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Original article

Evaluation of yield and drought tolerance indices in pure and intercropping of bread wheat (*Triticum aestivum* L.) genotypes under different nitrogen application

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Extended abstract

Introduction

World demand for yield of bread wheat (*Triticum aestivum*) and also other grain cereals is growing, consequently wheat yield production for food security needs to be increased (Curtis and Halford, 2014). Global average yield loss is about 17% due to variety of reasons which can be up to 70% as a consequence of drought stress. A wide range of Iran's wheat cultivating lands is located in dry and semi dry region and each year wheat yield loss occurs due to drought stress. Many researchers believe that the most sensitive stage of wheat growth to drought stress commences from flowering stage and water deficiency in this stage affects on1000- seed weight during seed filling period (Abid et al., 2016).

Materials and methods

This research was conducted at Darab College of Agriculture and Natural Resources, located at 7 km out of Darab city with longitude of 54° 26' and latitude of 28° 45', and 1180 m altitude above sea level. Field experiment was conducted as split factorial in randomized complete block design with three replicates. The factors included of irrigation regimes in two levels of normal irrigation (a1: control) and cut-off irrigation from late flowering to physiological maturity (a2: water stress), nitrogen fertilizer treatments in three levels: 33% less than recommended kg In hectare 180 (B1), the recommended amount on the basis of experimental soil was 120 (B2) kg ha^{-1} and 33% higher than the recommended level of 160 kg (B3) and the treatment of cultivation systems in four levels (using Three genotypes of bread wheat with different maturity: pure cultivation of Sirvan (intermediate maturity) (C1), pure cultivation of line S-92-19 (early maturity) (C2) pure cultivation of Khalil cultivar (late maturity) (C3) and mixed cultivation of Sirvan + Khalil + S-92-19 with the ratio of 1: 1: 1. Soil sampling and analysis was performed at depths of 0-15 and 30-15 centimeters before the experiment.

Results and discussion

Results of analysis of variance showed that the interaction of water stress × cropping system, nitrogen × cropping system, nitrogen × water stress and the interaction of water stress × nitrogen had a

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significant effect on all traits. The effect of water stress × cropping system × nitrogen was significant for all traits (table 2). The results of mean comparison showed that the highest yield in this experiment obtained in the treatment of intercropping of Sirvan, Khalil and S-92-19 (7742.7) under optimal irrigation and 120 kg ha-1 of nitrogen. Also the lowest amount of grain yield (3209.3) was obtained in pure cultivation of Khalil using 160 kg ha-1 of nitrogen under water stress conditions. Drought tolerance indices were calculated in this experiment and results demonstrated that YI, YSI, STI, GMP and MP were the highest for genotype intercropping emphasizing that the intercropping of genotypes was the most tolerant treatment in this experiment. Moreover, the SIIG index showed that the intercropping of genotypes is the ideal treatment in terms of water stress tolerance in this study.

Conclusion

The intercropping of genotypes is one of the strategies to promote the sustainability of wheat production by increasing the variation in the cultivation system of this product. The results of this study showed that water stress after flowering stage until the end of the growing season has a significant effect on grain yield. The use of drought tolerance indices is a common method to find the most tolerant genotypes. These indices were used in this study to compare different cropping systems. SIIG index was used to integrate all drought tolerance indices and proved that intercropping is superior compared to all pure cropping systems used in this experiment. Therefore, in warm and dry areas of southern Iran, where there is a risk of drought in the end of the season or tropical winds, intercropping of genotypes can be used as an agro-ecological solution to reduce the negative effects of drought and high temperature.

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Keywords**:** Row intercropping, Wheat cultivars, Water stress, Selection of ideal genotypes

Table1. Physicochemical characteristics of the soil depths of 0 to 30 cm

Ec	Clay	Silt	Sand	N	OC	P	K	pH
$ds.m^{-1}$	---------------------------------%---------------------------------					--------$mg.kg^{-1}$---------		
1.15	18.76	40.16	41.08	0.16	0.7	65	120	7.85

Table 2. Analysis of variance of water stress, nitrogen and cropping system on yield and yield components

S.O.V	df	No. of seeds per spike	No. of spikes per m^2	1000-seed weight	Biological yield	Grain yield
Replication	2	2.55^{ns}	1422.59^{ns}	10.58^{ns}	2576666.7*	110686.79^{ns}
Water stress(A)	1	18.04^{ns}	61250^{ns}	172.82**	32216346.4*	61274295.01**
Main Plot Error	2	3.59	4163.65	0.85	711529.3	91722.93
Nitrogen(B)	2	163.32**	40614.87**	20.09^{ns}	1168530.1^{ns}	8848757.63**
Cultivation system (C)	3	1417.97**	173806.45**	170.41**	35825508**	8308457.05**
A × B	2	29.23**	33252.87**	31.88*	4426081.9**	302744.01**
A ×C	3	160.41**	46034.33**	7.07^{ns}	2886739.9*	421035.61**
B × C	6	69.73**	48787.45**	14.44^{ns}	5370649.5**	1518597.55**
A ×B × C	6	88.45**	27717.20**	44.08**	3522998.8**	156898.61**
Subplot Error	44	5.14	2516.13	6.72	700742.5	47855.10
CV (%)		*4.66*	*8.16*	*6.12*	*7.01*	*4.09*

ns, * and **: Non-significant, significant at 5 and 1% probability levels, respectively.

Table 3. Comparison of the effect of triple interaction of water stress and nitrogen fertilizer on cropping system on yield components of bread wheat cultivars (C1: pure crop cultivar Sirvan, C2: pure crop line S-92-19, C3: pure crop cultivar Khalil, C4: Mixed crop cultivation with a ratio of 1: 1: 1)

Treatments						
Irrigation regimes after flowering	Nitrogen	Cropping system	No. of seeds per spike	No. of spikes per m^2	1000-seed weight (g)	Biological yield (kg ha^{-1})
Optimal irrigation	80 kg h^{-1}	C1	45.10^{b}	384.5^{c}	48^{a}	12536.1^{b}
		C2	51.65^{ab}	677.0^{a}	42^{b}	10066.6^{c}
		C3	55.00^{a}	518.0^{b}	47^{ab}	13200.0^{a}
		C4	39.80^{c}	703.5^{a}	43^{b}	13133.2^{a}
	120 kg h^{-1}	C1	32.14^{d}	556.5^{c}	53^{a}	12059.3^{b}
		C2	56.23^{b}	703.0^{bc}	38^{c}	9689.7^{c}
		C3	64.35^{a}	749.5^{b}	40^{c}	14235.6^{a}
		C4	39.95^{c}	910.0^{a}	45^{b}	14225.6^{a}
	160 kg h^{-1}	C1	49.10^{b}	595.5^{c}	49^{a}	12766.7^{b}
		C2	49.66^{b}	758.5^{b}	43^{b}	10912.0^{c}
		C3	62.43^{a}	505.5^{d}	40^{b}	13533.2^{ab}
		C4	44.40^{b}	960.0^{a}	43^{b}	14844.4^{a}
Water stress	80 kg h^{-1}	C1	43.00^{b}	499.0^{b}	45^{a}	11031.1^{b}
		C2	37.26^{c}	521.5^{b}	38^{b}	9866.8^{b}
		C3	63.70^{a}	458.5^{b}	41^{b}	10300.0^{b}
		C4	48.90^{b}	775.0^{a}	40^{b}	13964.4^{a}
	120 kg h^{-1}	C1	35.05^{c}	534.5^{c}	39^{ab}	10333.2^{b}
		C2	41.90^{b}	504.0^{c}	35^{b}	9600.0^{b}
		C3	57.03^{a}	672.5^{b}	41^{a}	14132.2^{a}
		C4	44.50^{b}	812.0^{a}	39^{ab}	13166.6^{a}
	160 kg h^{-1}	C1	42.20^{b}	649.0^{a}	42^{a}	12034.4^{a}
		C2	52.30^{b}	551.0^{b}	39^{a}	10177.8^{b}
		C3	64.90^{a}	397.0^{c}	41^{a}	9632.2^{b}
		C4	47.06^{b}	647.5^{a}	41^{a}	10919.6^{b}

Means in each column and treatment followed by similar letters are not significantly different at 1% probability level using LSD test

Table 4. Drought tolerance indices (water stress after flowering stage) in YP treatments yield of each genotype (kg/ha) under favorable irrigation and YS: yield of each genotype (kg/ha) under water stress conditions

Treatment	YI	YSI	STI	GMP	MP	Ys	Yp
cultivar Sirvan	0.88	0.63	0.61	4892	5019	3896	6143
S-92-19 Line	0.84	0.67	0.52	4542	4631	3731	5531
cultivar Khalil	1.04	0.7	0.78	5460	5542	4626	6457
Genotypes mixture	1.23	0.78	0.96	6150	6200	5448	6951

Table 5. Uncalculated values (r matrix), different indices of drought tolerance, values of ideal genotypes and non-ideal genotypes

Treatment	YI	YSI	STI	GMP	MP	Ys	Yp
Sirvan Cultivar	0.436	0.452	0.414	0.462	0.466	0.435	0.488
S-92-19 Line	0.416	0.481	0.353	0.429	0.43	0.417	0.44
Khalil Cultivar	0.515	0.502	0.529	0.515	0.515	0.517	0.513
Genotype mixture	0.609	0.559	0.651	0.581	0.576	0.608	0.552
Ideal genotype	0.609	0.559	0.651	0.581	0.576	0.608	0.552
Non-ideal genotype	0.416	0.452	0.353	0.429	0.43	0.417	0.44

Table 6. Ideal selectivity genotype (SIIG) values and distance from the ideal genotype (d +) and distance from non-ideal genotype (d-) and ranking of treatments

Treatment	rank	SIIG	d-	d+
Sirvan cultivar	3	0.055	0.009	0.158
S-92-19 Line	4	0.004	8E-04	0.226
Khalil cultivar	2	0.62	0.074	0.045
Genotypes mixture	1	1	0.232	0

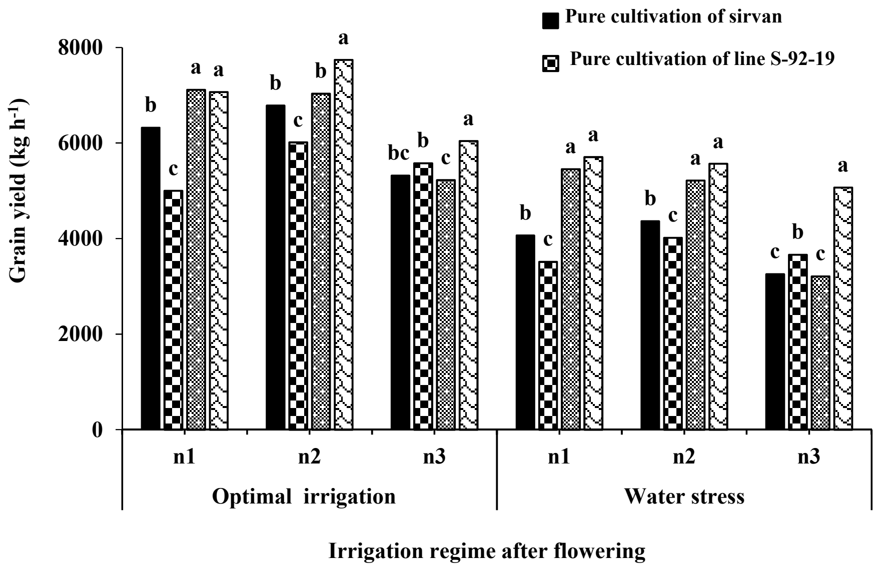

Fig. 1. Interaction of water stress and nitrogen fertilizer in cropping systems on grain yield in bread wheat (80 kg N/ha: n1, 120 kg N/ha: n2, 160 kg N/ha: n3) (Columns with the same letter do not have a significant difference based on LSD test at 1% probability level).

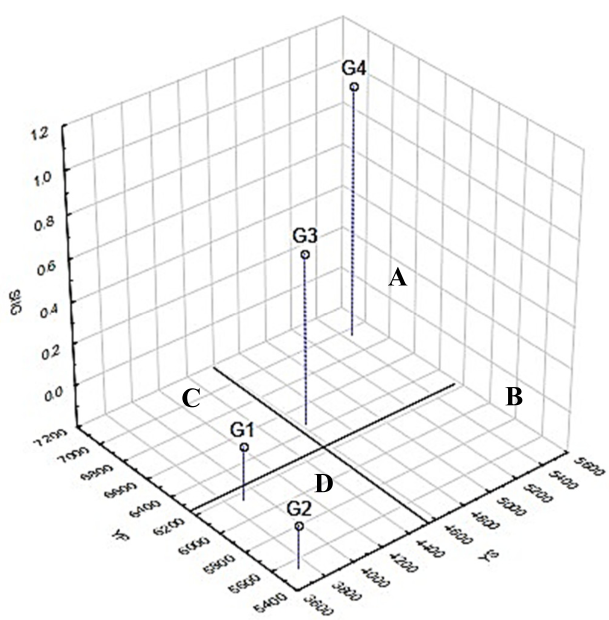

Fig. 2. Three-dimensional graph of drought resistance of genotypes or cropping system using SIIG index, yield under non- stress conditions (YP) under stress conditions (YS). A: genotypes or cropping system that have a high yield in both conditions. B: genotypes or cropping system whose yields are only higher in non- stress conditions. C: Genotypes or cropping system with relatively high yield under water stress conditions. D: genotypes or cropping system that have lower yields in both conditions.