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Short communication

Identification of suitable Iranian ecotypes of cumin for cold rainfed conditions

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ABSTRACT

Drought-tolerant cumin (*Cuminum cyminum* L.) genotypes could be used as an alternative crop in the cold drylands of Iran. In order to evaluate national cumin ecotypes for drought tolerance, 20 ecotypes of local cumin were tested in a complete randomized block design during the spring of 2013-2014. Several drought tolerance indices were calculated based on seed yield under drought and irrigated conditions. Our results showed that drought stress significantly influenced cumin performance. Seed yield in some ecotypes under drought stress was 35% lower than in non-stressed conditions. Screening Iranian cumin ecotypes using drought tolerance indices was able to discriminate accessions from Razavi-Khorasan and Southern-Khorasan provinces as being the most drought-tolerant ecotypes. Cluster analysis classified all 20 genotypes into three groups including tolerant, semi-tolerant and susceptible to drought. Variation to drought tolerance was observed between ecotypes, even those originating from the same province. It is concluded that drought-tolerant cumin ecotypes from Razavi-Khorasan and Southern-Khorasan provinces are suitable spring crops in cold drylands.

Key words: *Cuminum cyminum* L., drought indices, drylands, highlands.

Cumin (*Cuminum cyminum* L.) could serve as a useful alternative crop in the rotation of cold drylands. Cumin seed in the form of a powder serves as a spice in food flavouring, its volatile oil is used in perfumery, particularly cumin-aldehyde, which can account for as much as 40-50% of the essential oil yield, and the plant also has multiple medicinal and nutraceutical properties, including anti-allergic, anti-oxidant, anti-platelet aggregation, and hypoglycemic (Sowbhagya, 8). Cumin needs little water for its growth cycle and grows in arid and semi-arid regions of the world. It has been predicted that 350 mm of precipitation at the proper time is sufficient for normal cumin growth (Motamedi *et al*., 5). However, there is no guaranty of the timing or amount of precipitation in cold drylands and terminal drought is a typical phenomenon in Iranian cold drylands. Osmo-priming can improve the ability of cumin seeds to germinate under drought conditions (Rahimi, 6). Different cumin genotypes may display drought tolerance, influenced by genetic and environmental factors (Ahmadian *et al*., 2). Motamedi *et al.* (8) reported that Iranian cumin landraces are tolerant to drought, and number of seeds/ plant is the factor most negatively affected by drought stress.

The best prediction of drought tolerance can discriminate genotypes with similar desirable yield under stressed and non-stressed conditions while the best drought tolerance indices are those which display a high correlation with seed yield in both conditions. There are several selection criteria known as drought tolerance indices which are used to select genotypes based on their performance under two different humidity regimes. A drought tolerance index can also be defined as a function of a genotype's performance under stressed and non-stressed conditions. Stress tolerance index (STI) is a useful tool for determining the stress tolerance (TOL) potential of genotypes. It is suggested that the stress susceptibility index (SSI) can measure yield stability as well as potential and actual yields in variable environments. The objective of this study was to evaluate the response of select Iranian cumin ecotypes using five drought tolerance indices to assess whether such indices could be used as a reliable way of discriminating genotypes.

A total of 20 cumin ecotypes were evaluated in a complete randomized block design with three replications under both drought stress and non-stressed conditions at the main research station of the Dryland Agricultural Research Institute (37° 15¢ N, 46° 20¢ E, 1720 m) during the 2013-2014 growing season. The soil type was classified as Rajal Abad fine Mixed Mesic Calcixerollic Xero Chrepts, based on USDA soil taxonomy. Some meteorological data of the location has been summarized in Fig. 1. Seed of these ecotypes, which originate from sub-populations of seven populations in different provinces of Iran (Table 1), were collected from

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Table 1. Drought tolerance indices of cumin ecotypes under drought stressed and non-stressed conditions.

Ecotype	Origin /Province	MP	GMP	TOL	SSI	STI	Y_s	Y_p
EA-1	East Azarbaijan	185.95	185.12	35.10	0.78	0.72	168.4	203.5
EA-2	East Azarbaijan	212.25	211.05	45.10	0.87	0.93	189.7	234.8
Fa	Fars	187.75	186.52	42.90	0.93	0.73	166.3	209.2
Go	Golestan	199.05	198.08	39.30	0.81	0.82	179.4	218.7
Is-1	Isfahan	163.90	162.63	40.80	1.00	0.55	143.5	184.3
Is-2	Isfahan	172.80	172.75	8.00	0.20	0.62	168.8	176.8
Ke-1	Kerman	215.65	214.41	46.10	0.87	0.96	192.6	238.7
Ke-2	Kerman	205.85	204.68	43.90	0.87	0.88	183.9	227.8
Ke-3	Kerman	174.75	174.12	29.70	0.71	0.63	159.9	189.6
NK-1	Northern Khorasan	189.65	188.78	36.30	0.79	0.75	171.5	207.8
NK-2	Northern Khorasan	176.45	175.04	44.50	1.01	0.64	154.2	198.7
RK-1	Razavi Khorasan	204.55	200.73	78.70	1.46	0.84	165.2	243.9
RK-2	Razavi Khorasan	219.65	215.84	81.50	1.41	0.97	178.9	260.4
SK-1	Southern Khorasan	214.05	211.90	60.50	1.12	0.94	183.8	244.3
SK-2	Southern Khorasan	228.80	226.48	65.00	1.12	1.07	196.3	261.3
Se-1	Semnan	196.65	195.43	43.70	0.90	0.80	174.8	218.5
Se-2	Semnan	189.00	187.18	52.40	1.10	0.73	162.8	215.2
Ya-1	Yazd	180.30	177.72	60.80	1.30	0.66	149.9	210.7
Ya-2	Yazd	181.00	178.38	61.40	1.31	0.67	150.3	211.7
Ya-3	Yazd	189.95	188.11	52.70	1.10	0.74	163.6	216.3
	Mean						170.2	218.6
	(LSD $p \leq 0.05$)						33.6	48.1

MP = Mean production; GMP = Geometric mean productivity; SSI = Stress susceptibility index; STI = Stress tolerance index; TOL = Tolerance index. Y_p and Y_s are mean seed yield under non-stressed and stressed conditions, respectively. LSD 5%, least significant differences at 0.05 probability level

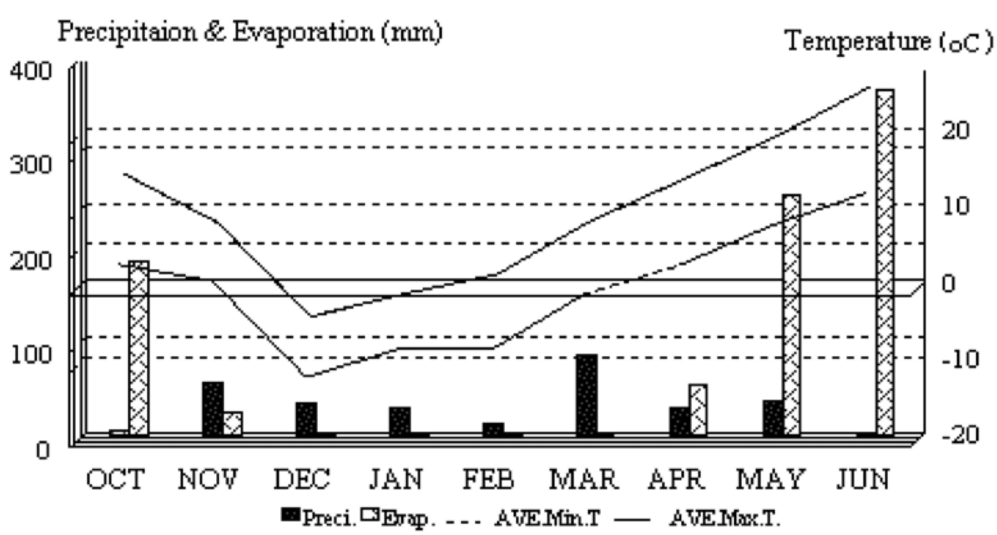

Fig. 1. Monthly precipitation, evaporation and mean temperatures during 2013-2014 at Maragheh Research Station, Iran.

Kerman and Khorasan Agricultural Research and Natural Resource Centres. Fertilizers were applied prior to sowing at 50 kg/ha in the form of ammonium phosphate and 100 kg/ha as urea. The ecotypes were planted in plots with 6 rows, each 4 m in length, with a row spacing of 30 cm and a distance between plants of about 5 cm. The ecotypes were sown on April 3, 2014. Stressed plots were not irrigated, while non-stressed plots were irrigated after sowing. Subsequent irrigations were carried out after 150 mm evaporation from class A pan.

Some drought tolerance indices including stress susceptibility index (SSI), stress tolerance index (STI), geometric mean productivity (GMP), tolerance index (TOL) and mean production (MP) were calculated using standard equations 1-5:

$$SSI = (1-(Y_s/Y_p)) / (1-(\bar{Y}\bar{Y}_s/\bar{Y}\bar{Y}_p)) \quad \text{Eq. 1}$$

$$STI = (Y_s \times Y_p) / (\bar{Y}\bar{Y}_p)^2 \quad \text{Eq. 2}$$

$$GMP = \sqrt{Ys \times Yp}\ \overline{\sqrt{Ys \times Yp}} \quad \text{Eq. 3}$$

$$TOL = Y_s - Y_p \quad \text{Eq. 4}$$

$$MP = (Y_s + Y_p)/2 \quad \text{Eq. 5}$$

where, Y_s, Y_p, $\bar{Y}\bar{Y}_s$ and $\bar{Y}\bar{Y}_p$ represent yield under stress conditions, yield under non-stress conditions, mean yield under stressed conditions, and mean yield under non-stressed conditions, respectively. The relationship between drought tolerance indices was evaluated by correlation studies. Grouping of different ecotypes based on various drought tolerance indices was performed by cluster analysis using Ward's method. SPSS (version 10) software was used for correlation studies and clustering (SPSS, 9).

Several Iranian cumin genotypes showed drought tolerance (Table 1), in cold highlands that receive less than 350 mm average precipitation over the long term. This would provide breeding material with traits suited to these conditions. There was large variability in drought tolerance among the 20 ecotypes as assessed by the five drought tolerance indices. SK-2 and RK-2 were found to be drought tolerant with highest STI and seed yield under irrigation (non-stressed condition) while IS-1 and IS-2 were most drought sensitive (lowest STI and seed yield) (Table 1). Other cumin ecotypes were either semi-tolerant or semi-sensitive to drought stress.

To determine the most desirable drought-tolerant criteria, the correlation coefficients between Y_p, Y_s, and other drought tolerance indices were calculated (Table 2). A suitable index must have a significant correlation with seed yield under both conditions. The highest positive correlation with seed yield was observed between MP and Y_p and between STI and Y_s, while the highest negative correlation (-0.16) was found between SSI and yield under drought (Table 2). Tabatabaii *et al.* (7) found that there was no correlation between stress susceptibility and yield under optimum conditions. Y_s was significantly and positively corrected with MP, GMP and STI and Y_p was significant and positively correlated with MP, GMP, TOL, SSI and STI (Table 2), indicating that all of these criteria were effective in identifying high-yielding genotypes cultivars under water-stressed and drought conditions.

Cluster analysis groupped the 20 ecotypes into three groups with 6, 4 and 10 ecotypes (Fig. 2). The first tolerant group had the highest MP, GMP and STI, and thus these ecotypes were considered to be the most desirable for both growth conditions. The

Table 2. Coefficient of correlation between studied criteria.

	MP	GMP	TOL	SSI	STI	Y_s
GMP	0.99**					
TOL	0.55*	0.51*				
SSI	0.32	0.27	0.96**			
STI	0.99**	0.99**	0.51*	0.27		
Y_s	0.88**	0.90**	0.09	-0.16	0.90**	
Y_p	0.95**	0.94**	0.78**	0.59**	0.94	0.69**

MP = Mean production; GMP = Geometric mean productivity; SSI = Stress susceptibility index; STI = Stress tolerance index; TOL = Tolerance index. Y_p and Y_s are mean seed yield under non-stressed and stressed conditions, respectively *, ** correlation is significant at $P < 0.05$ and 0.01, respectively.

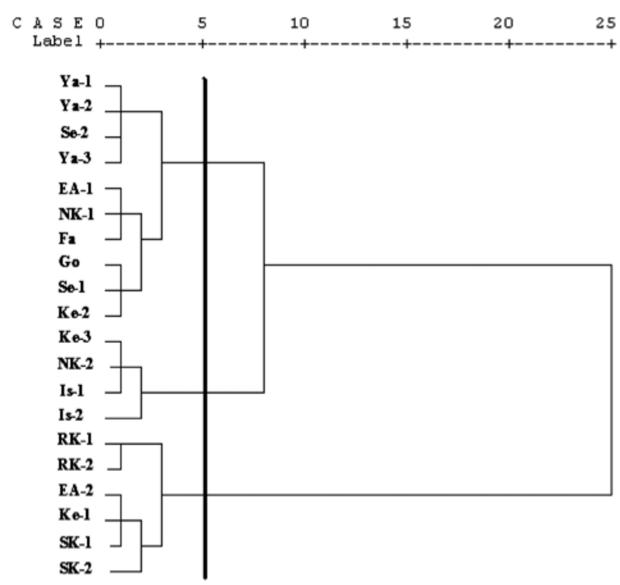

Fig. 2. Dendrogram using Ward's method between groups showing classification of cumin ecotypes based on some drought tolerance indices.

second group had intermediate index values and was thus considered to be stable in non-stressed conditions, *i.e.*, moderately tolerant. The third group included ecotypes with higher SSI values, *i.e.*, they were susceptible to drought and could be suitable ecotypes for irrigated conditions. Some ecotypes from the same province were clustered in different groups, demonstrating intra-provincial variation in drought tolerance. This variability has allowed for the selection of suitable cumin ecotypes for production in the cold, drought highland areas of Iran.

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