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Research Article

LEAF PROLINE CONTENT AND YIELD PERFORMANCE OF WHEAT GENOTYPES UNDER IRRIGATED AND RAIN-FED CONDITIONS

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ABSTRACT
Grain-protein content and amino acid composition are the most important characteristics in determining the nutritional value of wheat for human and animal diets. Protein content and amino acid profiles are also relevant traits that largely determine the quality of the wheat grain, which depends both on its physicochemical characteristics (dough physiology) and nutritional attributes (protein content and amino acid composition). The result of analysis of variance (Table 3) for some agronomic traits such as W1000, grain/spike and grain yield in irrigated conditions indicated that genotypic differences were significant ($P < 0.05$) and for leaf proline content was significant ($P < 0.01$). In rain-fed conditions the result of analysis of variance for W1000 and grain/spike indicated that genotypic differences were significant ($P < 0.01$) and for grain yield was significant ($P < 0.05$). No significant effect was observed for leaf proline content under rain-fed conditions. Leaf proline content increased in all of genotype under rain- fed conditions. Marvdasht cultivar had the highest grain yield in both conditions, while the lowest grain yield belonged to accessions 1 and 4 (Hamam-4). Marvdasht, M-81-13, WS-82-9, PYN and Shiraz were the most productive genotypes in irrigated conditions but in rain-fed site, Marvdasht followed by M-81-13, M-83-6, STAR, M-79-7 and TEVEES had the highest grain yield. Marvdasht was the superior wheat genotype under both rain-fed and irrigated conditions. Average grain yield in rain-fed conditions was 11.26% lower than that in irrigated conditions. Grain yield was positively correlated with grains/spike and biological yield (YB) in the both environments. Positive correlations ($P < 0.05$ and $P < 0.01$) were found between spike/m2 and grains/spike in irrigated and rain-fed conditions, respectively.

Key words: *Agronomic Traits, Grain Yield, Leaf Proline, Rain-Fed Condtions and Wheat*

INTRODUCTION
Insufficient water is the primary limitation to wheat production world-wide (Ashraf and Harris, 2005). Iran is one of the major wheat growing countries in west Asia. From 14.3 million tons of wheat produced in 2005, in Iran, 4.3 million tons was harvested from rainfed (4.3 mha) and 10 million tons from irrigated (2.6 mha) wheat growing areas. These statistics indicate that 2/3 of wheat growing areas suffer severe drought and moisture stress (Anonymous, 2005; Kamali *et al.*, 2009). Drought is one of the major ecological factors limiting crop production and food quality globally, especially in the arid and semi-arid areas of the world. Recent evaluations have shown that approximately 64% of the world's soils are located in desert or in areas with limited water availability and that 57% of the potentially arable area is located in soils for dry-land crops (FAO, 2000). When plants impose water or salt stress protein synthesis decrease, therefore accumulation of some amino acids will be increased (Writer).

For the purpose of crop production, yield improvement developing of drought tolerant varieties is the best option. Proline is one of osmolytes, which increase faster than other amino acids in plants under water stress and help the plants to maintain the cell turgor (Valentovic *et al.*, 2006). Therefore increasing proline concentration can be used as an evaluating parameter for irrigation scheduling and for screening drought resistant varieties (Bates *et al.*, 1973; Gunes *et al.*, 2008).

Osmotic adjustment is a mechanism to maintain water relations under osmotic stress. It involves the accumulation of a range of osmotically active molecules/ions including soluble sugars, sugar alcohols, proline, glycinebetaine, organic acids, calcium, potassium, chloride ions, etc. (Farooq *et al.*, 2009).

MATERIALS AND METHODS

Site Description and Plant Material

The experiment was carried out in 2009-2010 at the Research Farm of Kermanshah Azad University (latitude 34º20' N, longtitude 46º20' E, altitude 1351.6 m above sea level). Kermanshah is located in west of Iran and has a mean annual temperature of 13.8ºC and annual rainfall of 478 mm. The amount of rainfall during the growing season was 387.2 mm. The soil texture of the research area was sandy-loam. Fourteen wheat genotypes that had good yield potential were planted. List and pedigree of the wheat accessions are presented in table 1.

Table 1: List and pedigree of 14 wheat genotypes grown in rain-fed and irrigated treatments

Genotype No.	Name/Pedigree	Origin
1	OR F1.158/FDL//BLO/3/SHI4414/CROW/4/C ICWH99381-0AP-0AP-0AP-OMAR-6MAR	DARSI
2	PYN/BAU//VORONA/HD2402	DARSI
3	TEVEE'S'//CROW/VEE'S'	DARSI
4	HAMAM-4	DARSI
5	STAR/SHUHA-4	DARSI
6	M-83-6	ANRRC
7	M-79-7	ANRRC
8	M-81-13	ANRRC
9	M-83-17	ANRRC
10	WS-82-9	ANRRC
11	Pishtaz	ANRRC
12	Shiraz	ANRRC
13	Marvdasht	ANRRC
14	Bolani	ANRRC

DARSI: Dry land Agricultural Research Sub-Institute
ANRRC: Agricultural and Natural Resources Research Center

Experimental Procedure

The experiment was performed, based on randomized complete block design (RCBD) with three replications, in two environments (irrigated and rain-fed). The genotypes were sown in six rows of 3 m length, spaced 25 cm apart in early November. The final stand density was 400 plants per m^2. All of phosphorus (50 kg ha^{-1}, P_2O_5) and half of total nitrogen (45 kg ha^{-1}, N) was applied at sowing time. The other half of the N was split and given at tillering (as urea) and booting (as ammonium nitrate) stages, respectively. To minimize the probability of seed- and soil-borne diseases, seeds were pretreated with Mancozeb as a fungicide. Experimental plots were hand weeded. Plants in rain-fed plots didn't receive any water except rainfall during the experiment. In irrigated plots, three supplement irrigations were applied during flowering and grain filling period. Proline content was determined according to Bates *et al.*, (1973). Leaf tissues were rinsed with distilled water and oven-dried at 75°C for three days. Each dried leaf was crushed in a mortar with a pestle. 10 ml sulfosalicylic acid was added to each tube containing 0.1 g of the dried leaf. After 48 h, water extract, ninhydrin and glacial acetic were incubated in a water bath (100°C) for an hour. 0.2 ml toluene was added to each tube and the absorbance of top red aqueous layer was recorded at 520 nm in a spectrophotometer. The concentration of proline was calculated from a standard curve plotted with known concentrations of L-proline as standard. Number of spike per m^2, number of grain per m^2, hundred seed weight (W_{100}), grain/spike and biomass (YB).

To avoid border effects, central three rows were used to measuring the traits. At maturity, plants in 1 m^2 of middle part of each plot were hand harvested and oven dried at 80^{o}C for 48 h. Grain yield per unit area for each treatment at each replicate was determined.

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Stress intensity (SI) was calculated using the relationship $1-\left(\frac{\overline{Ys}}{\overline{Yp}}\right)$ where $\overline{Ys}$ and $\overline{Yp}$ are the mean yields of all genotypes under stress and irrigated conditions, respectively (Fischer and Maurer, 1978).

Statistical Analysis

Combined analysis of variance appropriate to RCBD was carried out using SAS (version 9.1). Environments (rain-fed and irrigated) were considered as fixed effects. Duncan test was used for mean comparisons. Correlation among characters was calculated by SPSS software.

RESULTS AND DISCUSSIONS

Combined analysis of variance of the data (Table 2) showed that the environment was a significant source of variation for leaf proline content (P ≤ 0.01) and grain yield (P ≤ 0.05). The wheat genotypes differed (P < 0.01) for W1000, grain/spike, grain yield, leaf proline and spike weight (P < 0.05). Two-way interaction of environment genotype was significant (P < 0.05) for W1000 and leaf proline conten (Table 2). Stress intensity was estimated to be 0.112, indicating a moderate water deficit stress.

Table 2: Combined analysis of variance for traits of 14 wheat genotypes under rain-fed and irrigated conditions

Source of Variation	df	W1000	Spike weight	Mean square Spike/m^2	YB	Grains/spike	Grain yield	Leaf Proline
Environment (E)	1	225.7	3.90	6027.8	16.07	1.01	2738.2*	261.1**
Error (R/E)	2	5.43	1.30	497.1	11830.3	8.04	3107.1	0.996
Genotype (G)	13	45.2**	4.9*	3390	28132.5	177.8**	5817.6**	2.216**
E×G	13	19.7*	2.30	2240	19477.6	24.96	2585.7	2.00*
Error (R×G/E)	26	8.28	2.41	1694	21264.9	24.98	2295.7	0.862
CV (%)		7.46	21.24	15.6	18.69	14.28	19.25	16.72

**, ** significant at 0.05 and 0.01, respectively*

Table 3: Analysis of variance for some characters of wheat genotypes in irrigated and rain-fed conditions

	df	W1000	Spike weight	**Mean of Square** Spike/ m2	YB	Grains/spi ke	Grain yield (gm^{-2})	Leaf Proline
Irrigated conditions								
Replication	1	9.81	2.117	782.28	19032.2	3.18	4282.98	1.05
Genotype (G)	13	13.2*	2.590	2475.2	27165.2	96.6*	5108.40*	3.28**
Error	13	4.23	1.23	1409.9	25332.2	27.07	2770.36	0.79
Rain-fed conditions								
Replication	1	1.05	0.488	211.75	4628.57	12.89	1931.24	0.939
Genotype (G)	13	51.7**	4.67	3154.9	20445.5	116.2**	3295.01*	0.928
Error	13	12.4	3.31	1977.9	17197.8	26.88	1821.05	0.926

The result of analysis of variance (Table 3) for W1000, grain/spike and grain yield in irrigated conditions indicated that genotypic differences were significant (P < 0.05) and for leaf proline content was significant (P < 0.01). In rain-fed conditions the result of analysis of variance (Table 3) for W1000 and grain/spike indicated that genotypic differences were significant ($P < 0.01$) and for grain yield was significant ($P < 0.05$). No significant effect was observed for leaf proline content under rain-fed conditions (Table 3). Leaf proline content increased in all of genotype under rain- fed conditions (Table 4). Increasing proline content in wheat and other plant also has been reported by Tatar and Gevrek (2008) and Vendruscolo *et al*., (2005).

The highest grains/spike and spike weight were observed for Marvdasht followed by M-81-13 and M-83-6 under rain-fed conditions (Table 4).

Table 4 also shows that Marvdasht cultivar had the highest grain yield in both conditions, while the lowest grain yield belonged to accessions 1 and 4 (Hamam-4). Marvdasht, M-81-13, WS-82-9, PYN and Shiraz were the most productive genotypes in irrigated conditions but in rain-fed site, Marvdasht followed by M-81-13, M-83-6, STAR, M-79-7 and TEVEES had the highest grain yield. Marvdasht was the superior wheat genotype under both rain-fed and irrigated conditions. Average grain yield in rain-fed conditions was 11.26% lower than that in irrigated conditions.

Table 4: Mean comparison of eight traits under rain-fed and irrigated conditions

	Genotypes	Leaf Proline	Grain yield (gm^{-2})	Grains/spike	YB	Spike/m2	Spike weight	W1000
Irrigated conditions	ORF1.158	4.902dc	186.4d	26.5d	760ab	270.5abc	7.11ab	44.88a
	PYN	6.542ab	299.2a	39.9abc	860ab	279abc	8.05a	40.58abc
	TEVEES	6.02abcd	222.3cd	34.1bcd	605ab	247bc	8.01a	38.87bc
	Hamaam-4	4.540d	220.2cd	31.1bcd	840ab	242.5bc	9.20a	42.99ab
	STAR	4.727d	243bcd	35.6abcd	810ab	277abc	7.35ab	39bc
	M-83-6	6.575a	291.6ab	43ab	720ab	305abc	7.63a	37.3c
	M-79-7	4.982bcd	271.4bc	41.8abc	790ab	245bc	7.95a	40.85abc
	M-81-13	4.577d	299.7a	44.8a	925ab	339.5a	7.11ab	37.17c
	M-83-17	6.412abc	262.7bc	33.8bcd	695ab	323ab	7.57a	43.57ab
	WS-82-9	5.39abcd	276.5bc	41.3abc	725ab	216.5c	8.92a	39.75bc
	Pishtaz	5.31abcd	226.7cd	29.8cd	980a	289abc	6.55ab	44.8a
	Shiraz	5.52abcd	261.1bc	37.7abcd	875ab	294.5abc	7.98a	40.2abc
	Marvdasht	6.29abc	319.1a	47.4a	775ab	290abc	8.13a	38.53bc
	Bolani	5.97abcd	224.4cd	26.08d	555b	233.5bc	4.44b	39.38bc
	Mean	3.396	263.72	36.49	779.64	275.142	7.575	40.562
Rain-fed conditions	ORF1.158	6.79a	183.1bc	27.65de	690ab	328.5a	5.24b	40.85abc
	PYN	6.76a	195.1bc	28.5cde	750ab	232.5abc	6.6ab	32.56cde
	TEVEES	7.43a	255.4ab	30.6bcde	890ab	292.5ab	6.47ab	30.79de
	Hamaam-4	7.56a	194.8bc	24.5e	775ab	259abc	5.72ab	43.07a
	STAR	7.63a	272.2ab	35.7bcde	740ab	277.5abc	6.74ab	31.89de
	M-83-6	8.98a	273.3ab	41.4ab	940a	296.5abc	8.28ab	34.35bcde
	M-79-7	7.58a	267.6ab	40.8abc	815ab	223abc	7.45ab	37.62abcd
	M-81-13	7.09a	275.1ab	48.4a	895ab	273abc	9.3a	31.13de
	M-83-17	8.4a	249.5b	39.8abcd	780ab	261abc	5.10b	36.76abcd
	WS-82-9	7.97a	226.9b	37.6abcd	715ab	229.5abc	8.44ab	43.07a
	Pishtaz	7.4a	196.3bc	35.7bcde	815ab	225.5abc	6.7ab	41.23ab
	Shiraz	7.36a	222.1b	40.2abcd	655ab	301.5ab	7.22ab	27.90e
	Marvdasht	8.74a	283.8a	48.6a	885ab	179c	10.06a	41.29ab
	Bolani	8.29a	204b	27.7de	585b	213.5bc	5.3b	39.14abcd
	Mean	7.714	234.05	36.22	780.71	254.39	7.047	36.546

Table 5: Correlation coefficients among some agronomic traits under irrigated (non-stress) conditions

	W1000	Spike weight	Spike/m2	YB	Grains/spike
Spike weight	-0.005				
Spike/m2	-0.101	-0.092			
YB	0.232	0.265	0.445		
Grain/spike	-0.633	0.526*	0.223	0.184	
Grain Yield	-0.260	0.160	-0.101	0.519*	0.581*

Table 6: Correlation coefficients among some agronomic traits under rain-fed (stress) conditions

	W1000	Spike weight	Spike/m2	YB	Grains/spike
Spike weight	-0.254				
Spike/m2	-0.465	-0.188			
YB	-0.131	0.229	-0.99		
Grain/spike	-0.168	0.995**	-0.274	0.546*	
Grain Yield	-0.071	0.414	-0.207	0.611*	0.836**

Grain yield was positively correlated with grains/spike and biological yield (YB) in the both environments. Positive correlations (P <0.05 and P <0.01) were found between spike/m2 and grains/spike in irrigated and rain-fed conditions, respectively (Table 5 and 6).

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