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Original article

Evaluation of of Iranian rye (*Secale cereale* L.) ecotypes under late season drought stress

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Extended abstract

Introduction

Rye is one of the imoptant cereals that have wide range of adaptation, its ability to grow and produce high yield in poor soil, has made it possible to exploit unfertilized lands. Since rye is a native plant of Iran, its ecotypes are predicted to be valuable genetic resources for adapting to the climatic conditions of this region. Based on the results of previous evaluations on the high adaptability of this plant, this study aims to determine the effects of drought stress on grain and forage yield in winter rye ecotypes.

Material and methods

In the current research project, 9 rye ecotypes, along with cultivar of rye (Danko), were evaluated for drought stress tolerance in a randomized complete block design with three replications in two cropping seasons (2016-17 and 2017-18) in the experimental field of Seed and Plant Improvement Institute. Morphological, phenological and agronomic traits as well as stress tolerance indices were calculated and their relationship was evaluated. Ecotypes were evaluated in plots containing 4 three-meter manually cultivated lines in two separate experiments, including normal and irrigation discontinuation after plant establishment. Growth was irrigated, while drought test ecotypes were irrigated in only two stages of planting and plant establishment. The beginning of the stalking stage (Z30) is considered to be a good time to harvest forage so that the maximum forage is obtained without damaging the spike buds (Kottmann et al., 2013). Fodder and grain yields were taken from one square meter of the middle section of the two middle lines of the plot.

Results and Discussions

Combined analysis of variance and mean comparision showed that drought stress accelerated phenological stages of the plant growth. Drought stress treatment caused a significant reduction in seed weight and grain yield in the ecotypes studied (83.29 and 29.66% respectively). Principle component analysis indicated that in both years ecotypes with early maturity had higher Stress Tolerance Index. Overall, the results of the components analysis and the evaluation of the position of the trait vectors relative to each other indicated that in both years the stress tolerance index vectors in the quarter are opposite to the phenological

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traits. Therefore, in both years, ecotypes that had lower values in the trait of day to spike emergence, or in other words, were earlier, had a higher tolerance index. Comparison of meteorological data of stress intensity index (SI) in the first and second years of the experiment and study of the reaction of rye ecotypes to drought stress in these two years showed that in the first year of the experiment when more severe drought stress was applied, Ecotype No. 119 compared to cultivar Danko excelled. While in the second year of the experiment, when the stress intensity was milder, Danko cultivar produced more yield.

Conclusion

In assessing the reaction of plants to stress, the severity of stress is of great importance, and this greatly affects the results of research. In this study, which evaluated the reaction of rye ecotypes to drought stress in two crop years, according to meteorological information, the distribution and different amount of rainfall in these two years were different. This indicates that in the first year, the occurrence of drought stress at the end of the season occurred earlier. A study of the reaction of rye ecotypes to drought stress in these two years also showed that in the first year of the experiment, when the drought stress was more severe, the ecotype No. 119 was superior to the Danko cultivar. While in the second year of the experiment, which was moderately intense, the Danko cultivar produced more performance. This indicates that the potential yield is higher in the Danco cultivar and it makes it superior in mild stress conditions, but in severe drought stress conditions, was less tolerant rather than No. 119 ecotype. This indicates higher adaptability and performance stability in native ecotypes, which is the result of their evolution over the years in the region's climatic conditions. In general, results indicated that ecotypes number 4 (KC13139) and number 119 (TN06-243) and Danko cultivar had higher tolerance to drought stress than other rye ecotypes. Therefore, these ecotypes can be used for further evaluations and application in breeding programs.

***Keywords*:** Forage, Genetic resources, Stress index, Tolerance, Yield

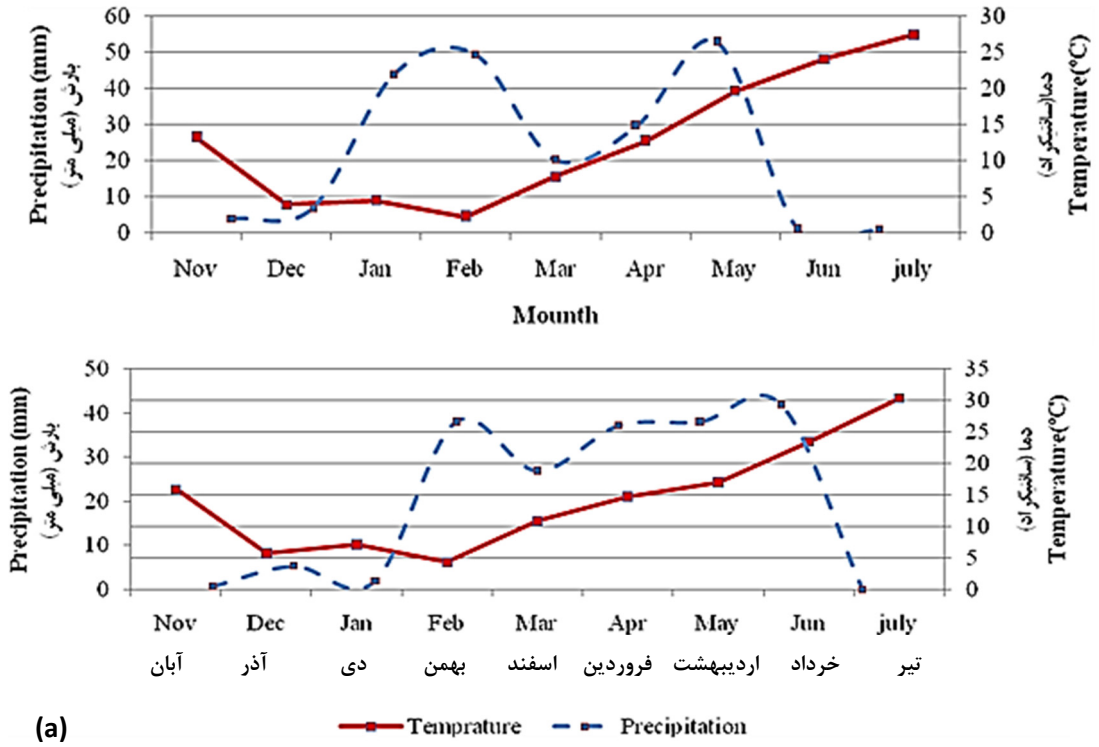

Fig. 1. Pattern of temperature and precipitation change in 2016-2017(a) 2017-2018 (b) cropping season in Karaj

Table1. Information of rye ecotypes evaluated in drought stress experiment

Number	Ecotype/Cultivar	TN	province	Origin
1	4	110026	Unknown	Iran
2	19	110072	Unknown	Iran
3	26	110085	Unknown	Iran
4	35	KC13139	Unknown	Iran
5	40	TN06-3	Fars	Iran
6	46	TN06-22	Azarbaijan Sharghi	Iran
7	78	TN06-91	Azarbaijan Sharghi	Iran
8	108	TN06-220	Kerman	Iran
9	119	TN06-243	Hamedan	Iran
10	Danko	-		-

Table 2. Soil analysis results for research field of Seed and Plant Improvement Institute (Karaj)

depth	EC	pH	OC	P	K	Texture	K^+	Na^+	Mg^{++}	Ca^{++}	SO_4^{--}	Cl^-	HCO_3^-	SAR
cm	$dS.m^{-1}$		٪	----$mg.kg^{-1}$-----			---------- $meq.l^{-1}$ ----------							
0-30	1.26	8.5	0.47	5.29	228	C.L	0.03	3.4	3.3	6.3	3.6	5.3	3.7	1.55

Table 3. Combined analysis of variance for traits in rye ecotypes in two growing seasons under normal and stress conditions

S.O.V	d.f	Days to Heading	Days to flowering	Flag leaf area	Dry forage yield	1000 Grain weight	Grain yield
Year (Y)	1	1470**	1366.87**	1647158**	1002081.1**	4.88*	626716.8**
Drought (D)	1	83.33^{ns}	60.21^{ns}	107249.1^{ns}	868203.7^{ns}	46.16^{ns}	1678284.4*
Y * D	1	2.7^{ns}	81.67**	96657.8^{ns}	6298.62^{ns}	25.49**	2864.564^{ns}
Rep (Y * D)	8	2.83	5.83	35676.6	25554.45	0.49	2313.8
Ecotype (E)	9	40.33**	57.88^{ns}	70071.24^{ns}	13215.06^{ns}	0.76^{ns}	8751.8^{ns}
E * Y	9	4.70^{ns}	18.97**	35724.88^{ns}	20810.97^{ns}	0.46**	6833.1**
E * D	9	5.52^{ns}	7.37^{ns}	19084.72^{ns}	14506.43^{ns}	0.09^{ns}	2663.5^{ns}
Y * D * E	9	4.99^{ns}	10.21*	35111.55^{ns}	19618.69^{ns}	0.09^{ns}	1215.02^{ns}
Error	72	6.87	3.95	20018.6	10475.6	0.11	1942.02
CV%		*1.67*	*1.18*	*15.19*	*16.9*	*8.58*	*13.03*

**and* significant at the 1% and 5% probability levels, respectively.

Table 4. Mean comparison of traits in rye ecotypes in 2 years study under drought and normal condition (LSD 5%)

Condition	Days to Heading	Dry Forage yield	1000 Grain weight	yield Grain
	kg/ha	g	kg/ha	
Normal	157.48	5735.5	44.59	4040.1
Drought	155.51	4034.3	32.19	674.8
LSD	*17.03*	*1007.9*	*52.3*	*554.9*

Table 5. Correlation coefficients of traits in normal (above diagonal) and stress condition (below diagonal) in first year

		1	2	3	4	5	6	7	8	9	10
1	**Days to Heading**	1	0.809**	-0.008	-0.010	-0.704*	0.429	0.192	0.639*	-0.402	-0.375
2	**Days to Flowering**	-0.130	1	0.237	0.135	-0.828**	0.300	0.054	0.537	-0.506	-0.462
3	**Leaf area**	-0.454	0.654*	1	0.886**	0.017	0.564	0.567	0.487	0.326	0.375
4	**Dry Forage Yield**	-0.368	-0.263	0.024	1	0.092	0.349	0.384	0.266	0.283	0.320
5	**Grain Weight**	-0.568	-0.166	0.248	0.901**	1	-0.255	-0.102	-0.393	0.272	0.245
6	**Grain yield**	-0.493	0.337	0.716*	0.594	0.703*	1	0.946**	0.932**	0.636*	0.675*
7	**Mean Productivity**	0.189	0.371	0.593	-0.186	-0.105	0.482	1	0.763*	0.704*	0.734*
8	**Tolerance**	0.576	0.166	0.135	-0.646*	-0.636*	-0.198	0.763*	1	0.080	0.123
9	**Geometric MeanProductivity**	-0.361	0.418	0.769**	0.409	0.516	0.959**	0.703*	0.079	1	0.99**
10	**Stress Tolerance Index**	-0.308	0.395	0.760*	0.409	0.534	0.950**	0.725*	0.111	0.993**	1

**and* significant at the 1% and 5% probability levels, respectively.

Table6. Correlation coefficients of traits in normal (above diagonal) and stress condition (below diagonal) in second year using Pearson method

		1	2	3	4	5	6	7	8	9	10
1	Days to Heading	1	0.776**	0.387	-0.195	-0.098	0.070	-0.087	0.383	-0.126	-0.113
2	Days to Flowering	-0.126	1	0.339	0.008	0.309	0.380	0.249	0.464	0.210	0.239
3	Leaf area	-0.054	0.686*	1	0.372	0.080	-0.109	-0.246	0.257	-0.269	-0.275
4	Dry Forage Yield	0.033	-0.769**	-0.376	1	-0.314	-0.340	-0.259	-0.335	-0.228	-0.258
5	Grain Weight	0.084	-0.352	0.156	0.806**	1	0.682*	0.606	0.478	0.578	0.616
6	Grain yield	-0.248	-0.506	-0.662*	0.304	-0.026	1	0.934**	0.601	0.896**	0.914**
7	Mean Productivity	-0.038	-0.674*	-0.616	0.529	0.267	0.898**	1	0.275	0.996**	0.997**
8	Tolerance	0.456	-0.402	0.069	0.517	0.651*	-0.177	0.275	1	0.185	0.227
9	Geometric mean productivity	-0.101	-0.647*	-0.628	0.486	0.205	0.944**	0.992**	0.155	1	0.997**
10	Stress Tolerance Index	-0.079	-0.678*	-0.644*	0.536	0.257	0.923**	0.996**	0.211	0.996**	1

**and* significant at the 1% and 5% probability levels, respectively.

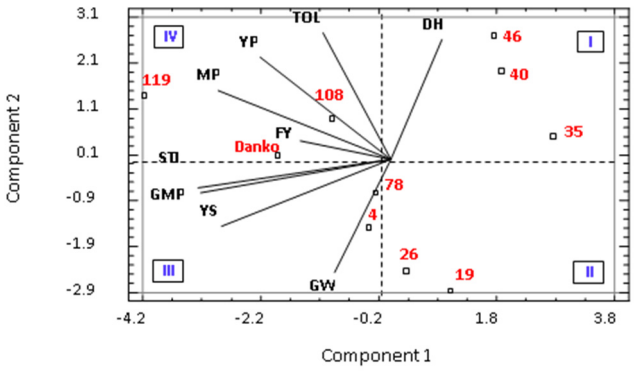

Fig.2. Bi-plot of first two principal components for characters and stress indices in rye ecotypes in water stress condition in first year (STI: stress tolerance index, GMP: geometric mean productivity, TOL: Tolerance, MP: Mean productivity, FY: Forage yield, YS: Stress grain yield, YP: Non stress grain yield, DH: days to Heading GW: Grain weight)

Table 7. Eigen values, relative variance and coefficients of principle components in rye ecotypes under water stress condition in first year

Traits	Component 1	Component 2
Days to Heading	0.1249	0.4687
Forage Yield	-0.2208	-0.0731
Grain Weight	-0.1361	-0.4443
Stress Grain Yield	-0.4139	-0.2615
Non stress Grain Yield	-0.3199	0.4011
Mean Productivity	-0.4209	0.2705
Tolerance	-0.1656	0.4954
Geometric Mean Productivity	-0.4648	-0.1310
Stress Tolerance Index	-0.4717	-0.1105
Eigenvalue	4.17	3.39
Percent of Variance	46.37	37.73
Cumulative Percentage	46.37	84.11

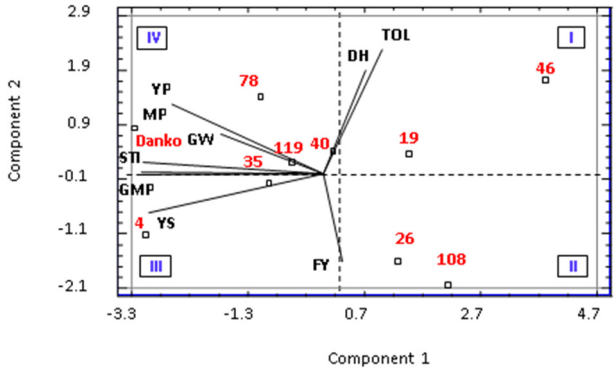

Fig. 3. Bi-plot of first two principal components for characters and stress indices in rye ecotypes in water stress condition in second year (STI: Stress tolerance index, GMP: geometric mean productivity, TOL: Tolerance, MP: Mean productivity, FY: Forage yield, YS: Stress grain yield, YP :Non stress grain yield, DH: days to Heading GW: Grain weight)

Table 8. Eigen values, relative variance and coefficients of principle components in rye ecotypes under water stress condition in second year

	Components		
Traits	**1**	**2**	**3**
Days to Heading	0.1031	0.5043	-0.1998
Forage Yield	0.0463	-0.4308	0.5735
Grain Weight	-0.2510	-0.1945	-0.4845
Stress Grain Yield	-0.4257	0.1916	-0.0979
Non stress Grain Yield	-0.3681	0.3404	0.3465
Mean Productivity	-0.4404	0.0580	0.1170
Tolerance	0.1426	0.6050	0.4935
Geometric mean productivity	-0.4430	-0.0054	0.0707
Stress Tolerance Index	-0.4436	0.0060	0.0658
Eigenvalue	5.02	1.59	1.12
Percent of Variance	55.85	17.23	2.40
Cumulative Percentage	55.85	73.09	85.55