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Original article

Quantification of salinity stress and drought effects on fourteen ecotypes of black caraway (*Nigella sativa* L.) medicinal plant

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Extended abstract

Introduction

Environmental stresses, especially drought and salinity stresses are considered as inhibitors of plant growth and development. The salinity stress cause delay in germination, decrease in the rate and percentage of germination and delay in the emergence of roots and stems in the germination stage. It seems that if seed could pass through the germination stage under stress conditions, the seedling will have more opportunity to grow and develop, and will have the higher ability to tolerate and overcome adverse environmental conditions. This greatly depends on the biochemical and physiological structures of the seedlings. The response is also species and genotypes dependent and depends on the length and severity of the salinity, the age, and stage of development. Differences in the salt tolerance have variation among species within a genus, and of genotypes within a species. Black caraway (*Nigella sativa* L.) is an annual plant with valuable medicinal properties belong to Ranunculaceae family. Because Black caraway growth is slow at the beginning of the season, and on the other hand, salinity and drought are some limiting and effective factors on germination and other stages of plant growth, the aim of this study was to evaluate different N. sativa ecotypes in terms of tolerance to salinity and drought.

Materials and methods

In order to investigate the effects of salinity and drought stress on seed germination factors of fourteen black caraway, two separate experiments were carried out in a completely randomized design in the Seed Technology Laboratory of the University of Tehran in 2018. The treatments consisted of fourteen black caraway ecotypes (Ashkzar, Arak, Isfahan, Eqlid, Bejestan, Khaf, Khomeini Shahr, Razan, Zabol 1, Zabol 2, Sarayan, Semirum, Gardmiran, Hamedan), six salinity stress levels (0 , 40, 80, 120, 160 and 200 mM) and four levels of drought stress (0, 0.3, -0.6 and -0.9 MPa) with four replicates in each level. Salinity stress levels were due to different concentrations of sodium chloride and levels of drought stress were due to different concentrations of polyethylene glycol 6000. Distilled water was used to create a zero stress level (control treatment) in both experiments. To conduct the experiments, 50 seeds were placed on filter paper in 8 cm diameter Petri dishes containing 7 mL of each solution. Petri dishes were kept in the growth chamber at a constant temperature of 20°C. The number of seeds germinated was recorded daily until no germination was observed for two consecutive days. The Germin program was

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used to calculate germination percentage and rate of germination. In addition, to illustrate the germination response to drought stress, the hydrotime model was used.

Results and discussion

Salinity experiment

The highest Ymax (germination percentage) was found in Razan, Arak, and Ashkzar ecotypes (99.5, 99.33 and 99.16% respectively) and the lowest in Khomeini-e-Shahr ecotype (85.83%). The highest salinity tolerance threshold (X0) was detected in Semirum ecotype (37.17 mM). Arak ecotype had the highest rate of germination (0.013 per hour) in salinity conditions. Thus, Semirom ecotype was the most tolerance ecotype due to the higher salinity tolerance threshold.

Drought experiment

The minimum hydrotime constant (θH= 284.040 MPa h) was related to the Bejestan ecotype, and the lowest water potential [Ψb(50)= -0.563 MP] was observed in the Isfahan ecotype. Since there is a positive correlation between the less water potential [Ψb(50)] and the emergence percentage and rate of seedling emergence, the Isfahan ecotype was the most tolerant among biotypes that were studied.

Conclusion

In general, the results of these experiments showed that salinity and drought stresses reduced the percentage and rate of germination. Germination percentage response shape and germination rate were different between various ecotypes. Hydrotime model and salinity regression have high ability in separating ecotypes for germination components. The Bejestan and the Isfahan ecotypes are recommended for cultivation in drought conditions. In salt stress conditions, the Semirom ecotype was the most tolerant ecotype among ecotypes.

***Keywords*:** Drought tolerance threshold, Hydrotime, Regression model, Salinity tolerance threshold

Table 1. Estimate of germination parameters of salinity model for black caraway in a range of salinity. Ymax; Maximum germination percentage, X0; Salinity tolerance threshold, b; reducing slope for the response of germination percentage to salinity, R^2; Coefficients of determination.

Ecotype	Y_{max}	X_0	b	R^2	Ecotype	Y_{max}	X_0	b	R^2
Eshkzar	99.16	106.4	1.16	0.91	**Razan**	99.5	98.9	0.83	0.74
Arak	99.33	116.9	0.06	0.87	**Zabol1**	97.66	105.5	0.96	0.93
Esfahan	97.83	103.2	1.14	0.90	**Zabol2**	98.5	91.54	0.98	0.91
Eghlid	99	95.5	0.80	0.89	**Sorayan**	97.33	111	1.15	0.94
Bejestan	87.5	71.55	0.51	0.78	**Semirom**	97.62	137.7	1.48	0.97
Khaf	97.33	100.3	1.1	0.91	**Gerdmiran**	99	111.2	0.77	0.87
Khomeini Shahr	85.83	98.12	0.8	0.96	**Hamedan**	95.25	128.1	1.13	0.91

Table 2. Estimate of parameters of hydrotime model for germination of black caraway at a range of water potentials. θ_H is the hydrotime constant (MPa h); $\psi_{b(50)}$ is the fifty percent germination base water potential (MPa); $\sigma_{\psi b}$ is standard deviation of base water potential distribution in the population; R^2; Coefficients of determination.

Ecotype	θ_H	$\psi_{b(50)}$	$\sigma_{\psi b}$	R^2	Ecotype	θ_H	$\psi_{b(50)}$	$\sigma_{\psi b}$	R^2
Eshkzar	53.99	-0.452	0.134	0.95	**Razan**	36.82	-0.494	0.130	0.98
Arak	37.53	-0.490	0.177	0.96	**Zabol1**	35.76	-0.523	0.133	0.94
Esfahan	87.26	-0.563	0.163	0.93	**Zabol2**	42.69	-0.386	0.120	0.82
Eghlid	36.32	-0.437	0.141	0.97	**Sorayan**	47.28	-0.363	0.102	0.94
Bejestan	28.04	-0.383	0.183	0.97	**Semirom**	34.30	-0.506	0.117	0.97
Khaf	51.36	-0.400	0.129	0.92	**Gerdmiran**	33.14	-0.466	0.142	0.97
Khomeini Shahr	30.03	-0.340	0.195	0.91	**Hamedan**	34.34	-0.467	0.146	0.98

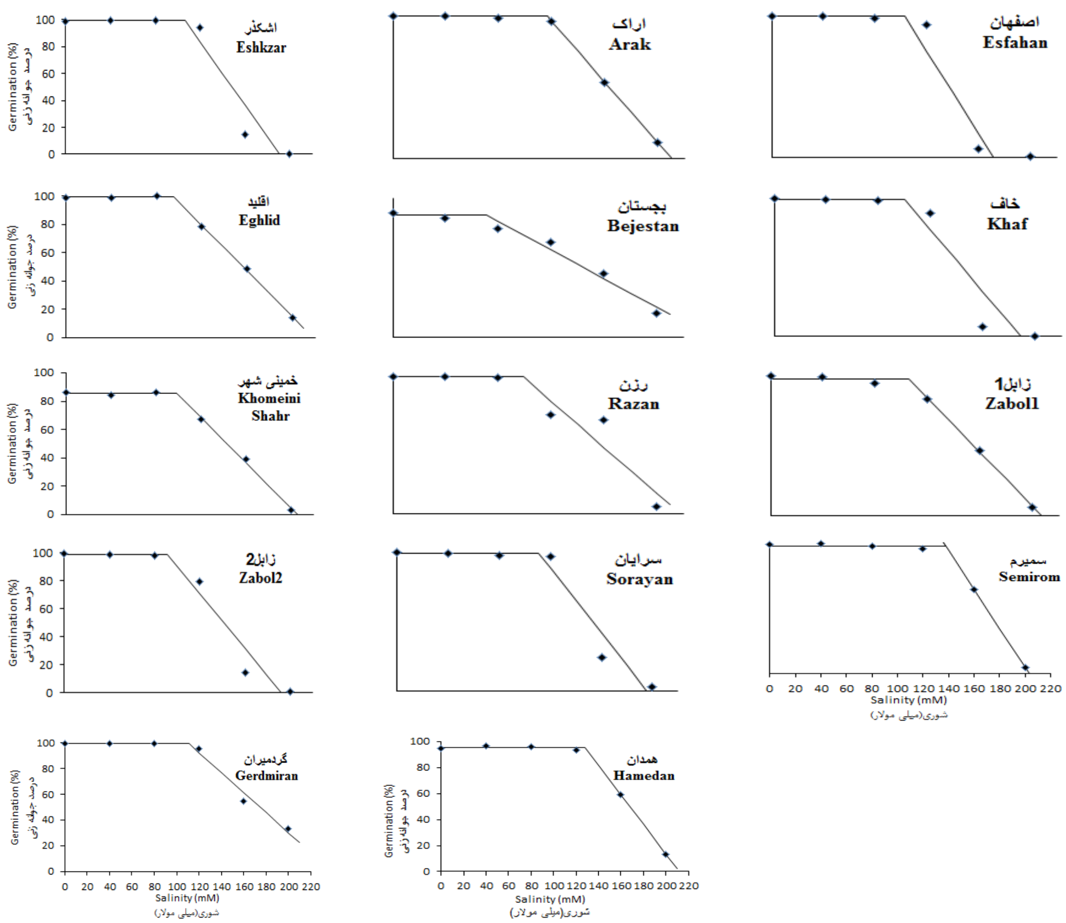

Fig. 1. Regression model used to describe the response of cumulative germination percentage of black caraway to salinity difference levels

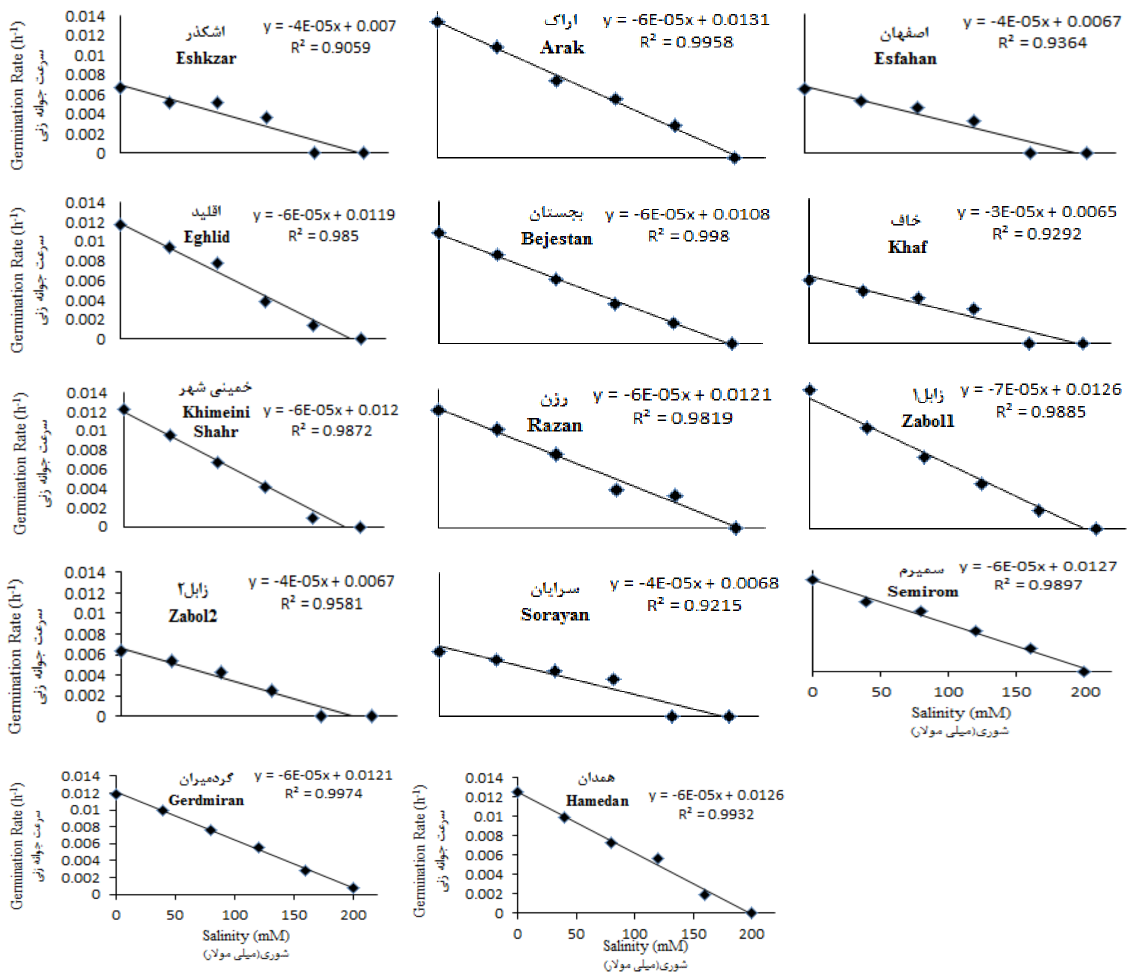

Fig. 2. Regression model used to describe the response of germination percentage of black caraway to salinity difference levels

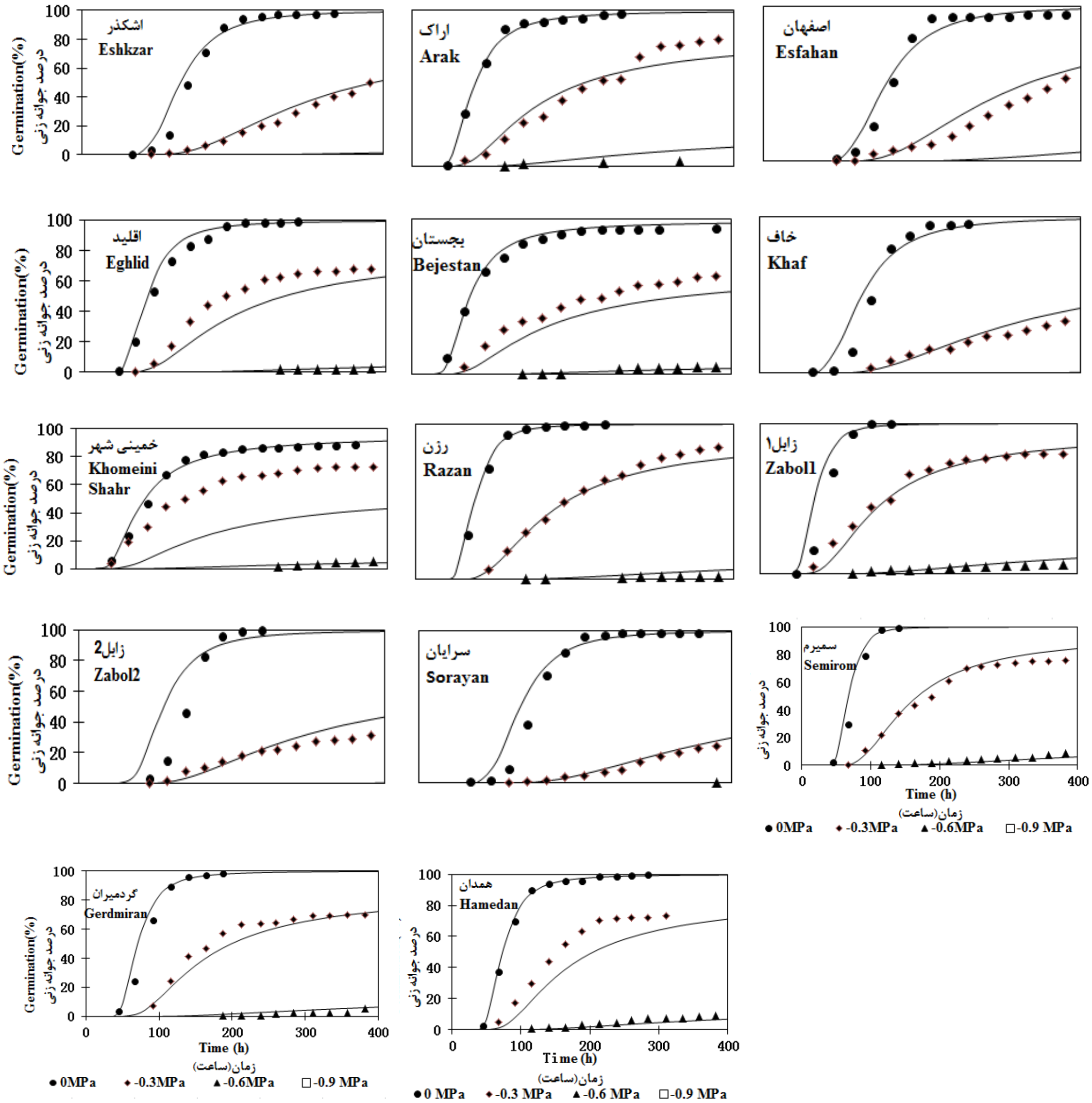

Fig. 3. Trend of cumulative germination percentage of black caraway in drought difference levels estimated by Hydrotime model. Symbols indicate interpolations of observed germination data and lines cumulative germination percentage predicted by the hydrotime model