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Original article

Effect of salt stress on some morphological traits of fenugreek and determination of the salt tolerance threshold at vegetative stage using some experimental models

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Extended abstract

Introduction

Iran, the second largest country in the Middle East, has an area of 165 million ha. Approximately, 90% of the country is classified as arid and semi-arid region, most of which is faced with low rainfall, high evapotranspiration, salinization, shortage of fresh water, erosion, excessive heat and desertification. Fresh water resources are declining in the central plateau of the country as a result of overusing underground water and severe drought in recent years. Land salinization is a major limiting factor for conventional crop production in the country. Continuous cropping together with an excessive use of chemical fertilizers and ill-managed irrigation has turned hundreds of cultivated fertile fields into saline ones. These limitations have great impacts on the welfare of the farmers whose income is solely dependent to agriculture. Regarding the increasing trend in the salinity of soil and water resources, cultivation of salt tolerant medicinal plants has been suggested as one of the strategy for utilizing saline soil and water resources. One of the medicinal plants that has a long history of use in traditional medicine and has also many therapeutic properties is fenugreek (*Trigonella foenum-graecum* L.). This research was conducted to determine the salt tolerance threshold, yield reduction slope and to evaluate effects of utilizing saline water on yield (shoot dry weight) at vegetative stage under greenhouse conditions**.**

Materials and methods

In this experiment, treatments were included seven levels of salinity (0.5, 2, 4, 6, 8, 10 and 12 dS/m) obtained by mixing a saline groundwater resource (with electrical conductivity of 14 dS/m) and a fresh water resources (tap water). A leaching fraction of 30% was considered to wash out some excess salts from soil profile and preventing their accumulation in the root zone. In order to control soil salinity, the amount and electrical conductivity of both irrigation and drainage water was measured in all irrigation practices. Furthermore, athe soil salinity was monitored using a soil salinity bridge instrument. The statistical design was arranged as a complete randomized block design with three replications. In this study, different experimental models were used to determine the salt tolerance threshold, the slope of

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yield (shoot dry weight) reduction, the amount of salinity at which yield was reduced by 50% (EC_{50}) and the salt tolerance index, as well.

Results and discussion

Results showed that there was a statistically significant difference among different salinity levels. Based on the results, salinity reduced shoot height (27.66%), number of leaves (18.03%), number of branches (5.14%), number of nodes (8.77%), stem diameter (27.04%), internodes length (54.21%), mean of expanded leaves area (46.91%), root to shoot ratio (16.97%), water content (14.62%), water use efficiency (14.70%) and increased leaf thickness (73.55%) and greenness index (47.58%), however, salinity had no significant effect on special leaf area. Although salinity stress had an adverse effect on most studied traits, the trend of this effect was varied depending on the trait. Based on the linear model, the salt tolerance threshold of fenugreek and the slope of yield reduction was estimated 1.28 dS/m and 4.91 percent, respectively. However, according to non-linear models, a reduction of 10 and 25 percent in relative grain yield was occurred at 3.38 and 6.28 dS/m, respectively. Based on the results of this research, the salinity at which the relative yield decreased by 50% percent was observed at soil salinity of 11.67 dS/m.

Conclusions

In this research, the fenugreek salt tolerance index was calculated as 12.24. Therefore, based on both the salinity tolerance threshold, the slope of yield reduction and salinity tolerance index, fenugreek can be classified into the group of moderately sensitive to salinity stress at the vegetative growth stage.

***Keywords*:** Leaf area, Legumes, Plant height, Saline soils, Salt, Vegetables

Table 1. Physicochemical peroperties of soil used in the experiment before leaching

Peroperty	Unit	Symbol	Value	Method / Device	Reference
Electrical conductivity	دسی‌زیمنس بر متر	EC	11.91	EC meter, WTW Co.	–
pH	–	pH	7.48	pH meter, Metrohm Co.	–
Carbonate	Meq/lit	CO_3^{-2}	0.00	Complexometric titration	ISRIC, 1986
Bicarbonate	Meq/lit	HCO_3^-	1.21	Complexometric titration	ISRIC, 1986
Chloride	Meq/lit	Cl^-	61.8	Complexometric titration	ISRIC, 1986
Sulphate	Meq/lit	SO_4^{2-}	66.54	Computational	ISRIC, 1986
Calcium (aq)	Meq/lit	Ca^{2+}	61.1	Complexometric titration	ISRIC, 1986
Magnesium (aq)	Meq/lit	Mg^{2+}	21.18	Complexometric titration	ISRIC, 1986
Sodium	Meq/lit	Na^+	47.3	Flamephotometric	ISRIC, 1986
Aqueous Potassim	Meq/lit	K^+	little	Flamephotometric	ISRIC, 1986
Sodium absorbtion ratio	–	SAR	7.37	Computational	ISRIC, 1986
Organic matter	%	O.M.	0.02	Walkley-Black	ISRIC, 1986
Total nitrogen	%	T.N.	0.001	Computational	ISRIC, 1986
Available phosphorous	mg/kg	P_{av}	6.64	Olsen, $KHCO_3$ extractor	ISRIC, 1986
Available potassium	mg/kg	K_{av}	155	Ammonium Acetate	ISRIC, 1986
Sand	%	Sand	80.36	Hydrometric	Carter and Gregorich, 2008
Silt	%	Silt	8.64	Hydrometric	Carter and Gregorich, 2008
Clay	%	Clay	11	Hydrometric	Carter and Gregorich, 2008
Soil texture	–	Texture	Sandy loam	Soil texture triangle	Carter and Gregorich, 2008

Table 2. Chemical analysis of saline water used in the experiment

Electrical conductivity (dS/m)	pH	Cations (meq/lit)				Anions (meq/lit)				SAR
		K^+	Na^+	Mg^{2+}	Ca^{2+}	SO_4^{2-}	Cl^-	HCO_3^-	CO_3^{2-}	
14	8.26	0.41	141	42.81	22.19	22.36	184.5	1.98	0.92	24.73

Table 3. Electrical conductivity of irrigation water, total volume of water and the average salinity of soil saturated extract

Electrical conductivity (dS/m)	Total valume (lit)	Average salinity of soil saturated extract (dS/m)			
		Replicate 1	Replicate 2	Replicate 3	Average
0.5	75.01	1.46	1.37	1.37	1.40
2	62.99	3.52	3.48	3.57	3.52
4	54.01	5.40	5.45	5.43	5.43
6	47.88	7.15	6.97	7.30	7.14
8	37.38	9.36	8.82	9.36	9.18
10	32.34	10.69	10.70	10.41	10.60
12	30.24	11.51	11.56	11.62	11.56

Table 4. Analysis of variance for mean squars of measured different traits

S.O.V	df	Height	Number of leaves	Number of branches	Number of nodes	Stem diameter	Internode length	Leaf thickness
Replicate	2	4.884^{ns}	1.576^{ns}	0.0278^{ns}	0.2356^{ns}	0.0139^{ns}	0.2785^{ns}	33.286^{ns}
Salinity	6	403.73^{**}	234.53^{**}	0.2299^{**}	6.1265^{**}	1.1325^{**}	740.83^{**}	28465^{**}
Error	12	8.0519	4.3604	0.0226	0.1243	0.0117	1.2227	129.05
C.V%		*5.50*	*4.57*	*1.96*	*1.89*	*3.28*	*3.16*	*2.67*

Table 4. Continued

S.O.V	df	Shoot dry weight	Leaf area	SPAD number	Special leaf area	LS ratio	Water content	WUE
Replicate	2	0.0213^{ns}	385.89^{ns}	2.8483^{ns}	3.3194^{ns}	0.0011^{ns}	412.34^{ns}	0.0021^{ns}
Salinity	6	0.3763^{**}	4103.3^{**}	200.82^{**}	11.507^{ns}	0.0115^{**}	11953^{**}	0.0503^{**}
Error	12	0.0160	122.33	1.6619	9.2726	0.0023	385.36	0.0058
C.V%		*9.21*	*11.72*	*2.83*	*9.98*	*14.09*	*3.29*	*6.11*

**:Significant at the level of 1%, *: Significant at the level of 5%, ns: not significant

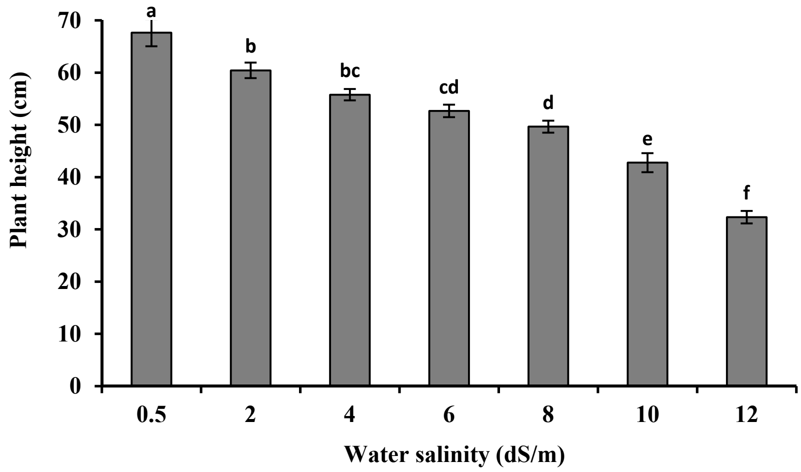

Fig. 1. Effect of different levels of salinity stress on height (cm) of fenugreek

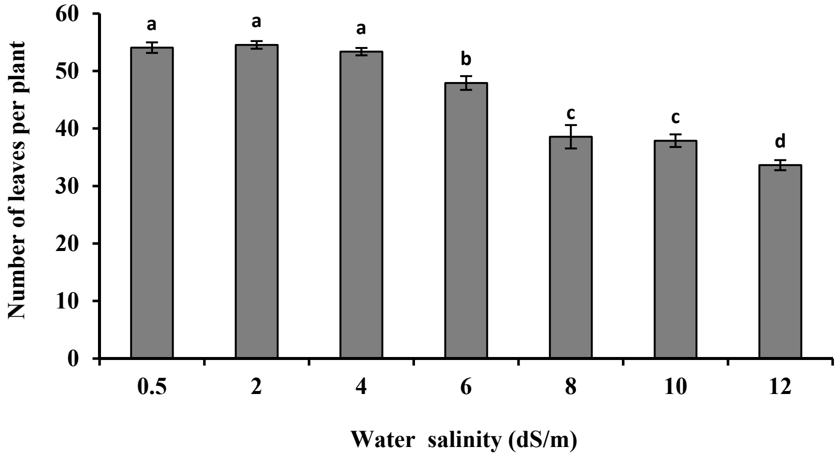

Fig. 2. Effect of different levels of salinity on the numper of leaves per plant

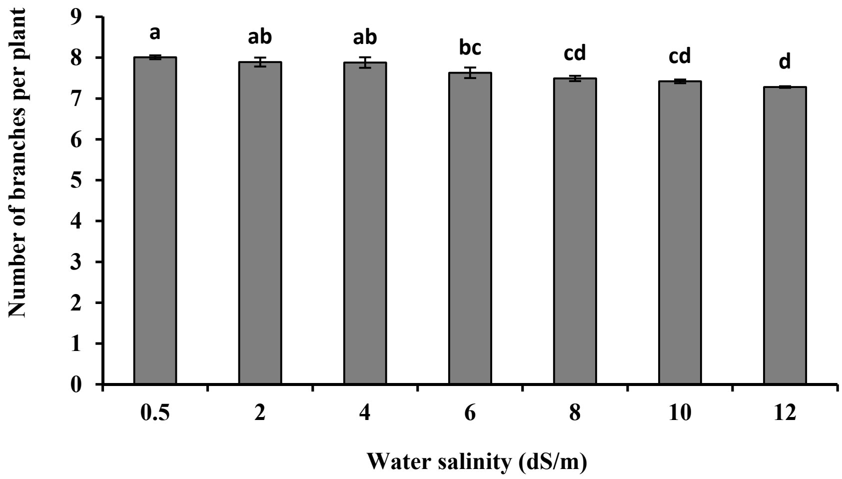

Fig. 3. Effect of different levels of salinity on the numper of branches per plant

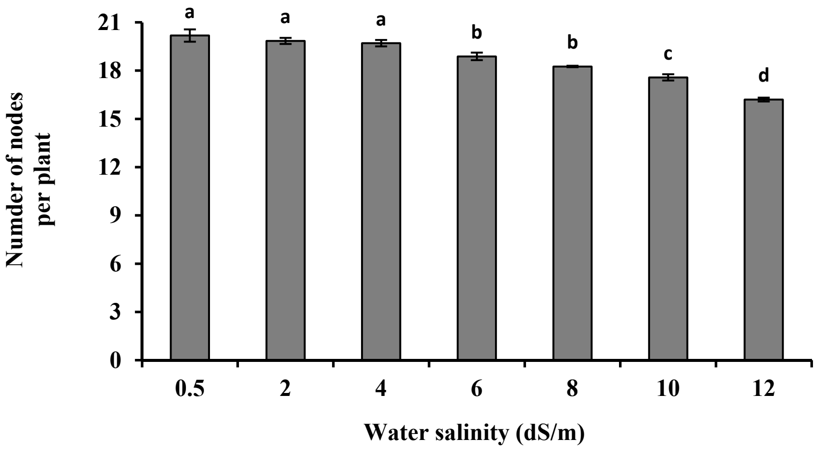

Fig. 4. Effect of different levels of salinity on the numper of nodes per plant

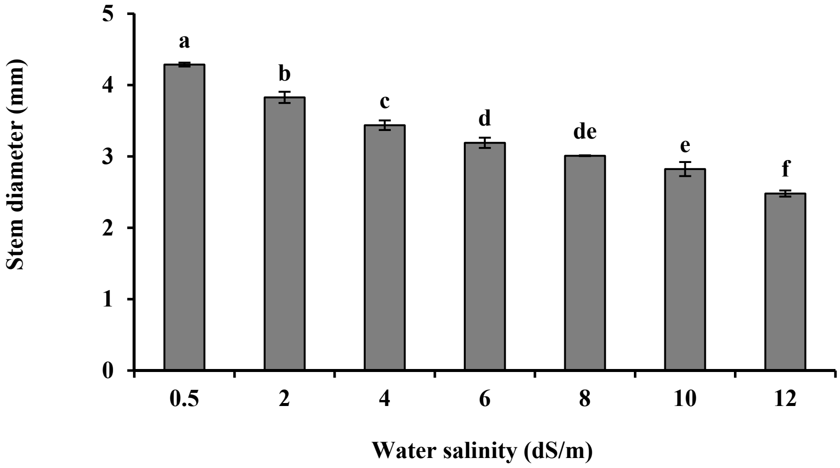

Fig. 5. Effect of different levels of salinity stress on stem diameter (mm) of fenugreek

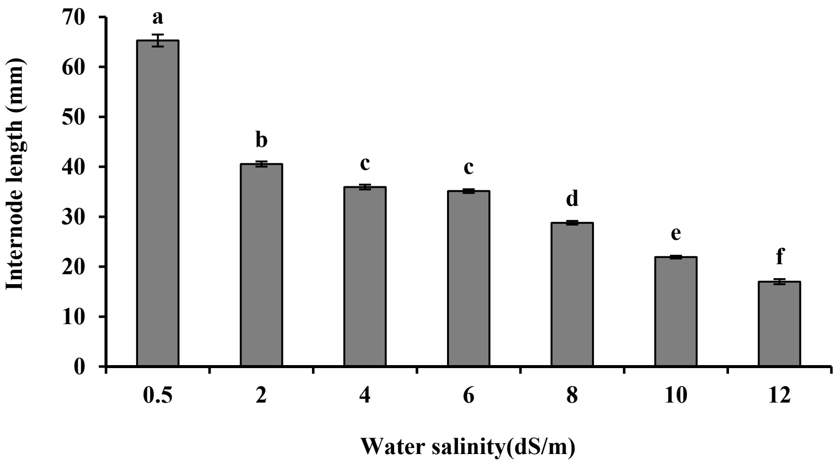

Fig. 6. Effect of different levels of salinity stress on stem internode length (mm) of fenugreek

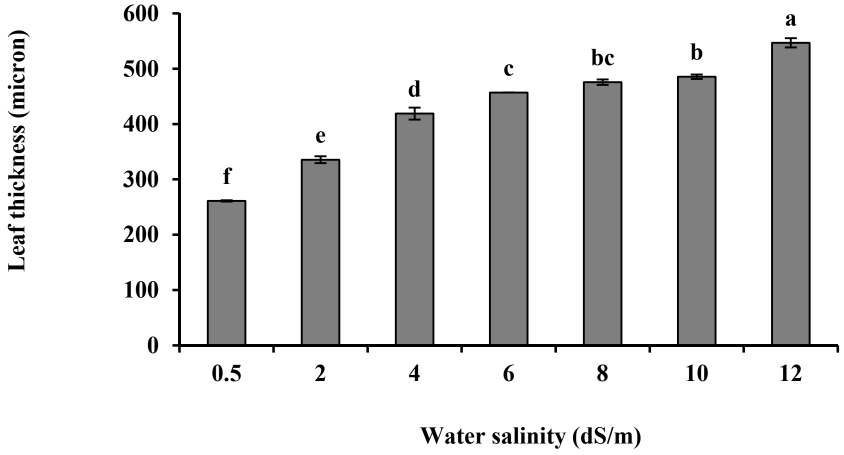

Fig. 7. Effect of different levels of salinity on leaf thickness (µm) of fenugreek

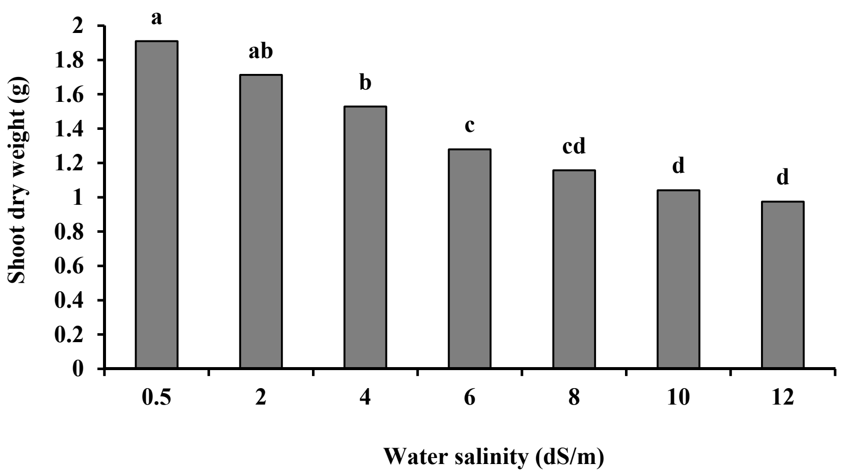

Fig. 8. Effect of different levels of salinity on shoot dry weight (g) of fenugreek

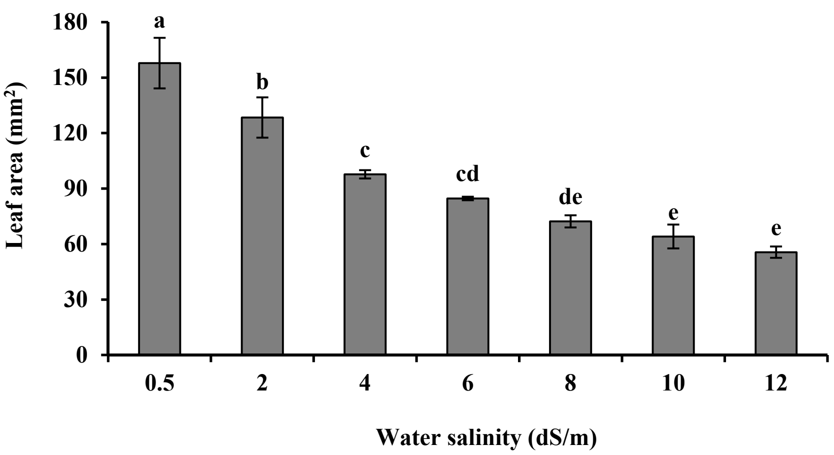

Fig. 9. Effect of different levels of salinity stress on leaf area (mm^2) of fenugreek

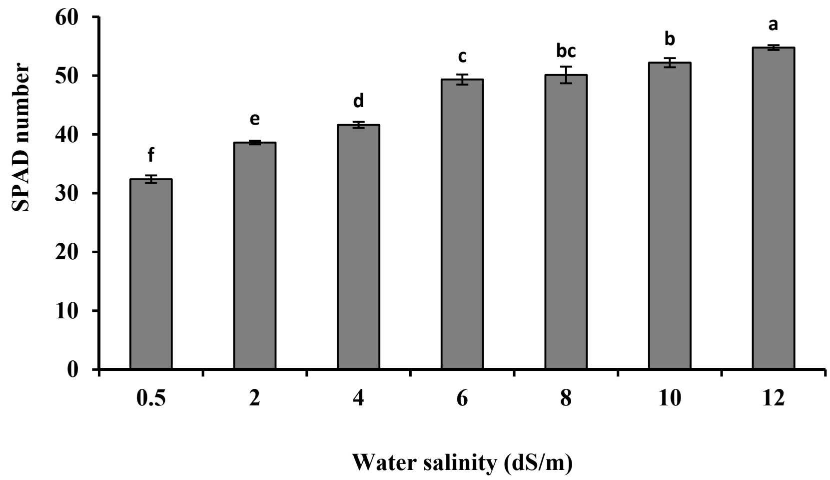

Fig. 10. Effect of different levels of salinity on leaf SPAD number of fenugreek

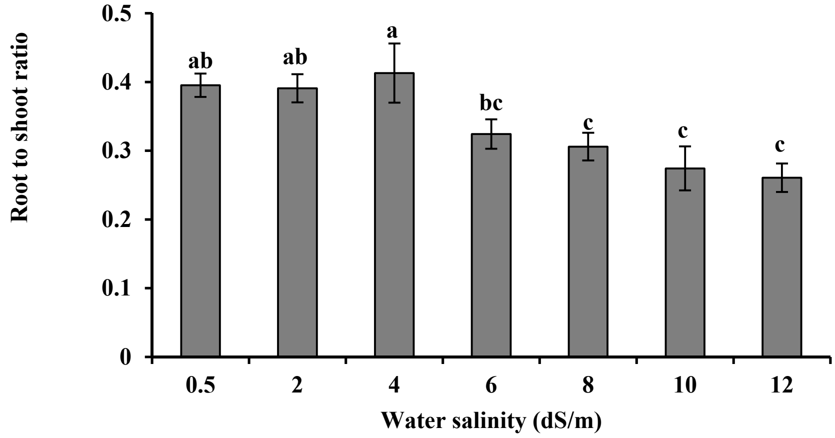

Fig. 11. Effect of different levels of salinity on the root to shoot ratio of fenugreek

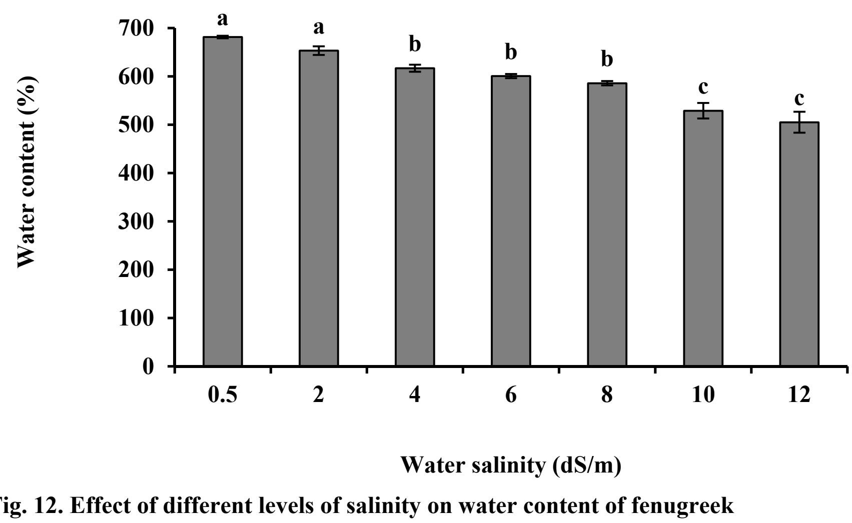

Fig. 12. Effect of different levels of salinity on water content of fenugreek

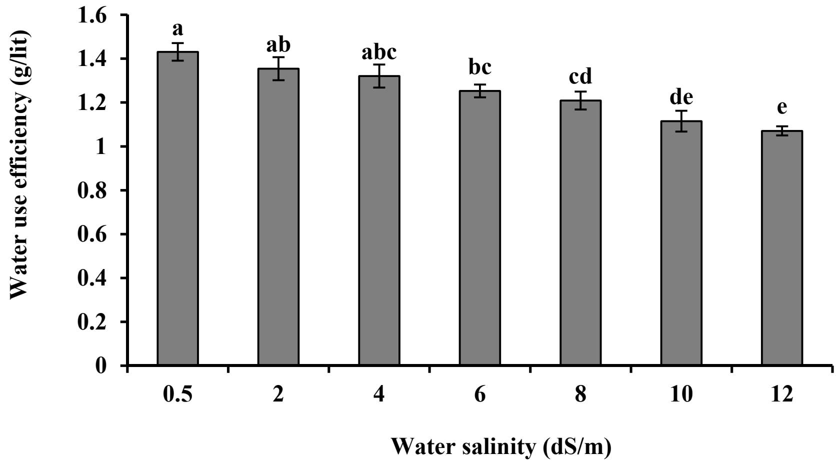

Fig. 13. Effect of different levels of salinity on water use efficiency of fenugreek

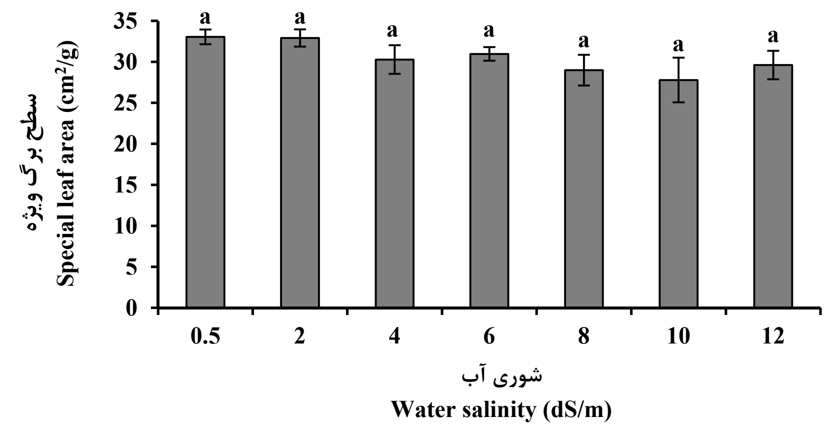

Fig. 14. Effect of different levels of salinity on special laef area (cm^2/g) of fenugreek

Table 5. Fitted functions for responses of fenugreek to salinity using experimental models

Type of model	Reference function	Fitted function	Reference
Three-piece linear model	Y=100-l*(EC-a$_0$)	Y=100-4.91*(EC-1.28)	Maas and Hoffman, 1977
Sigmoidal model	$Y = \frac{Y_m}{1+\left(\frac{EC}{EC_{50}}\right)^P}$	$Y = \frac{Y_m}{1+\left(\frac{EC}{11.67}\right)^{1.77}}$	Van Genuchten and Hoffman, 1984
Modified multi-component discount model	$Y = \frac{Y_m}{1+\left(\frac{EC}{EC_{50}}\right)^{\exp(s*EC_{50})}}$	$Y = \frac{Y_m}{1+\left(\frac{EC}{11.67}\right)^{\exp 0.572}}$	Steppuhn, Van Genuchten and Grieve, 2005a
Duble expontial factor model	Y=100*exp[a(EC)-b(EC)^2]	Y=100*exp[-0.0236(EC)-0.00323(EC)^2]	Wang *et al.*, 2002

In these functions, Y_m, Y, EC, EC_{50} are maximum yield, relative yield (%), the average of soil salinity saturated extract during the growth season (dS/m), soil salinity saturated extract for yield reduction by 50% (dS/m), respectively. a$_0$, l, p and s are the salt tolerance threshold, line slope, empirical constant and curve slope as well, and the values of a and b are the constant coefficients of each equation.

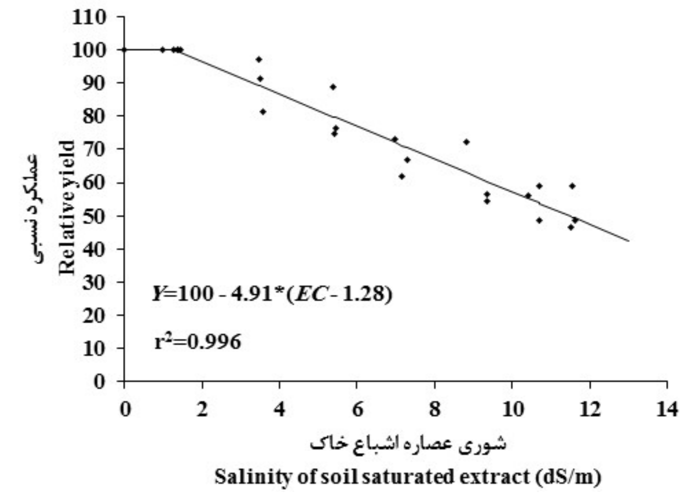

Fig. 15. Responces of dry matter ralative yield to soil salinity of saturated extract acorning to linear model.

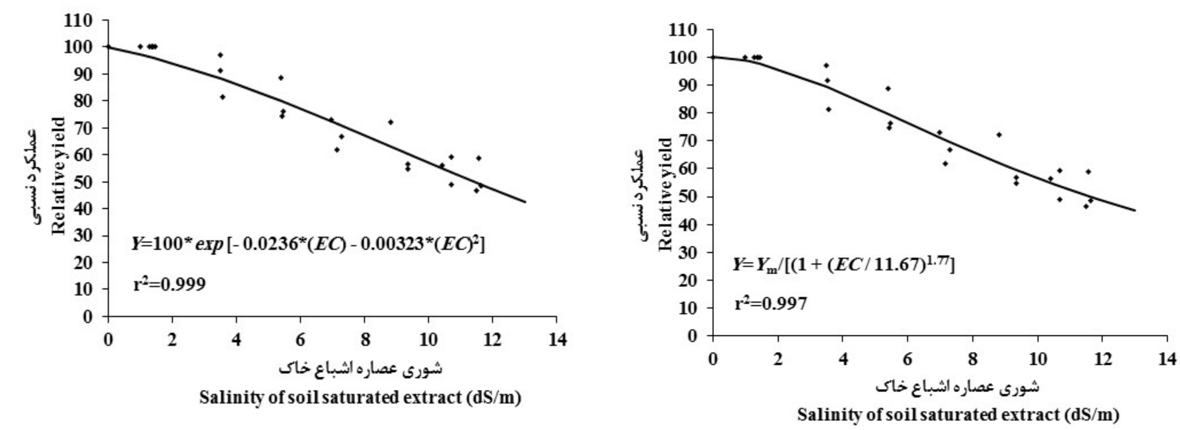

Fig. 16. Estimation of the changes in dry matter relative yield to soil salinity of saturated extract acording to non-linear models. Sigmoidal (right), expontial (left)

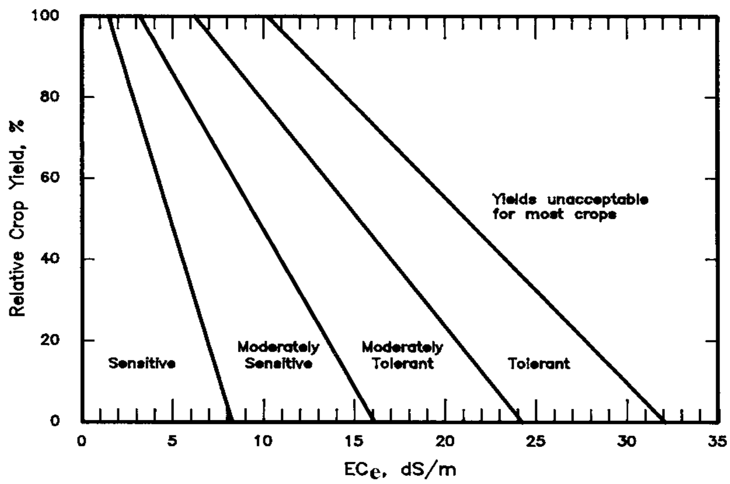

Fig. 17. Classification of crops for salinity tolerance (Adapted from Ayers and Wescot, 1989)