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Grain Yield and Quality Traits of Bread Wheat Genotypes under Mediterranean Semi-arid Conditions

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Abstract: A field experiment was carried out in the high plains of Sétif region (Northeastern Algeria) on winter wheat (*Triticum aestivum* L.) to investigate the effect of water deficit at different growth stages on grains yield and quality with the aim to select the most appropriate varieties for the locally Mediterranean conditions. Two newly introduced genotypes from ACSAD (*The Arab Center for the Studies of Arid zones and Dry lands*) institution and two previously ameliorated ones were grown in the (2014-2015) growing season. The supplemental irrigation caused the grain yield to increase significantly up to 25%. The highest grain protein content, sedimentation volume, ash content and falling number values have been obtained for all varieties under rain-fed conditions. Increases in grain moisture content were observed with supplemental irrigation. Statistically, optimum levels of quality characteristics were obtained with W2 supplemental irrigation regime which also suited to a significant grain yield score. Nevertheless, the study also suggests that, under rain-fed conditions, the locally cultivated variety Hidhab with an acceptable grain yield and better quality traits, in comparison with introduced varieties, remains the most suitable variety for region.
Keywords: *Triticum aestivum* L., Supplemental irrigation, genotype introduction, Grain yield, Quality traits.

INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is one of the most widely grown and consumed food crops all over the world [1].

Compared to other cereals, it provides food for human with more calories and proteins in the daily diet. Its suitability and superiority in bread-making with viscoelastic dough properties has been well known and documented [2-5].

As reported by Tayyar [6] selection of new bread wheat genotypes with higher grain yield and quality is the primary aim of breeding programs. According to Feillet [2]**,** the bread wheat flours derive from different histological regions of the grain and are differentiated by their chemical composition, quantitative (proteins and mineral contents), qualitative (gluten and degree of starch granules damage) and by their physical properties (color and particle seize distribution). All these properties are genetically controlled but may vary widely depending upon both genetics and environmental conditions, as discussed by Johansson [4]**.**

Wheat grain quality grown under Mediterranean rainfed conditions suffered largely from differences in grain composition as a result of changes in relative rates of assimilates accumulation induced by water and heat stress. Due to such water deficit, low grain yield has been associated, in particular, with high grain protein content as reported by Ozturk and Aydin [7].

In fact, many efforts have been made to release new bread varieties with both high grain yield and good bread making quality that respond to improved agricultural practices [8, 6, 9] and which still, up today, the main priority for bread wheat breeding programs. The objective of the present investigation was (i) to compare the grain yield and grain quality of the local ameliorated varieties with two newly introduced varieties in respect of higher grain yield with better quality traits, and (ii) to examine the correlation coefficients between grain yield and grain quality parameters.

MATERIALS AND METHODS

Experimental site

The experiment was conducted in Bouteraa Mahmoud pilote farm, localized 36Km far from Sétif, Algeria (36° 06'N, 5°54' E) during the 2014-2015 growing season. The soil of the upper 30cm experimental field was a silty-clay texture with 7.4 pH reaction, 2.1% organic matter, 0.15% (1500ppm) total Nitrogen contents and 7.9 C/N ratios. Weather data of the experimental site are shown in table 1.

Table-1: Weather data during the growing season (2014-2015)

Month	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
Precipitation(mm)	6.1	21.6	62.0	68.8	61.0	52.8	5.1	25.9	26.2
Temperature (°C)	17.9	12.3	5.3	4.6	4.5	8.6	14.0	18.4	21.6
Humidity (%)	47.5	63.4	82.1	76.8	80.0	66.7	55.6	49.9	44.5

The treatments comprised four bread wheat genotypes (G) and six water regimes (W). The plots were replicated three times in randomized complete block design. The selected area of an individual experimental unit was 1.20 m^2 (1.20 by 1.0m).

Plant material

Four bread wheat (*Triticum aestivum* L.) cultivars were used as plant materials as shown in table 2. Hidhab (HD1220) and El-wifak, two commonly ameliorated varieties grown locally by farmers in the high plains of Sétif region, as control, and two newly introduced varieties provided by ACSAD (The Arab Center for the Studies of Arid Zones and Dry Lands**,** Aleppo, Syria**)** institution**;** Djemila (ACSAD 969) and Djanet (ACSAD 899). Crop development was categorized using the Zadoks scale [10].

Table- 2: Pedigree and source of plant materials

Genotype	Pedigree	Source of materiel
Hidhab (HD1220)	HD1220/3*Kal/Nac CM40454	CIMMYT[1](Mexico)
El-wifak	K134/4/Tob/Bman/Bb/3/Cal/5/Bucc	CIMMYT(Mexico)
Djemila (ACSAD 969)	Acsad 529// prl4S4/ VEE's'	ACSAD[2] (Syria)
Djanet (ACSAD 899)	Acsad529/4/C182.24/C168.3/3/Cno*2/7C// CC/Tob-1s	ACSAD (Syria)

[1]CIMMYT: International Maize and Wheat Improvement Center;
[2]ACSAD: Arab Center for the Studies of Arid zones and Dry lands

Crop management

The seeds were planted in six 17 cm row's interval at a seed rate of 250seeds m^{-2}. The seeds were planted on December, 8th 2014 and plots were harvested on June 25th 2015. Nitrogen application (urea) was splitting; half at sowing and half in the beginning of stem elongation stage (total 80kg.ha^{-1}). Phosphorus was applied at the sowing as basal dressing in triple-superphosphate form (46% P_2O_5) at the rate of 7g.m^{-2} (70kg.ha^{-1}). Weed control was achieved both by application of post emergence herbicides and eventually by hand. Grain yield and other agronomic data (presented in another article) were determined by the four center rows in each plot to avoid edge effects.

Irrigation treatments

Six supplemental irrigation regimes (W), including a rain-fed regime as control, were applied to the various plots differing in amounts and timing (crop development stages) application to ensure:

- W0 : Rain-fed without irrigation;
- W1 :Irrigated only during the stem extension stage from the second node detectable to the flag leaf ligule\collar just visible (Z32-Z39);
- W2: Irrigated during two stages; jointing at the first node detectable (Z31) and flowering (half-way to complete anthesis) stage (Z65-Z69);
- W3: Irrigated during three stages; tillering (Z21-Z29), (Z32-Z39) and milky grain filling (Z70-Z77).
- W4: Irrigated during four stages; (Z21-Z29), (Z32-Z39), (Z65-Z69) and (Z70-Z77).
- W5: Fully irrigated at the five grow stages; (Z21-Z29), (Z31), (Z32-Z39), (Z65-Z69) and (Z70-Z77).

Quality characteristics analysis

Harvested grains were subjected to quality analysis in duplicate. Grain samples from two replicates of the investigated varieties were milled with a disc grinder mill (Buhler mod.cMLI-204) and evaluated for quality characteristics. Grain total protein content (TP) and Sedimentation volume (SV) values were determined on a dry weight basis by near-infrared reflectance spectroscopy (NIRS), using a Percon Inframatic 8600 instrument (Perten Co., Huddinge, Sweden). Grain ash (AC) content and grain moisture (GM) content were performed according to standard procedures of the ICC [11], wet gluten content (GC) was determined by the ICC standards 137 [12] using a Perton Glutork 2020 instrument (NCI Co., North Dakota, USA). The Falling number (FN) values were determined according to the ICC standard method 107/1 [13] using a Falling Number 1400 Device for wheat/grain testing (Perten Co., Huddinge, Sweden).

Statistical Analysis

Data were analyzed using statistical software package SPSS Version 23.0. The Least Significant Differences among means were used at the P<0.05 level of probability as described by Steel *et al.* [14].

RESULTS

Results from analysis of variance for the investigated characteristics are presented in Table 3. Effect of water Regime (W) was found to be significant for all parameters except for wet gluten content (GC) trait. Genotype (G) effect was also found to be significant for most traits except for falling number (FN) and grain moisture (GM). W× G interaction was no significant for all measured parameters.

Table-3: Analysis of variance for grain yield and quality traits

SOV	DF	GY	TP	SV	AC	GC	FN	GM
W	5	3368,06*	1,45***	53,72***	0,04**	25,38	14827,08**	1,08***
G	3	11104,41**	7,44***	235,12***	0,67***	107,94***	8195,14	0,07
W×G	15	462,69	0,23	8,59	0,01	5,85	3386,81	0,13
CV(%)		16.79	3.41	5,59	4,89	12,21	13,53	3,87
R^2		.661	.882	.901	.944	.708	.658	.695

GY= Grain yield, TP= Total proteins content, SV= Sedimentation volume, AC=Ash content, WG= Wet gluten content, FN= Falling number , GM= Grain moisture content.
*, ** and *** indicates the significance of 5, 1 and 0.1% respectively.

Effect of water regimes on grain yield and quality traits

Differences among the water regimes were significant for grain yield and all grain quality traits except for wet gluten content. Grain yield was significantly influenced by the supplemental irrigation. The grain yield depending on irrigation application ranged between 161.14g.m^{-2} in rain-fed treatment and 201.64 gm^{-2} under fully irrigated treatment (Table 4). Comparatively to rain-fed treatment, grain yield should be in peak with supplemental irrigation regimes of W2, W4 and W5 which increased grain yield by 11%, 15% and 25% respectively.

Table-4: Mean grain yield and quality traits scores by the water regimes

Water regimes	GY (g.m^{-2})	TP (%)	SV (ml)	AC (%)	GC (%)	FN (s)	GM (%)
W0	161,14b	13,64a	44,06a	1,68a	36,37	498a	10,17c
W1	168,54b	13,25a	43,44a	1,62ab	35,47	421b	10,14c
W2	179,03ab	12,67b	37,25c	1,56bc	33,19	426b	10,46bc
W3	173,11b	12,77b	39,25bc	1,62ab	34,19	386b	10,67ab
W4	185,38ab	12,68b	40,81b	1,54c	33,66	382b	10,94a
W5	201,64a	12,57b	39,81b	1,49c	31,61	395b	10,98a
Mean	178,14	12,93	40,77	1,59	33,76	417,71	10,56
LSD (5%)	24.21	0,36	1,88	0,06	NS	47,49	0,32

GY= Grain yield, TP= Total proteins content, SV= Sedimentation volume, AC=Ash content, GC= Wet gluten content, FN= Falling number, GM= Grain moisture content.
Values with the same letter in one column are not significantly different from each other.
NS indicates that the differences were not significant

Quality parameters of rainfed varieties were found significantly higher than values obtained from the supplemental irrigation treatments, except for grain moisture content. Protein content ranged between 13.64% under rainfed conditions (W0) and 12.57% under fully irrigated treatment (W5). Sedimentation volume values of the varieties ranged between 44.1ml under rain-fed treatment (W0) and 37.3ml under W2 supplemental irrigation regime. Ash content values ranged between 1.68% under rain-fed treatment (W0) and 1.49% under fully irrigated treatment (W5). The highest average value of wet gluten content, even without significant differences, was found for the rain-fed treatment (W0) similar to the previously given quality traits. Falling number values ranged between 498s under W0 (rain-fed treatment) and 382s under W4 water regime. As far as grain moisture content (GM) related to water regimes was considered, the fully irrigated regime W5 (10.98%) and W4 (10.94%) resulted in the highest grain moisture contents, whereas W0 (10.17%) and W1 (10.14%) resulted in the lowest.

Effect of genotype on grain yield and quality traits

Differences among varieties were significant for grain yield and all grain quality characteristics except for grain moisture (Table 5). Under the conditions of the experiment, grain yield varied among varieties from 138.12gm^{-2} for local variety El-wifak to around 200g.m^{-2} for the introduced varieties ; Djanet (199.2 gm^{-2}) and Djemila (200.6 gm^{-2}) which had the highest grain yield, while the second local variety Hidhab has average yielder (168.3 gm^{-2}) compared to all varieties.

Table-5: Mean grain yield and quality traits scores by genotypes

Genotype	GY (g.m^{-2})	TP (%)	SV (ml)	AC (%)	GC (%)	FN (s)	GM (%)
Hidhab	168,31b	13,86a	44,25a	1,63b	38,5a	421	10,64
El-wifak	138,12c	12,90b	44,42a	1,90a	32,3b	453	10,47
Djemila (ACSAD969)	200,62a	13,02b	39,21b	1,37d	34,0b	398	10,54
Djanet (ACSAD899)	199,25a	11,94c	35,21c	1,44c	32,1b	397	10,59
Mean	176,58	12,93	40,77	1,59	33,76	417	10,56
LSD(5%)	19,77	0,29	1,53	0,05	2,24	NS	NS

GY= Grain yield, TP= Total protein contents, SV= Sedimentation volume, AC=Ash content, GC= Wet gluten content, FN= Falling number, GM= Grain moisture content.
Values with the same letter in one column are not significantly different from each other.
NS indicates that the differences were not significant

Grain protein content was significantly different among the varieties. The local variety Hidhab had the highest protein content (13.86%), while the introduced one Djanet had the lowest (11.94%). Moreover it's important to note that Djemila with a notably high grain yield had relatively considerable grain protein content with 13.02%. With respect to sedimentation volume, local varieties El-wifak (44.4ml) and Hidhab (44.3ml) had the highest values, whereas Djanet (35.2ml) had the lowest value. In the same trend, El-wifak with 1.90% and Hidhab with 1.63% grain ash content had the highest values. The genotypes used in the study resulted in significant differences in gluten values; Hidhab (38.5%) had the highest wet gluten content value, while both varieties El-wifak (32.3%) and Djanet (32.1%) had the lowest values. The differences among the varieties were insignificant neither for falling number (FN) nor for grain moister content; the highest FN value was obtained from the variety El-wifak (453s), while the lowest was equally recorded from the two introduced varieties Djemila and Djanet (398s). Grain moister content ranged around 10.5% for all varieties.

Correlation coefficients analysis, presented in table 6, revealed negative relationship between grain yield and most quality traits; sedimentation volume (r=-0.627**), ash content (r=-0.874***), total protein content (r=-0.310*) and wet gluten content (r=-0.046*). This confirmed the results of previous studies [7, 15] that correlated negative relationship of grain yield with both protein content and sedimentation volume. Protein was positively correlated with sedimentation volume (r=0.823***) and wet gluten content (r=0.758***), similar results were reported by Pittman and Tipples [17]. While ash content was positively correlated to sedimentation volume (r=0.685**) and falling number (r=0.477*), no relationships were observed between grain moisture and other investigated traits except with falling number (r=-0.512*).

Table-6: Correlation coefficients between grain yield and quality traits

Trait	GY	TP	GM	SV	AC	GC
TP	-,310*	1				
GM	,277^{ns}	-,272^{ns}	1			
SV	-,627**	,823***	-,218^{ns}	1		
AC	-,874***	,346^{ns}	-,237^{ns}	,685***	1	
GC	-,046*	,758***	-,081^{ns}	,526**	,012^{ns}	1
FN	-,266^{ns}	,344^{ns}	-,512*	,386^{ns}	,477*	,174^{ns}

GY= Grain yield, TP= total proteins, GM= Grain moisture content, SV= Sedimentation Volume, AC=Ash content, WG= Wet Gluten content, FN= Falling Number.
Ns not significant *, ** and *** indicates the significance of 5, 1 and 0.1% level of probability respectively.

DISCUSSION

During this study, relatively considerable whole winter-early spring rainfalls have stimulated the vegetative period, which shortened generative period and led to insufficient grain formation due to poor remobilization of carbohydrates during grain filling stage, which consequently reduced grain yields. This approach is closely aligned with that given by Tahir and Nakata [20]. In addition, this has given extra time, so necessary for newly introduced varieties, to acclimate with the environmental conditions of the region and to restart growth into more favorable water statue. Furthermore, the supplemental irrigation amounts applied at the target stages of plant development, particularly at flowering stage (half-way to complete anthesis), significantly increased the yield of the grown varieties. This seemed much more remarkable since the rainfalls were much lower in the early April. In the dry period, from April, scheduled supplemental irrigation improved the conditions of growth and development by stimulating the post-anthesis photosynthesis cadence and thereby increased the amount of remobilizable assimilates. Similar findings were recorded by Ozturk and Aydin [7]. Grain yield of introduced varieties was higher than that of local varieties reflecting their good response to applied water regimes.

Wheat grain quality is a combination of some physical and chemical characteristics. Their expression depends on their genetic nature as well as the influence of environment [4, 5]. According to Feillet [2], the grain protein content ranges between 8 and 18% of dry matter. The grain protein content of wheat is a critical factor in bread-making and high protein content of wheat is associated with good bread making characteristics [15]. Under rain-fed conditions, lowest grain yield was obtained (161.14g.m^{-2}) but with the highest protein content (13.64%). Similar results have been reported by Saint Pierre *et al.* [8]. Similarly, Gooding *et al.* [16] confirmed that high temperatures and water stress may lead to an increase in grain protein content. Furthermore, with the application of supplemental irrigation, the protein content of the varieties begins to decrease as expected.

Erekul *et al.* [9] reported that the sedimentation test indicates gluten swelling capacity and is largely influenced by proteins content. In all varieties, sedimentation volume values largely exceeded the accepted value (20 ml) for bread-making wheat. Sedimentation values ranged between 35 for Djanet variety and 44 ml for the two local varieties. The different water regimes had caused considerable differences in this trait. The high sedimentation values obtained under the rain-fed treatment plots (W0), indicating good flour quality, could be due to higher protein contents, which is in agreement with Saint Pierre *et al.* [8].

Measurement of ash content (mineral composition) is often used to characterize the degree of flour purity [2]. Bread wheat normally contains 1.20 to 2.30% whole-grain ash and flours presenting high ash content are not desirable [17]. In our study, ash contents exceeded 1.5% for all water regimes. Nevertheless, the new introduced varieties showed values around 1.4%. According to Feillet [2], Flours with a high ash content (>1.4%) are used to make whole wheat bread.

Generally, wet-gluten content of approximately 25% of dry matter is in the middle level [2]. In this trial the highest wet gluten content was measured under rain-fed treatment (36%). The supplemental irrigation caused gradually decreases in gluten contents from 36% under W0 to 32% under W5. Similar results were reported by Shahryari *et al.* [18]. This situation indicated that some losses certainly happen in the quality of measured characteristics with application of supplemental irrigation, as reported by Erekul *et al.* [9]. Similarly, significant differences among the varieties were also observed for this trait, particularly, for Hidhab variety with a considerable high values (39%) which might reflect the adaptability of this variety to water stress under rainfed conditions.

According to Gooding and Davies [19], the falling numbers, representing the enzymatic state of the grain and the degree of pre-harvest sprouting and thereby estimating the expected baking volume, had the optimum range from 220–250 seconds for wheat. This optimal range exceeded by all the tested wheat genotypes and indicates flour relatively poor in enzymes going from 398seconds for the newly introduced varieties to 453sseconds for Hidhab variety. The remarkable differences among rain-fed treatment (498seconds) and the supplementary water regimes until W5 treatment (395seconds), showed a decrease of about 25% in falling number values. According to Erekul *et al.* [9] this situation might be due to the high humidity caused by the microclimate formed in irrigated plots as a result of high temperature in that grain filling period.

The grain moisture content of bread wheat is of crucial importance for post-harvest processing. High grain moisture results in higher microbial activity which is not appreciable for conservation or milling industry. In this study, the supplemental irrigation increased significantly grain moisture content which stays, according to Feillet [2]; Ozturk and Aydin [7], in very acceptable values (<11%) more favorable for storage and/ mill processing conditions.

CONCLUSION

Based on the results of this study it could be concluded that under rainfed conditions, the lowest grain yield were obtained for all tested varieties while some of their quality traits such as protein content, sedimentation volume and wet gluten content have been found at high levels. The results of quality characteristics determination indicated that yield and quality could be combined in a suitable management practice; supplemental irrigation provided in two applications (W2); at jointing stage corresponding to the first node detectable (Z31), and flowering (half-way to complete anthesis) stage (Z65-Z69), was sufficient for a relatively high grain yields and acceptable grain quality characteristics and could be recommended for the region. Nevertheless, the study also suggested that, under rain-fed conditions, the local bread wheat variety Hidhab with an acceptable grain yield and better quality characters, in comparison with introduced varieties, remains the most suitable variety for the region.

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