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Response of Yield and Yield Component of Fenugreek to Irrigation Intervals, Potassium and Zinc

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Authors' contributions

This work was carried out in collaboration between all authors. Author MS designed the study and wrote the protocol and manuscript. Author GM performed the statistical analysis and managed the literature searches. Author RM managed the farm activity. Author HZ prepared the experimental materials. All authors read and approved the final manuscript.

Research Article

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ABSTRACT

Aims: This study was conducted to evaluate the effect of irrigation intervals, potassium and zinc fertilizers treatments on fenugreek,
Place and Duration of Study: The experiment was conducted in Agriculture and Natural Resources Research Center of Khorasan-e-Razavi, Mashhad, Iran in 2010.
Methodology: Experimental design was split plot based on randomized complete block with three replications. Irrigation intervals (5, 10 and 15 days) and fertilizers (50 kg ha^{-1} Zn, 250 kg ha^{-1} K, Zn+K and control) were as main plot and sub plot, respectively.
Results: The results showed that the highest biomass (120.8 $g.m^{-2}$) and seed (36.39 $g.m^{-2}$) yield were related to irrigation interval 5 days. Between two irrigation interval 10 and 15 days, no significant differences were observed. The effect of fertilizer on biological and seed yield was not significant. The effects of irrigation and fertilizer levels on any of the seed yield components were not significant.
Conclusion: The insignificant response of the plants to fertilization might be caused by

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meeting plants K and Zn demand by soil and/or the sensitivity and low K and Zn demand of the plants.

Keywords: Water stress; fertilizer; medicinal plant; yield.

1. INTRODUCTION

Fenugreek (*Trigonella foenum-graecum* L.) is an important medicinal plant that is grown mainly in order to use its seeds. This plant has originated from Iran and West Asia and to other parts of the world has moved [1]. In order to meet the needs of growing medicine herbs, medicinal plants should be planted to crops. Medicinal plant cultivation needs to information about its response to irrigation and fertilizer.

Water stress is the most important factor affecting crop yield, especially in arid and semi arid regions. The result of reference [2] in fennel showed that increasing irrigation intervals from 10 to 20 and 30 days declined plant height, shoot and total dry weight, number of secondary branches per m^2, umbels and umbrella number per plant, number of fertile umbrella per branch, umbrella number per umbel, 1000 seed weight and seed yield significantly. With increasing stress severity, essential oil, total carbohydrate and proline content of *Salvia officinalis* L. increased [3].

In water scarcity condition optimizing irrigation scheduling associated with the selection of suitable crops for cultivation are very important [4]. On the other hand the improvement of plant nutrition can contribute to increased resistance and production when the crop is submitted to water stress [5]. Proper use of elements and nutrients during the cultivation of medicinal plants, not only has an important role in increasing their yields, but also in the quantity and quality of product ingredients. Among macro and micro elements, potassium and zinc have an important role in plants survival under environmental stress conditions. Potassium is essential for a lot of physiological processes such as photosynthesis, photosynthates translocation in the plants, turgor maintenance and enzymes activation [6]. The reason for the enhanced need for K by plants under stress could be related to the fact that K is required for maintenance of photosynthetic CO_2 fixation [7,8]. Plants suffering from K deficiency show decrease in turgor and become flaccid under water stress particularly during the midday period [8]. The protective role of potassium in stress by maintaining high pH in the stomata and the oxidative damage to chloroplasts has been reported [8].

Zinc may be involved in stomatal regulation due to its role in maintaining membrane integrity. Thus the level of zinc may affect plant water relations [9]. The result of Khan *et al.* (2004) indicated that Zn deficiency reduced the ability of chickpea to adjust osmotically to changes in water availability [9]. Reference [10] stated that zinc influence auxin production. This micro-element is a co-enzyme for production of tryptophane, a precursor to the formation of auxin. Increase in auxin production as a result of Zn application enhances the root growth and drought tolerance in plants [7]. On the other hand Zn application reduces the activity of membrane-bound NADPH oxidase which in turn decreases the generation of reactive oxygen species (ROS) and protects cells against ROS attack under water stress [10].

In cauliflower, reduction in photosynthesis induced by Zn deficiency was associated with reducing stomatal conductance and low concentrations of inter cellular carbon dioxide [11].

The result of reference [12] reported that Zn application increased the yield of peas in non-stress conditions but in stress condition this increase not occurred, except for a stress-resistant genotype. This study was conducted to evaluate the effect of irrigation intervals and different levels of potassium and zinc fertilizer on yield and yield components of fenugreek.

2. MATERIALS AND METHODS

This experiment was conducted in Agriculture and Natural Resources Research Center of Khorasan-e-Razavi, Mashhad, Iran in 2010**.** Climate of Mashhad is semi dry. Longitude, latitude and altitude of Mashhad are 59º 15', 35º 43' and 985 m, respectively. Experimental design was a split plot based on randomized complete block with three replications. Irrigation intervals (5, 10 and 15 days) were as the main plot. Four fertilizer levels (no fertilizer as control, 50 $kg.ha^{-1}$ zinc sulfate, 250 $kg.ha^{-1}$ potassium sulfate, and Zn+K) were considered as sub-plots. Seeds (one locally genotype) planted in April 18. The spacing between the seeds was 8cm on rows and the row spacing was 30 cm. Each sub-plot consisted of six 5-m-long rows. Potassium fertilizer treatments were applied at planting stage. Fertilization with Zn was conducted after plant thinning. With respecting the soil analysis results, urea (300 $kg.ha^{-1}$) was applied at two stages (concurrent with planting and at the start of flowering as top dress) equally. Soil analysis results have been shown in Table 1.

Seed harvesting was done when the plants were yellow and at least 80 percent pods were maturated. After eliminating two side rows and 0.5 m from both sides of the plots as the marginal effect, 10 plants were randomly harvested from each plot. Seed and biomass yield were determined after harvesting of 2 m^{-2} in each sub-plot. The data were statistically analyzed by software MSTAT-C and SPSS and the means were compared by Duncan Multiple Range Test at P = .05 probability level.

Table 1. Some measured traits of soil properties (0-30 cm)

Soil texture	OC (%)	K ($mg.kg^{-1}$)	P ($mg.kg^{-1}$)	N ($mg.kg^{-1}$)	Fe ($mg.kg^{-1}$)	Zn ($mg.kg^{-1}$)	Mn ($mg.kg^{-1}$)	pH	EC ($dS\ m^{-1}$)
loam	0.18	14.8	7.2	0.025	2.5	0.32	9.8	7.9	0.9

3. RESULTS AND DISCUSSION

Results of analysis of variance showed that irrigation interval significantly affected biomass and seed yield at 5% level, but its impact was insignificant on yield components including the number of pods per plant, the number of seeds per pod and 1000-seed weight (Table 2).

Table 2. Mean square of effect of irrigation, potassium and zinc on seed yield and yield components of Fenugreek

sov	df	Biomass yield	Seed yield	Harvest index	Pod number per plant	Seed number per pod	1000 Seed weight	Plant height
Replication	2	1632.191	71.318	0.001	14.868	1.588	1.051	1.734
Factor A (Irrigation)	2	14020.362^{*}	1273.547^{*}	0.00^{ns}	11.808^{ns}	3.549^{ns}	1.200^{ns}	83.769^{ns}
Error1	4	1687.095	275.730	0.009	14.563	4.644	0.532	22.776
Factor B (Fertilizer)	3	60.077^{ns}	14.627^{ns}	0.001^{ns}	0.867^{ns}	0.018^{ns}	0.420^{ns}	2.316^{ns}
A*B	6	183.997^{ns}	36.465^{ns}	0.003^{ns}	10.285^{ns}	3.169^{ns}	0.125^{ns}	8.601^{ns}
Error2	18	349.66	50.392	0.003	4.62	1.536	0.362	3.389
CV %		22.95	28.96	17.27	19.40	15.42	5.36	7.33

** shows significantly different at the 5% probability level, and ^{ns} is not significantly different.*

Means comparison for the effect of irrigation interval on biological yield revealed that 5-day irrigation interval gave rise to the highest biological yield (on average, 120.8 $g.m^{-2}$) and 15-day irrigation interval gave rise to the lowest one (on average, 58.40 $g.m^{-2}$) (Table 3). The decrease in irrigation interval from 10 to 5 days resulted in 85% increase in total biomass of fenugreek. No significant difference was observed between 10 and 15-day irrigation intervals (Table 3). In a study on sesame, Reference [13] concluded that water stress decreased biological yield by 10%. In another research [14] it has been reported that drought stress resulted in the loss of yield and physiological traits of two rapeseed cultivars. They concluded that K application was able to improve seed yield and physiological traits by mitigating the adverse effects of water stress on them.

The loss of leaf area as a result of the loss of available water has been reported by [15]. The loss of leaf area will decrease the production of dry matter through reducing the absorption of photosynthetic active radiation (PAR). Reference [16] reported the increase in the growth of mint plants under adequate irrigation. Also, in a greenhouse experiment, it has been indicated that the highest dry matter of basil was obtained from the treatment of irrigation to recover 90% of field capacity [17].

The effect of fertilization was not significant on biological yield (Table 2), which shows that the existing Zn and P content of soil was probably able to meet the plants demand for these nutrients. Given the low vegetative biomass of fenugreek, these results were expectable (Table 3). Also another formulation of zinc such as ZnO may be more effective in this situation.

It has been stated that Zn was capable of affecting auxin production and was known as a co-enzyme for the production of tryptophan as the primary precursor of auxin [7]. Higher auxin production caused by Zn application increases the growth of the roots which in turn, improves the tolerance of the plants to drought. Thus, maintaining adequate hormonal level is regarded as a competitive advantage in tough conditions. In another mechanism, Zn application reduces the activity of NADPH oxidase banded in membrane which reduces the production of active oxygen species and oxidative injuries under water stress conditions. Reference [18] showed that Zn spraying (6:1000) along with the application of 120 $kg.ha^{-1}$ K significantly increased seed Zn content, carbohydrate percentage, protein percentage, protein yield, leaf chlorophyll, light use efficiency, the number of harvests, the number of pods per unit area, the number of seeds per pod, 100-seed weight, green pod yield, seed yield and biological yield of beans. In another experiment [19] it has been stated that Zn application was much more useful for most traits of forage sorghum with the increase in K application. They showed that the application of 60 kg $K.ha^{-1}$ + 10 kg $Zn.ha^{-1}$ resulted in 25% higher fresh yield, 36-38% higher dry matter yield and 38% higher protein yield than those obtained from Zn-free K fertilization.

Table 3. Effect of irrigation intervals on seed yield, yield components and harvest index of Fenugreek

Irrigation interval	Biomass yield ($g.m^{-2}$)	Seed yield ($g.m^{-2}$)	Harvest index %	Pod number per plant	Seed number per pod	1000 Seed weight (g)	Plant height (cm)
5 days	120.8 a*	36.38 a	30.3 a	12.08 a	8.55 a	11.30 a	28.07 a
10 days	65.32 b	17.95 b	30.6 a	10.10 a	8.09 a	10.89 a	24.35 a
15 days	58.40 b	19.21 b	29.4 a	11.05 a	7.46 a	11.52 a	22.97 a

**Means, in each column, followed by similar letter are not significantly different at the 5% probability level*

Means comparison for the effect of irrigation level on grain yield revealed that 5-day irrigation interval resulted in higher seed yield (36.39 $g.m^{-2}$) than 10 and 15-day irrigation intervals (17.95 and 19.21 $kg.m^{-2}$, respectively) (Fig. 1). In other words, 5-day irrigation interval increased yield by 102% and 89% compared to 10 and 15-day irrigation intervals, respectively. Reference [20] found that water stress decreased yield and yield components of vetch and the adverse effect of this stress was greater when it happened during vegetative growth. In a study on sesame [13] it has been concluded that water stress resulted in 10% lower biological yield and that the highest seed yield was obtained from the treatments of full irrigation, the application of 100 kg $S.ha^{-1}$ and foliar application of Fe (3:1000).

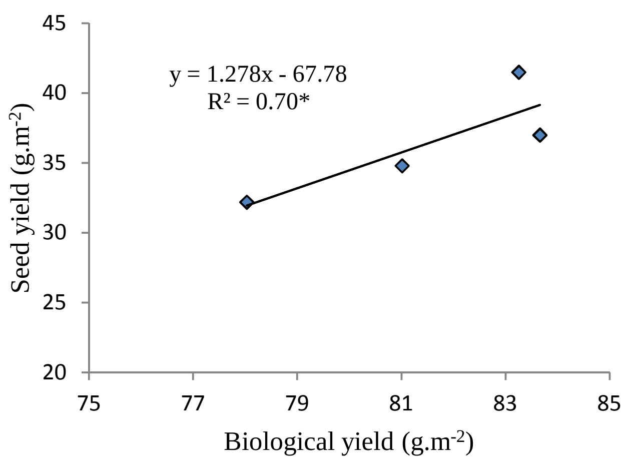

Fig. 1. Linear regression between biological and seed yield of fenugreek in fertilizer levels

Results of analysis of variance (Table 1) showed that irrigation interval did not significantly affect yield components (Table 3**)**; nonetheless the decrease in irrigation interval from 15 to 5 days led to 9.3% more number of pods per plant and 14.5% more number of seeds per pod. Seemingly, these insignificant, slight changes in yield components finally resulted in significant effect of irrigation interval on the yield of fenugreek. Refernce [21] showed that seed growth rate of corn and sorghum decreased under drought stress. Leaf length and width, height and the number of tillers decreased under stress which resulted in the loss of dry matter production. K application had no significant impact on seed growth rate under drought stress. Reference [13] concluded that water stress decreased biological yield of sesame and the number of capsules per plant.

The occurrence of water deficit stress at different developmental stages, particularly during reproductive stage, decreases seed yield through reducing the duration of photosynthesis period, the mobilization of assimilates to seeds and the contribution of retranslocation of stem reserves to seeds [22,23]. Water limitation influences seed yield by reducing cell division and elongation as well as by decreasing the mobilization of current assimilates and the retranslocation of produced materials to seeds. Therefore, it is necessary to meet plant water demand during the short period of pollination until seed filling stage in order to obtain optimum seed yield [22,23].

Like the effect of fertilization on biological yield, the effect of fertilization levels was not significant on seed yield (Table 1). Given the positive, significant correlation between seed and biological yield (Fig. 1), it seems that fertilization treatment did not significantly impact seed yield, too (Table 4).

Table 4. Effect of fertilizer levels on seed yield, yield components and harvest index of Fenugreek

Fertilizer levels	Biomass yield ($g.\ m^{-2}$)	Seed yield ($g.\ m^{-2}$)	Harvest index %	Pod number per plant	Seed number per pod	1000 Seed weight (g)	Plant height (cm)
Control	81.01 a	23.32 a	28.8 a	11.11 a	7.99 a	11.51 a	25.54 a
Zn	83.66 a	22.78 a	30.7 a	10.96 a	8.01 a	11.16 a	25.11 a
K	78.03 a	23.52 a	31.1 a	10.76 a	8.09 a	11.29 a	25.44 a
Zn+ K	83.26 a	25.43 a	29.9 a	11.49 a	8.06 a	11.00 a	24.42 a

**Means, in each column, followed by similar letter are not significantly different at the 5% probability level*

In a two-year study on the effect of different levels of N, P and Zn on groundnut [24] it has been concluded that the yield was not influenced by treatments. They related this finding to high level of nitrate at subsurface level and moderate level of P in soil. By spraying various levels of K on potatoes, it has been showed that higher level of KNO_3 fertilization brought about significantly higher plant height, leaf number, leaf area, leaf relative water content and chlorophyll concentration, but tuber number and yield did not exhibit significant increase which shows that the amount of K applied with irrigation water was adequate under the conditions of the current study [25]. Reference [26] revealed that the application of 200 kg $N.ha^{-1}$ improved root penetration of corn, sorghum and millet under drought stress. K application mitigated the damage of drought stress to plants.

Results revealed that yield components of fenugreek including the number of pods per plant, the number of seeds per pod and 1000-seed weight did not significantly respond to fertilization levels (Table 1). Despite that Zn plays a vital role in sustaining the stability of cell membrane and the deficiency of Zn availability causes the leakage of such ions as K and Cl from root system which in turn, low Zn concentration in soil radically affects root system efficiency [27], fenugreek did not significantly respond to fertilization levels under the conditions of the current study (Table 4). In an experiment on basil [28] it has been concluded that chemical fertilizers did not significantly influence reproductive traits compared to control, whereas organic and biological fertilizers significantly increased these traits. Reference [29] shows that although Mn foliar application improved grain yield of sunflower, this increase was not significant. The combination of Mn and Fe had no significant effect on yield which could be associated with antagonistic effect between these two elements.

Irrigation and fertilization treatments did not significantly impact harvest index of fenugreek and no significant difference was observed between different levels of irrigation and fertilization in terms of harvest index (Table 2). In a study on rice cultivars [30] it has been concluded that K fertilization improved yield under rain-fed conditions and harvest index increased with K fertilization under both irrigation systems. In the current study, no significant difference in harvest index as affected by treatments could be related to their similar effects on reproductive and vegetative structures.

Results of analysis of variance showed that simple effect of fertilization and irrigation levels and their interactions did not significantly impact on plant height (Table 2).

Means comparison for the effect of irrigation interval on plant height revealed that the highest and lowest plant height was obtained from 5 and 15-day irrigation intervals (28.07 and 22.96 cm), respectively, although this decrease in height under drought stress was not significant (Table 3). Probably, this insignificant increase in plant height under 5-day irrigation interval along with the bearing of more auxiliary branches (from main branches) resulted in significantly higher biomass compared to the other irrigation treatments. Reference [31] indicated that the highest shoot yield, height and leaf length and width of lemon balm was obtained from no-stress treatment.

4. CONCLUSION

In total, the results indicated that fenugreek plants were more sensitive to irrigation and soil moisture supply than to fertilization under the conditions of the current study. The insignificant response of the plants to fertilization might be caused by meeting plants K and Zn demand by soil and/or the sensitivity and low K and Zn demand of the plants. Therefore, it is required to conduct complementary studies to specify fenugreek nutrient demand and to determine its tolerance threshold to the availability of different nutrients.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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