Bulgarian Journal of Agricultural Science, 30 (No 1) 2024, 88–95

Grain yield and yield-related traits of hulled and hull-less spring barley accessions

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Abstract

Dyulgerova, B. & Dyulgerov, N. (2024). Grain yield and yield-related traits of hulled and hull-less spring barley accessions. *Bulg. J. Agric. Sci., 30*(1), 88–95

The aim of the study was to evaluate the grain yield and yield-related traits of 20 hulled and 20 hull-less spring barley accessions under conditions of South-eastern Bulgaria. Field experiments were carried out from 2017 to 2019 in the experimental field of the Institute of Agriculture – Karnobat. The effects of years and year by genotype interactions on grain yield and studied yield-related traits were considerably higher in hull-less accessions compared to hulled accessions. Highest broad-sense heritability was found for spike length, 1000-grain weight and number of spikelets per spike in both barley types. Hull-less accessions showed a lower average number of spikes per plant, number of grains per spike, weight of grains per spike, 1000-grain weight and grain yield. The number of grains per spike had a maximum direct effect on grain yield, followed by the number of spikes per plant and weight of grains per spike in hulled accessions. While in hull-less genotypes, the number of spikes per plant had the highest direct effect on grain yield, followed by the number of grains per spike and spike length. Therefore, direct selection for these traits would be an effective breeding strategy for increasing the grain yield of spring barley.

Keywords: hulled barley; hull-less barley; grain yield; yield-related traits; correlations; path analysis

Introduction

Globally, barley ranks fourth among cereals in terms of production, after maize, rice, and wheat (Zhou, 2009). In Bulgaria, barley is the third most important cereal crop and occupies a significantly smaller area than wheat but despite this is an economically important crop. About 75% of world barley production is used for animal feed, 20% for malting, and only 5% for human food.

Most of the currently grown barley varieties are hulled and their caryopsis is enclosed by outer lemma and inner palea, which remain firmly attached to pericarp endosperm at maturity. Hull-less or naked barley differs from hulled or cover barley by the loose husk cover of caryopses that is easily separable upon threshing.

Hull-less barley has a number of nutritional benefits compared to hulled barley because of higher digestible energy due to higher starch and reduced fiber content (Griffey et al., 2010). Naked barley is particularly suitable for non-ruminants that have limited ability to deal with high levels of dietary fiber (Bleidere & Gaile, 2012). The high protein content of hull-less barley is also valuable when barley grain is used for food and animal feeds.

The interest to the incorporation of hull-less barley in the human diet is associated with a high content of β-glucans, vitamins and minerals in its grain (Shaveta and Kaur, 2019). Hull-less barley can be used with minimal processing and with the intact bran layer in food products to get the health benefits of the whole grain (Liu, 2007).

The lower grain yield of hull-less barley is the main factor that prevents acceptance of hull-less barley as an alternative of hulled barley. It has been reported that the yield of hull-less barley is about 10% to 30% less than those of hulled barley (Choo et al., 2001; Thomason et al., 2009).

Taketa et al. (2008) reported that the covered/naked caryopsis is controlled by a single locus (*nud*) on chromosome 7HL. Choo et al. (2001) assumed that the *nud* gene may have a pleiotropic effect on yield or might be linked to a yield QTL. Contrarily, Barabaschi et al. (2012) concluded that the effect of the *nud* gene on grain yield is due only to the lack of hulls, and they did not find any pleiotropic effect of *nud* gene on other yield-related traits.

While many studies have been conducted to determine the association between grain yield and yield-related traits in hulled barley, few such studies have been conducted in hull-less barley. Studies focusing on factors contributing to yield differences between hulled and hull-less genotypes have been limited (Choo et al., 2001; Thomason et al., 2009; Barabaschi et al., 2012; Berger et al., 2013). Information about differences between hulled and hull-less genotypes in yield-related traits and determine the traits that have a high direct effect on grain yield could be useful in yield improving both hulled and hull-less barley.

The aim of the present investigation was to evaluate the grain yield and yield-related traits of hulled and hull-less spring barley accessions under conditions of South-eastern Bulgaria.

Materials and Methods

The study was conducted in 2017–2019 on the experimental field of the Institute of Agriculture – Karnobat, South-eastern Bulgaria (42°39′ N, 26°59′ E). For the years of the study, average air temperature during the growing period of spring barley was higher than the long-term average (Table 1). In particular months of the period, the air temperature was generally higher than long-term average temperatures. Monthly average temperatures were slightly below the long-term average only in April 2017 and 2019. In 2018, total rainfall during the growing period of barley (III–VII) exceeded the long-term average with 175.3 mm. In 2017 and 2019 total rainfall were lower than the long-term average with 61.2 mm and 17.0 mm, respectively. The most abundant rainfalls were recorded in July and March, 2018. April 2018 was the month with the lowest sum of precipitation for the three years.

The field experiment was set up on leached chernozem soil under rain-fed conditions. The design was a randomized complete block design with 3 replications on plots of 10 m^2. Plots were seeded at a density of 450 germinating seeds per m^2. Field management followed local practices.

The trail consisted of 40 six-rowed accessions of spring barley from ICARDA – 20 hulled from International Barley Yield Trail for high input conditions – 2015 and 20 hull-less – 18 from International Naked Barley Yield Trail for high input conditions – 2015 and 2 from International Naked Barley Observation Nursery – 2015.

The studied traits included: number of spikes per plant (SP), spike length (SL, cm), number of spikelets per spike (NSS), number of grains per spike (NGS), weight of grains per spike (WGS, g), 1000-grain weight (TGW, g), grain yield (GY, kg ha^{-1}). The data were recorded on a plant basis by randomly chosen 20 plants from each plot. Grain yield was estimated on a plot basis.

Data were analysed by analysis of variance (ANOVA) and linear correlation analysis using the SPSS19.0 software. The mean values were compared by the least significant difference (LSD) at the 0.05 probability level. The portion of sums of squares (SS) attributed to genotype, year and genotype × year interaction (GxY) was presented as a percentage of the total sums of squares remaining after removing sums of squares due to replication and error. Broad-sense heritability (h_{bs}) was calculated as the ratio of the genotypic variance to the phenotypic variance (Allard, 1960). The path

Table 1. Average temperatures and sums of precipitation in months III–VII compared to long-term averages (1931–2019) in Karnobat, Southeast Bulgaria

Years	Months					
	III	IV	V	VI	VII	III–VII
Average temperature, °C						
2017	8.3	10.0	16.1	21.7	23.4	15.9
2018	6.4	14.0	17.9	20.8	23.1	16.4
2019	8.6	10.3	17.1	22.6	22.9	16.3
Average 1931–2019	5.3	10.5	15.6	19.5	22.0	14.6
Sum of precipitation, mm						
2017	24.1	35.4	36.6	55.0	40.7	191.8
2018	121.2	5.9	68.6	98.6	134.0	428.3
2019	8.9	52.9	44.9	95.6	33.7	236.0
Average 1931–2019	34.1	45.3	58.5	65.2	49.9	253.0

analysis performed by using the statistical software GENES (Cruz, 1997) was used to split correlations between grain yield (dependent variable) and other traits into direct and indirect effects.

Results and Discussion

The accessions showed highly significant differences ($p \leq 0.001$) for all traits measured (Table 2). Mean squares due to years and genotype by year interaction were also highly significant for all traits. Mean squares revealed the presence of variability among studied barley accessions and the growing years in which the trials were carried out. Wide variation among weather conditions in different years is typical for this region, which makes growing year an important source of variation. The effect of the genotype by year interaction was observed for all traits studied, which indicated the importance of the evaluation of barley accessions in different years to assure the selection of more adapted and stable genotypes in the conditions of South-eastern Bulgaria. Similar effects of genotypes, environments and their interaction for grain yield and other agronomic traits were reported for barley genotypes under rain-fed conditions (Bahrami et al., 2009; Saad et al., 2013).

The percentages of sums of squares due to the genotype for all traits in hulled accessions were higher than those of hull-less accessions (Table 3). The effect of genotype was highest for the number of spikelets per spike, followed by 1000-grain weight and spike length in both types of barley. The portion of sums of squares for the number of spikes per plant, plant height, number of grains per spike and weight of grains per spike attributed to year was about two times higher in hill-less accessions compared to hulled accessions. The influence of the genotype by year interaction was most important for 1000-grain weight, the number of spikelets per spike and spike length in hull-less genotypes. In hulled barley, 46.48% of the variation of grain yield was attributed to the genotype, 20.44% to the effect of year and 33.08% to the genotype by year interaction. While in hull-less accessions only 3.30% of the grain yield variation was due to the genotype and 41.13% to the year and 55.57% to the interaction between genotype by year. The percentages of sums of squares due to the genotype in hull-less accessions were considerably lower compared to hulled genotypes for the number of spikes per plant, the number of grains per spike and the weight of grains per spike indicated that those yield associated traits were more environmentally sensitive in the naked barley.

The *highest coefficient* of *variation* (CV) was observed in *grain yield* and the number of spikelets per spike had the lowest *coefficient* of *variation* in both barley types.

The estimates of broad-sense heritability (h_{bs}) were grouped according to Singh et al. (2001) into the following categories: low < 40%, medium – 40–59%, high – 60–79% and very high heritability > 80%.Very high heritability values were observed for spike length, number of spikelets per spike, number of grains per spike, weight of grains per spike and 1000-grain weight in hulled genotypes and for number of spikelets per spike and 1000-grain weight in hull-less accessions. Heritability was high for number of spikes per plant, plant height and grain yield in hulled lines and for plant height, spike length, number of grains per spike and weight of grains per spike in hull-less lines. Medium heritability of number of spikes per plant and grain yield in hull-less accessions was found. The values of heritability of barley grain yield reported in the different studies differ significantly because the magnitude of heritability depends on genetic material and environmental conditions. Our findings are in agreement with Marquez-Cedillo et al. (2001), who observed a high heritability of grain yield in hulled barley and with Eshghi et al. (2012) and Matin et al. (2019), who reported moderate values of heritability of yield in hull-less barley.

Table 2. Mean squares for yield and yield-related traits of 20 hulled and 20 hull-less barley accessions (2017–2019)

Source of variation	SP	PH	SL	NSS	NGS	SW	TGW	GY
Hulled accessions								
G	1.1*	332.3*	3.8*	160.1*	470.1*	1.3*	160.6*	1965706.0*
Y	12.0*	7664.0*	18.7*	173.9*	5637.6*	10.2*	280.6*	8209972.0*
GxY	0.2*	129.0*	0.2*	16.8*	86.4*	0.2*	13.6*	699517.6*
Hull-less accessions								
G	0.5*	544.8*	3.4*	240.6*	214.4*	0.4*	127.8*	1339159.2*
Y	28.9*	10215.6*	13.4*	215.9*	9420.6*	26.5*	248.1*	8341504.3*
GxY	0.2*	127.5*	0.7*	16.7*	73.3*	0.2*	24.9*	593140.6*

*significantly different at $p \leq 0.001$; G – genotype; Y – year; GxY – genotype by year interaction; SP – number of spikes per plant; PH – plant height; SL – spike length; NSS – number of spikelets per spike; NGS – number of grains per spike; WGS – weight of grains per spike; TGW – 1000-grain weight; GY – grain yield

Table 3. The portion of sums of squares attributed to genotype (SS G), year (SS Y), and genotype by year interaction (SS GxY) as a percentage of the total sums of squares, coefficient of variation (CV, %) and broad-sense heritability (h_{bs}, %)

Source of variation	SP	PH	SL	NSS	NGS	WGS	TGW	GY
Hulled accessions								
SS G	39.33	23.79	62.8	75.54	38.02	47.86	73.90	46.48
SS Y	43.78	57.75	32.24	8.64	48.00	39.01	13.59	20.44
SS GxY	16.89	18.46	4.95	15.82	13.98	13.13	12.51	33.08
CV, %	15.14	7.99	7.82	5.72	14.04	17.44	9.72	18.08
h_{bs}, %	78.52	61.20	96.07	89.53	81.62	86.26	91.53	64.41
Hull-less accessions								
SS G	0.73	2.11	5.86	18.39	0.98	0.72	8.15	3.30
SS Y	87.94	79.13	46.59	33.00	86.26	88.87	31.64	41.13
SS GxY	11.33	18.76	47.55	48.61	12.75	10.40	60.22	55.57
CV, %	11.77	10.15	6.84	7.10	12.14	12.79	9.27	20.46
h_{bs}, %	59.17	76.60	78.65	93.04	65.81	62.09	80.55	55.71

SP – number of spikes per plant; PH – plant height; SL – spike length; NSS – number of spikelets per spike; NGS – number of grains per spike; WGS – weight of grains per spike; TGW – 1000-grain weight; GY – grain yield

The mean values of studied traits for the period from 2017 to 2019 are presented in Table 4. The number of spikes per plant was higher in studied hulled accession than in hull-less genotypes. Plant height, spike length and the number of spikelets per spike did not differ significantly between two types of barley. Hulled lines showed a higher average number of grains per spike, weight of grains per spike and 1000-grain weight. Hulless barley lines were previously reported to have 5% fewer spikes per m^2 and 30% fewer grains per spike (Thomason et al., 2009). The mean grain yield of hulled accessions was with 700 kg ha^{-1} higher compared with that of naked accessions. The lower grain yield of hull-less accessions, when compared to hulled accessions obtained in this study, was in line with the findings of other studies (Choo et al., 2001; Thomason et al., 2009; Berger et al., 2013; Sturite et al., 2019).

The values for yield-related traits and grain yield of hulled and hull-less accessions are presented in Table 5 and Table 6. The grain yield ranged from 1760 kg ha^{-1} (IBYT-HI-15-12) to 3575 kg ha^{-1} (IBYT-HI-15-8) in hulled accessions, and from 1318 kg ha^{-1} (INBYT-HI-15-23) to 2830 kg ha^{-1}(INBON-15-21) hull-less accessions. The grain yield recorded for the hulled accessions included the hull in addition to the grain. The hull content of the hulled accessions was not determined in this study. The mean yield of naked accessions was 72.92% of the mean grain yield of covered genotypes. It should be noted that when hulled barley is used for human food it must first be pearled, which reduces grain weight with about 20–30% (Newman & Newman, 2005). This indicates that if the grain yield of hulled accessions is adjusted for hull content, it becomes possible to select hull-less accessions that give similar grain yield as hulled accessions. The mean

Table 4. Mean comparison of yield-related traits and grain yield of hulled and hull-less

Traits	Hulled accessions	Hull-less accessions	Sig.
Number of spikes per plant	2.35	1.96	***
Plant height, cm	76.08	76.67	ns
Spike length, cm	8.35	8.94	ns
Number of spikelets per spike	73.73	72.82	ns
Number of grains per spike	51.47	40.21	***
Weight of grains per spike, g	2.19	1.72	***
1000-grain weight, g	43.45	40.65	**
Grain yield, kg ha^{-1}	2585	1885	***

ns – non-significant at $p \leq 0.05$; ** significantly different at $p \leq 0.01$; *** significantly different at $p \leq 0.001$

number of spikes per plant in naked genotypes was 2.35 and varied from 1.61 to 3.07. In hulled accessions, the number of spikes per plant varied from 1.71 to 2.54 with a mean value of 1.96.The number of grains per spike among hulled accessions ranged from 40.47 to 67.09 and from 29.26 to 51.61 among hull-less accessions. The weight of grains per spike ranged from 1.71 g to 2.88 g in hulled lines and from 1.23 g to 2.16 g in hull-less lines. The mean 1000-grain weight was 43.4 g in hulled accessions and 40.65 g in hull-less accessions. Bleidere (2007) and Sayd et al. (2018) also reported that grain of hull-less genotypes was characterized by lower 1000-grain weight than that of hulled barley.

Based on mean performance, IBYT-HI-15-8, IBYT-HI-15-10, IBYT-HI-15-11 and IBYT-HI-15-18 hulled lines, and INBON-15-21, INBYT-HI-15-11, INBYT-HI-15-16, and INBYT-HI-15-21 hull-less lines were identified as the superior lines for these environmental conditions.

Table 5. Mean values for yield-related traits and grain yield of 20 hulled accessions of spring barley (2017–2019)

Genotypes	SP	PH	SL	NSS	NGS	WGS	TGW	GY
IBYT-HI-15-1	2.21	67.52	7.77	73.28	53.92	2.21	41.36	2502
IBYT-HI-15-2	2.15	85.17	8.08	70.05	49.16	1.87	46.04	2278
IBYT-HI-15-3	2.58	85.83	8.33	66.92	55.12	2.15	44.68	2737
IBYT-HI-15-4	2.01	85.97	7.41	73.09	47.05	1.71	34.63	2205
IBYT-HI-15-5	2.13	69.86	9.13	79.18	53.63	2.31	44.24	2443
IBYT-HI-15-6	1.92	69.17	8.15	69.42	51.81	1.87	36.96	2518
IBYT-HI-15-7	2.84	84.63	8.73	75.59	61.56	2.64	43.25	2958
IBYT-HI-15-8	2.59	79.41	9.07	75.73	67.09	2.65	46.88	3575
IBYT-HI-15-9	2.44	68.38	7.61	78.06	43.20	1.74	36.22	2253
IBYT-HI-15-10	2.72	79.96	9.20	71.92	60.37	2.80	49.30	3407
IBYT-HI-15-11	2.89	75.77	8.83	73.80	54.25	2.65	49.08	3165
IBYT-HI-15-12	1.61	75.35	8.95	74.52	40.99	2.10	43.18	1760
IBYT-HI-15-13	2.40	72.43	9.06	74.72	46.94	1.92	44.19	2217
IBYT-HI-15-14	2.33	77.27	8.32	79.99	40.47	2.02	44.68	2377
IBYT-HI-15-16	3.07	78.69	6.75	78.19	59.87	2.88	46.45	3213
IBYT-HI-15-18	2.03	78.40	8.46	67.61	47.66	2.53	42.43	2575
IBYT-HI-15-19	2.30	70.58	8.75	79.32	50.91	1.93	38.59	2505
IBYT-HI-15-20	2.21	72.20	8.38	75.64	54.91	2.22	47.71	2652
IBYT-HI-15-21	2.36	74.83	7.72	65.79	42.39	1.79	47.68	2273
IBYT-HI-15-22	2.22	70.28	8.27	71.82	48.11	1.76	41.43	2082
LSD ($p \leq 0.05$)	0.21	2.44	0.43	1.12	1.19	0.26	1.19	424

SP – number of spikes per plant; PH – plant height, cm; SL – spike length, cm; NSS – number of spikelets per spike; NGS – number of grains per spike; WGS – weight of grains per spike, g; TGW – 1000-grain weight, g; GY – grain yield, kg ha^{-1}

Table 6. Mean values for yield-related traits and grain yield of 20 hull-less accessions of sping barley (2017–2019)

Genotypes	SP	PH	SL	NSS	NGS	WGS	TGW	GY
INBYT-HI-15-2	1.77	80.86	9.82	78.91	40.92	1.81	40.76	1842
INBYT-HI-15-5	1.85	74.78	9.59	80.60	42.40	1.87	41.57	2210
INBYT-HI-15-6	1.88	79.19	8.31	68.07	34.77	1.41	47.95	1863
INBYT-HI-15-7	2.06	84.14	8.26	66.56	38.48	1.73	40.08	2030
INBYT-HI-15-9	1.85	57.79	9.08	73.83	32.91	1.49	38.59	1642
INBYT-HI-15-10	2.44	83.37	8.83	78.92	39.17	1.65	38.75	2068
INBYT-HI-15-11	2.07	80.30	9.30	76.73	51.61	1.96	42.88	2232
INBYT-HI-15-12	1.77	78.50	8.70	70.32	40.98	1.76	40.22	1762
INBYT-HI-15-13	1.94	75.75	9.78	74.37	37.27	1.67	43.36	1842
INBYT-HI-15-14	1.96	72.01	8.00	69.23	39.39	1.87	44.34	1395
INBYT-HI-15-15	1.81	76.51	8.08	69.05	41.79	1.55	37.15	1877
INBYT-HI-15-16	2.26	70.72	9.58	73.95	40.35	1.71	39.29	2388
INBYT-HI-15-17	1.71	64.04	8.85	63.57	40.48	1.52	39.07	1805
INBYT-HI-15-18	1.83	81.52	9.37	73.35	40.42	1.85	37.59	2025
INBYT-HI-15-19	1.98	73.94	8.29	71.47	38.40	1.64	34.48	1405
INBYT-HI-15-21	2.09	76.99	9.11	79.53	45.55	1.85	39.41	2249
INBYT-HI-15-22	1.78	85.64	8.05	64.56	40.25	2.03	47.54	1544
INBYT-HI-15-23	1.74	77.75	9.09	70.96	29.26	1.23	33.58	1318
INBON-15-21	2.54	67.62	8.98	80.12	48.22	2.16	41.55	2830
INBON-15-27	1.80	92.06	9.73	72.21	41.67	1.62	44.83	1379
LSD ($p \leq 0.05$)	0.24	2.99	0.48	1.38	1.15	0.25	1.52	247

SP – number of spikes per plant; PH – plant height, cm; SL – spike length, cm; NSS – number of spikelets per spike; NGS – number of grains per spike; WGS – weight of grains per spike, g; TGW – 1000-grain weight, g; GY – grain yield, kg ha^{-1}

Table 7. Correlation coefficients among grain yield and yield-related traits of hulled accessions (above diagonal) and hull-less accessions (below diagonal)

Traits	SP	PH	SL	NSS	NGS	WGS	TGW	GY
SP	1	0.272	-0.087	0.189	0.604**	0.619**	0.476*	0.764**
PH	-0.103	1	-0.053	-0.289	0.257	0.274	0.233	0.294
SL	0.024	0.025	1	0.099	0.199	0.24	0.328	0.158
NSS	0.515*	-0.044	0.629**	1	0.095	0.154	-0.103	0.089
NGS	0.400	0.130	0.152	0.403	1	0.743**	0.365	0.873**
WGS	0.414	0.117	0.044	0.363	0.780**	1	0.597**	0.833**
TGW	-0.023	0.300	-0.068	-0.139	0.238	0.372	1	0.506*
GY	0.695**	-0.184	0.277	0.561*	0.627**	0.533*	0.038	1

SP – number of spikes per plant; PH – plant height; SL – spike length; NSS – number of spikelets per spike; NGS – number of grains per spike; WGS – weight of grains per spike; TGW – 1000-grain weight; GY – grain yield

Grain yield was significantly and positively correlated with the number of spikes per plant, number of grains per spike and weight of grains per spike for both barley types (Table 7). The 1000-grain weight was found to positively associate with grain yield in hulled accessions, whilst there was a non-significant correlation in hull-less lines. There was no significant relationship between grain yield and the number of spikelets per spike in hulled barley, whereas there were significant positive associations in hull-less accusation.

Path coefficient analysis (Table 8) revealed that the number of grains per spike had a maximum direct effect on grain yield (0.458), followed by the number of spikes per plant (0.323) and the weight of grains per spike (0.307) in hulled accessions. The correlation coefficient of 1000-grain weight was positive and significant with grain yield while the direct effect on grain yield was very low and negative. For hull-less genotypes, the number of spikes per plant had the highest direct effect on grain yield (0.507), followed by the number of grains per spike (0.400) and spike length (0.216). Plant height had direct negative effects on grain yield of hull-less accessions (-0.198).High dependence of barley grain yield on the tilling capacity was found by Tofiq et al. (2014) and Markova Ruzdik et al. (2015) in cover barley and by Ram et al. (2006), Kundalia et al. (2006), Drikvand et al. (2011) and Abdel-Moneam et al. (2014) in naked barley. A positive direct effect on yield by the number of grains per spike in hull-less barley was reported by Zaefizadeh et al. (2011). Abdel-Moneam et al. (2014) found a positive correlation between yield and grain number per spike under drought stress conditions in hull-less barley genotypes.

Table 8. Path analysis showing direct and indirect effect of traits on grain yield

Traits	Direct effect	Indirect effect						
		SP	PH	SL	NSS	NGS	SW	TGW
	Hulled accessions							
SP	0.323		-0.003	-0.003	-0.013	0.277	0.190	-0.006
PH	-0.011	0.088		-0.002	0.020	0.118	0.084	-0.003
SL	0.032	-0.028	0.001		-0.007	0.091	0.074	-0.004
NSS	-0.071	0.061	0.003	0.003		0.043	0.047	0.001
NGS	0.458	0.195	-0.003	0.006	-0.007		0.228	-0.005
WGS	0.307	0.200	-0.003	0.008	-0.011	0.340		-0.008
TGW	-0.013	0.154	-0.003	0.011	0.007	0.167	0.183	
	Hull-less accessions							
SP	0.507		0.020	0.005	-0.006	0.160	0.009	0.000
PH	-0.198	-0.052		0.005	0.001	0.051	0.003	0.006
SL	0.216	0.012	-0.005		-0.007	0.061	0.001	-0.001
NSS	-0.011	0.261	0.009	0.136		0.161	0.008	-0.003
NGS	0.400	0.203	-0.026	0.033	-0.005		0.017	0.004
SW	0.022	0.210	-0.023	0.010	-0.004	0.312		0.007
TGW	0.019	-0.012	-0.059	-0.015	0.002	0.095	0.008	

SP – number of spikes per plant; PH – plant height; SL – spike length; NSS – number of spikelets per spike; NGS – number of grains per spike; WGS – weight of grains per spike; TGW – 1000-grain weight; GY – grain yield

Conclusions

The genotype has a lower influence on total variability of grain yield and yield-related traits in hill-less genotypes than in hulled accessions. The impact of weather conditions during the crop season and interaction between genotype and environment was considerably higher in hull-less accessions compared to hulled lines, especially on traits such as the number of spikes per plant, the number of grains per spike and the weight of grains per spike. Highest broad-sense heritability was observed for spike length, 1000-grain weight and number of spikelets per spike in both barley type indicated that these traits could be relatively easily improved via selection. Hull-less accessions showed a lower average number of spikes per plant, number of grains per spike, weight of grains per spike, 1000-grain weight and grain yield. Hulled accessions IBYT-HI-15-8, IBYT-HI-15-10, IBYT-HI-15-11 and IBYT-HI-15-18 hulled lines and hull-less accessions INBON-15-21, INBYT-HI-15-11, INBYT-HI-15-16 and INBYT-HI-15-21 were identified as high yielding and can be used parents in spring barley breeding program. The number of grains per spike had a maximum direct effect on grain yield, followed by the number of spikes per plant and weight of grains per spike in hulled accessions. While in hull-less genotypes, the number of spikes per plant had the highest direct effect on grain yield, followed by the number of grains per spike and spike length. Therefore, direct selection for these traits would be an effective breeding strategy for increasing the grain yield of spring barley.

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Received: **October, 11, 2022**; *Approved*: **April, 19, 2023;** *Published:* **February, 2024**