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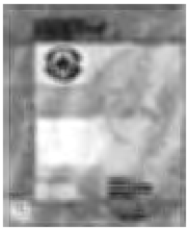

Performance of 50 Lebanese barley landraces (*Hordeum vulgare* L. subsp. vulgare) in two locations under rainfed conditions

Lamis Chalak [a,*], Rim Mzid [b], Wissam Rizk [a], Haytham Hmedeh [a], Rabih Kabalan [c], Joelle Breidy [c], Bariaa Hamadeh [c], Hassan Machlab [d], Hélène Rizk [a], Samih Elhajj [a]

[a] *Department of Plant Production, Faculty of Agriculture, The Lebanese University, Dekwaneh, Beirut, Lebanon*
[b] *Laboratoire de Physiologie Moléculaire des Plantes, Centre de Biotechnologie de Borj-Cédria, B.P. 901, Hammem Lif 2050, Tunisia*
[c] *Lebanese Agricultural Research Institute, P.O. Box 287, Zahlé, Lebanon*
[d] *ICARDA Country Office, P.O. Box 114/5055, Verdun, Beirut, Lebanon*

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Abstract Breeding activities in Lebanon have attributed limited interest to barley and landraces have not been exploited before. In this study, 50 Lebanese barley landraces were experimented rainfed in Northern Bekaa in comparison with two checks, Assi and Rihane-3. Two field trials were conducted, the first at 1000 m a.s.l. and 171.6 mm precipitations, and the second at 648 m a.s.l. and 119.4 mm. Out of the 50 landraces, five named LR9, LR12, LR16, LR30 and LR32 were early in heading and maturity in both trials, similarly to checks. Landraces showed a large variability for yield components, particularly grain number per spike and thousand grain weight. Number of spikes per plant and grain weight per plant were twice greater in Kfardan than Qaa location. The best plant productivity in Kfardan was 3.8 g/plant recorded for LR11 *vs.* 3.46 g/plant obtained with LR33 in Qaa. The higher yield was recorded in Qaa trial with 255 g/m^2 for LR31 and 244 g/m^2 produced by LR32, while 211 and 200 g/m^2 were recorded in Rihane-3 and Assi checks respectively. Principal components analysis allowed to distinguish several landraces that were clustered next to the checks sharing similar features of plant height, spike length and yield per m^2. At the level of individual plants and based on the grain yield per plant, a set of 47 plants were found to be similar or even greater to the checks. These plants should be further evaluated for their agronomic performance within national breeding program.

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* Corresponding author.
E-mail address: lamis.chalak@gmail.com (L. Chalak).

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Introduction

Landraces are recognized to present a tangible crop genetic resource of actual or potential economic benefit for humankind at national, regional and global levels. They provide a large gene pool for future genetic improvement programs and food security (Ceccarelli, 1994). Landraces ecological amplitudes may exceed those of the varieties derived from them in terms of evolution and adaptation to change in agricultural systems under specific cultural and environmental stresses (Kneupffer et al., 2003). Actually, landraces are developed during long-term traditional cultivation at the same location where they are exposed to both human selection and ecogeographic pressures. Landraces are to a much larger part selected or adapted to fit the environment of their location of origin while modern cultivars are developed for high yield and seldom targeted at a particular location (Gepts and Papa, 2002; Lasa et al., 2001). There is now an increasing recognition of the importance of on farm maintenance of these locally adapted genotypes as a component of conservation efforts together with the recognition of the role of farmers and environment as significant factors influencing the maintenance of genetic diversity (UNEP, 1994). However, little is known about the genetic structure of landraces populations, the amount of genetic variation they possess and its impact on the ability of landraces to adapt to harsh environments. In general, landraces constitute one of the most valuable sources of genetic diversity. This diversity has become now more accessible thanks to the advances in genomics and recombinant DNA technology (Newton et al., 2010) and is hopefully exploited.

Originated from the Eastern Mediterranean in the area of Fertile Crescent, the cultivated barley (*Hordeum vulgare* L.) is one of the first domesticated crops having long history of adaptation to cultivation worldwide (Zohary and Hopf, 1993; Bothmer et al., 2003; Zohary et al., 2012). Wild populations of *Hordeum spontaneum* L. are still widely grown in this area (Jana and Pietrzak, 1988). To date, barley is grown in a wide ecogeographic range around the world and is thus one of the best-adapted crops to diverse cultivation conditions. Nevertheless the use of barley in the Near East countries is still mostly limited to feed, despite the increased demand by local industries in imported malt and the new trend of barley food.

Yet, a major loss of barley genetic resources is witnessed in the Near East caused by substituting gradually the landraces by newly uniform bred cultivars that are high yielding and specifically improved for the challenges of modern agriculture. This may result in making agricultural productivity extremely vulnerable to various stresses including climate change. Nevertheless in Lebanon, landraces persisted through successive generations in dry and marginal areas, probably due to their stable agronomic performance. So far, germplasm assessment and breeding activities in Lebanon have attributed limited interest to barley and Lebanese landraces have not been exploited before although they may constitute a distinct genetic resource with potential to contribute favorable traits to barley breeding. The reasons for this are mostly the lack of pre-breeding characterization and phenotyping investigation that are prevalent in the region. Actually, since the primary evaluation of diversity landraces collected along the Fertile Crescent in Syria and Jordan for morphological and agronomic traits and resistance to diseases (Ceccarelli et al., 1987; Jaradat et al., 1987; Van Leur et al., 1989; Jaradat, 1991), few efforts have been displayed in that regards. Russell et al. (2003) examined the patterns of polymorphism detected in the chloroplast and nuclear genomes of barley landraces sampled from Syria and Jordan in relation to different ecogeographic origin to further understand the farmer's selection practices. In the Western Mediterranean, barley landraces have not either been widely used in modern breeding, probably with the exception of the Coast types (of Spanish or North African origin) that were introduced in California by Spanish settlers in the 18th century and constituted later the founding germplasm groups of current North American barleys (Kneupffer et al., 2003). More recently phenotyping effort has been conducted on Spanish barleys from the agronomic point of view and to assess their potential to contribute to favorable traits (Yahiaoui et al., 2014).

This study is a part of an effort to overcome this lack of phenotyping efforts through the evaluation of genetic variability of a set of Lebanese barley landraces under rainfed conditions. The objectives of this work are to evaluate the Lebanese barley landraces for their agronomic traits under the rainfed conditions in comparison with modern cultivars widely grown in Lebanon, and to raise the attention of the barley community in the Near East on the potential of the Lebanese landraces as valuable phytogenetic resource for further use in breeding programmes.

Materials and methods

Plant material

A total of 50 Lebanese landraces of barley were used in this study including two sets of materials: (i) 35 landraces collected in 2011 from different agro-climatic areas in Lebanon (LR1–LR35) and stored at the national gene bank of the Lebanese Agricultural Research Institute and (ii) 15 landraces recovered from the gene bank of ICARDA-Aleppo and initially collected from Lebanon in the nineties (LR36–LR50). Additionally two barley varieties, namely Rihane-3 (6-rowed) and Assi (2-rowed), initially released by ICARDA and commonly used in Lebanon and the Near East for the last 20–25 years were also used. The geographic data and the agro-climatic conditions of the barley landraces under study are shown in Fig. 1 and Table 1.

Field trials

Two field trials were conducted in northern Bekaa – Lebanon. The first one is at Kfardan LARI station at 1000 m a.s.l. and 171.6 mm precipitations, and the second one in Qaa – Aarzal farmers' cooperative field at 648 m a.s.l. and 119.4 mm precipitations. The trials conditions are presented in Table 2. The trials were carried out in Randomized Complete Block Design with three replications. The size of experimental unit was 2.5 m × 1.8 m making an area of 4.5 m^2. The seeding rate was 150 g/plot. Seeds of the different genotypes were sown by the end of December 2013 in both sites. The border was planted with the check Rihane-3.

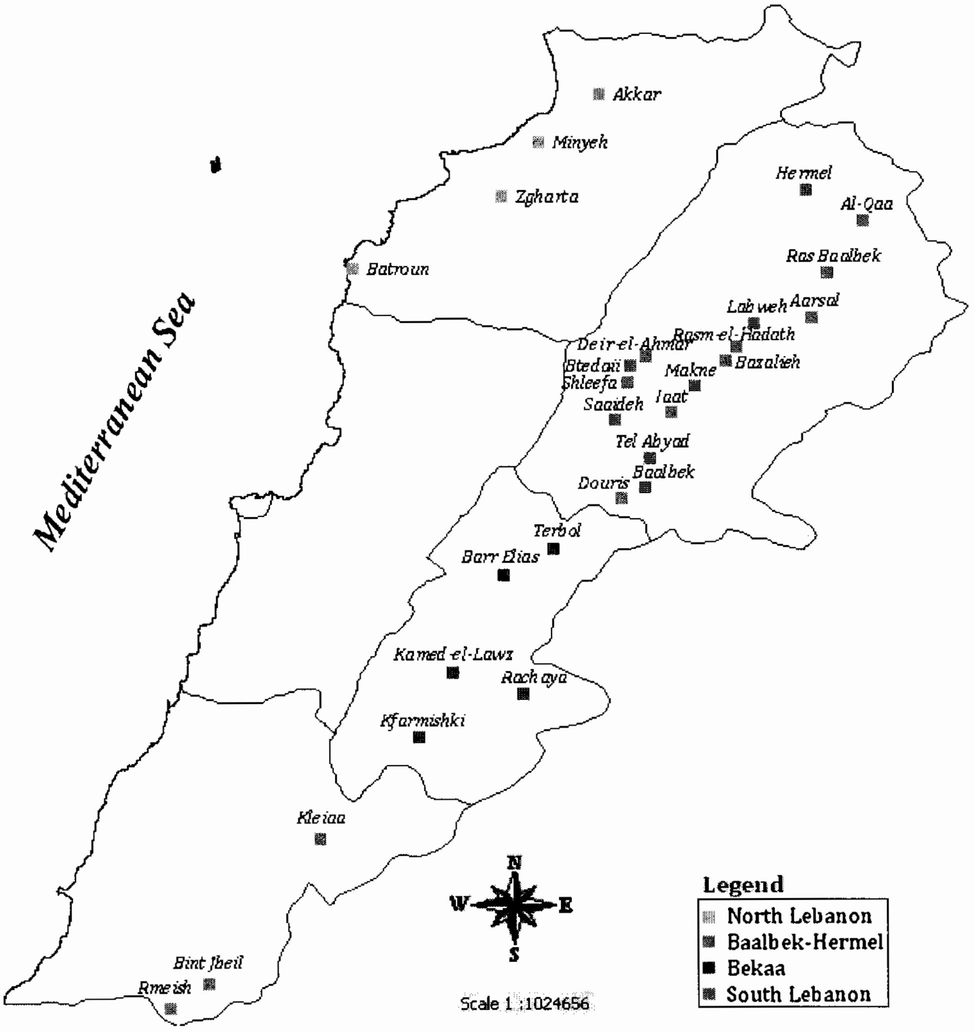

Fig. 1 Geographic distribution of barley landraces collected from Lebanon. Landraces collected from Bekaa caza are presented in red, the ones from Baalbek-Hermel in blue, the ones from South Lebanon in green and the ones from North Lebanon in yellow.

Traits examined

Phenological characteristics were determined in the field by considering the days from sowing to heading (DHE), when 50% of spikes were out from the boot, and days to maturity (DMA), when 50% of spikes reached cropping maturity. Fifteen consecutive plants were randomly collected from each experimental unit at maturity time and nine traits were examined: plant height (PH) in cm measured from soil surface to the top of the main stem; number of spikes per plant (S/P); spike length (SL) in cm; number of grains per spike (G/S); grain weight per spike (GW/S); grain number per plant (G/P) estimated as G/S × S/P; grain weight per plant (GW/P) in g estimated as GW/S × S/P; thousand grains weight (TGW) in g estimated as (1000 × GW/P)/G/P; yield per meter square (Y/m^2) in g harvested from each experimental plot.

Statistical analysis

For each landrace and for each trait, mean ± standard deviation and coefficients of variation, and their correlative links were determined. In order to unify the traits variation, the total interval of variation was divided into categories into which the studied genotypes were grouped. The frequency distribution of all traits within each group of genotypes was represented in histograms. Pearson correlation coefficient between traits was also calculated. Principal Component Analysis (PCA) was performed in order to identify the most discriminant quantitative and qualitative traits in a small number of synthetic components and to assess the level of similarity between the landraces studied (Saporta, 1990). Data processing was performed using an excel add-in Xlstat 7.5.2 (Addinsoft, 2004).

Results

Landraces major characteristics

A wide range of variability was revealed among the landraces in both Kfardan and Qaa trials as shown in Table 3. The effect of location, genotype and their interaction was clearly expressed at the highest significance level ($P < 0.001$) for all

Table 1 Climatic and geographic distribution of the locations surveyed in Lebanon for collecting barley landraces.

Caza	Location	Altitude (m)	Rain-fall (mm)	T min[a] (°C)	Latitude (°N)	Longitude (°E)	Landraces collected[b,c]
Bekaa	Terbol	887	253.2	−0.2	33.8181	35.9831	LR1(6-rowed)
	Kfarmishki	1195	1089	3.38	33.5153	35.7667	LR2(2-rowed)
	Kamed Lawz	1222	847	−0.06	33.6203	35.8214	LR3(6-rowed)
	Barr Elias	879	318	−0.06	33.7747	35.9042	LR4(2-rowed), LR5(6-rowed)
	Rachaya	1480	1123	−5.72	33.5833	35.9333	LR50(2-rowed)
South Lebanon	Bint Jbeil	724	937.2	6.27	33.12	35.43	LR6(6-rowed), LR7(6-rowed), LR8(2-rowed)
	Kleiaa	714	1000	6.56	33.3311	35.6204	LR9(6-rowed)
	Rmeish	562	308	4.64	33.08	35.37	LR10(2-rowed), LR11(6-rowed)
Baalbek-Hermel	Deir-el-Ahmar	986	1200	−7	34.1253	36.1311	LR12(6-rowed)
	Shleefa	990	427	−0.88	34.0853	36.1003	LR13(6-rowed)
	Iaat	1083	253	0	34.0369	36.1714	LR14(2-rowed)
	Btedaii	998	432	−0.83	34.1122	36.1061	LR15(6-rowed)
	Saaideh	1018	185	0	34.0258	36.0817	LR16(6-rowed)
	Douris	1134	423.6	−1.57	33.8978	36.0919	LR17(6-rowed), LR18(2-rowed)
	Bazalieh	1041	350	0	34.1197	36.2584	LR19(2-rowed), LR20(6-rowed)
	Tel Abyad	1025	423.6	−1.57	33.95	36.15	LR21(2-rowed)
	Makne	1068	350	−0.06	34.0797	36.2067	LR22(2-rowed)
	Rasm Al-Hadath	958	300	0	34.1414	36.2756	LR23(6-rowed)
	Ras Baalbek	1214	300	−1.76	34.2589	36.4192	LR24(2-rowed), LR25(2-rowed), LR26(6-rowed)
	Hermel	696	208.4	1.19	34.3942	36.3847	LR27(6-rowed), LR28(2-rowed)
	Al-Qaa	648	225.8	0.35	34.3442	36.4744	LR29(2-rowed), LR30(6-rowed), LR31(2-rowed), LR32(6-rowed)
	Aarsal	1228	432	−0.74	34.1886	36.3923	LR33(6-rowed), LR34(2-rowed)
	Labweh	1007	350	0	34.1789	36.3021	LR35(2-rowed)
	Baalbek	1050	383.6	−5.81	33.9333	36.1002	LR36(2-rowed), LR37(2-rowed), LR38(2-rowed)
North Lebanon	Batroun	150	900	6.78	34.2667	35.6667	LR39(6-rowed), LR40(6-rowed), LR43(6-rowed), LR48(6-rowed), LR49(6-rowed)
	Zgharta	426	1148	6.17	34.440	35.903	LR41(6-rowed), LR42(6-rowed)
	Minyeh	150	837.9	7.45	34.4333	36.05	LR47(6-rowed)
	Akkar	100	539.2	7.20	34.5258	36.0119	LC44(6-rowed), LR45(6-rowed), LR46(6-rowed)
Control	Rihane-3						6-rowed, delivered by ICARDA – Lebanon
	Assi						2-rowed, delivered by ICARDA – Lebanon

[a] T min is calculated from the average of the coldest month.

[b] LR1–LR35: Landraces collected in 2011 from different agro-climatic areas in Lebanon.

[c] LR36–LR50: 15 landraces recovered from the gene bank of ICARDA-Aleppo and initially collected in the nineties from different agro-climatic areas in Lebanon.

studied traits except the number of grains per spike. Days to heading and days to maturity manifested the lowest variability with a coefficient of variation of 5% and 4%, respectively, followed by plant height, spike length and thousand grains weight. At the same time, grain yield and yield components were the most variable traits with coefficients of variation ranging from 20% for thousand kernels weight to 42% for number of kernels per head.

Variability values of traits recorded in Kfardan and Qaa trials allowed distributing the 50 landraces and the two checks in seven to 11 sub-groups as shown in Fig. 2.

Both checks Assi and Rihane-3 were 20 days earlier in Qaa than Kfardan. Days to heading allowed the distribution of genotypes studied in nine groups in both Qaa and Kfardan trials. Five landraces namely LR9, LR12, LR16, LR30 and LR32 were the earliest in heading and positioned next to checks, while two landraces, LR1 and LR3, marked a later stage of heading. As to the days to maturity, variability between genotypes divided them into six groups in both location trials. A set of 11–13 landraces were the earliest in maturity similar to checks in both location trials.

Plant height allowed dividing the landraces in 10 groups in Kfardan *vs.* nine in Qaa location. Eight landraces namely LR6, LR9, LR10, LR11, LR12, LR13, LR49 and LR50 in Kfardan had longer plant height than Rihane-3. In Qaa, landraces LR24, LR26, LR29, LR32 and LR33 expressed taller plant stature than both checks. Globally, the greatest values of plant height (78–87 cm) were noticed for landraces LR20, LR26 and LR33.

Number of spikes per plant was twice greater in Kfardan than Qaa location. Moreover several landraces e.g. LR2, LR24, LR25, LR28, LR29, LR34 and LR35 had higher number of spikes per plant than checks in both Kfardan and Qaa trials. Conversely, spikes were much longer in Qaa than

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

Location characteristics	Kfardan (North Bekaa)	Qaa (North Bekaa)
Latitude	34.0208 °N	34.3442 °N
Longitude	36.0818 °E	36.4744 °E
Altitude	1000 m	648 m
Rainfall (December–June)	171.6 mm	119.4 mm
Minimal temperature	0°	−2°
Maximal temperature	31.22°	34.9°
ETP	2.24	3.23
Rainfall/ETP ratio	278.16	74.4
Soil characteristics	Clay with 1.4% organic matter	Sandy clay with 1% organic matter

Kfardan trial. The checks marked the longest spikes in Qaa while the landraces LR2, LR4, LR8, LR14, LR18, LR19, LR28, LR29 and LR36 produced longer spikes than checks in Kfardan. Number of grains per spike divided the landraces in 10 groups in both Kfardan and Qaa trials with however higher values in Kfardan than Qaa. Several landraces e.g. LR1, LR5, LR7, LR12, LR13, LR15 and LR16 in Kfardan exceeded the two checks, while landrace LR33 had this specification in Qaa.

Number of grains and grain weight per plant was almost two times higher in Kfardan than in Qaa trial. The best plant productivity in Kfardan was recorded for LR11 where grain weight per plant ranged from a minimum of 1.2 to a maximum of 6.5 g/plant and an average of 3.8 g/plant. In Qaa, only LR33 (3.46 g/plant) performed almost similar to Rihane-3. Here it is worthy noted the significant difference between the two checks with the superiority of Rihane-3 in both trials.

Thousand grains weight presented higher variability in Qaa than in Kfardan trial with 10 groups *vs.* seven. Four landraces LR10, LR11, LR14 and LR19 presented closer values to checks in Kfardan, while seven landraces LR2, LR6, LR7, LR33, LR34, LR35 and LR48 presented a higher value than Assi in Qaa. The highest values were recorded for LR11 in Kfardan and LR34 in Qaa with 59 g and 51 g, respectively.

As to the yield per m^2, a large variability was also recorded among landraces in both trials. Nevertheless higher values were recorded in Qaa with 211 and 200 g/m^2 in Rihane-3 and Assi respectively, surpassed by five landraces, LR26, LR31, LR32, LR33 and LR34, yielding up to 244 g/m^2 by LR32 and 255 g per m^2 by LR31. In Kfardan nine landraces, LR2, LR4, LR5, LR6, LR8, LR9, LR11, LR12 and LR14 overcome the checks Assi and Rihane-3 which produced 200 and 172 g per m^2, respectively.

Given the large variability revealed within each landrace for most studied traits, selection of distinguished plants could be envisaged. The harsh environmental conditions of the experimental sites especially those of the Qaa area where rainfall didn't exceed 119 mm during the period of the experiment, are quite satisfactory to carry out selection for drought. At the level of individual plants, a total of 47 plants belonging to 17 landraces produced the highest grain weight per plant (data not shown). The number of selected plants per landrace varied between one and six. Among the 47 selected plants, and compared to the checks, 30 plants had grains weight per plant equal to or greater than Rihane-3 while 17 plants were greater or equal to Assi.

Beside genetic variability, the study of correlative links between quantitative traits of any crop is of major importance for successful selection, since selecting for a certain trait may negatively influence the expression of other traits. In our study, days to heading showed a very strong positive correlation with number of days to maturity in both locations with $r = 0.85$ (Table 4). At the same time, number of days to heading and days to maturity established a negative link with grain yield per m^2. Both variables were negatively correlated with grain weight per spike and per plant and thousand grain weight in Kfardan trial, which might indicate that earlier heading date may serve as an effective criterion for selecting high yielding genotypes especially under dry conditions where plants will escape the harshest conditions of drought and heat. As expected, most of yield components were positively intercorrelated. Plant height was positively correlated with all yield components, except thousand grains weight in both Kfardan and Qaa trials.

Table 3 Statistical data recorded with 11 agronomic traits for 50 barley landraces in Kfardan and Qaa trials.

Traits studied	Kfardan					Qaa				
	Mean ± SD	Min	Max	*P* value	% CV	Mean ± SD	Min	Max	*P* value	% CV
DHE	137.58 ± 6.41	128.67	154.33	< 0.001	5	117.26 ± 6.47	108.66	134.33	< 0.001	5
DMA	163.45 ± 5.85	158	187	< 0.001	4	143.26 ± 5.82	137	167	< 0.001	4
PH	55.77 ± 8.39	41.67	71.67	< 0.001	15	59.96 ± 8.67	43.2	87	< 0.001	10
S/P	2.6 ± 0.63	1.5	3.9	< 0.001	24	1.67 ± 0.52	1	3	< 0.001	31
SL	5.93 ± 1.52	3.54	8.86	< 0.001	25	11.25 ± 1.34	7.8	14.7	< 0.001	12
G/S	29.62 ± 12.87	13.67	58.93	2.3	42	26.08 ± 8.92	13.3	47.1	2.3	34
GW/S	1.23 ± 0.49	0.55	2.43	< 0.001	41	0.96 ± 0.33	0.52	1.65	< 0.001	33
G/P	73.13 ± 26.93	41	148.26	< 0.001	36	38.79 ± 14.99	18.2	86.7	< 0.001	38
GW/P	3.06 ± 1.11	1.22	6.54	< 0.001	37	1.43 ± 0.54	0.657	3.46	< 0.001	38
TGW	42.64 ± 7.18	28.34	58.44	< 0.001	20	39.52 ± 4.64	30.4	50.4	< 0.001	12
Y/m^2	153.11 ± 62.19	63.33	291.85	< 0.001	39	129.62 ± 50.62	51.11	255.55	< 0.001	39

DHE, days to heading; DMA, days to maturity; PH, plant height; S/P, spike per plant; SL, spike length; G/S, grain number per spike; G/P, grain number per plant; GW/P, grain weight per plant; TGW, thousand grains weight; Y/m^2, yield per m^2.

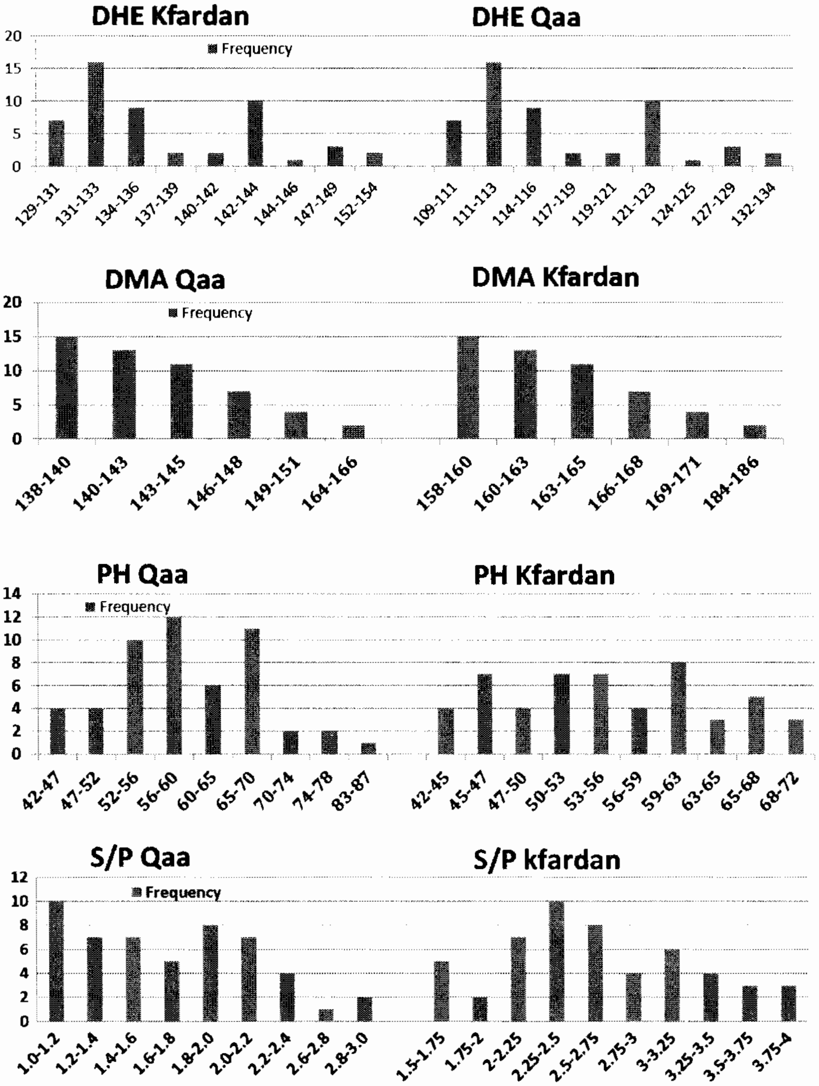

Fig. 2 Distribution of 50 barley landraces based on the traits studied as recorded in the two field trials of Kfardan and Qaa locations in comparison with the checks Assi and Rihane-3. DHE, days to heading; DMA, days to maturity; PH, plant height; S/P, spike per plant; SL, spike length; G/S, grain number per spike; G/P, grain number per plant; GW/P, grain weight per plant; TGW, thousand grains weight; Y/m^2, yield per m^2.

Relationships among landraces

Principal component analysis allowed to separate the 50 landraces based on the traits studied by placing the values below the average on the negative side of coordinate 1 while the ones with values from the average are placed on the positive side of coordinate 2 (Fig. 3a and b) with, however, some differences according to the field trial location.

In Kfardan trial (Fig. 3a) coordinate 1 accounting 24.94% of the total variation allowed to discriminate landraces according to days to heading and days to maturity and grain weight per plant. Additional discrimination was shown by the second principal coordinate contributing by 15.21% of the total variation, separating the landraces according mostly to their yield per m^2. Globally PCA revealed the presence of three main groups. The first one resembles landraces LR2, LR4, LR14 and LR50 with intermediate days to heading and days to maturity, and a high grain weight per plant. The second one contained LR1, LR3, LR40, LR41, LR43 and LR48 sharing longer heading and maturity times and a low yield per m^2. The third group is constituted of LR9, LR11, LR13, LR16 and LR32 which were early in heading, and had a high grain weight per plant and high yield per m^2.

As to Qaa trial (Fig. 3b), coordinate 1 accounting 19.87% of the total variation allowed to discriminate landraces according to days to heading and days to maturity and yield per m^2. Additional discrimination was shown by the second principal coordinate contributing by 13.87% of the total variation, separating the landraces according mainly to their grain weight per plant. Globally, PCA revealed the presence of three main groups that are different from Kfardan trial. The first one resembling LR1, LR3, LR41, LR43 and LR48 with long days to heading and maturity, high grain weight per plant and low yield per m^2. The second group contained LR2, LR4, LR11,

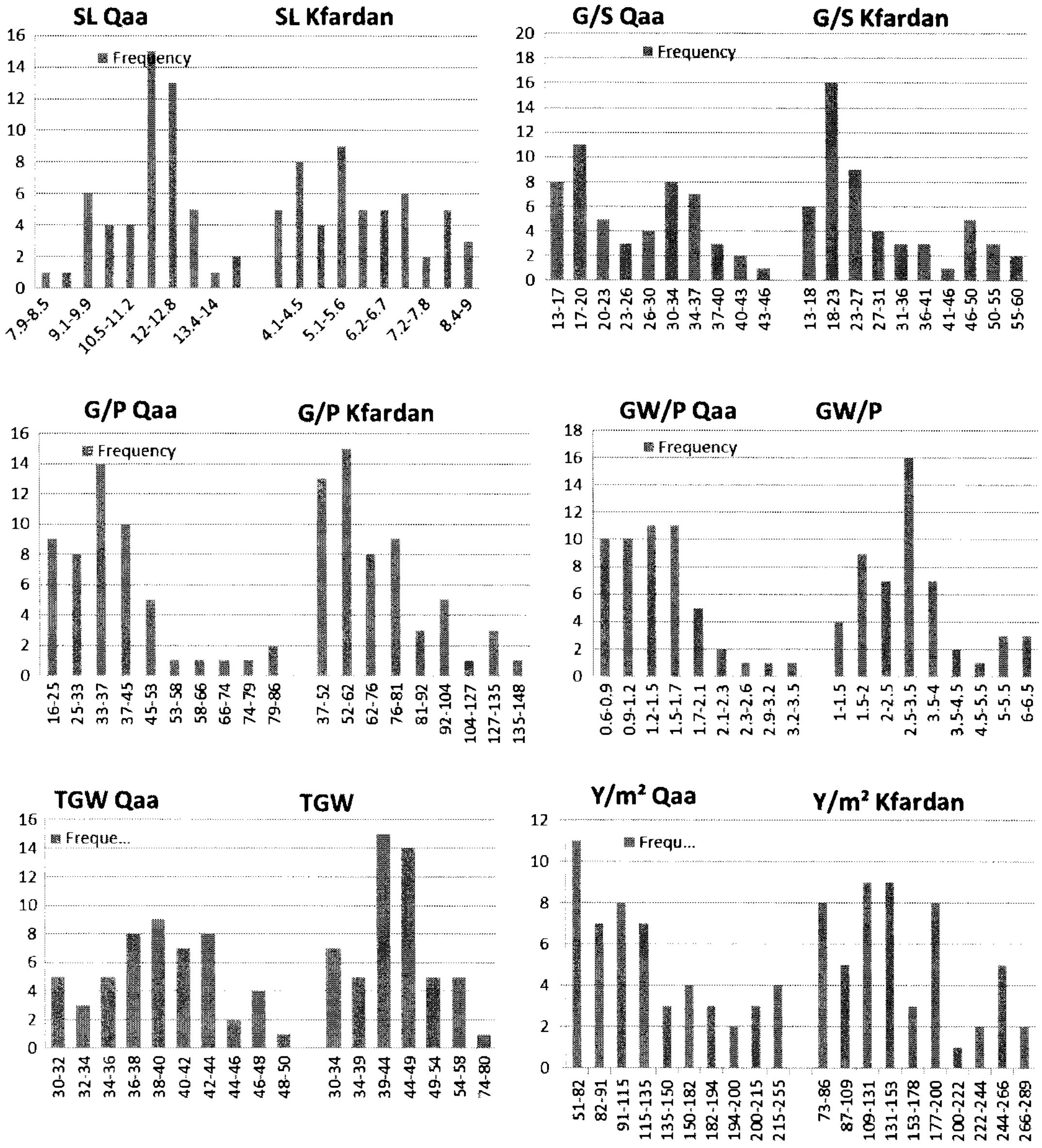

Fig. 2 (*continued*)

LR14 and LR50 with low days to heading, intermediate grain weight per plant and high yield per m^2. The third group gathers the high yielded landraces LR5, LR9, LR16, LR17, LR23, LR26 and LR33 with 120–250 g/m^2 next to Assi (200 g/m^2) and Rihane-3 (211 g/m^2) which are also classified as the earliest in heading and maturity.

It is worthy noted that landraces LR1 and LR3 appeared as outstanding in terms of high yield per m^2 in both Kfardan and Qaa trials. On the other hand some landraces showed different performance according to the trial location. For instance LR14 yielded better in Kfardan than in Qaa, whereas LR33 presented higher yield in Qaa than the one recorded in Kfardan.

Discussion

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 grain yield per meter square followed by yield components grain weight per spike, grain weight per plant and number of grains per spike with respective values of 39%, 38.5%, 37.5%, and 36% coefficient of variation. 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) reported similar pattern of variability in winter wheat grown at a wide range of plant population densities.

Days to heading and days to maturity expressed the lowest variability with a coefficient of variation of 5% for each,

Table 4 Correlation between quantitative traits studied for 50 barley landraces in Kfardan and Qaa field trials

Traits	Kfardan											Qaa										
	DHE	DMA	PH	S/P	SL	G/S	GW/S	G/P	GW/P	TGW	Y/m²	DHE	DMA	PH	S/P	SL	G/S	GW/S	G/P	GW/P	TGW	Y/m²
DHE	1	0.85	0.08	−0.11	−0.04	−0.13	−0.41	−0.14	−0.44	−0.51	−0.26	1	0.85	−0.13	−0.05	0.07	0.02	0.01	0	−0.07	0.04	−0.44
DMA		1		−0.22	−0.06	0.14	−0.11	0.11	−0.21	−0.46	−0.07		1	−0.03	−0.07	−0.08	0.23	0.11	0.17	0.01	−0.12	−0.31
PH			1	0.52	−0.04	0.53	0.59	0.29	0.35	0.04	0.52			1	0.11	0.37	0.41	0.48	0.47	0.54	0.03	0.32
S/P				1	0.52	−0.51	−0.45	0.02	0.12	0.19	0.04				1	0.01	−0.29	−0.21	0.41	0.39	0.03	−0.01
SL					1	0.09	−0.03	0.18	0.28	0.24	0.51					1	0.02	0.13	0.04	0.15	0.22	0.41
G/S						1	0.86	0.79	0.57	−0.27	0.41						1	0.34	0.36	0.41	−0.16	0.35
GW/S							1	0.66	0.79	0.21	0.49							1	0.61	0.71	0.16	0.39
G/P								1	0.72	−0.21	0.43								1	0.91	−0.07	0.36
GW/P									1	0.41	0.52									1	0.25	0.42
TGW										1	0.23										1	0.19
Y/m²											1											1

DHE, days to heading; DMA, days to maturity; PH, plant height; S/P, spike per plant; SL, spike length; G/S, grain number per spike; G/P, grain number per plant; GW/P, grain weight per plant; TGW, thousand grains weight; Y/m², yield per m²

followed by spike length (10%) and thousand kernels weight (11.8%). These results match with the findings of Singh (2011), who reported that days to heading and days to maturity were the most stable traits, whereas yield and yield components were noticed for strong phenotypic and genotypic variability about 28%.

As illustrated previously, spike length and number of spikes per plant also expressed strong variability of 32% and 34% coefficient of variation, and since these spike traits were strongly correlated with grain yield they could be used as selection criteria for the development of higher yielding genotypes. Abdullah et al. (2011) came out with a similar conclusion concerning the number of spikes per plant and spike length.

Regarding the agronomic traits used in this study, all appeared to have a discrimination power to differentiate the landraces and the two field trials Kfardan and Qaa. This finding is in line with those of Acevedo et al. (1991) and Van Oosterom and Acevedo (1992) who stressed on the effectiveness of these traits for the evaluation of barley genotypes in areas of the Mediterranean.

Studying the correlation among the traits, both heading and maturity periods were negatively correlated with thousand grains weight in Kfardan and with yield per m^2 in Qaa, since long heading and maturity periods increase the plant growth and might decrease the productivity (Janusauskaite et al., 2013). Plant height was positively correlated with all yield components, except thousand grain weight in both Kfardan and Qaa trials. Similar finding was reported in previous studies on cereals where long plant stature enhanced the productivity (Niazi-Fard et al., 2012). As for the high positive correlation found between the yield components in the two field locations, it is in line with the ones reported in multiple previous studies (Shakhatreh et al., 2001; Niazi-Fard et al., 2012). It means that an increase in one of these traits should lead to the increase in other related traits. Finally, given the high positive correlation between grain weight per plant and the other yield components, this trait could be used as selection criteria among and within landraces.

The environmental factors had the main impact on the phenological and yield components of barley landraces. The main limitation to release higher yield in Mediterranean environment is limited water availability (Rizza et al., 2004) and, therefore, any superior germplasm under these 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).

In this regard, the distribution of landraces by both PCA biplot and their clustering with Euclidian distance in both Kfardan and Qaa was quietly coherent with the initial origin of sampling of the landraces and the agro-climatic conditions of the location field trial. Actually many landraces initially collected from south Lebanon (LR7, LR8, LR10 and LR11) and central Bekaa (LR1, LR2, LR14) from altitudinal ranges of 800–1300 m, demonstrated good overall performance in Kfardan trial where rainfall didn't exceed 171 mm during the barley growth period. On the other hand, many landraces initially collected from Baalbek Hermel region (LR26, LR31, LR32, LR33 and LR34) from altitudinal ranges of 600–1000 m and rainfall of 100–350 mm, demonstrated good overall performance in Qaa trial (altitude 648 m) although rainfall was limited to 119 mm in that trial location during the experiment period.

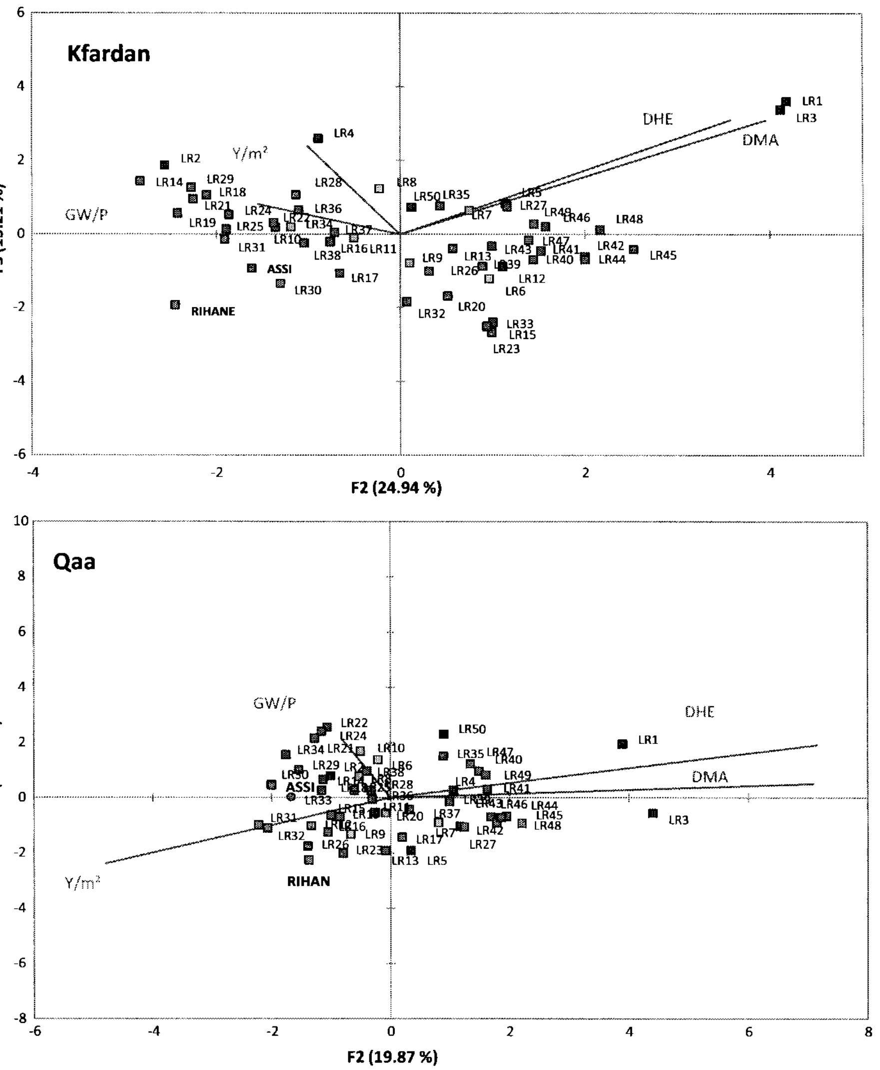

Fig. 3 PCA biplot of the 50 barley landraces and the checks in Kfardan (a) and Qaa (b) trials. Accessions are colored depending on their geographic origin (yellow to north Lebanon, blue to Baalbek-Hermel, red to Bekaa, green to south Lebanon).

At the individual level, a total of 47 plants may be selected from the 50 landraces experimented in Qaa harsh conditions for their superior production of grain weight per plant as compared to the checks. Among them, 30 plants acquired grains weight per plant higher or equal to Rihane-3 and 17 lines proved to be better than check Assi. These plants should be further evaluated as lines, either separately or in bulk, within further relevant breeding program. The presence within landraces of different genotypes able to cope with different types of stress, as well as with their different timing and severity, might explain their yield stability especially in harsh environments (Ceccarelli et al., 1987).

The results of this study indicate a large variability among the Lebanese barley landraces that are expected to be suitable for marginal, drought stressed environments (Ceccarelli, 1994). This variability is not surprising because in the long cultivation history of barley in this country, wide differences in the type and intensity of selection pressure must have occurred as a result of the large inter- and intra-seasonal climatic variation. Moreover this variability may match with that of wild populations of *H. spontaneum*, growing in the same region (Jana and Pietrzak, 1988). Therefore genetic analysis of variability of barley landraces by DNA markers would be further necessary to elucidate the structure of this local germplasm (Baum et al., 2007; Comadran et al., 2008; Varshney et al., 2010; Baloch et al., 2014). An understanding of the relationship between amount of genetic diversity, expression of morphological and agronomical characteristics, and tolerance to environmental stresses, may be further exploited in breeding programs for adaptation to climate change.

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