8.22
100% RR*	7.33	8.67	9.67	8.55	7.67	9.33	10.67	9.22
Mean (H)	5.92	7.25	8.17		6.58	7.58	9.00	
LSD at 5%	(F)= 0.50	(H)= 0.35	(F×H)= 0.76		(F)= 0.25	(H)= 0.31	(F×H)= 0.56	
	Number of leaves / plant							
Control	17.33	20.67	26.67	21.56	19.00	22.67	27.33	23.00
50% RR	19.33	27.00	29.00	25.11	23.00	29.67	30.67	27.78
75% RR	25.67	32.67	39.00	32.44	30.67	32.67	42.00	35.11
100% RR*	29.33	31.67	42.00	34.33	31.00	41.33	46.67	39.67
Mean (H)	22.92	28.00	34.17		25.92	31.58	36.67	
LSD at 5%	(F)= 1.53	(H)= 1.16	(F×H)= 2.43		(F)= 1.34	(H)= 1.12	(F×H)= 2.26	
	Total dry weight/plant (g)							
Control	11.73	12.48	13.50	12.56	11.55	12.74	13.86	12.72
50% RR	12.10	13.22	13.94	13.09	12.46	13.37	14.15	13.33
75% RR	12.50	13.40	14.27	13.39	12.85	13.75	14.90	13.83
100% RR*	12.55	13.95	14.45	13.65	12.97	14.01	14.83	13.93
Mean (H)	12.22	13.26	14.04		12.46	13.47	14.44	
LSD at 5%	(F)= 0.36	(H)= 0.26	(F×H)= 0.60		(F)= 0.24	(H)= 0.22	(F×H)= 0.43	

*Recommended rate = N fertilizer at 200 + K fertilizer at 50 kg/fed.

Yield components:

Effect of nitrogen and potassium fertilization rates:

Presented data in Table 3 demonstrate that, number of pods/ plant, seed yield per plant and per feddan was gradually increased with increasing nitrogen and potassium rates. The maximum increase in this respect was obtained from the treatment of 100% of recommended rate of NK compared with the other ones under study during the two tested seasons. Moreover, the abovementioned parameters were significantly increased with all N+K fertilization treatments compared with control during both seasons.

In addition, the obtained increase in fenugreek yield components as a result of nitrogen and potassium fertilization, which might be attributed to the increase in crop photosynthetic ability, as a result of good vegetative growth induced by these treatments, as explained by Okosun (2000). Also, Abdul Al-Kiyyam *et al.* (2008) on caraway found similar results.

Effect of humic acid levels:

The data given in Table 3 show that, number of pods/plant and seed yield/plant and /feddan increased by increasing humic acid levels. Moreover, the humic acid levels (one and two l/fed.) gave significant increases compared to control in the two seasons. Also, the highest values obtained from humic acid rate at 2 l/feddan with significant differences compared to the other ones. This trend was repeated during both seasons. These results are in accordance with Parakash *et al.* (2011) on *Spirulina plantisis* plant, Akbari and Gholam (2016) on fennel and Ariaifar and Forouzandeh (2017) on black

cumin. Also, humic acid effects on plant physiology are mainly positive, and they include enhancement of biomass yields (Arancon *et al.*, 2006).

Table 3: Effect of nitrogen and potassium fertilization rate, humic acid level and their interactions on yield components of fenugreek plant during 2014/2015 and 2015/2016 seasons

NK fertilization rates (F)	Humic acid level (HL/Fed)							
	Control	1	2	Mean (F)	Control	1	2	Mean (F)
	2014/2015 season				2015/2016 season			
	Number of pods/plant							
Control	16.33	18.67	21.67	18.89	17.33	20.00	23.33	20.22
50% RR	18.00	21.00	26.00	21.67	19.33	22.67	27.00	23.00
75% RR	18.67	22.67	28.00	23.11	20.33	26.33	30.33	25.67
100% RR*	27.00	33.00	34.67	31.56	25.00	43.33	37.00	32.11
Mean (H)	20.00	23.83	27.58		20.50	25.83	29.42	
LSD at 5%	(F)= 0.81	(H)= 0.66	(F×H)= 1.34		(F)= 0.63	(H)= 0.89	(F×H)= 1.58	
	Seed yield / plant (g)							
Control	5.63	6.06	6.66	6.11	5.62	6.48	6.76	6.29
50% RR	5.75	6.32	6.95	6.34	5.77	6.75	7.31	6.61
75% RR	6.83	7.16	8.67	7.55	7.07	7.54	9.12	7.91
100% RR*	7.40	8.00	8.28	7.89	7.29	8.11	9.09	8.16
Mean (H)	6.40	6.88	7.64		6.44	7.22	8.07	
LSD at 5%	(F)= 0.51	(H)= 0.27	(F×H)= 0.67		(F)= 0.26	(H)= 0.23	(F×H)= 0.45	
	Seed yield / feddan (kg)							
Control	394.10	424.20	465.97	428.09	393.40	453.60	473.43	440.14
50% RR	402.27	442.40	486.73	443.80	404.13	472.50	511.47	462.70
75% RR	477.87	500.97	606.90	528.58	494.90	527.57	638.17	553.54
100% RR*	518.00	560.00	579.37	552.46	510.07	567.93	636.30	571.43
Mean (H)	448.06	481.89	534.74		450.62	505.40	564.84	
LSD at 5%	(F)= 35.54	(H)= 18.98	(F×H)= 47.04		(F)= 18.03	(H)= 16.07	(F×H)= 31.78	

*Recommended rate = N fertilizer at 200 + K fertilizer at 50 kg/fed.

Effect of interaction between NK fertilization and humic acid:

Results under discussion in Table 3 demonstrate that, yield components of fenugreek were significantly increased with interaction between NK rates and humic acid levels compared to control in the two seasons, in most cases. Furthermore, the interaction treatment (75 and 100 % of NK recommended rate plus 2 l of humic acid/fed., respectively) gave the highest values in this connection with significant increase compared to other treatments in the first and second seasons. Also, all interaction treatments were higher than individual N + K rates or individual humic acid levels. Such results might be attributed to humic acid is a bioactive organic biological slow-release fertilizer and together with the chemical fertilizers (N and K), forms an organic-inorganic complex fertilizer which holds the humic acid as the core. This can effectively improve the supply of nutrition leading to more yield of fenugreek plant (Wang and Qin, 2009).

Fixed oil production:

Effect of nitrogen and potassium fertilization rates:

Data of both seasons in Table 4 demonstrate that, increasing nitrogen and potassium rates gradually increased fixed oil percentage and fixed oil yield per plant and per feddan. The maximum increase with significant differences in this regard was achieved by the highest rate of NK fertilization (RR 100%) compared to control and the other rates under study in the first and second seasons. However, Soil fertility could be maintained and oil yields of rosemary from four harvests could be increased by application of 150 kg N and 100 kg K per hectare (Puttanna *et al.*, 2010). Also, Omar *et al.* (2014) on *Artemisia annua* reported that application of mineral fertilizers (nitrogen and potassium) had a significant effect on essential oil % and yield (ml/plant and l/fed) comparing with untreated plants (control) in the two seasons. Also, the positive effect of NPK fertilization which noticed in this

study was previously demonstrated by Matter and El Sayed (2015) since they found that NPK fertilizer led to enhance essential oil percentage of caraway plant.

Table 4: Effect of nitrogen and potassium fertilization rate, humic acid level and their interactions on fixed oil production of fenugreek plant during 2014/2015 and 2015/2016 seasons

NK fertilization rates (F)	Humic acid level (HL/Fed)							
	Control	1	2	Mean (F)	Control	1	2	Mean (F)
	2014/2015 season				2015/2016 season			
	Fixed oil percentage							
Control	10.13	10.17	10.23	10.18	9.97	10.37	10.53	10.29
50% RR	10.27	10.34	10.50	10.37	10.33	10.50	10.60	10.48
75% RR	10.27	10.47	10.67	10.47	10.63	10.70	11.03	10.79
100% RR*	10.60	10.83	11.20	10.88	10.47	11.07	11.67	11.07
Mean (H)	10.32	10.45	10.65		10.35	10.66	10.96	
LSD at 5%	(F)= 0.13	(H)= 0.10	(F×H)= 0.21		(F)= 0.08	(H)= 0.13	(F×H)= 0.22	
	Fixed oil yield / plant (ml)							
Control	0.57	0.62	0.68	0.62	0.56	0.67	0.71	0.65
50% RR	0.59	0.65	0.73	0.66	0.60	0.71	0.77	0.69
75% RR	0.70	0.75	0.92	0.97	0.57	0.81	1.01	0.85
100% RR*	0.78	0.87	0.93	0.86	0.76	0.90	1.06	0.91
Mean (H)	0.66	0.72	0.82		0.67	0.77	0.89	
LSD at 5%	(F)= 0.014	(H)= 0.013	(F×H)= 0.025		(F)= 0.028	(H)= 0.028	(F×H)= 0.053	
	Fixed oil yield / feddan (l)							
Control	39.95	43.14	47.70	43.60	39.30	47.03	49.88	45.40
50% RR	41.31	45.75	51.12	46.06	41.78	49.62	54.21	48.54
75% RR	49.06	52.45	64.79	55.43	52.62	56.46	70.43	49.84
100% RR*	54.91	60.66	64.89	60.15	53.39	62.87	74.24	63.50
Mean (H)	46.31	50.50	57.12		46.77	53.99	62.19	
LSD at 5%	(F)= 3.04	(H)= 2.09	(F×H)= 4.56		(F)= 1.96	(H)= 1.96	(F×H)= 3.75	

*Recommended rate = N fertilizer at 200 + K fertilizer at 50 kg/fed.

Effect of humic acid levels:

The data illustrated in Table 4 show that fixed oil percentage of fenugreek seeds and yield per plant (ml) and per faddan (l) gradually increased by increasing humic acid level in both seasons. Moreover, the humic acid rates (2 l/fed.) gave high significant increases in this connection compared to control and other ones in the two seasons. Humic acid (HA) is a promising natural resource to be utilized as an alternative for fertilizers to improve crop production (Nikbakht *et al.*, 2008). Humic substances (HS) have beneficial effects on plant growth, nutrient uptake, root development, yield, and plant photosynthesis which reflected in oil production (Nardi *et al.*, 2002).

Effect of interaction between NK fertilization and humic acid:

Table 4 reveals that, all interaction treatments between NK fertilization rates and humic acid levels were higher in this concern than individual N + K rates or individual humic acid levels in both seasons. Moreover, fixed oil production parameters of fenugreek were significantly increased with interaction between NK rates and humic acid levels compared to control in the two seasons, in most cases. Generally, the interaction treatment of (75 and 100 % of NK recommended rate plus 2 l of humic acid/fed., respectively) gave the highest values in fixed oil percentage and fixed oil yield per plant and per feddan with significant increase compared to other treatments in both seasons. Also, such results might be attributed to humic acid is a bioactive organic biological slow-release fertilizer and together with the chemical fertilizers (N and K), forms an organic-inorganic complex fertilizer which holds the humic acid as the core. Organic manure can serve as alternative practice to mineral fertilizers (Naeem *et al.*, 2006) for improving soil structure, plant growth and yields which reflected in oil production. This can effectively improve the supply of nutrition leading to more fixed oil production of fenugreek plant (Wang and Qin, 2009).

Chemical constituents:

Effect of nitrogen and potassium fertilization rates:

The data given in Table 5 suggest that nitrogen, phosphorus and potassium contents (g/plant) per plant were increased gradually with increasing nitrogen and potassium rates. In addition, all NK fertilization treatments significantly increased total carbohydrates, total chlorophyll and trigonilline contents of fenugreek plant compared with control (Table 6). Furthermore, the maximum increase in fenugreek seeds chemical constituents were obtained from the treatment of 100% recommended rate of nitrogen (200 kg ammonium sulfate per faddan) compared with the other ones under study. These results hold true in the two seasons. In addition, Samane *et al.*, (2014) found an increase in chlorophyll density of sweet basil as affected by nitrogen fertilization application compared to untreated plants. In the same time, such effects of the used treatments on oil production might be due to the important role of nitrogen in building metabolites which used in carbohydrates, chlorophyll and trigonilline formation metabolism as reported by Matter and El Sayed (2015).

Effect of humic acid levels:

It is quite clear from the data in Table 5 that, (N, P and K contents) in fenugreek seeds increased by increasing humic acid level. Also, all humic acid levels gave significant increases compared to control. In addition, the highest values in this connection in the first and second seasons were obtained from the humic acid level of 2 l/fed., followed by 1 l/fed. with no significant differences between them in the two seasons, in most cases. These resulted are in harmony with those reported by Mohammad (2009) on *Catharanthus roseus*. Also, in Table 6, total carbohydrates content (g/plant), chlorophyll content (SPAD unit) and trigonilline content (mg/100g) in fenugreek seeds were increased by increasing humic acid level in both seasons. Moreover, all humic acid level gave significant increase in this regard compared to control in the two seasons.

Table 5: Effect of nitrogen and potassium fertilization rate, humic acid level and their interactions on N, P and K contents (g/plant) of fenugreek plant during 2014/2015 and 2015/2016 seasons

NK fertilization rates (F)	Humic acid level (HL/Fed)							
	Control	1	2	Mean (F)	Control	1	2	Mean (F)
Total nitrogen content (g/plant)								
Control	0.190	0.216	0.244	0.217	0.177	0.205	0.237	0.206
50% RR	0.203	0.232	0.267	0.234	0.183	0.227	0.258	0.223
75% RR	0.232	0.255	0.322	0.270	0.231	0.256	0.319	0.269
100% RR*	0.259	0.288	0.312	0.286	0.245	0.287	0.330	0.287
Mean (H)	0.221	0.248	0.286		0.209	0.244	0.286	
LSD at 5%	(F)= 0.014	(H)= 0.013	(F×H)= 0.025		(F)= 0.012	(H)= 0.008	(F×H)= 0.018	
Total phosphorus content (g/plant)								
Control	0.026	0.031	0.037	0.031	0.025	0.033	0.038	0.032
50% RR	0.036	0.040	0.033	0.036	0.029	0.037	0.047	0.038
75% RR	0.033	0.040	0.052	0.041	0.037	0.040	0.058	0.045
100% RR*	0.042	0.049	0.053	0.048	0.038	0.050	0.059	0.049
Mean (H)	0.034	0.040	0.044		0.032	0.040	0.050	
LSD at 5%	(F)= 0.003	(H)= 0.002	(F×H)= 0.005		(F)= 0.002	(H)= 0.002	(F×H)= 0.004	
Potassium content (g/plant)								
Control	0.142	0.157	0.182	0.160	0.138	0.172	0.183	0.165
50% RR	0.157	0.191	0.220	0.189	0.156	0.209	0.233	0.200
75% RR	0.182	0.201	0.277	0.220	0.178	0.226	0.309	0.238
100% RR*	0.208	0.238	0.264	0.237	0.192	0.258	0.323	0.258
Mean (H)	0.172	0.197	0.236		0.166	0.216	0.262	
LSD at 5%	(F)= 0.009	(H)= 0.011	(F×H)= 0.020		(F)= 0.006	(H)= 0.008	(F×H)= 0.015	

*Recommended rate = N fertilizer at 200 + K fertilizer at 50 kg/fed.

Effect of interaction between NK fertilization and humic acid:

From data recorded in Tables 5 and 6, the different interaction treatments gave significant increases in N, P and K contents, total carbohydrates and chlorophyll contents as well as trigonilline content compared to control in both seasons, in most cases. Also, the highest values in these chemical constituents of fenugreek seeds were obtained from the interaction treatments between 75 and 100 % RR of NK with humic acid rate (2 l/fed.) in the two seasons, in most cases. Furthermore, there was no significant difference between both combination treatments with all chemical constituents in the two seasons. However, N and P concentrations of post harvest soil and their accumulation by wheat increased significantly (P less than 0.05) over control with 0.5 and 1.0 kg ha⁻¹ HA applied alone and in combination with NPK (Sharif *et al.*, 2003). Also, the stimulatory effect of the treatments of nitrogen fertilization on chlorophyll content might be due to the known function of some elements like nitrogen which was found in such important molecules as parphyrin. The parphyrin structure was found in such metabolically important compounds in the chlorophylls as reported by Devlin (1979). However, Awad (2016) reported that foliar application of humic acid and the recommended NPK dose significantly increased N, P and K contents of caraway plants.

Table 6: Effect of nitrogen and potassium fertilization rate, humic acid level and their interactions on total carbohydrates, chlorophyll and trigonilline contents of fenugreek plant during 2014/2015 and 2015/2016 seasons

NK fertilization rates (F)	Humic acid level (HL/Fed)							
	Control	1	2	Mean (F)	Control	1	2	Mean (F)
	2014/2015 season				2015/2016 season			
Total carbohydrates content (g/plant)								
Control	2.160	2.443	2.747	2.450	2.173	2.630	2.783	2.529
50% RR	2.230	2.520	2.853	2.534	2.317	2.807	3.117	2.747
75% RR	2.707	2.943	3.730	3.127	2.757	3.060	3.933	3.250
100% RR*	2.983	3.307	3.597	3.296	2.927	3.433	3.980	3.447
Mean (H)	2.520	2.803	3.232		2.543	2.982	3.453	
LSD at 5%	(F)= 0.191	(H)= 0.134	(F×H)= 0.290		(F)= 0.083	(H)= 0.099	(F×H)= 0.181	
Total chlorophyll content (SPAD unit)								
Control	37.67	38.67	41.00	39.11	38.67	40.00	41.67	40.11
50% RR	38.33	38.67	42.00	39.65	39.33	40.33	43.00	40.89
75% RR	39.67	40.67	46.00	42.11	41.33	43.33	46.67	43.78
100% RR*	40.00	42.00	45.67	42.56	40.67	43.33	45.33	43.11
Mean (H)	38.92	40.00	43.67		40.00	41.75	44.17	
LSD at 5%	(F)= 0.628	(H)= 0.661	(F×H)= 1.246		(F)= 0.999	(H)= 0.742	(F×H)= 1.567	
Trigonilline content (mg/100g dry weight)								
Control	0.323	0.331	0.343	0.332	0.334	0.350	0.360	0.348
50% RR	0.333	0.341	0.350	0.341	0.348	0.367	0.370	0.362
75% RR	0.334	0.359	0.374	0.356	0.358	0.369	0.379	0.369
100% RR*	0.363	0.373	0.389	0.375	0.362	0.387	0.391	0.380
Mean (H)	0.338	0.351	0.364		0.351	0.368	0.375	
LSD at 5%	(F)= 0.009	(H)= 0.007	(F×H)= 0.014		(F)= 0.006	(H)= 0.004	(F×H)= 0.009	

*Recommended rate = N fertilizer at 200 + K fertilizer at 50 kg/fed.

Conclusion

From growth and productivity parameters i.e; (number of branches and leaves per plant, total dry weight, seed yield components, fixed oil production and trigonilline content) supported this result since 75% or 100% of recommended rate with foliar fertilization by humic acid at 2 l/feddian level product were more advantageous than other interaction treatments and seem promising in the development of sustainable fenugreek production.

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