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Grain yield and yield components of barley (*Hordeum vulgare* L.) in the lower Cheliff region Algeria

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ABSTRACT

In Algeria, barley cultivation comes after wheat cultivation. Low rainfall and high temperature affected barley yield. This experiment consists of evaluating the parameters of 16 local barley cultivars in our semi-arid conditions. Two experiments were carried out at the INRAA experimental station (Hmadna) in the Bas-Cheliff plain, for two years 2017/2018 and 2018/2019. The parameters studied are: the height of the plant, the length of the edges, the length of the ears, the ears per square meter, the grains per ear, the biological yield, the grain yield, the weight of a thousand grains, the harvest index, straw yield and cycle. The results showed greater variability between genotypes on parameters (plant height, ear length, biological yield, grain yield and straw yield). The first season divided the cultivars into two groups, the second season assembled the cultivars into four groups. Also, the cultivars expressed a better adaptation and kept the best values of the yield parameters (grains per cob, thousand grain weight, grain yield, organic and straw yields). Genotypes 12, 15, 16, 17, 18, 25, the control Saida (23) was almost late, except for the two-row genotype 14. Also, the great utility of variability between cultivars, 14 and two controls, 07 cultivars behaved well in our difficult climate and soil conditions.

Keys words: Adaptation; Barley; Landraces; Irregular rainfall; Yield components.

INTRODUCTION

Barley is one of the oldest domesticated food sources and is currently a widely adopted grain crop. Compared to other crops, it is less demanding in terms of environmental conditions and is economically viable with fewer inputs and easier agronomic management (Bort *et al.,* 1994). In Algeria, barley (*Hordeum vulgare* L.) is the second most important cereal after durum wheat (Clarke *et al.,* 2019). This crop plays an important role in the balance of the Algerian economy, it is likely to contribute to the increase in fodder production, particularly in semi-arid zones where it demonstrates adaptation compared to other cereals (Bouzerzour and Monneveux, 1992).

In these areas, lack of water significantly affects agricultural land due to soil salinity (Kilic *et al.,* 2022). Soil salinity is an important environmental factor with serious adverse effects on agricultural productivity and sustainability in semi-arid regions. This situation constitutes a major problem which slows down the productivity of barley production. Official statistics from the Ministry of Agriculture mention a barley yield which fell significantly to reach 18.1 quintals per hectare in 2018 (MADR, 2021). Indeed, soil salinity is one of the main abiotic environmental stresses affecting agricultural productivity (Grewal, 2010).

Research and selection of genotypes with high yield potential and more regular production, less sensitive to climatic variations from one production location to another and from one year to the next (Madic *et al.,* 2012). Based on the tolerance index, a selection of barley genotypes tolerant to abiotic stress made it possible to select genotypes that can adapt to different stresses (Ladoui *et al.,* 2020). The development and obtaining of varieties resistant to difficult conditions giving good production in a wide range of environmental conditions is a major breeding objective (Hamli *et al.,* 2018).

Local varieties could be a means of research to choose the best barley cultivars in Algeria. In this context, trials were implemented with performance tests based on local species and varieties by Rahal *et al.* (2015). Sehrawat and Khan (2017) clarified that the most essential prerequisite for planning and executing a successful breeding program is the desirable availability of genetic variability for important traits in the germplasm collections of the Plant species and genetic variability is the key factor that determines the success of every breeding program.

Finally, conventional breeding requires the identification of genetic variability in salinity among different varieties or cultivars of a crop, or in sexually compatible species, and the selection of this tolerance into lines with appropriate agronomic characteristics (ISAAA, 2007). The main objective of this study was to evaluate among others some components of yield and variability of 16 barley cultivars *Hordeum vulgare* L., from different Saharan regions of Algeria, in the semiarid climate of Hmadna region, situated in the northwestern Algeria and characterized by its very hot summers and low temperatures in winter and in general by its salt soils.

MATERIAL AND METHODS

Site description and weather data:

The tests were carried out during two successive seasons: 2017/2018 and 2018/2019 at the Hmadna experimental station (35 ° 54 °north latitude and 0 ° 47' east longitude, and altitude of 48 m) belonging to the National Institute of Agricultural Research of Algeria. The study area characterized by a semi-arid to arid climatic trend where irrigation is essential for crops. Table 1 shows the monthly average temperatures (T) and precipitations (R) of the 2017/2018 and 2018/2019 growing seasons.

Table 1. Monthly average temperatures (T) and rainfall (R) of the growing seasons 2017/2018 and 2018/2019.

	2017/2018		2018/2019	
Month	**T (°C)**	**R (mm)**	**T (°C)**	**R (mm)**
September	22.99	21.50	26.83	40.10
October	20.58	18.10	19.47	20.20
November	13.22	21.90	14.99	84.70
December	09.96	36.30	11.83	32.80
January	10.49	34.70	09.47	92.00
February	10.16	50.80	11.21	05.80
March	13.14	134.80	16.03	19.90
April	17.02	56.70	18.25	69.00
May	19.71	17.60	22.73	05.00
June	24.45	33.50	23.84	00.00

Plant material:

Fourteen barley landraces from different Saharan zones of Algeria **(Table 2)**, were tested via two seasons in presence of two Algerian approved varieties (Saida and Tichedrett) as controls. Seedbed preparation included plowing, harrowing and disc dressing.

Table 2. List of 16 barley genotypes evaluated, local appellation and geographical origin

Genotypes	**Local appellation**	**Geographical origin**
Adrar (P2)	Azrii	Adrar (Tsabit Ksar Oudjlane) South-West of Algeria.
Adrar (P4)	Bourabaa	Adrar (Tsabit Ksar Hammad) South–West of Algeria.
Ouaragla (P12)	-	Ouargla: South-East of Algeria. Low Sahara
Béchar (2 row) (P14)	-	Béchar: South-Western of Algerian Sahara
Béchar (P15)	-	Béchar: South-Western of Algerian Sahara
Biskra P16)	-	Biskra: South-East of Algeria (Low Sahara)
Tougourt (P17)	Chair de Meggarine	Touggourt (Haut Oued Righ – Ksar Meggarine): Southeast of Algeria. Low Sahara.
Tougourt (P18)	Chair de Blidet Ammour	Touggourt (Haut Oued Righ – Blidet Ammour): Southeast of Algeria. Low Sahara.
Adrar-Ras El Mouch (P20)	Ras El Mouch	Adrar (Tsabit): South-West of Algeria.
Adrar (P21)	Safira Hammad	Adrar (Ksar Hammad): South-West of Algeria.
Adrar (P22)	Safira Oudjlane	Adrar (Tsabit Ksar Oudjlane): South-West of Algeria.
Saïda* (P23)	Saïda	ITGC. Algeria
Adrar (P24)	Selt	Adrar (Ksar Ouled ALI): South-West of Algeria.
Touggourt-Témacine (P25)	-	Touggourt (Haut Oued Righ – Temacine): Southeast of Algeria. Low Sahara.
Tamanrasset (P30)	-	Tamanrasset (In Amguel): Central Sahara of Algeria
Tamanrasset (P31)	-	Tamanrasset (In Dalegue): Central Sahara of Algeria
Tamanrasset (P32)	-	Tamanrasset (Tahifet): Central Sahara of Algeria
Tichedrett* (P33)	Tichedrett	ITGC. Algeria

* Saida (P23) and Tichedrett (P33) are the two controls

Soil:

The soil was characterized by a loamy clay texture. At the start of the first and second campaigns, soil samples were taken at horizon (0-20cm) to evaluate the electrical conductivity of the soil (CE) by the technique of soil: water extract of 1:5 as developed by the USDA Salinity Laboratory[7]. Results gave: 2 dS/m for the first campaign (slightly saline soil) and 1.14 dS/m for the second campaign (non-saline soil). Soil pH at 0-20 horizon was 7.32 in the first test and 7.98 in the second one.

Experimental design and treatment details:

Sowing was performed by hand during the second week of November 2017 and 2018 with 50 kg/ha seed rate for all cultivars. The design of the experiment was totally randomized with two homogeneous plots. In each plot, two lines of 2 m each spaced one meter apart represented each cultivar. This experiment was carried out in natural conditions (without irrigation, fertilization and pesticides).

Data collection:

Yield parameters concerning grain yield (GRY) (qx/ha), straw yield (STY) (qx/ha), biological yield (BIY) (qx/ha), spikes per square meter (SSM), harvest index (HAI), thousand grain weight (TGW) (g) were taken with two replications each randomly chosen per plot per cultivar. The other traits: plant height (PLH) (cm); spike length (SPL) (cm); awn length (AWL) (cm); grains per spike (GRS) were recorded on 10 plants taken at random by repetition and for each cultivar during the two test seasons. All these parameters were studied at maturity. Beside these traits cycle (CYC) was determined as the number of days from the sowing date to the maturity.

Statistical analyzes:

The Analysis of variance (one-way ANOVA) was performed by Gen Stat Discovery (edition 3 stat soft inc.) to analyze these quantitative traits and principal component and group analysis (Ward8 method) were obtained by Statistica (version 6 stat soft inc.) and were performed based on the average values of the following parameters: Plant height (PLH), Spike length (SPL), Awn length (AWL), Grains per spike (GRS), Thousand grain weight (TGW), Spikes per square meter (SSM), Grain yield (GRY), Straw yield (STY), Biological yield (BIY), Harvest index (HAI) and Traits cycle (CYC).

RESULTS

Analyze of variance for the two seasons 2017/2018 and 2018/2019:

Results of analyzes of variance for the two seasons are taken in **Table 3**. Means are taken in **Table 4**.

Plant Height (PLH):

Differences were very highly significant for the two campaigns studied thus confirm existence of variability among genotypes for this trait **(Table 3)**. In the first season, the highest value was 76.15 cm and concerned the control P23 (Saïda), followed by the cultivars from Touggourt, P17 and P18 (74.85 and 74.4 cm, respectively). The lowest values concerned the cultivars from Adrar with 44.15 cm as a lowest mean registered for P2. Concerning the second year, the highest value given by P16 from Biskra with 44.2 cm (group A). The lowest value was for P24 from Adrar (28.5 – group G). Plant height values varied greatly between seasons, mainly due to the large variation in rainfall **(Table 1)**.

Awn length (AWL):

For the two seasons, awn length had very high differences among genotypes. The highest value in the first year concerned the control P33 (Tichedrett) with 12.4 cm (group A) and the lowest values were those of the earliest cultivars from Adrar (group F) with the lowest value for P4 (7.9 cm). In the second season, also P33 given the highest value which was better than the first year (14.85 cm – group A). The lowest value was noted with P15 from Béchar (5.95 cm – group G).

Spike length (SPL):

For two seasons, spike length exhibited high variation among genotypes with very high significant differences ($P<0.001$). In the first test, the highest value given by barley with two rows (P14) giving 6.95 cm (group A). The lowest mean value concerned P4 from Adrar with 3 cm (group I). In the second campaign also, barley with two rows (P14) given the highest value but slightly better than in the first year (7.7 cm – group A). The lowest value concerned P24 from Adrar (4.65 cm – group G).

Grains per spike (GPS):

Very high significant differences registered among genotypes for this trait via the two seasons showing a great variation between cultivars. In the first year, the highest mean value concerned the genotype P 12 (39.3 – group A) and the lowest values were given by cultivars from Adrar and P30 from Tamanrasset. Note that birds have attacked these cultivars, which are the earliest, which caused losses in number of grains per ear. During the second season, and in order to avoid the attack of the birds, the anti-sparrow net hatched the test. To this end, the results showed results than the first campaign and the highest number of grains per ear was that of cultivar 25 (from Touggourt - Témacine) with 55 grains per spike (in the first year it given 32.15). The lowest value was given by barley with two rows (P14) with 21.4 and for barley with six rows, the lowest mean value concerned P24 from Adrar (34.7) **(Table 3)**.

Table 3. ANOVAs of agro-morphological traits in 16 barley genotypes via two experiments

	Maximum value	**Minimum value**	**Grand mean**	**SE**	**LSD (0.05)**	**CV (%)**	**P value**
			2017/2018 experiment				
Plant height	76.15	44.15	60.30	1.70	3.35	8.9	<**0.001**
Awn length	12.4	7.9	10.13	0.46	0.91	14.4	**<0.001**
Spike length	6.95	3	4.83	0.32	0.63	21.0	**<0.001**
Grains per spike	39.3	6.35	25.43	2.74	5.39	34.0	**<0.001**
Thousand grain weight	52.55	20.09	38.53	4.66	9.88	12.1	**<0.001**
Spikes per square meter	103	13.5	54.6	26.35	55.87	48.2	**0.027**
Harvest index	0.61	0.09	0.44	0.18	0.39	42.5	**0.174**
Straw yield	52.1	9.8	31.8	10.31	21.87	32.4	**0.002**
Grain yield	73.6	2.6	35.1	24.91	52.80	71.1	**0.095**
Biological yield	123.8	12.7	66.9	**10.31**	**21.87**	45.5	**0.015**
			2018/2019 experiment				
Plant height	44.2	28.5	37.71	2.12	4.18	17.8	**<0.001**
Awn length	14.85	5.95	10.24	0.40	0.79	12.4	**<0.001**
Spike length	7.7	4.65	6.07	0.39	0.77	20.4	**<0.001**
Grains per spike	55	21.4	43.62	3.09	6.08	22.4	**<0.001**
Thousand grain weight	48.70	28.45	38.74	4.02	8.51	10.4	**<0.001**
Spikes per square meter	92.5	33	56.9	20.6	43.67	36.2	**0.317**
Harvest index	0.57	0.26	0.39	0.04	0.09	11.1	**<0.001**
Straw yield	78.6	10.8	51.5	19.09	40.48	37.1	**0.082**
Grain yield	63.8	14.3	35.2	10.55	22.37	30.0	**0.019**
Biological yield	141.4	25.1	66.9	19.09	40.48	30.1	**0.025**

Thousand grain weight (TGW):

Differences between genotypes were very high significant (P<0.001) via the two tests **(Table 3)**. In the first season, P14 (two rows) given the highest mean value (52.55 g – group A) and the lowest value concerned P24 from Adrar with 20.09 g (group G). For the second season, P15 from Béchar given the highest value (48.7 g) and the lowest value concerned P20 from Adrar called locally “Ras El Mouch” with 28.45 g (group G).

Spikes per square meter (SSM):

In the first campaign, differences were significant between cultivars (P<0.05). The control Saida (P23) given the highest mean value (103) with A group. The lowest values for this trait were given by cultivars from Adrar with 13.5 as a minimum value given by P4. Cultivars from Touggourt (P18 and P17) given the best values after the control P23 (93 and 88, respectively). For the second campaign, differences between genotypes were no significant thus; show that expression of this trait is influenced by environment factors notably by rainfall, which varied greatly between the two seasons of the tests (**Table 1**). In this second season, the highest mean value concerned P22 from Adrar (92.5) and the lowest value was that of P24 from Adrar (33) **(Table 3)**.

Harvest index (HAI):

For 2017/2018, no significant differences existed between genotypes. In contrary, in the second season of 2018/2019, very high significant differences noted among cultivars **(Table 3)**. Therefore, this trait is also fluctuating within cultivars in function with environment conditions notably by rainfall in this case. The highest harvest index in the first year noted for P20 from Adrar called “Ras El Mouch” (0.61) and the lowest mean value was that of P24 from Adrar (0.09). In the second year, the highest value was registered for P24 from Adrar (group A=0.57). The lowest value concerned the control P33 (0.26) forming an isolate group F.

Straw yield (STY):

Differences among genotypes for straw yield were highly significant in the first year but no significant in the second one. In the first test, the better straw yield (group A) was given by cultivars P25, P16, P23 (control), P18, P17, P12 and P15 (52.1; 50.6; 50.23; 50.08; 45.73; 43.55 and 40.45 qx/ha, respectively). The lowest value concerned P4 from Adrar (9.75 qx/ha) forming the isolate group D. In the second season, P12 from Ouargla gave the better mean value (78.6 qx/ha) and the lowest value concerned P24 from Adrar (10.8 qx/ha).

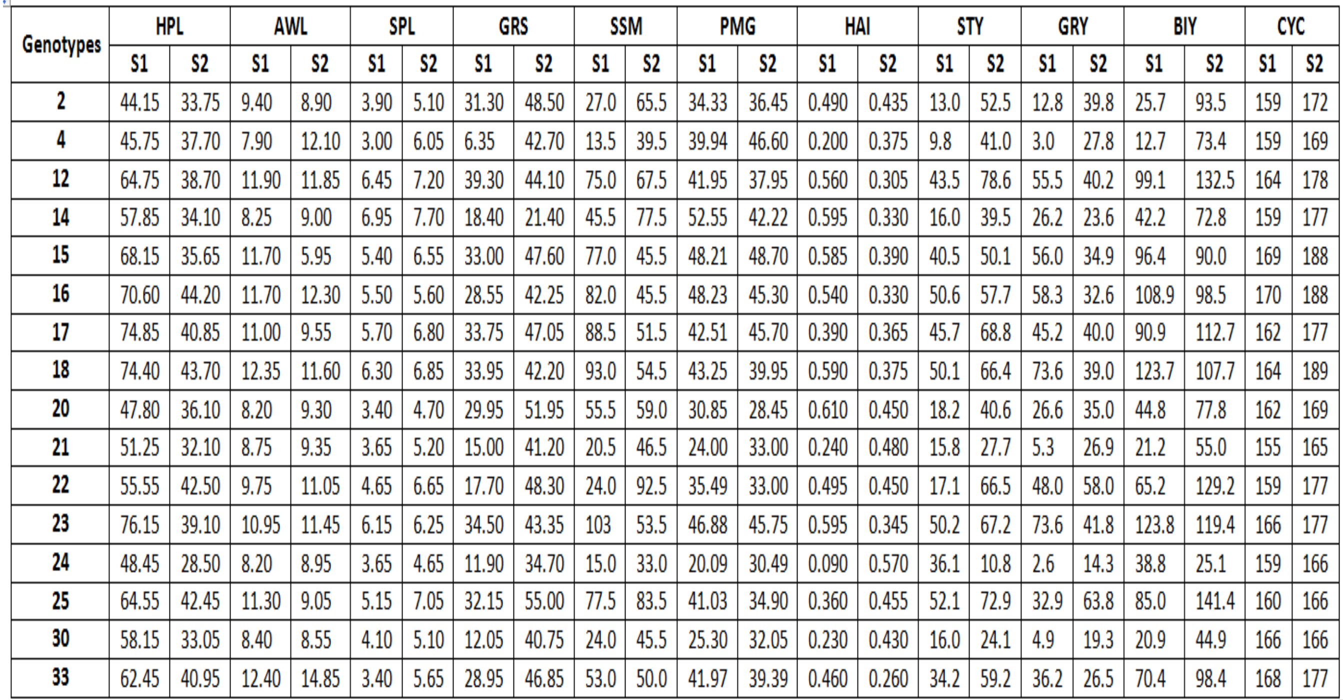
Grain yield (GRY):

Differences among genotypes for grain yield in the first season were no significant but they were significant (P<0.05) in the second year. In the first season, the best grain yield was done by P16 from Biskra with 58.28 qx/ha and the lowest grain yield concerned P24 from Adrar with only 2.07 qx/ha. For the second year, P25 from Touggourt given the highest value for this trait (63.8 qx/ha with group A). As it was the case for the first season, the lowest value concerned P24 from Adrar but with a better grain yield (14.32 qx/ha – group E).

Biological Yield (BIY):

The first season showed significant differences between cultivars for this trait but in the second year, differences were no significant **(Table 3)**. In the first year, the highest value was given by P25 from Touggourt (141.43 qx/ha – group A) and the lowest value concerned P24 from Adrar (20.9 qx/ha – group F). In the second season, the highest value was 141 qx/ha (P25 from Touggourt) and the lowest value was 25.1 qx/ha (P24 from Adrar).

Table 4. Mean values of pheno-agro-morphological traits of two seasons



Genotypes	HPL		AWL		SPL		GRS		SSM		PMG		HAI		STY		GRY		BIY		CYC	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
2	44.15	33.75	9.40	8.90	3.90	5.10	31.30	48.50	27.0	65.5	34.33	36.45	0.490	0.435	13.0	52.5	12.8	39.8	25.7	93.5	159	172
4	45.75	37.70	7.90	12.10	3.00	6.05	6.35	42.70	13.5	39.5	39.94	46.60	0.200	0.375	9.8	41.0	3.0	27.8	12.7	73.4	159	169
12	64.75	38.70	11.90	11.85	6.45	7.20	39.30	44.10	75.0	67.5	41.95	37.95	0.560	0.305	43.5	78.6	55.5	40.2	99.1	132.5	164	178
14	57.85	34.10	8.25	9.00	6.95	7.70	18.40	21.40	45.5	77.5	52.55	42.22	0.595	0.330	16.0	39.5	26.2	23.6	42.2	72.8	159	177
15	68.15	35.65	11.70	5.95	5.40	6.55	33.00	47.60	77.0	45.5	48.21	48.70	0.585	0.390	40.5	50.1	56.0	34.9	96.4	90.0	169	188
16	70.60	44.20	11.70	12.30	5.50	5.60	28.55	42.25	82.0	45.5	48.23	45.30	0.540	0.330	50.6	57.7	58.3	32.6	108.9	98.5	170	188
17	74.85	40.85	11.00	9.55	5.70	6.80	33.75	47.05	88.5	51.5	42.51	45.70	0.390	0.365	45.7	68.8	45.2	40.0	90.9	112.7	162	177
18	74.40	43.70	12.35	11.60	6.30	6.85	33.95	42.20	93.0	54.5	43.25	39.95	0.590	0.375	50.1	66.4	73.6	39.0	123.7	107.7	164	189
20	47.80	36.10	8.20	9.30	3.40	4.70	29.95	51.95	55.5	59.0	30.85	28.45	0.610	0.450	18.2	40.6	26.6	35.0	44.8	77.8	162	169
21	51.25	32.10	8.75	9.35	3.65	5.20	15.00	41.20	20.5	46.5	24.00	33.00	0.240	0.480	15.8	27.7	5.3	26.9	21.2	55.0	155	165
22	55.55	42.50	9.75	11.05	4.65	6.65	17.70	48.30	24.0	92.5	35.49	33.00	0.495	0.450	17.1	66.5	48.0	58.0	65.2	129.2	159	177
23	76.15	39.10	10.95	11.45	6.15	6.25	34.50	43.35	103	53.5	46.88	45.75	0.595	0.345	50.2	67.2	73.6	41.8	123.8	119.4	166	177
24	48.45	28.50	8.20	8.95	3.65	4.65	11.90	34.70	15.0	33.0	20.09	30.49	0.090	0.570	36.1	10.8	2.6	14.3	38.8	25.1	159	166
25	64.55	42.45	11.30	9.05	5.15	7.05	32.15	55.00	77.5	83.5	41.03	34.90	0.360	0.455	52.1	72.9	32.9	63.8	85.0	141.4	160	166
30	58.15	33.05	8.40	8.55	4.10	5.10	12.05	40.75	24.0	45.5	25.30	32.05	0.230	0.430	16.0	24.1	4.9	19.3	20.9	44.9	166	166
33	62.45	40.95	12.40	14.85	3.40	5.65	28.95	46.85	53.0	50.0	41.97	39.39	0.460	0.260	34.2	59.2	36.2	26.5	70.4	98.4	168	177

Multivariate analyzes for 2017/2018 season:

PCA for traits recorded under drought conditions:

Under fist year conditions, The PCA carried out 16 cultivars and 11 recorded showed that the first axis (71,48% of the variation) Principal component analyze done on 16 cultivars and 11 traits showed that two components be considered basing on their Eigen values greater than one. These two components absorbed 81.11 % of total variation. The first component explained the greater variation and counted 71.48 % of total variation. The majority of the traits studied correlated to this component all negatively. These traits explaining more the variability between the cultivars were per importance order according to their absolute values of correlation coefficients: BIY, SSM, GRY, PLH, AWL, STY, GRS, SPL, TGW and CYC. The second component accounted only 9.63 % of variation and was represented mostly by harvest index which had the biggest absolute value of correlation coefficient on the second component **(Table 5 and Figure 1a and b).**

Table 5. Principal component analysis (PC) of 16 barley genotypes based on 11 traits (season 2017/2018)

Parameters	**PC 1**	**PC 2**
Eigen values	7.86	1.06
% of variance	71.48	9.63
Cumulative %	71.48	81.11
Characters		
Plant height	-0.911	-0.196
Awn length	-0.874	-0.261
Spike length	-0.762	0.339
Grains per spike	-0.837	0.052
Thousand grain weight	-0.751	0.437
Harvest index	-0.719	0.589
Biological yield	-0.968	-0.136
Grain yield	-0.947	0.081
Straw yield	-0.839	-0.448
Traits cycle	-0.669	-0.256
Square meter	-0.957	-0.046

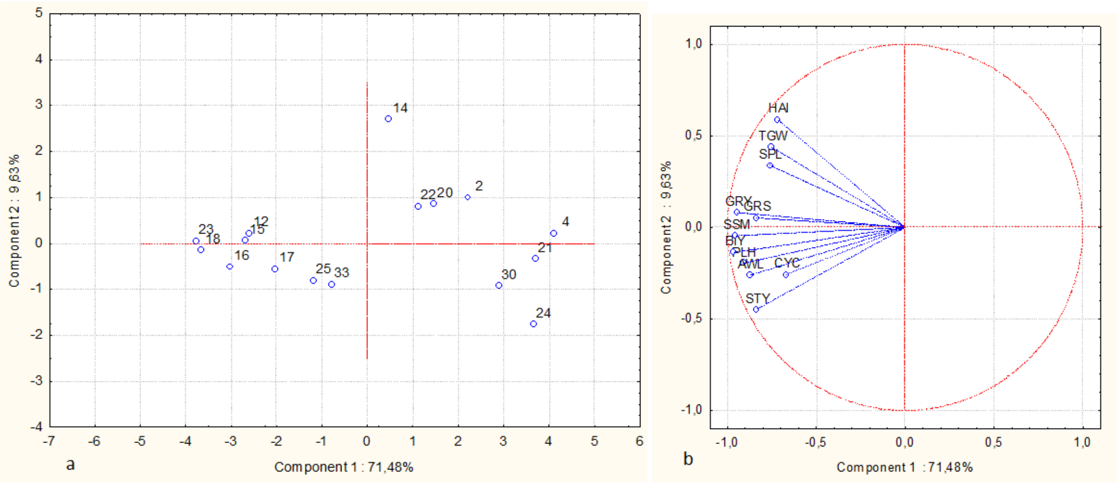


Fig. 1. (a) Projection of cultivars on the first two components (Season 2017-2018); (b) Projection of variables on the first two components (Season 2017-2018)

Cluster and biplot analyzes:

Dendrogram for the first year 2017/18 **(Figure 2a)** based on eleven traits, beside the biplot **(Figure 2b)** showed a structuration of genotypes on two clusters. Cluster one performed with genotypes 2, 4, 21, 30, 24, 14, 20, 22 and 33 characterized by the lowest values in PLH, SSM, STY and BIY and for their majority the lowest values of SPL, GRS, TGW, GRY and CYC. The second cluster performed by genotypes 12, 15, 16, 17, 25, 18 and 23, which had the highest mean values in PLH, SSM, STY and BIY. In general, they had also for their majority the highest mean values in SPL, GRS, TGW, GRY and CYC.

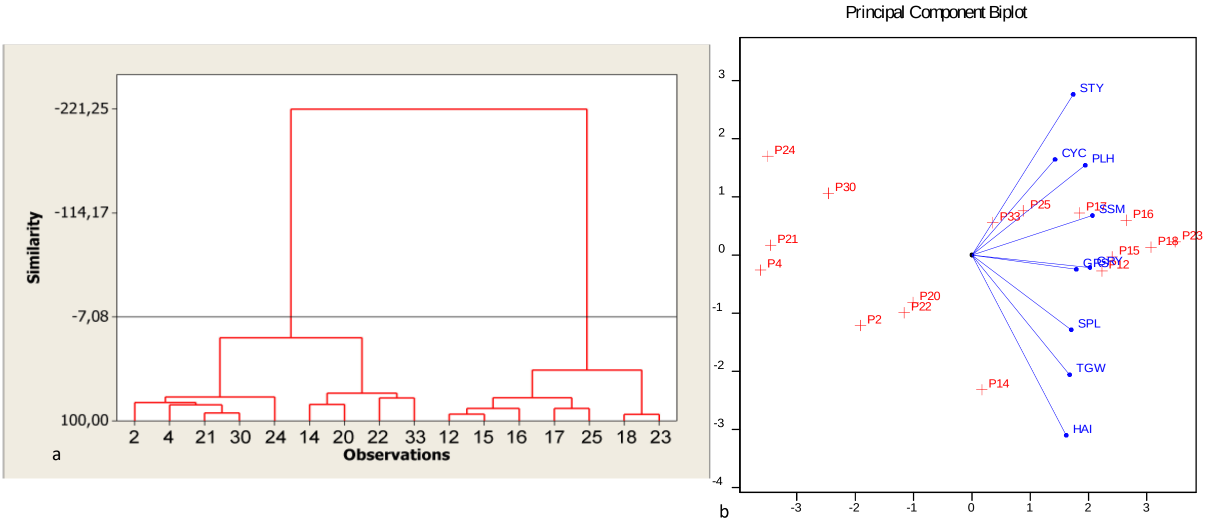


Fig. 2. (season 2017/2018): (a) Dendrogram of 16 barley genotypes for eleven traits; (b) Biplot for 16 barley cultivars and 11 traits.

Multivariate analyzes for 2018/2019 season:

Principal Component analyze for 2018/2019:

Principal component analyzes performed on the second season showed that three components could be taken basing on their Eigen values more than (Table 6). First component explaining the greatest percentage of variation (49.06 %) showed correlations with these following parameters: STY, BIY, PLH, GRY, SPL, HAI and CYC. The second component accounting 22.02 % of total variation showed correlation with these following traits: TGW, SSM and GRS. Finally, awn length correlated to component 3 absorbing 12.06 % of total variation (Table 6, and Figure 3a and b).

Table 6. Principal component analysis (PC) of 16 barley genotypes based on 11 traits (season 2018/2019)

Parameters	PC 1	PC 2	PC 3
Eigen values	5.396	2.423	1.326
% of variance	49.06	22.02	12.06
Cumulative %	49.06	71.08	83.14
Characters			
PLH	0.898	-0.025	-0.267
AWL	0.418	-0.315	-0.601
SPL	0.724	-0.150	0.608
GRS	0.382	0.587	-0.542
TGW	0.480	-0.691	0.132
HAI	-0.643	0.617	0.100
BIY	0.957	0.248	-0.008
GRY	0.758	0.616	-0.067
STY	0.971	0.103	-0.059
CYC	0.601	-0.574	0.059
SSM	0.548	0.561	0.436

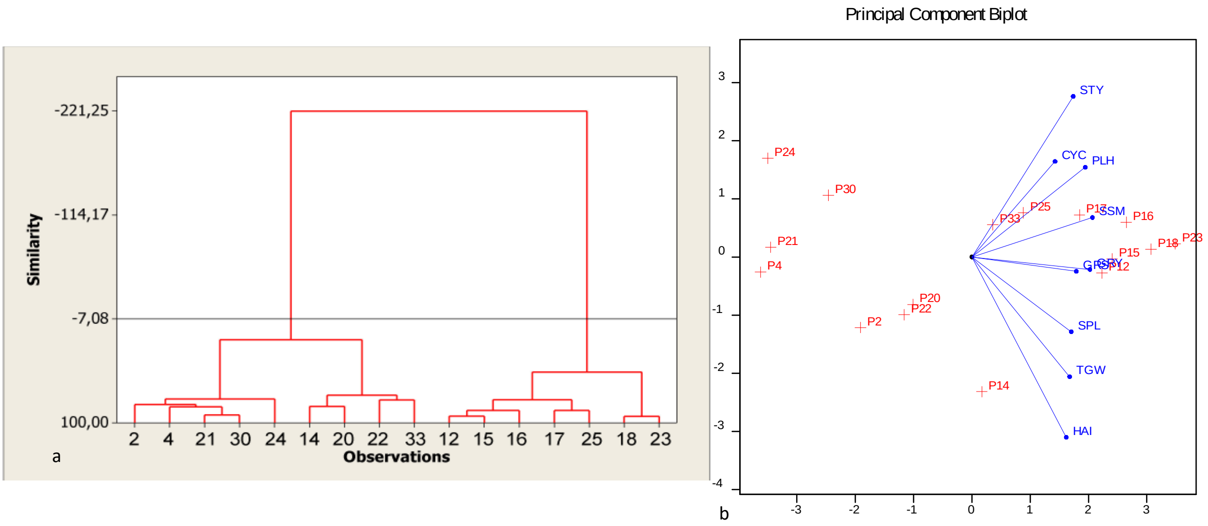


Fig. 3. Results recorded in 2018/2019 season, a: Projection of cultivars on the two first components; b: Projection of traits on the two first components.

Cluster and biplot analyzes for the 2018/2019 season:

Both clusters analyze (Figure 4a) and biplot analyze (Figure 4b) of the second season generated four clusters. Cluster one formed by genotypes 2, 20, 4, 14, 15, 16 and 33, which had intermediate mean values of PLH and STY. The second cluster ungloved genotypes 21, 30 and 24 with the lowest values of PLH and STY. Third cluster composed with genotypes 12, 17, 23 and 18 having high values of SPL. The last cluster (fourth cluster) represented by only the two genotypes 22 and 25 with the highest mean values of GRY and SSM and with genotype 25 having the highest value of GRS.

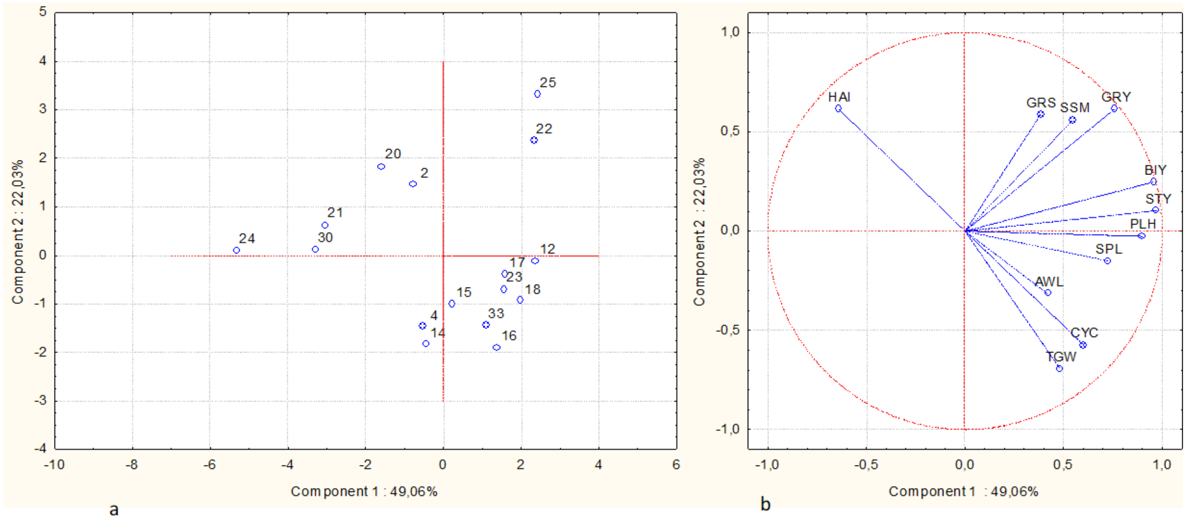


Fig. 4. Results recorded in 2018/2019 season, a: Dendrogram of 16 barley genotypes for eleven traits); b:Biplot for 16 barley cultivars and 11 traits (season 2018/2019)

DISCUSSION

Reducing yield gaps in dryland cropping depends on our ability to identify combinations of genetics (G) and management (M) that best suit site-specific and seasonal conditions (the environment, E) (Pankova *et al.,* 2018). Many studies have examined the role of mean climate change in agriculture; however, understanding the influence of inter-annual climate variations on crop yields in different regions remains elusive (Bennouna *et al.,* 2020).

The study conducted in semi-arid environments showed variations between the two seasons in the expression of parameters, particularly yield parameters. These results demonstrated the influence of environmental changes on rainfall, soil electrical conductivity, and temperatures, which differed between the seasons. Ray *et al.* (2015) found that global climate variability accounts for approximately one-third (32-39%) of the observed yield variability. In our study, the electrical conductivity of soil was 2 dS/m in the first test and 1.4 dS/m in the second experiment, indicating slightly saline conditions in the first campaign and non-saline conditions in the second campaign, according to the soil salinity grades cited by Pankova and Chernousenko (2020).

According to Ahmed *et al.* (2022), without CO2 fertilization, effective adaptation, and genetic improvement, each degree Celsius increase in global mean temperature would, on average, reduce global yields of wheat by 6.0%, rice by 3.2%, maize by 7.4%, and soybeans by 3.1%. The study conducted by Vogel *et al.* (2019) used Random Forest models, which included both growing season climatic averages and extremes as predictors, and was able to explain almost half of the variance in overall yield anomalies for maize, spring wheat, rice, and soybeans. The findings indicated that temperature-related predictors are more relevant to yield predictions than precipitation-related climatic factors, such as extreme rainfall or drought. The strong link between temperature indicators, especially high-temperature indices, and yields is consistent with studies revealing that heat waves are significantly associated with grain yields. However, in the specific cases of maize and taro, rainfall has a greater influence on yields than temperature (Vogel et al., 2019). The different groupings in clusters revealed variations in cultivars across seasons and through the parameters in our study. In the first year, lower variation was shown among cultivars, which were assembled into two clusters. However, greater variability was expressed among them in the second season, with an assembly into four clusters. Studying 52 barley landraces from Ethiopia, Enyew *et al.* (2019) found a grouping into six clusters.

In the first year, almost all the traits studied explained the variability among the genotypes. However, in the second season, it was different. Three components absorbed the variation among genotypes, with the first component explaining the greatest percentage of variation (49.06%) and showing correlations with the following parameters: STY, BIY, PLH, GRY, SPL, HAI, and CYC. These results for the second season are more or less in agreement with those found by Enyew *et al.* (2019), where principal component one (PC1) alone contributed 49.96%. The total variations were primarily due to grain yield, biomass yield, thousand-grain weight, and plant height, in that order. Yadav *et al.* (2018) studied 25 barley landraces from Nepal, using quantitative and qualitative traits, and found that the landraces formed five clusters. Grain yield, plant height, earliness, and some qualitative traits were the principal discriminatory characters.

In the studies conducted by Bchini *et al.* (2019), yield components related to final grain yield were severely affected by salinity; spike length, spikelet number per spike, and grain yield were significantly reduced after salt treatments. In our study, grain yield, spike length, grains per spike, biological yield, and straw yield, as well as awn lengths, performed better in the second trial, which was characterized by lower electrical conductivity of the soil but was less rainy and warmer. It is important to note that awns in barley play a significant role in resistance to drought conditions and in grain filling, as indicated by several authors including Yadav *et al.* (2018), Zhao *et al.* (2017) and Ladoui *et al.* (2020).

Concerning the variability among genotypes, both analyzes of variance and multivariate analyzes showed that via the two seasons, the common traits having explained the greatest variability were plant height, spike length, biological yield, grain yield and straw yield. In the study taken by Sehrawat and Khan (2017), plant height, grain yield and biological yield were also among traits with high variability among the barley genotypes studied. The diversity could be explored as a potential source of traits for crop improvement. A wide variation among genotypes of North Africa's barley was shown for morphological traits (Ben Naceur et al., 2012).

Study of pheno-morphological and agronomic characters among traditional barley genotypes in Algeria confirmed the existence of genetic variability and a great morphological distinction between the different genotypes for all the quantitative characters analyzed (Rahal *et al.,* 2015). Ladoui *et al.* (2020) worked on 7 varieties of barley to test their performance under stress and in the absence of stress, this evaluation made it possible to subdivide into tolerant and efficient varieties, giving good yields both under stress and in the absence of stress; only tolerant varieties that perform relatively better under water stress and varieties that perform less well under both environmental conditions.

Diversity could be explored as a potential source of traits for crop improvement. Morpho-agronomic traits constitute a substantial database on an unknown genetic material and should be considered for breeding programs. The confirmation of these results and the study of other agronomic parameters and those linked to different stresses will serve to better identify this genetic material and to better directing the selection work for varieties that are moderately tolerant to the difficult conditions of lack of water and soil salinity.

CONCLUSION

Barley is a crop that tolerates fairly harsh soil and climatic conditions (insufficient rainfall, soil salinity, high temperature, frost resistance). The study over two years of the agro-morphological characters of barley landraces from southern Algeria has allowed us to raise great variability especially interesting for useful characters related to yield. This variability observed among genotypes for different traits indicates that genetic improvement is possible for obtaining new barley varieties that are more profitable and more adaptable to different agro-ecological zones. Otherwise, seven cultivars and the control “Saida” performed well in the difficult conditions of Hmadna and have maintained the best values of yield parameters (grains per spike, thousand grain weight, grain yield, biological and straw yields) via the two experiments despite the differences in soil salinity and climatic conditions during the two seasons. In addition to their usefulness alongside other cultivars for genetic improvement, they can be integrated into the agricultural production systems of this region and those similar to it.

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