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Evaluation of agronomic performances of rainfed barley double-haploids (DHs) lines under semi-arid conditions

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Abstract. *Karkour L, Fenni M, Ramla D, Gaad D, Benbelkacem A. 2019. Evaluation of agronomic performances of rainfed barley double-haploids (DHs) lines under semi-arid conditions. Biodiversitas 20: 1398-1408.* Sixty-six doubled-haploid (DHs) barley lines derived from F2 plants of three bi-parental single crosses, between the local variety (Tichdrett) and three introduced genotypes (Express, Plaisant, and Exito) were evaluated in 2017 for agronomic performance. The experiment was undertaken at two locations under rainfed conditions in semi-arid zone of Algeria in a randomized block design with three replications. Each line was scored for fifteen quantitative traits: number of days to heading, thousand grains weight, number of grains per spike, spikes number per m^2, plant height, spike length, leaf relative water content, awn length, peduncle length, spike weight, grain weight per spike, leaf area, specific leaf weight, grain yield and harvest index. The results indicated that the presence of highly significant genotype effect for all traits except for leaf area and highly significant environment effect for all characters, except spikes number per $m^2$and awns length. Genotype x environment interaction was highly significant for all traits, except specific leaf weight and leaf area. Significant positive correlation between the twelve agronomic traits, ranging from 0.45 to 0.87, were observed among the number of grains per spike, thousand grains weight, the number of spikes per m^2, yield of grains and harvest index. The principal component analysis showed that four components could describe 72% of total variances. Cluster analysis divided all genotypes studied into three cluster groups. Overall, results of agronomic parameters and those related to the biotic and abiotic stresses will be used for better identifying this germplasm and better-directing studies of genetic improvement.

Keywords: Cluster analysis, *Hordeum vulgare*, quantitative traits, Tichedrett, yield components

INTRODUCTION

Barley (*Hordeum vulgare* L.), is one of the first domesticated cereals, which contributes from approximately 6% global cereals and 11.5-12% of the coarse cereals production (Pal et al. 2012; Kumar et al. 2013b; Kumar et al. 2014). Barley is used as food crop in many countries of Africa, Middle East, South America, and Asian. During 2013, barley was grown on 49.14 million hectares with a production of 143 million metric tonnes (FAOSTAT 2015). In Algeria, barley is the second most important rainfed cereal after durum wheat (*Triticum durum* Desf.) with 1 million ha harvested annually (Ramla et al. 2017). Its production is mainly located in semi-arid, highland climatic zones (300-400 mm rainfall) characterized by highly variable and severe of climate conditions (irregular quantity and distribution of rainfall, spring frost, low winter temperatures and high temperatures of end growing period. These harsh climatic conditions have a negative impact on the level and stability of grain yields which varied between 11.0 q ha^{-1} in dry years and 27 q ha^{-1} in rainy years (MADR 2014). For a long time, the national food security program focused on grain yield as criteria of selection. However, this strategy was conditioned by favorable and stable conditions (Ceccarelli 1996). Consequently, few varieties have been released and released varieties have poor adaptation and low stability. Therefore, they have not been adopted by the farmers. Only two varieties, Tichedrett, and Saida, selected from within local germplasm, remain widely used and cover the major areas occupied by this crop (Ceccarelli et al. 2011; Rahal-Bouziane et al. 2015). In regions with unfavorable cultivation conditions, the creation of genetic gain varieties is an important research objective (Ceccarelli and Impiglia 1998). Obtaining these varieties is, however, conditioned by the use of local germplasm and by the implementation of the selection process in the environment for which these new varieties are intended (Ceccarelli 1996; Ceccarelli et al. 2004). Compared to conventional breeding, plant biotechnologies, and more precisely haploid production techniques, are a powerful tool for rapidly obtaining new pure lines from hybrids, thus simplifying and shortening the selection cycle (Ma et al. 1999; Gomez-Pando et al. 2009).

The adaptability of a variety of diverse environments is usually tested by the degree of its interaction with different environments under which it is grown. Particular genotypes normally demonstrate their full genetic potential only under optimum environmental conditions. Therefore, relative performance in a set of varieties should be evaluated over a series of environments. Unstable varieties are those that show significant fluctuations in agronomic performance across different environments which is due to the presence of Genotype × Environment interactions (GEI) (Alberts 2004). Because of their importance in plant breeding and evolution, G × E of quantitative traits have been the subject of extensive investigations for several crops including barley (Teulat et al. 2001; Pillen et al. 2003; Peighambari et al. 2005; Sameri et al. 2006; Shahinnia et al. 2006; Von Korff et al. 2006).

The objectives of this study are to evaluate doubled-haploid (DHs) barley lines that are derived from the crossing between the local variety Tichedrett and the three introduced lines: Express, Plaisant and Exito, for their agronomic characteristics and to analyze their agronomic performance in two locations under rainfed conditions of Algerian semi-arid zones.

MATERIALS AND METHODS

Plant materials

Plant material consisted of sixty-six (66) doubled-haploid (DHs) along with fourth six-row barley parental genotypes (Table 1).These double-haploids derived from F2 plants of 3 bi-parental single crosses between the local variety (Tichedrett) and three introduced genotypes (Express, Plaisant, and Exito) using anther culture as described by Jacquard et al. (2006) cited by Ramla et al. (2017). Tichedrett is characterized by drought resistant and low yielding (Khaldoun et al. 1990), and the three genotypes Express, Plaisant and Exito are high yieldings and susceptible to drought stress (Teulat-Merah et al. 1998). The cross was carried out at the National Agronomic Research Institute of Algeria (INRAA).

Experimental design

These materials were evaluated at two locations in 2017/2018 year, under rainfed conditions in the Algerian semi-arid region. The locations were: the field Crop Institute of Agricultural Experimental Station of Setif (ITGC-AES) at 979 m above sea level with 334.7mm precipitations and the second locations was: Crop Institute-Agricultural Station of EL-Khroub (ITGC-AES), Constantine at 584 m altitude with 403 mm rainfall. Details of the geographic and climatic conditions of trials conditions are presented in Table 2. Field experiments were conducted at each location in a randomized complete block design with three replications. The experimental plots were 2.5 m long and 1.20 m wide with 20 cm between rows. The seeding rate was 270 seeds m^2. Sowing was performed on 11/12/2017 and 29/12/2017 at the Setif and Constantine station, respectively. Recommended cultural practices for the area were followed.

Table1. Name and code of tested genotypes (parental varieties and double-haploid lines)

Genotypes/Lines	Code
Tichedrett	Ti
Express	EXP
Plaisant	PLAI
Exito	EXI
DH3 F2 Tichedrett*express	HD3
DH4 F2 Tichedrett*express	HD4
DH8 F2 Tichedrett*express	HD8
DH12 F2 Tichedrett*express	HD12
DH18 F2 Tichedrett*express	HD18
DH19 F2 Tichedrett*express	HD19
DH10 F2 Tichedrett*express	HD10
DH22 F2 Tichedrett*express	HD22
DH23 F2 Tichedrett*express	HD23
DH27 F2 Tichedrett*express	HD27
DH28 F2 Tichedrett*express	HD28
DH11 F2 Tichedrett*express	HD11
DH14 F2 Tichedrett*express	HD14
DH15 F2 Tichedrett*express	HD15
DH34 F2 Tichedrett*express	HD34
DH35 F2 Tichedrett*express	HD35
DH38 F2 Tichedrett*express	HD38
DH21 F2 Tichedrett*express	HD21
DH44 F2 Tichedrett*express	HD44
DH47 F2 Tichedrett*express	HD45
DH47 F2 Tichedrett*express	HD47
DH48 F2 Tichedrett*express	HD48
DH49 F2 Tichedrett*express	HD49
DH131 F1Tichedrett*express	HD131
DH130 F1Tichedrett*express	HD130
DH52 F2 Tichedrett*express	HD52
DH94 F1Tichedrett*express	HD94
DH95 F1Tichedrett*express	HD95
DH96 F1Tichedrett*express	HD96
DH98 F1Tichedrett*express	HD98
DH99 F1Tichedrett*express	HD99
DH104 F1Tichedrett*express	HD104
DH106 F1Tichedrett*express	HD106
DH108 F1Tichedrett*express	HD108
DH110 F1Tichedrett*express	HD110
DH112 F1Tichedrett*express	HD112
DH113 F1Tichedrett*express	HD113
DH114F1Tichedrett*express	HD114
DH116 F1Tichedrett*express	HD116
DH117 F1Tichedrett*express	HD117
DH119 F1Tichedrett*express	HD119
DH120 F1Tichedrett*express	HD120
DH122 F1Tichedrett*express	HD122
DH125 F1Tichedrett*express	HD125
DH126 F1Tichedrett*express	HD126
DH127 F1Tichedrett*express	HD127
DH132 F1Tichedrett*express	HD132
DH133 F1Tichedrett*express	HD133
DH134 F1Tichedrett*express	HD134
DH26F2 Tichedrett*express	HD26
DH30 F2 Tichedrett*express	HD30
DH39 F2 Tichedrett*express	HD39
DH38 F2 Tichedrett*express	HD38
DH46 F2 Tichedrett*express	HD46
DH62 F2 Tichedrett*express	HD62
DH84 F2 Tichedrett*express	HD84
DH85 F2 Tichedrett*express	HD85
DH89 F2 Tichedrett*express	HD89
DH90 F2 Tichedrett*express	HD90
DH91 F2 Tichedrett * plaisant	HD91
DH92 F2 Tichedrett * plaisant	HD92
DH74 F1Tichedrett*Exito	HD74
DH77 F2Tichedrett*Exito	HD77
DH80 F2Tichedrett*Exito	HD80
DH82 F2Tichedrett*Exito	HD82
DH135 F1Tichedrett*Exito	HD135

Table 2. Geographic coordinates and climatic characteristics of the two-field trial locations

Location characteristics	Experimental sites	
	Institute-Agricultural Experimental Station of EL-Khroub, (ITGC-AES)	**Institute-Agricultural Experimental Station of Setif (ITGC-AES)**
Geographic coordinate	High plains	Highlands
Latitude	36°29' N	36°10'N
Longitude	6°41'E	5'21'E
Altitude	584	979
Climate type	Mediterranean type, Semi-arid	Mediterranean type, continental, Semi-arid
Rainfall (Novembre-June) mm	403	334.7
Temperature Minimal (°C)	8.7	6.87
Temperature Maximal (°C)	20.4	18.48
Soil characteristics	clay-loam with clay varies from 30 to 39% and organic matter 0.95-1.25 %, rich in limestone with a content of 12% (Derbal 2015)	silt-clay soil with calcium carbonate and organic matter contents of 30.4 % and 1.4%, respectively (Kribaa et al. 2001; Chennafi et al. 2008).

Notation and measurements

DHs lines were evaluated for the fifteen agronomic traits: Number of days to heading (DHE) was recorded as the number of calendar days from the date of sowing to the time when 50% of the spikes were halfway out from the flag leaf. At the heading stage, four leaves were sampled per plot from each DH line and parents to measure leaf relative water content (RWC), leaf area (LA) and specific leaf weight (SLW). The leaf area was estimated using the method described by Bekherchouche et al. (2009). Specific leaf weight was calculated according to the following formulae: SLW= FW/LA, where FW is the sample fresh weight and LA is the leaf area (Araus et al. 1998).

The same leaf samples were used to measure leaf relative water content (RWC) using Barrs and Weartherly (1962) method described by Pask et al. (2012). At maturity, Plant height (PH) was calculated as the average height of five randomly selected plants per line measured from the ground to the top of the terminal spikelet (excluding awns). Ten consecutive plants were randomly collected from each plot were used to calculate: spike length (SL); number of grains per spike (NGS); grain weight per spike (GWS); peduncle length (PL); awns length (AL) and spike weight (SW). Spikes number per m^2 (SN) and grain yield (GY) were recorded from a vegetative sample harvested from one row, 1.0 m long per plot. Harvest index (HI) was derived as 100 times the ratio of grain yield to above ground biomass: HI = 100 x GY/BIO. Thousand grains weight (TGW) was determined as the weight of a sample of 250 grains after harvest.

Statistical methods

PROC GLM within Statistical Analysis System (SAS) version 9 was used for the statistical analyses of quantitative data (SAS, 2015) For each Location and for each trait, mean± standard deviation, coefficients of variation, and treatment means were compared statistically using Student-Newman-Keuls test at p=0.05. Pearson‘s correlation coefficient between traits was also calculated. Principal Component Analysis (PCA) was performed in order to identify the most discriminant quantitative and traits. The nearest neighbor option based on Euclidean distances was used to explore relationships among the accessions, which were performed using Ward‘s minimum variance method. PCA and cluster analysis were performed with XLSTAT v13.01 software (Addin Soft, New York, USA). Furthermore, significance was determined a priori at alpha = 0.05 probability.

RESULTS AND DISCUSSION

The summary statistics of the phenotypic performance of the 66 DHs lines and 4 parents for 15 agronomic traits assessed in two each location are shown in Table3. The mean phenotypic values of the twelve significant characters for both locations are reported in Table 4.

Single location

Analysis of variance across environments indicated the presence of highly significant genotype effect for all traits except leaf area (LA) and a highly significant environment effect for all characters studied, except spikes number per m^2 (SN) and Awns length (AL). The effect for location was height significant for harvest index. HI was earlier at Setif location (mean 29.8%) with coefficients of variation (CV) (38%), and late at Constantine location (mean 19.54%), with CV (30%). If average data of the two locations are considered, line HD10 (28.88%), HD39 (25.30%) and HD11 (24.77%) with the lowest Harvest index at Constantine, and line HD11 (59.54%), HD10 (42.21%), and HD126 (42.15%) that has showed the highest harvest index at Setif.

Location effect is very significant (p< 0.001) for number of days to heading (DHE). At Constantine location, the days to heading ranged between 106 and 121 days after sowing (DAS) with a mean of 112 DAS. The lines HD39, HD10, HD11, HD14, and HD46 were the earliest for number of days to heading (107 at 109 DAS). Whereas, the locale variety Tichedrett (Ti) was later in days to heading (mean 112DAS). At Setif location, days to heading was greater ranged between 125 and 135 DAS with a mean of 132 DAS. The lines HD38, HD11, HD80, HD92, and HD91 were the earliest for days to heading (128 at 129DAS) and the lines HD10, HD126 was later in days to heading (130 DAS).

Highly significant differences have existed between various barley genotypes in thousand grains weight (TGW). Lines HD11, HD90. HD10, HD81, and HD26 at Setif location and lines HD39, HD38, HD26 and HD112 at Constantine location gave the highest values for thousand grains weight. Variation was observed for number of grains per spike over the two locations. Lines HD104, HD62, HD48, HD52, HD12, HD84, and HD92 recorded the highest number of grains per spike at Constantine. At Setif location the highest number of grains per spike was recorded by the lines HD84, HD39, HD110, HD98, HD130, and HD92.

The grain yield (GY) was influenced by location. It was higher at Constantine (70.1 $Qx.ha^{-1}$) compared to the Setif. Significant ($P<0.001$) grain yield differences were observed among lines of barley for both locations. The lines HD116, HD91, HD62, HD38, HD90, and HD11, had the highest grains yield at Constantine; whereas, the lines HD84, HD39, HD110, HD98, HD130, and HD92 had the highest grain yields at Setif location.

At Constantine location the highest Spike weight was produced by the linesHD26 (5.64g), HD45 (3.87g) followed by HD52 (4.16g). At Setif, the highest Spike weight was 3.13g, 2.93g, 2.88g, and 2.56g obtained by the HD96, HD135, HD94, and HD30 respectively. At Setif location the tallest lines were at Setif location HD15 (97.67cm), HD133 (97.00cm) followed by HD44 (96.00cm); however, genotype express produced minimum plants height (78.67cm). At Constantine, maximum plant heights were 111.00, 109.67, 108.00 and 107.67cm, obtained by HD62, HD90, HD119, and HD44 respectively.

Variation was observed for peduncle length over the two locations. The lines HD11, HD125, HD38, and HD62 recorded the longest peduncles measuring 28.33, 28.33, 27.67 and 27.33cm respectively at Setif. The shortest peduncle length was recorded for Exito (21.00cm). At Constantine the longest peduncle lengths were 32.67, 34.33 and 31.00 cm for HD84, HD117 and Plaisant respectively, the shortest was recorded for HD116 (21.67cm).

Combined locations

Among the traits reported here, except the specific weight leaf and Awns length, days to heading and plant height manifested the lowest variability with a coefficient of variation of 8.53% and 9.69%, respectively, followed by peduncle length, spike length, thousand-grain weight and grain weight per spike. At the same time, grain yield and yield components were the most variable traits with coefficients of variation ranging from 12.37% for thousand grains weight to 17.46% for number of grains per spike. Number of days to heading was influenced by genotype location. Lines HD38, HD91, and HD90 are early with flowering dates 116.3, 117.3 and 117.2 days respectively. The latest flowering was the introduction of genotype (Plaisant) at 126 days.

A significant genotype x location interaction for Harvest index. The lines HD11, HD10, and HD39 with 58. 38.16 and 36.34% respectively, gave the highest value for harvest index while HD49 had the lowest harvest index at15.32%.

Table 3. Statistical data recorded with fifteen agronomic traits for sixty-six double-haploid (DH) barley lines and four parents evaluated in two locations (Constantine and Setif)

	Mean squares					Mean Min. and Max. values and coefficients of variation (%)							
SV	**Block**	**Loc**	**Gen**	**Loc*Gen**	**Resi**	**Constantine location**				**Setif location**			
DF	**2**	**1**	**69**	**69**	**138**	**Mean ± SD**	**Min**	**Max**	**CV**	**Mean ± SD**	**Min**	**Max**	**CV**
HI	9.06	11126^{***}	226.76^{***}	142.50^{***}	32.70	19.54± 5.81	6.24	51.5	30	29.8± 11.48	9.76	60	38
TGW	0.23	158.35^{***}	164.90^{***}	16.29^{***}	0.44	45.27± 8.48	30.2	56.5	12	44± 5.651	29.3	55.4	13
NGS	5.95	5378.59^{***}	183.77^{***}	100.84^{***}	8.17	49.8±15.66	35	78	16	42.6± 6.638	25	58	16
GY	65.08	17051.3^{***}	316.31^{***}	114.25^{***}	30.13	40.13±11.73	11.1	70.1	29	30.5±11.37	11	61.6	35
SN	7740.3	9737.61^{ns}	9241.77^{***}	4533.7^{***}	1927.4	183.6±61.83	40.6	391	34	174±58.41	50	376	34
RWC	109.5	45005.1^{***}	308.37^{***}	208.12^{***}	70.72	84.09±9.694	33.5	97.2	12	63.4± 13.11	15.6	89.4	21
PH	91.8	10510^{***}	160.37^{***}	125.11^{***}	20.27	101.4±8.104	75	124	8	91.4± 7.511	70	107	8
SL	1.02	30.56^{***}	5.83^{***}	3.16^{***}	0.40	5.696±1.405	3	10	25	5.16± 1.244	3	9	24
AL	1,04	2.95^{ns}	9.08^{***}	7.33^{***}	0.80	13.23±1.597	10	17	12	13± 2.011	10	24	15
PL	8.06	239.26^{***}	55.09^{***}	41.30^{***}	4.97	29.02±4.75	18	40	16	27.5± 3.991	15	36	16
SW	1.32	80.58^{***}	1.03^{***}	0.53^{***}	0.21	2.978±0.79	1.47	9.39	27	2.2± 0.444	1.04	3.54	21
GWS	0.31	56.49^{***}	0.81^{***}	0.39^{***}	0.09	2.46±0.62	1.02	5.5	25	1.73± 0.376	0.87	3.16	22
LA	50.6	506.73^{***}	22.15^{ns}	17.52^{ns}	17.05	8.143±5.44	1.39	75.7	67	5.94± 2.575	0.5	14.7	43
SLW	31.10^{-3}	32.10^{-3ns}	30.10^{-3ns}	34.10^{-3ns}	35.10^{-3}	0.017±0.13	0.01	0.18	75	0.02± 0.018	001	0.2	88
DHE	0.37	42280.4^{***}	29.65^{***}	13.08^{***}	0.80	112 ±3.27	106	121	3	132 ± 2.112	125	135	2

Note: DF: degrees of freedom, SV: Source of variation, Loc: location, Gen: Genotype, Resi: Residual. *** Significant at p_< 0.001, NS= Non-significant at p_< 0.05. HI: Harvest index, TGW: Thousand grains weight, NGS: Number of grains per spike, GY: Grain yield, SN: Spike number per m^2 RWC: leaf relative water content, PH: Plant height, SL: Spike length, AL: Awns length, PL: peduncle length, SW: Spike weight, GWS: grain weight per spike, LA: leaf area, SLW: specific leaf weight, DHE: Number of days to heading.

Plants height (PHT) varied significantly (p <0.001) among genotypes and across locations. The maximum height was attained by the lines HD89 (108.5cm), HD133 (106.3cm) followed by another line HD85 with 105.2cm, while the shortest line was HD28 (77.66cm) and the genotype Exito (84cm). It was observed that the thousand-grain weight (TGW) differed between accessions for genotype x location. The grand mean was 44.65 g and mean values varied from 55.92 to 34.08g. The heaviest weight was detected in the lines HD10 (55.95g), HD39 (54.17g) and HD26 (54.15g), the lightest weight (34.08g) was the line HD35. The lines HD62 and HD11 had the great value for spike length with 8.1and 7.3cm respectively. The lowest value was recorded for HD92 about 3.5cm. For the character of peduncle length, the lines HD90 and HD89 had the greatest value by 34.33 and 34.16 cm. Signification variation for leaf relative water content (RCW) detected for genotype x, it varied from52.54 to 86.07% the height value for was observed in two lines HD38 (86.07 mg.cm$^{-2)}$ followed by HD84 (85%) and the light value was recorded in the line HD3 (52.54%).

The Grain yield (GY) was influenced by genotype x location interaction, the grand mean was 36.92 Qx.ha^{-1}and mean values varied from 22.43 to 57.27 Qx.ha^{-1}. The heaviest value of grain yield was detected in the lines HD10 (57.27 Qx.ha^{-1}), HD11 (55.12Qx.ha^{-1}) and HD30 (50.03Qx.ha-1). The lightest value of grain yield (22.43Qx.ha^{-1}) was the line HD80. Number of grain per spike differed among genotype x location interaction, ranged from32.8 to 56.83grains with an overage mean of 46.21grains. The lines HD84, HD98, and HD62 had greatest number of grains per spike with 56.83, 56.5 and 56 grains respectively. The line Hd116 had the least of NGS (32.83 grains).

Variation was observed for grain weight per spike (GWS) over two, the lines HD15 (3.18g), HD52 (3.01g) and HD92 (2.72g) recorded the highest grain weight per spike. The minimum number was also obtained by HD28 (1.21g).

Correlation between characters

The correlation coefficients between 70 barley genotypes including 66 double-haploid (DHs) and their four parents (*Hordeum vulgare)* evaluated in two locations are presented in Table 5.

Harvest index was highly significant and positive correlation with grain yield (r= 0 .741, p < 0.001), spikes number (r= 0.567, p< 0.001) and thousand grains weight (r= 0.366, p<0.01). However, HI was negatively correlated with number of days to heading (r=-0.315, p<0.01). Thousand grain weight is highly significant and correlated positively with grain yield (r= 0.511, p<0.001), leaf relative water content (r= 0 .369, p<0.01), spike weight (r= 0.316, p<0.01) and grain weight per spike (r= 0. 321, p<0.01). Number of grains per spike weight exhibited highly significant and positive correlation with spike weight (r=0.560, p<0.001) and grain weight per spike (r= 0.576, p<0.001). Grain yield exhibited highly significant and positive correlation with thousand grain weight (r= 0.511, p< 0.001), spike number per m^2 (r= 0.597, p< 0.001) and relative leaf water content (r= 0.410, p< 0.001). However, negative correlation of this character was noted with number of days to heading (r=-0.465, p<0.001). Peduncle length exhibited highly significant and positive correlation with plant height (r=0.405, p<0.001). Spike length exhibited highly significant and negative correlation with grain weight per spike (r=-0.253, p<0,001). Spike weight was highly significant and positively correlated with number of grains per spike (r= 0.576, p<0.001) and grain weight per spike (0.875, p< 0.001).

Principal compound analysis

Principal compound analysis (PCA) was performed based on twelve characters. There were four Eigenvalues greater than one, which determined the choice of the four components (Table 6). The PCA exhibited variances of 25.07, 23.35, 12.13 and 9.79%, were extracted for the first four principal components and accounts about 72% of total variation. Harvest index, relative leaf water content, thousand grains weight, grain yield and number of days to heading showed greater loading for variation in the first principal component. For Number of grains per spike, spike length, spike weight, grain weight per spike and spikes number most variation was explained by the second principal component. Variation in the third principal component was mainly due to plant height and peduncle length, while the fourth principal component showed 10% of total variation with greater loading from spike length and number of grains per spike. In line with the present finding, Bedasa et al. (2015) employed principal component analysis for detecting variation in 49 barley population in which the first four PCs contributed 70.36% of total variation. Generally, days to 50% flowering, days to maturity, and number of seeds per spike was the most loading character for the variation among accessions

Based on the 2D graph analysis, five major classes were formed (Figure 1). The first class contained all lines characterized by the highest number of grains per spike, grain weight per spike and spike weight. Class 2 contains primarily the lines belonging with highest value of harvest index, grain yield, and thousand grains weight. The third class contained the lines characterized by the highest value of spike length and spikes number per m^2. Class four contained the line characterized by long number of days to heading. The fifth class was characterized by tall Lines and those with long peduncles.

Cluster analysis

The dendrogram performed by cluster analysis confirmed the PCA results and indicated that the sixty-six double-haploid (DHs) barley lines and four parents could be divided into three major groups (Figure 2).

Table 4. Mean values, coefficient of variation (%) for twelve quantitative traits recorded at Constantine and Setif locations

Gen.	HI (%)	TGW (g)	NGS (nbr)	GY (Qx/ha)	SN (nbr/m2)	RWC (%)	PH (cm)	SL (cm)	PL (cm)	SW (g)	GWS (g)	DHE (days)
HD10	38.16_{b}	55.95_{a}	42_{u-x}	57.27_{a}	244.7_{b-f}	83.57_{a-d}	96.6_{k-x}	6.33_{e-l}	25.66_{s-z}	2.23_{n-u}	1.92_{o-y}	119.83_{yz}
HD11	58.70_{a}	53.00_{c}	41.5_{v-y}	55.12_{ab}	280.34_{ab}	79.35_{a-j}	97.16_{j-v}	7.33_{b}	29.83_{f-m}	2.43_{j-S}	1.97_{m-x}	119.33_{az}
HD30	28.00_{d-i}	50.38_{ef}	48_{j-q}	50.03_{bc}	206.95_{d-l}	79.12_{a-k}	93.33_{s-z}	6.75_{c-g}	24.3_{axyz}	2.60_{f-p}	2.02_{k-w}	118.5_{ab}
HD38	29.81_{d-g}	49.24_{ghi}	50.83_{f-k}	49.62_{bcd}	198.95_{e-o}	86.07_{a}	96.83_{k-w}	6.25_{f-l}	28.83_{j-p}	2.19_{o-u}	1.88_{p-z}	116.33_{e}
HD39	36.34_{bc}	54.17_{b}	41.16_{v-y}	49.19_{b-e}	220.67_{c-h}	80.68_{a-h}	101_{c-l}	6.08_{g-n}	29.5_{h-o}	1.82_{tuv}	1.53_{abc}	117.33_{cde}
HD46	25.96_{e-o}	34.37_{l}	45.16_{o-u}	47.57_{c-f}	306.40_{a}	81.61_{a-f}	92.33_{u-z}	5.5_{m-t}	22.3_{b}	2.03_{r-v}	1.48_{bc}	120.16_{w-z}
HD14	28.47_{d-i}	49.57_{gh}	49.83_{g-l}	46.92_{c-g}	201.14_{e-n}	68.30_{n-v}	95.83_{m-y}	6.58_{c-h}	29_{j-p}	2.32_{k-t}	1.82_{q-z}	120_{xyz}
HD26	26.81_{d-l}	54.15_{b}	47.83_{j-q}	46.65_{c-h}	186.20_{f-u}	83.37_{a-e}	92_{w-z}	5.16_{r-w}	24.83_{v-z}	3.79_{a}	2.42_{c-j}	120.66_{u-y}
HD62	26.39_{d-n}	40.49_{b-e}	56_{abc}	46.30_{c-h}	205.49_{d-m}	84.75_{abc}	102.33_{b-i}	8.08_{a}	27.16_{n-v}	3.06_{c-h}	2.46_{c-g}	121.16_{s-w}
HD89	31.7_{bcd}	48.4_{j-m}	48.16_{j-p}	44.52_{c-i}	191.11_{f-s}	70.54_{i-t}	108.5_{a}	4.83_{t-z}	34.16_{ab}	2.31_{l-u}	2.07_{j-u}	120_{xyz}
Ti	21.80_{i-y}	49.7_{fgh}	43.16_{s-v}	44.41_{c-i}	207.53_{d-l}	76.97_{a-o}	99.33_{e-q}	3.66_{bcd}	25.16_{t-z}	2.39_{j-s}	2.03_{k-v}	121.16_{s-w}
HD94	27.37_{d-j}	49.6_{gh}	49_{h-m}	44.16_{c-i}	179.02_{f-w}	79.64_{a-i}	92.5_{t-z}	4.16_{abcdz}	23.33_{abz}	2.97_{c-i}	2.63_{cd}	122.33_{l-r}
HD90	28.13_{d-i}	49.38_{gh}	48.5_{i-n}	43.79_{d-j}	175.07_{g-y}	82.03_{a-f}	102.66_{a-f}	6.16_{g-m}	34.33_{a}	2.57_{g-q}	2.01_{l-x}	117.33_{cde}
HD91	26.3_{d-n}	49.98_{efg}	44.83_{q-u}	43.02_{e-k}	189.13_{f-t}	81.91_{a-f}	97.5_{i-u}	4.6_{u-z}	30.83_{c-j}	2.72_{d-n}	2.12_{g-t}	117_{de}
HD85	26.45_{d-m}	47.28_{nop}	45.16_{o-t}	42.63f-l	193.55_{f-r}	78.85_{a-k}	105.16_{abc}	5_{s-y}	33.5_{ab}	2.60_{f-p}	2.10_{h-t}	122.5_{k-q}
HD84	26.49_{d-m}	48.35_{j-m}	56.83_{a}	42.22_{f-m}	154.24_{n-z}	85.00_{ab}	104.66_{a-d}	5.33_{o-u}	32_{a-h}	2.8_{c-j}	2.35_{d-l}	120_{xyz}
HD126	$32,88_{bcd}$	44.11_{vw}	39.83_{w-z}	41.93_{f-m}	225.74_{c-f}	74.30_{d-r}	103.66_{a-f}	5.16_{r-w}	32.16_{a-g}	2.24_{n-u}	1.68_{v-z}	125.16_{abc}
HD12	30.87_{c-f}	38.72_{g}	47.66_{k-q}	41.38_{g-n}	226.96_{c-f}	78.41_{a-l}	104_{a-e}	5.75_{k-r}	30.83_{c-j}	2.73_{c-n}	2.37_{c-k}	124.16_{c-g}
HD92	26.41_{d-n}	50.66_{e}	53.5_{b-f}	40.72_{g-o}	150.38_{r-z}	78.15_{a-m}	88.83_{cde}	3.5_{bcd}	29.16_{i-p}	3.10_{c-f}	2.72_{bc}	118_{bcd}
HD104	27.10_{d-k}	45.82_{rst}	53_{c-g}	40.71_{g-o}	175.38_{g-x}	62.36_{t-v}	104.16_{a-e}	4.66_{u-z}	29_{j-p}	2.78_{c-m}	2.31_{e-m}	124_{d-h}
HD44	29.42_{d-h}	39.97_{def}	46.66_{l-r}	40.52_{h-o}	210.37_{d-j}	75.52_{b-q}	93.83_{r-z}	5.5_{m-t}	26_{r-y}	2.23_{n-u}	1.67_{w-z}	122.66_{j-p}
HD98	25.6_{e-q}	45.34_{tu}	56.5_{ab}	40.05_{i-o}	148.21_{s-z}	71.39_{g-t}	96.66_{k-x}	3.83_{bcd}	23.83_{abyz}	3.25_{bc}	2.57_{cde}	120.66_{u-y}
HD45	25.78_{e-p}	49.975_{efg}	44_{r-v}	39.89_{i-p}	183.44_{f-v}	77.59_{a-n}	95.66_{m-y}	5.81_{j-q}	27.83_{k-s}	2.46_{i-s}	2.07_{j-u}	121.66_{p-u}
HD52	24.89_{f-t}	44.70_{uv}	55.66_{abc}	39.85_{i-p}	160.24_{k-z}	83.88_{abc}	93_{t-z}	4.33_{axyz}	25.33_{s-z}	3.04_{c-h}	3.01ab	122.83_{i-o}
HD82	28.48_{d-h}	46.97_{opq}	53.16_{c-f}	39.68_{i-p}	159.33_{l-z}	65.65_{r-v}	87.66_{de}	4.83_{t-z}	23.8_{abyz}	2.64_{e-o}	2.27_{e-o}	122.16_{m-s}
HD15	30.77_{c-f}	51.78_{d}	55.33_{a-d}	38.95_{i-p}	139.39_{t-z}	75.81_{b-p}	94.33_{q-z}	5.83_{i-q}	29.83_{f-m}	3.45_{ab}	3.18a	123.83_{e-i}
HD99	24.80_{f-u}	48.25_{klm}	45.83_{m-s}	38.88_{i-p}	164.70_{j-z}	73.88_{e-r}	97.33_{i-v}	4.41_{axyz}	27.41_{m-u}	2.69_{e-o}	2.28_{e-n}	123.66_{e-j}
HD131	$21,66_{i-y}$	43.82_{wx}	52.83_{c-g}	38.52_{i-p}	180.06_{f-w}	55.87wx	93.16_{s-z}	5.25_{p-v}	25.3_{s-z}	3.06_{c-h}	2.46_{c-g}	122.16_{m-s}
HD113	21.93_{i-x}	39.83_{ef}	50.66_{f-k}	37.85_{j-r}	173.70_{h-y}	60.61_{u-v}	91.33_{ayz}	4.41_{axyz}	27_{o-w}	2.58_{f-q}	2.18_{f-p}	124_{d-h}
HD119	21.39_{j-y}	44.4_{vw}	37.33_{az}	37.63_{j-s}	224.60_{c-g}	74.31_{d-r}	100.5_{d-m}	4.16_{abcdz}	28.6_{j-q}	2.25_{m-u}	1.96_{m-x}	123.5_{f-k}
HD112	25.34_{e-r}	49.10_{hij}	43.66_{r-v}	37.25_{k-t}	184.43_{f-v}	76.69_{a-p}	97.5_{i-u}	4.5_{xyz}	26.83_{p-x}	2.66_{e-o}	2.21_{f-p}	121.83_{o-t}
HD27	25.22_{f-s}	46.78_{pqr}	42.5_{t-x}	37.22_{k-t}	194.62_{e-q}	70.69_{i-t}	94.16_{r-z}	5.08_{r-x}	26.16_{q-x}	3.15_{b-e}	2.17_{g-q}	121.16_{s-w}
HD108	24.01_{g-u}	40.74_{bc}	48.33_{j-o}	37.20_{k-t}	177.68_{f-w}	73.01_{f-r}	98.83_{f-r}	6.55_{c-i}	31.66_{b-i}	3.23_{bcd}	2.58_{cde}	123.66_{e-j}
HD28	25.15_{f-s}	35.65_{k}	39.5_{xyz}	37.19_{k-t}	252.31_{bcd}	67.26_{p-v}	77.66_{f}	6.58_{c-h}	27.66_{l-t}	1.65_{v}	1.21_{c}	122.66_{j-p}
HD95	23.5_{g-v}	47.85_{lmn}	43.16_{s-v}	37.17_{k-t}	175.40_{g-w}	71.99_{g-s}	97.66_{h-t}	4.08_{a-d}	32.83_{a-e}	2.43_{j-s}	2.06_{k-u}	122.5_{k-q}
HD106	24.91_{f-t}	41.83_{yz}	44.33_{r-v}	36.46_{l-u}	200.74_{e-n}	67.97_{o-v}	97.5_{i-u}	4.08_{a-d}	30.25_{f-k}	2.42_{j-s}	2.37_{c-k}	123.83_{e-i}
HD127	$20,59_{l-y}$	37.83_{hij}	43.83_{r-v}	36.16_{m-u}	209.62_{d-k}	77.74_{a-n}	101.16_{c-k}	4.8_{t-z}	28.8_{j-p}	1.95_{s-v}	1.66_{xyz}	123.66_{e-j}
HD19	28.68_{d-h}	47.19_{n-q}	52.16_{e-h}	36.02_{m-u}	152.7_{1n-z}	80.82_{a-g}	90.66_{a-d}	5.5_{m-t}	28.8_{j-p}	2.86_{c-j}	2.31_{e-m}	122.83_{i-o}
HD3	24.68_{f-u}	42.12_{y}	46.66_{l-r}	35.68_{n-v}	180.08_{f-v}	52.54_{x}	95.66_{m-y}	6.58_{c-h}	32.33_{a-f}	2.66_{e-o}	2.17_{g-q}	124.66_{b-e}
HD110	21.86_{i-x}	48.57_{i-l}	46_{m-s}	35.52_{n-v}	141.96_{s-z}	62.12_{t-v}	91.5_{y-z}	5.08_{r-x}	27.83_{k-s}	3.13_{b-e}	2.53_{c-f}	123.83_{e-i}
HD18	19.94_{n-y}	46.43_{qrs}	55.83_{abc}	35.38_{n-v}	118.67_{abz}	74.17_{d-r}	95.33_{n-z}	6.41_{d-k}	27.83_{k-s}	2.66_{e-o}	2.13_{g-s}	122_{n-s}
HD4	22.94_{h-x}	41.01_{ab}	50.5_{f-k}	34.65_{o-w}	162.76_{k-z}	66.09_{q-v}	98.83_{f-r}	5.66_{l-s}	29_{j-p}	2.40_{j-s}	2.03_{k-v}	121.5_{q-v}
HD23	19.61_{o-y}	37.02_{j}	39.66_{x-z}	33.76_{p-x}	207.45_{d-l}	67.30_{p-v}	94.33_{q-z}	7_{be}	23_{a-b}	2.06_{q-v}	1.51_{bc}	125.16_{abc}
HD21	18.83_{s-y}	46.95_{pq}	36.66_{az}	32.63_{q-y}	149.73_{r-Z}	77.06_{a-o}	102.16_{c-j}	7.08_{bcd}	25.66_{s-z}	1.96_{s-v}	1.67_{w-Z}	121_{t-x}
HD96	25.2_{f-s}	44.11_{vw}	46.5_{m-r}	32.21_{r-y}	151.15_{n-z}	71.33_{g-t}	98.16_{g-s}	4.91_{t-y}	24.5_{xyz}	2.46_{i-s}	2.19_{f-p}	122.83_{i-o}
HD116	18.81_{s-y}	48.95_{h-k}	32.83_{b}	32.20_{r-y}	177.16_{g-w}	76.75_{a-p}	93_{t-z}	3.91_{bcd}	25_{u-z}	2.08_{p-v}	1.77_{t-z}	123_{h-n}
HD38-	18.90_{r-y}	44.83_{uv}	41.5_{v-y}	31.92_{r-y}	147.86_{s-z}	83.18_{a-e}	95_{o-z}	7.16_{bc}	29.83_{f-m}	2.36_{j-s}	1.89_{p-z}	117.16_{cde}
HD22	19.20_{q-y}	41.24_{abz}	39.66_{w-z}	31.65r-z	171.72_{h-y}	75.33_{c-q}	90.16_{a-d}	$5s_{-y}$	25.16_{t-z}	2.24_{n-u}	1.80_{r-z}	123.33_{f-l}
HD35	23.11_{h-w}	34.08_{l}	45_{p-u}	31.58_{s-z}	209.98_{d-k}	73.05_{f-r}	103_{b-g}	6.63_{c-g}	27.16_{n-v}	2.45_{i-s}	1.57_{acyz}	121.16_{s-w}
HD130	$20,29_{m-y}$	49.35_{gh}	48.66_{i-n}	31.40_{s-z}	123.21_{abyz}	71.23_{i-t}	100.16_{d-n}	5.16_{r-w}	27.6_{l-t}	2.55_{h-r}	2.07_{j-u}	123_{h-n}
HD122	$26,55_{d-m}$	45.17_{tu}	39.83_{w-z}	31.23_{t-z}	156.31_{m-z}	77.82_{a-n}	91.66_{x-z}	4.55_{w-z}	30.83_{c-j}	2.85_{c-k}	2.71_{bc}	125.5_{a-b}
HD117	18.59_{t-y}	50.54_{e}	37.16_{az}	31.23^{t-z}	160.17^{k-z}	73.94^{e-r}	101^{c-l}	5.5^{m-t}	33.3_{abc}	2.63^{e-o}	1.96_{m-x}	123.6_{e-j}
HD133	$18,78_{s-y}$	43.09_{x}	45.66_{n-t}	31.12^{t-z}	139.41^{t-z}	69.70^{k-u}	106.33^{ab}	4.65^{u-z}	27^{o-w}	2.22^{n-u}	1.79^{s-z}	124.16_{c-g}
HD132	$21,74_{i-y}$	37.22_{hij}	42_{u-x}	31.11_{t-z}	217.68_{c-i}	76.37_{b-p}	97.83_{h-t}	4.91_{t-y}	29.16_{i-p}	2.30_{l-u}	1.87_{p-z}	124.33_{c-f}
HD47	17.97_{v-y}	40.69_{bcd}	42.83_{t-w}	31.10_{u-z}	136.68_{u-z}	73.83_{e-r}	95.66_{m-y}	6_{h-o}	27.33_{m-u}	2.23_{n-u}	1.79_{s-z}	120.5_{v-y}
EXP	25.88_{e-p}	40.81_{ab}	35.66_{ab}	30.89_{u-z}	260.88_{abc}	69.74_{k-u}	94.83_{o-z}	4.5_{xyz}	30_{F-l}	1.94_{s-v}	1.54_{acbz}	125.16_{abc}
HD125	$20,82_{k-y}$	36.05_{k}	44_{rv}	30.86_{u-z}	205.3_{d-m}	68.85_{m-v}	99.5_{e-p}	5.5_{m-t}	33.16_{a-d}	1.79_{uv}	1.52_{abc}	122.5_{k-q}
HD8	25.83_{e-p}	34.36_{l}	44.83_{q-u}	30.61_{u-z}	196.94_{e-p}	69.97_{k-u}	96.33_{k-y}	5.16_{r-w}	29.5_{h-o}	2.62_{e-o}	2.15_{g-r}	122.83_{i-o}
HD77	21.15_{j-y}	40.91_{ab}	42_{u-x}	30.46_{u-z}	179.88_{f-w}	71.50_{g-t}	89.83_{bcd}	4.83_{t-z}	24.83_{v-z}	2.21_{n-u}	1.78_{s-z}	122.33_{l-r}
HD48	23.61_{g-v}	37.95_{h}	54.83_{a-e}	30.28_{u-z}	170.28_{i-y}	70.02_{j-u}	93.16_{s-z}	5.71_{k-s}	22.83_{ab}	2.62_{e-o}	2.20_{f-p}	123_{h-n}
HD120	18.91_{r-y}	47.7_{mno}	46.83_{l-r}	29.75_{v-z}	142.22_{s-z}	76.40_{b-p}	98.16_{g-s}	6_{h-o}	29.5_{h-o}	2.3_{l-u}	1.93_{n-x}	123.83_{e-i}
EXI	27.09_{d-l}	37.10_{ij}	51_{f-j}	29.56_{v-Z}	170_{i-y}	59.5_{vWx}	84_{e}	6.5_{c-j}	27.5_{l-u}	1.95_{s-v}	1.74_{u-z}	123.16_{g-m}
HD34	16.68_{xy}	45.83_{rst}	44_{r-v}	29.56_{v-z}	137.18_{u-z}	78.66_{a-k}	94.5_{p-z}	5.91_{h-p}	33.83_{ab}	2.81_{c-l}	2.16_{g-q}	122_{n-s}
HD134	$19,05_{r-y}$	46.57_{qrs}	45.5_{n-t}	28.61_{w-z}	143.85_{s-z}	78.37_{a-m}	96_{l-y}	4.83_{t-z}	27_{o-w}	2.65_{e-o}	2.32_{e-m}	123.16_{g-m}
PLAI	18.32_{u-y}	39.99_{c-f}	51.66_{e-i}	28.10_{w-z}	135.35_{v-z}	79.37_{a-j}	94.83_{o-z}	5.83_{i-q}	30.66_{d-j}	2.3_{l-u}	1.9_{p-z}	126_{a}
HD114	19.41_{p-y}	43.78_{wx}	44.83_{q-u}	27.44_{abyz}	128.9_{w-z}	62.74_{s-v}	99.66_{d-o}	4.16_{abcdz}	28.5_{j-r}	2.40_{j-s}	2.09_{i-u}	125_{a-d}
HD135	$23,28_{h-x}$	41.57_{ayz}	50.5_{f-k}	27.39_{abyz}	123.88_{xyz}	77.38_{a-o}	93.33_{s-z}	5.5_{m-t}	30.83_{c-j}	3.08_{c-g}	2.46_{c-g}	121.33_{r-v}
HD49	15.32_{y}	45.81_{st}	44.83_{r-u}	25.66_{abz}	111.95_{ab}	70.02_{j-u}	97.33_{i-v}	5.41_{n-t}	23.66_{abyz}	2.55_{h-r}	2.20_{f-p}	122.66_{j-p}
HD74	17.00_{wxy}	39.26_{fg}	51.66_{e-i}	23.47_{ab}	101.64_{b}	61.98_{t-v}	94_{r-z}	6.91_{c-f}	29.66_{g-n}	3.01_{c-h}	2.45_{c-i}	122_{n-s}
HD80	21.95_{i-x}	41.25_{abz}	38.5_{ayz}	22.43_{b}	146.38_{s-z}	69.06_{l-u}	96_{l-y}	6.16_{g-m}	30.5_{e-j}	2.20_{n-u}	2.21_{f-p}	118.16_{bc}
M A	24.68	44.65	46.21	36.92	178.82	73.73	96.40	5.42	28.26	2.53	2.09	122.06
CV (%)	42.31	12.37	17.46	31.10	33.68	21.00	9.61	24.92	15.73	30.56	30.23	8.53
LSD	6.49	0.76	3.25	6.23	50.33	9.55	5.11	0.72	2.53	0.53	0.35	1.01

Note: In a column, numbers with same letter (s) do not differ significantly at p= 0.05. Gen: Genotype, MA: Mean of accessions

Table 5. Pearson's correlation coefficients

Traits	HI	TGW	NGS	GY	SN	RWC	PH	SL	PL	SW	GWS	DHE
HI	**1**											
TGW	**0.366**	**1**										
NGS	0.078	0.028	**1**									
GY	**0.741**	**0.511**	0.171	**1**								
SN	**0.567**	-0.138	**-0.354**	**0.597**	**1**							
RWC	**0.246**	**0.369**	-0.033	**0.410**	0.179	**1**						
PH	0.058	0.148	-0.037	0.136	0.016	0.185	**1**					
SL	0.172	-0.142	0.053	0.081	0.092	0.067	-0.013	**1**				
PL	0.107	0.064	-0.075	-0.070	-0.061	0.036	**0.405**	0.091	**1**			
SW	0.036	**0.316**	**0.560**	0.099	**-0.393**	0.069	-0,041	-0.136	-0.015	**1**		
KWS	0.049	**0.321**	**0.576**	0.028	**-0.478**	0.045	-0.035	**-0.253**	0.030	**0.875**	**1**	
DHE	**-0.315**	**-0.395**	-0.099	**-0.465**	-0.113	**-0.435**	-0.044	**-0.260**	-0.022	-0.006	0.052	**1**

Note: The values in bold are different from zero to a level of significance alpha=0.05

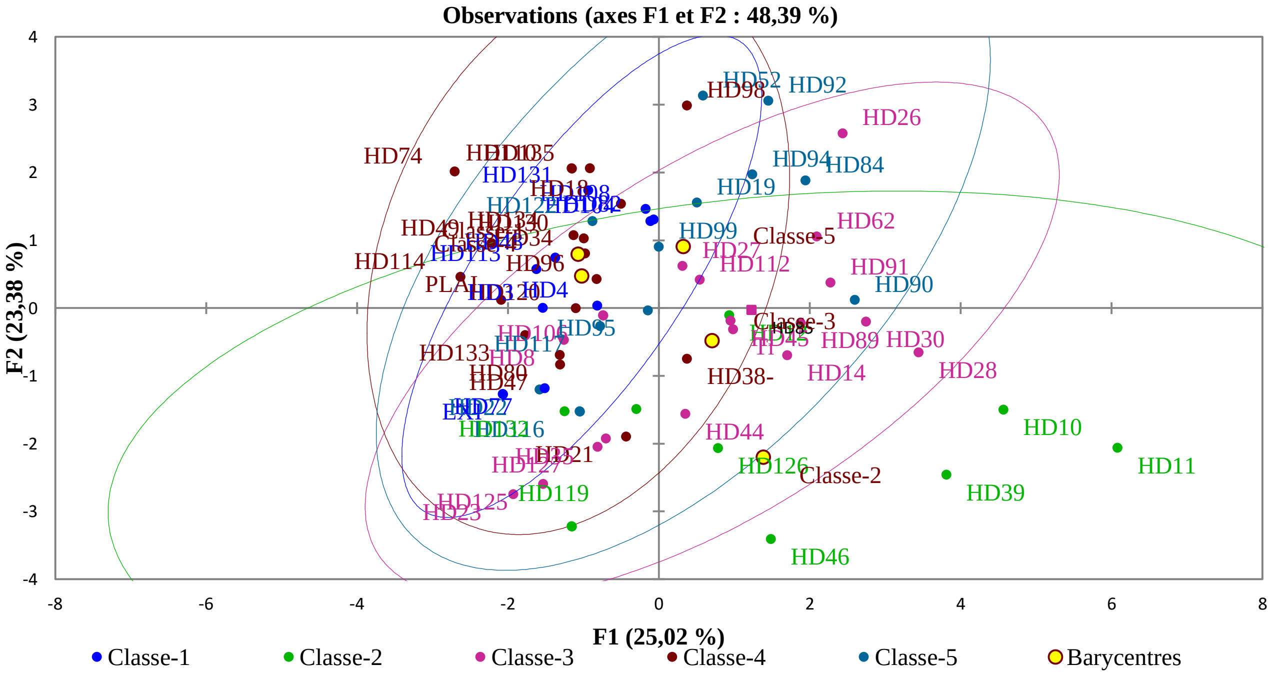

Figure 1. Scatter diagram with the distribution of sixty-six double-haploid (DH) barley line and four parents according to the first two principal components (PC1 and PC2)

The first group includes 38 genotypes, where the first subgroup contains 21doubled haploid (DHs) barley lines (HD15, HD91, HD52, HD45, HD112, HD90, HD89, HD94,HD26,HD77, HD22, HD116, HD95, HD108, HD4, HD104, HD82, HD48, HD131, HD113, HD3 and the variety Exito (Exi).The second subgroup of the first group consisted of 17 double-haploid (HD) barley lines HD27, HD23, HD132, HD127, HD35, HD8,HD125, HD126, HD119, HD44, HD12,HD30,HD14,HD62,HD28 and Tichedrett (Ti) local variety. The second group consisted of the lines HD10, HD11, HD38, HD39, HD46, HD126 and HD119. The third group includes 26 genotypes, where the first subgroup contains 12 double haploid (DHs) barley lines HD134, HD120, HD47, HD34, HD135, HD133, HD114, HD49, HD130, HD18, HD74 and Plaisant (PLAI). The second subgroup of third group consisted the lines HD99. HD96, HD122, HD110, HD80, HD 117, HD21, HD 98, HD15, HD 84, HD92, HD19 and HD85.

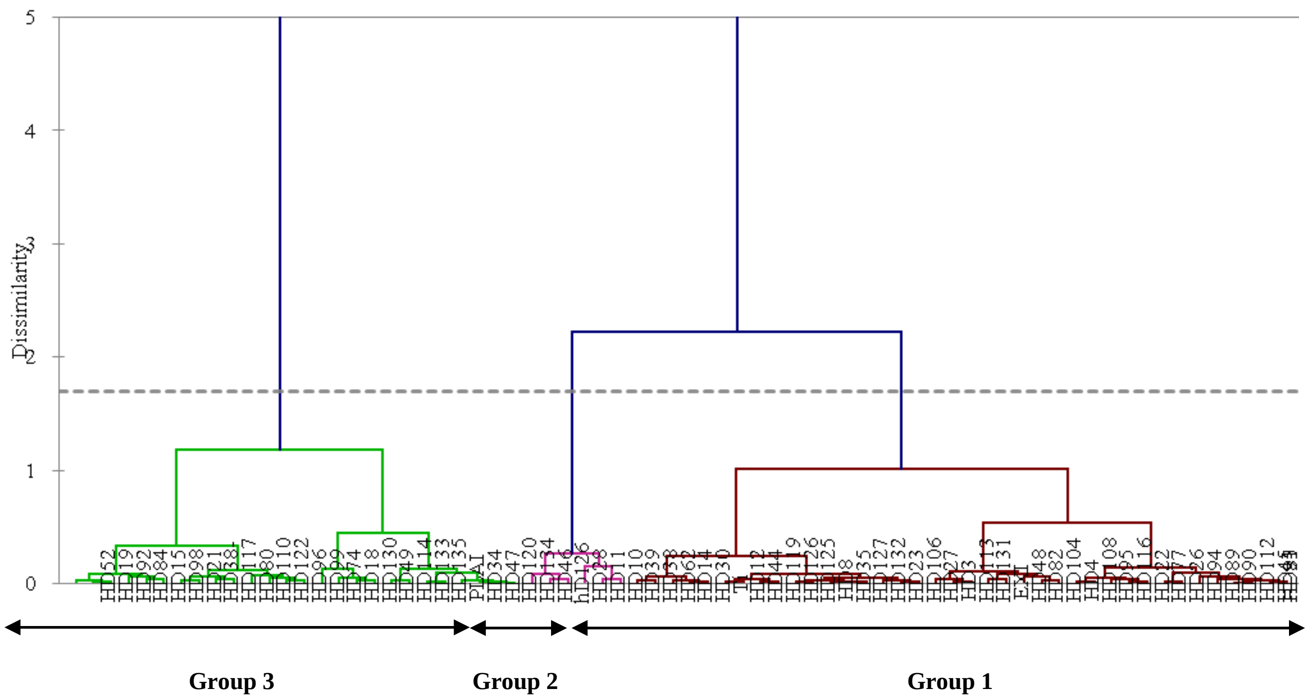

Figure 2. Dendrogram computed from the Euclidean distance for sixty-six double-haploid (DH) barley line and four parents

Table 6. Eigenvalues, individual and cumulative percentage variations, and Eigenvector explained by four vectors explained by four principal components based on agronomic traits in sixty-six double-haploid (DH) barley line and four parents evaluated in two locations (Constantine and Setif)

Parameters	**PC1**	**PC2**	**PC3**	**PC4**
Eigen value	3.009	2.803	1.456	1.176
% of variance	25.077	23.358	12.132	9.798
Cumulative %	25.077	48.434	60.567	70.364
Characters	**Eigenvector**			
HI	0.797	-0.106	-0.153	-0.031
TGW	0.625	0.367	0.181	-0.281
NGS	0.111	0.695	-0.212	0.377
GY	0.909	-0.044	-0.195	-0.11
SN	0.486	-0.666	-0.256	-0.197
RWC	0.614	0.014	0.178	-0.026
PH	0.215	-0.035	0.771	-0.065
SL	0.174	-0.254	-0.021	0.064
PL	0.082	-0.011	0.786	0.153
SW	0.134	0.893	-0.074	0.006
GWS	0.079	0.93	-0.022	-0.081
DHE	-0.651	0.012	-0.015	-0,349

Discussion

Sixty-six doubled-haploid (DHs) barley lines derived from F_2 plants of 3 bi-parental single crosses, between the local variety (Tichdrett) and three introduction varieties (Express, Plaisant, and Exito) were evaluated in 2017 using randomized block design with three replication at two locations under rainfed conditions of semi-arid zone in Algerian. Pooled analysis of variance across environments indicated the presence of highly significant genotype effect for all traits except leaf area (LA) and a highly significant environment effect for all characters studied, except spikes number per m^2 (SN) and Awns length (AL).

The results of ANOVA for quantitative traits indicated the influence of climatic conditions on phenological, and traits related to yield. Setif has a semi-arid climate, with winter rainfall (annual rainfall of 334.7 mm) as well as in Constantine location (annual rainfall of 403 mm. According to Ramla et al. (2015), barley production is mainly located in the highland semi-arid agro-climatic zone (300-400 mm rainfall) characterized by variable and severe climatic conditions. These environmental factors appear to have substantial impact on the phonological and yield components of barley. The main limitation to higher yield in the Mediterranean environment is water availability (Rizza et al. 2004); therefore, superior germplasm under the water-limited growing conditions may carry some positive drought tolerance traits. Abundant research on drought tolerance of crops indicates that different mechanisms may be relevant at different productivity levels (Cattivelli et al. 2008).

A wide range of variations was found among the DHs lines for all the traits. Moreover, the HDs lines expressed better performance for seed production in Constantine. At Setif earlier heading and a higher vegetative development were observed. Generally, DHs lines grown in Constantine produced longer spikes with higher number of grains per spike (NGS) and superior thousand-grain weight (TGW), than those grown in Setif. In addition, the mean grain yield

(GY) and Harvest index (HI) were superior at Constantine compared to Setif. Whereas, Results indicated also that more important DHs lines proportion were associated with leaf relative water content (RWC) and plant height (PHT) in Constantine region. These results would suggest that high temperature and rainfall distribution during the vegetative growth are among the factors that enhanced the expression of these traits. The mode of inheritance of grain yield and most agronomic traits is complex, governed by several genes and influenced by environmental conditions (Falconer 1981; Peighambari et al. 2005). A number of genes control these traits, and in general, they react in the same manner according to environmental conditions (Bellatreche 2017).

Genotypes x location interaction was height significant for all traits, except specific weight leaf (SWL) and leaf area (LA). These results agree much with those found bay Drikvand et al. (2012) where traits contributing to the most variance concerned awn length, plant height, grain yield, grain number per spike, peduncle length, spike length, and 1000-grain weight. Many of these traits have also contributed to the genetic differentiation among accessions of barley (Setotaw et al. 2010). Previous studies have also reported significant G x E effect for different agronomic characters in barley populations (Teulat et al. 2001; Pillen et al. 2003; Peighambari et al. 2005; Von Korff et al. 2006; Chand et al. 2008; Schmalenbach et al. 2009).

Genotypes x environment interactions are important sources of variation in any crop and the term stability is sometimes used to characterize a genotype, which shows a relatively constant yield, independent of changing environmental conditions (Becker and Leon 1988).

Significant differences were observed among barley cultivars for grain yield, 1000-grain weight, plant height and heading date (Mut et al. 2010). The significant estimates of G x E interaction indicated that the characters were unstable and may considerably fluctuate with change in environments (Chand et al. 2008). These results indicated the presence of variability among genotypes as well as environments under which the experiments were conducted. Therefore, an understanding of genotypes x environments interaction provides valid insights to words the selection of new stable genotypes in the diversified environmental conditions prevailing in a region.

Variability of quantitative traits of any crop is influenced by genetic factors, environmental factors, and their interaction. Uniformity of individuals and stability of quantitative traits are major requirements for the development of improved varieties and their release. Since the preservation of broad genetic base of landraces could be much appreciated, then the study of variability of quantitative traits becomes increasingly important. In our experiment, the most variable trait was harvest index (HA) followed by yield components: spike number per m^2 (SN), grain weight per spike (GWS), gains yield of grains (GY) with respective coefficient of variation values of 42.33%, 33.68%, 30.23%, and 31.10%. Such a strong variability was caused by the fact that grain yield is a complex trait controlled by a polygenetic system and is strongly influenced by environmental factors. Darwinkel (1978) in Chalak et al. (2015) reported similar pattern of variability in winter wheat grown at the Netherlands a wide range of plant population densities.

Days to heading expressed the lowest variability with a coefficient of variation of 8.53%, followed by plant height (9.6%) and peduncle length (15.73%). These results match with the findings of Singh (2011), who reported that days to heading were the most stable traits, whereas yield and yield components were noticed for strong phenotypic and genotypic variability about 30%.

The genetic correlations among the twelve agronomic traits were estimated from data combined across environments table. Significant positive correlation, ranging from 0.45 to 0.87, were observation among number of grains per spike, thousand grains weight, spikes number per m^2, grain yield and harvest index. Similar results have been reported by Peighambari et al. (2005) in Iran and Rajiv and Yashasvita (2018) in India. Many workers have also reported similar positive and significant association of grain yield with Spikes number per m^2 (Akdeniz et al. 2004; Ataei 2006), number of grains per spike (Drikvant et al. 2011). Thousand-grain weight and with harvest index (Khajavi et al. 2014; Kumar et al. 2014).The same finding for grain yield and plant height were reported by other studies (Samarrai et al. 1987; Kisana et al. 1999; Bhutta et al. 2005). Akdeniz et al. (2004) observed positive and significant correlations between grain yield and yield components such as plant height, spike length and spike number per m^2 but found negative and non-significant correlations between grain yield and grains number per spike. Ataei (2006), reported positive and significant correlations of grain yield with spike number per m^2 and thousand grains weight.

Principal component analysis was used to observe the general pattern for variation of traits. The first four principal components with eigenvalues greater than unity (1) together extracted about 72 % of the total variation. According to Johnson and Wichern (2002), based on the Eigenvalues and vectors, it is possible to indicate which traits are mainly responsible to explain the variation. Accordingly, the first principal components, which contributed about 48.42% of total variation, were due to harvest index, leaf relative water content, thousand grains weight, grain yield and number of days to heading, respectively (Table 4). Similarly, about 23.35% of the variation, accounted for by the second principal component, was due to contributions of number of grains per spike, spike length, spike weight, grain weight per spike and spikes number.

On the other hand, the third principal component, which explained about 12.13% of the variation, mainly planted height followed by Peduncle length, while the fourth principal component showed 10% of total variation with greater loading from spike length and number of grains per spike. In the work of Abebe et al. (2010) for Ethiopian barleys in relation to geographic regions and altitudes, the first three principal components (PCs), with eigenvalues greater than unity, explained about 73% of the total variation among accessions for the nine quantitative traits. Hence, even if the genotypes and the number of traits used vary, the value of the first three principal components greater than unity shows a better percentage in this study than the genotypes investigated by Abebe et al. (2010). According to the study of Zaheer et al. (2008) in Pakistan, the variation studied through Principal Component Analysis revealed that five principal components having greater than 1eigenvalues contributed 83.40% of the total variation.

Although the cluster analysis grouped, barley accessions with greater morphological similarity, the dendrogram of the evaluated sixty-six double-haploid (DHs) barley lines and four parents genotypes grouped into three cluster groups. Konichi et al. (1993) in Bhutan, six-row barley genotypes investigated were also classified into three groups. It is the same for a study by Dimitrova-Doneva et al. (2014).

The first group includes 38 genotypes which was 54.28% of the total experimental materials, where the first subgroup contains 21double-haploid (DHs) barley lines, among these lines: HD77, HD4, HD104, HD82, HD48, HD131, HD113, HD3 and the variety Exito (Exi), characterized by the highest number of grains per spike, grain weight per spike and spike weight. The second subgroup of the first group consisted of 17 double-haploid (HD) barley lines, among which: HD27, HD23, HD132, HD127, HD35, HD8, HD125, HD44, HD28 and a local variety Tichedrett (Ti), characterized by the highest value of spike length and spikes number per m^2. The second group consisted of the lines HD10, HD11, HD38, HD39, HD46, HD126 and HD119, characterized by the highest values of harvest index, thousand grains weight, and grain yield.

The third group includes 25 genotypes, 35.71% of the population, where the first subgroup contains 12 double haploids (DHs) barley lines HD134, HD120, HD47, HD34, HD135, HD133, HD114, HD49, HD130, HD18, HD74, and the introduced variety Plaisant (PLAI), characterized by long number of days to heading. The second subgroup of third group consisted of 13 lines, among them: HD122, HD117, HD84, HD92, HD19, and HD95, characterized by long plant height and peduncle length. The confirmation of these results and the study of other agronomic parameters and those related to the biotic and abiotic stresses will be used for better identifying this germplasm and better directing works of genetic improvement.

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