Agronomic Performance and Quality Properties of Malting Barley Genotypes Assessed Rain Fed in Bekaa Province, Lebanon

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Abstract

The use of barley in Lebanon is still limited to feed despite the increased beer consumption and the amplified demand by local industries of imported malt. In the present work, the performance of 11 foreign malting genotypes delivered by ICARDA was assessed in addition to three varieties, Assi, Rihane-3 and Atahualpa, used as checks. Two field trials were conducted in 2013, the first one at Kfardan LARI station at 1000 m a.s.l. and 171.6 mm precipitations, and the second one in Qaa farmer field at 648 m a.s.l. and 119.4 mm precipitations. The trials were carried out rain fed in Randomized Complete Block Design with three replications. In both fields, the results showed that at least one malting genotype was early in heading and maturity aligning checks patterns. Genotypes displayed a large variability for yield components, particularly for grain number per spike and thousand grains weight. The higher yields were recorded in Qaa trial for the malting genotypes designated as Malt-9, Malt-10 and Malt-11 with 274.4 g/m^2, 232.2 g/m^2, and 231.1 g/m^2 respectively; whereas in Kfardan trial, Malt-11 and Malt-7 had the highest yields with 245 g/m^2 and 222 g/m^2 respectively. Atahualpa variety produced 244 g/m^2 in Qaa *vs.* 178 g/m^2 in Kfardan overcoming both Rihane-3 and Assi. Based upon Euclidean distance, the hierarchical classification permitted the distribution of studied genotypes into three mains clusters and identified those positioned next to the checks. A preliminary assessment of malting quality attributes carried out on grain samples taken from Kfardan trial confirmed the suitability of the foreign genotypes for malting and revealed a promising potential for the common varieties Assi and Rihane-3.

Keywords: Malting Barley, Foreign Genotypes, Common Varieties, Phenological Stages, Quantitative Traits, Malting Attributes.

Introduction

Originated from the region of Fertile Crescent, the cultivated barley (*Hordeum vulgare* L.) is one of the first domesticated crops with long history of adaptation to cultivation (Zohary and Hopf, 1993; Bothmer *et al.*, 2003; Zohary *et al.*, 2012). Archaeological evidence in Iran indicates that barley was first used at that time in making alcoholic beverages (e.g. barley wine in Babylonia, 2800 BC) and was part of the staple diet of ancient Egyptians, Greek and Chinese, before being later introduced by Europeans to the New World in the sixteenth and seventeenth centuries (Borgstron, 1968).

Barley is grown in a wide eco-geographic range including rain fed conditions and is therefore considered among the best-adapted crops to diverse cultivation conditions. Barley is the most worldwide cereal crop used in malting, brewing and feed industries (Brennan *et al*., 1997). Barley is classified as either six-row or two-row with the latter having lower protein and therefore is more suitably used in malt production (Agu, 2005).

Lebanon, part of the Fertile Crescent, contains a wide diversity of crop genetic resources including barley wild relatives such as *Hordeum spontaneum* (Jana and Pieterzak, 1988). In Lebanon, barley is the second cereal cultivated after wheat with around 2000 hectares concentrated in North Bekaa (70%), Akkar (20%) and South Lebanon (5%), and an average production of 6000 tons (Anonymous, 2011). Barley is grown under rain fed conditions and is recognized to be one of the most tolerant crops for drought. Yet, the use of barley in Lebanon is still mostly limited to feed (Sardana and Zhang, 2005). Beer consumption grew more than 165% between 1965 and 2005. Along with this, the demand of imported malt by local industries was increased. A yield of 400 hectoliters of beer is produced per year, equivalent to 5.5 liters per capita (Chakrani, 2012). The industry of beer in the country is well developed with mainly three Lebanese breweries namely Almaza, Laziza and 961 (a new Lebanese beer brand). The local beer production needs for malt are completely covered by imports where about 6 153 tons of malt per year are regularly introduced from Iraq and Egypt, in the absence of local malting barley production (Chakrani, 2012).

Furthermore, crop production in Lebanon is seriously threatened by the climate change where temperatures are predicted to increase by 3.5°C to 5°C and precipitations may decline by 25-45% by the end of the current century (Ministry of Environment, 2011). Temperature and precipitation extremes will also intensify while drought periods, over the whole country, will become longer. This will greatly affect crop yield and further aggravate the already existing abiotic and biotic stresses. On the other hand, the increased demand from emerging markets, price volatility, and speculation on raw materials form major challenges impeding the capacity of the country to meet the increasing future food demands.

One approach to mitigate the effects of climate change is by encouraging the wider use of already existing drought tolerant species of barley (*Hordeum vulgare* L.). This can be achieved through the enlargement of barley germplasm to other genotypes that are interesting for malt production. Hence, the main objective of this study is to assess the agronomic performance of foreign barley genotypes cultivated rain fed in the region of northern Bekaa, Lebanon. Such initiative should contribute to adaptation of improved barley to the impact of climatic change and ensure a stable and profitable income to farmers and local communities.

Materials and Methods

Plant material: A set of 11 malt genotypes kindly delivered by ICARDA-Lebanon were used in this study in addition to three checks constituted of Rihane-3 and Assi improved varieties, initially released by ICARDA and commonly used for feed in Lebanon and the Near East for the last 20-25 years, and Atahualpa variety introduced from Ecuador (Table 1).

Field trials: Two field trials were conducted in northern Bekaa (Lebanon), the first one 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. Seeds of the different genotypes were sown by the end of December 2013 in both sites. Six-row plots of 2.5 m long and 0.3 m apart with a total area of 4.5 m^2 and a planting density of 150 g for each plot. The border was planted with the check Rihane-3.

Table 1. List of barley genotypes and varieties used in this study.

Initial name	Designation	Origin	Barley type
SJ055004	Malt-1	Denmark	2-row
SJ055110	Malt-2	Denmark	2-row
Moronera	Malt-3	Peru	2-row
Bodrga	Malt-4	Germany	2-row
Victoriana	Malt-5	Germany	2-row
Braemar	Malt-6	UK	2-row
Cristalia	Malt-7	UK	2-row
MERIT,B/AF9216//CANELA	Malt-8	ICARDA	2-row
MSEL/LOGAN-BAR	Malt-9	ICARDA	2-row
BRS195/ND19098-1	Malt-10	ICARDA	2-row
Harmal-02/ Soufara (Reem)	Malt-11	ICARDA	2-row
Atahualpa	Atahulpa	Ecuador	2-row
Assi	Assi	ICARDA	6-row
Rihane-3	Rihane-3	ICARDA	6-row

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

Location characteristics	Kfardan (North Bekaa)	Qaa (North Bekaa)
Latitude	34.0208 ^{o} N	34.3442^{o} N
Longitude	36.0818 ^{o} E	36.4744 ^{o} E
Altitude	1000 m	648 m
Rainfall (December-June)	171.6 mm	119.4 mm
Minimal temperature	0 ^{o}	-2 ^{o}
Maximal temperature	31.22 ^{o}	34.9 ^{o}
ETP	2.24	3.23
Rainfall / ETP ratio	278.16	74.4
Soil Characteristics	Clay soil, normal fertility level, 1.4 organic matter ratio.	Sandy clay soil, normal fertility level, 1 organic matter ratio.

Traits examined: Phenological characteristics were determined in the field by considering the days from sowing to heading (DHE), when 50% of the plot reaches the heading stage; and days to maturity (DMA), when 50% of spikes in the plot are mature. Fifteen consecutive plants were randomly collected from experimental unit at maturity time and eight traits were examined: plant height (PH) in cm calculated by estimating the mean plant height from the base to the top of the main stem; spike length (SL) in cm; number of grains per spike (G/S); grain weight per spike (GW/S); grain number per plant (G/P); grain weight per plant (GW/P) in g estimated as GW/S x S/P; thousand grains weight (TGW) in g estimated as (1000 x GW/P) / G/P; yield per meter square (Y/m^2) in g harvested for each genotype. Beside the studied agronomic traits, preliminary assessment of malting attributes of the genotypes was carried out on the seed samples taken from Kfardan trial following the methods of analysis of the American Society of Brewing Chemists (ASBC, 1958). These traits included the germination capacity (%), moisture content (%), protein content using Kjeldahl method (%), diastatic power (°WK), malt extract (%) and β-glucan (%).

Statistical analysis: For each landrace and for each agronomic trait, mean ± standard deviation and coefficient of variation and their correlative links were determined. Principal Component Analysis (PCA) was performed in order to determine the degree of contribution of each of the characters to the total variation (Saporta, 1990). To assess the level of similarity between the landraces tested and understand the relationships between them, an agglomerative hierarchical clustering analysis was executed following the Ward's method by calculating the dissimilarity using Euclidean distance for the most discriminant traits (1963). Data processing was performed using an excel add-in Xlstat 7.5.2 (Addinsoft, 2004).

Results

Agronomic characteristics

The barley genotypes studied exhibited different performances for the ten traits examined in both Kfardan and Qaa trials as shown in Table 3.

Table 3. Statistical data recorded with agronomic traits for 11 malting genotypes and Rihane-3, Assi and Atahualpa varieties in Kfardan and Qaa trials.

Traits Studied	Kfardan				Qaa				*P* value
	Mean ± SD	Min	Max	CV (%)	Mean ± SD	Min	Max	CV (%)	
DHE	138.5±5.9	129	146.3	4	118.5±5.9	109	126.3	5	<0.001
DMA	166.1±4.5	157	172	3	145.8±4.7	137	152	3	<0.001
PH	62±6.3	53.3	73.3	10	63.3±6.9	54.7	78.7	11	0.623
S/P	2.4±0.15	2.1	2.7	6	2.6±0.9	1	4.6	35	<0.001
SL	7.5±1.2	5.4	9	16	15.8±1.1	4.1	8.1	7	<0.001
G/S	23.9±4.2	17.9	32	18	21.4±11	12.7	42.7	51	0.442
G/P	66.1±11.8	39.4	83.75	21	47±14.6	28.2	79.3	31	<0.001
GW/P	2.97±1.3	1.67	6.5	45	1.95±0.6	1.06	3.1	31	<0.001
TGW	51.5±11.9	37.4	78.2	23	37.6±3.4	32.8	45	9	<0.001
Y/m²	177.32±33.75	115.56	245.19	19	198.86±39.4	137.78	274.44	19	0.133

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 m^2.

As to the factors significance, both the effect of field trial location, the effect of genotype, and their interaction were significant ($p<0.001$) for all traits studied except for plant height, grain number per spike, and yield per m^2 which was not significantly influenced by the field trials location. The most stable traits in Kfardan trial were days to heading, days to maturity, plant height, spike length, grain number per spike, per plant, yield per m^2 as well as spike length, while a large variability was recorded for grain weight per plant and thousand grains weight. In Qaa trial, the most stable traits were days to heading, days to maturity, plant height, spike length, thousand grain weight and yield per m^2. Figure 1 illustrated the results recorded for the 11 malting genotypes and the checks, Assi, Rihane-3 and Atahualpa varieties in both Kfardan and Qaa trials.

Days to heading and maturity. Phenological stages differed according to the field trial location with an approximate interval of 20 days between Qaa (earlier) than Kfardan. As to days to heading recorded in Qaa trial, the two checks Assi and Rihane-3 reached heading in 110 days and Atahualpa in 112 days. Regarding the malting genotypes, Malt-11 was the earliest in reaching heading in both sites with 111 days while Malt-3 was the latest one with 126.3 days as recorded in Qaa trial (Figure 1). The checks Assi and

Rihane-3 were also the earliest in reaching maturity with 137 days and 140 days respectively as recorded in Qaa trial. Atahualpa variety showed similar result with 141 days. Among the malting genotypes Malt-8, Malt-9 and Malt-11 were the earliest in maturity in both Qaa and Kfardan trials while the latest genotypes were Malt-2 and Malt-5.

Plant height. Atahualpa variety showed higher plants than the two checks in both trial locations with 73.3 cm and 67 cm Kfardan and Qaa respectively (Fig. 1). Malt-3 was also distinguished by its plant height with 70 cm in Kfardan and 78.7 cm in Qaa respectively while Malt-2 grows least with an average of 53-54 cm.

Spikes number per plant and spike length. Many genotypes overcome the checks with higher number of spikes per plant. The average number of spikes per plant was significantly favored in Kfardan trial for both checks and genotypes studied (Figure 1) with a maximum recorded for Assi (2.75) followed by Atahualpa (2.5), Malt-2 (2.6), Malt-8 (2.55), Malt-7 (2.5), Malt-9 (2.45), Malt-5 (2.4) and Malt-1 (2.4). As expected and conversely to spikes number per plant, spike length values were significantly greater in Qaa field trial than in Kfardan reaching a maximum of 18.1 cm with Malt-3.

Grain number per spike. Average number of grain per spike varied significantly according to the interaction between field trial locations and genotypes. Globally checks and Atahualpa variety produced more grains than malting genotypes and much better in Qaa ranging from 40 to 45 grains per spike compared to an average of 30 grains in Kfardan. Malting genotypes produced better in Kfardan trial with a maximum of 25.73 grains per plant recorded for Malt-1 (Figure 1).

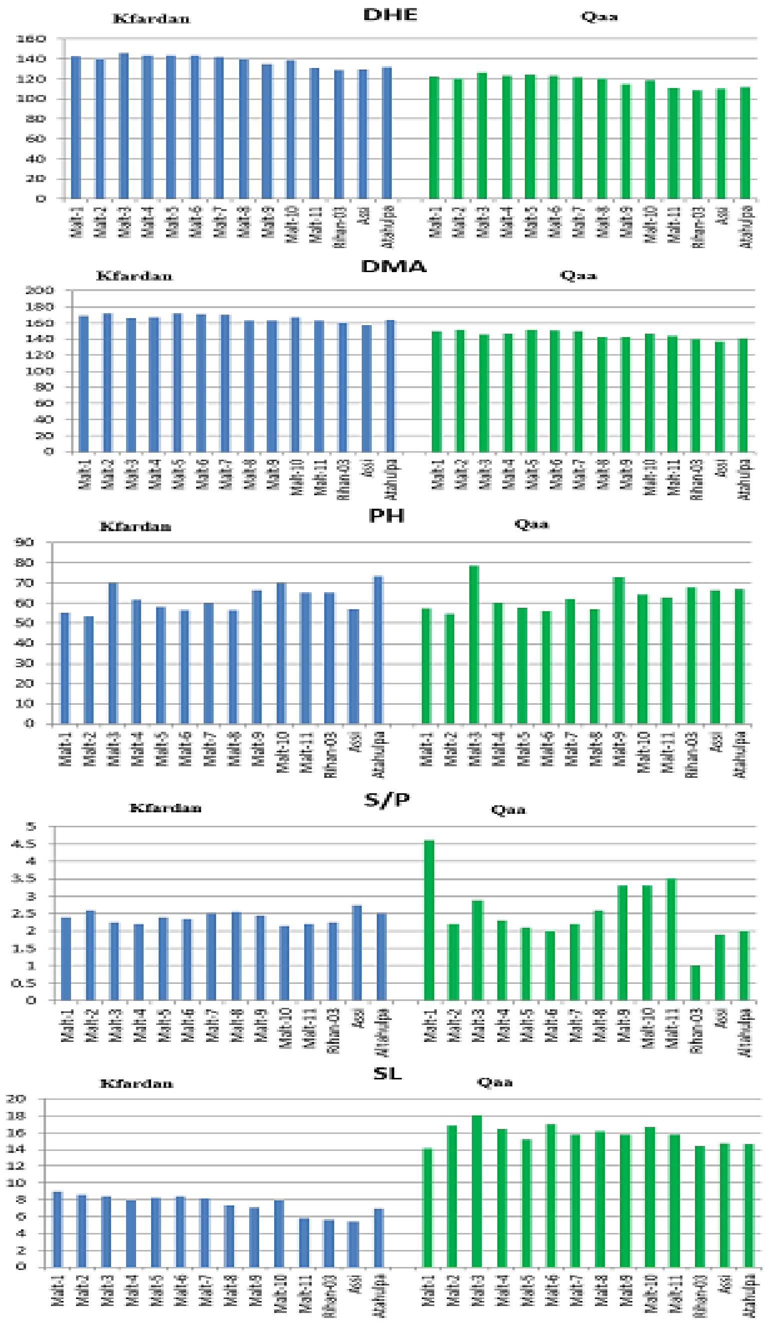

Figure 1. Agronomic traits recorded in the two field trials of Kfardan and Qaa locations in comparison with the varieties Rihane-3, Assi, and Atahualpa. DHE, days to heading; DMA, days to maturity; PH, plant height; S/P, spike per plant; SL, spike length; G/S, grain number per spike; G/P, grain number per plant; GW/P, grain weight per plant; TGW, thousand grains weight; Y/m², yield per m^2.

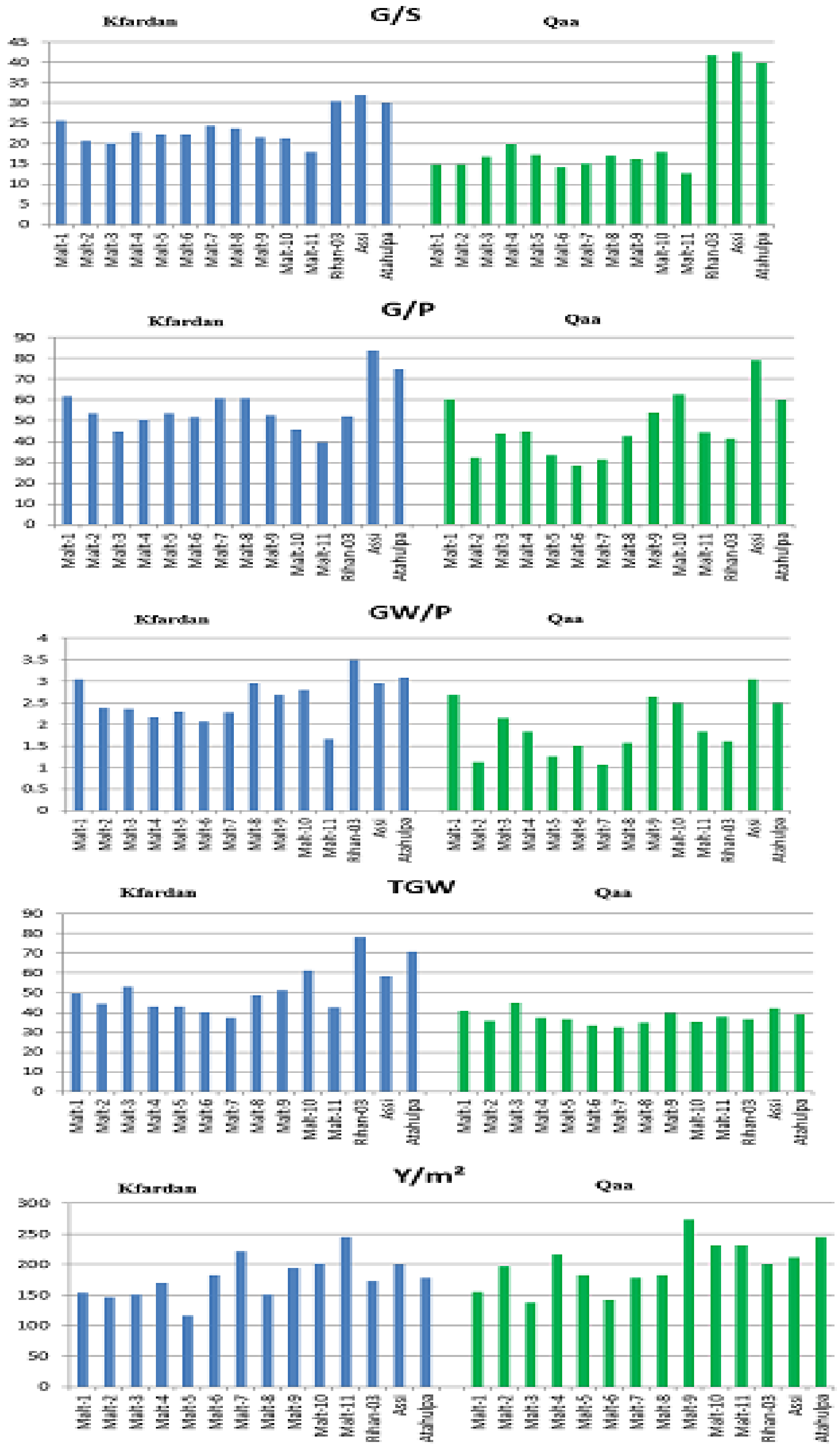

Figure 1 cont. Agronomic traits recorded in the two field trials of Kfardan and Qaa locations in comparison with the varieties Rihane-3, Assi, and Atahualpa. DHE, days to heading; DMA, days to maturity; PH, plant height; S/P, spike per plant; SL, spike length; G/S, grain number per spike; G/P, grain number per plant; GW/P, grain weight per plant; TGW, thousand grains weight; Y/m², yield per m^2.

Grain number and weight per plant. Globally all genotypes produced better in Kfardan trial where highest average number of grains per plant was obtained with Assi (83.75) and Atahualpa (74.8) and best average grains weight per plant with Rihane-3 (3.5 g) and Atahualpa (3.10 g). In terms of grains number per plant, several malting genotypes e.g. Malt-1 (61.7 in Kfardan, 60.4 in Qaa), Malt-7 (61 in Kfardan, 31.2 in Qaa), Malt-8 (60.7 in Kfardan, 42.5 in Qaa), Malt-2 (53.5 in Kfardan, 32.4 in Qaa), Malt-5 (53.3 in Kfardan, 33.3 in Qaa), Malt-4 (50.4 in Kfardan, 44.7 in Qaa), Malt-6 (51.8 in Kfardan, 28.2 in Qaa), Malt-9 (52.6 in Kfardan, 54 in Qaa), Malt-10 (45.6 in Kfardan, 62.6 in Qaa) were positioned next to Rihane-3 check (52 in Kfardan, 41.1 in Qaa) (Fig. 7). Whereas for the grain weight per plant, Malt-8 (2.96 in Kfardan, 1.57 in Qaa), Malt-9 (2.6 in Kfardan, 2.65 in Qaa), Malt-10 (2.7 in Kfardan, 2.5 in Qaa) were positioned next to Assi check (2.9 in Kfardan, 3.06 in Qaa) (Figure 1).
Thousand grains weight. Globally, higher thousand grains weights were recorded in Kfardan than Qaa trial. Values ranged from a minimum of 32.8 in Qaa and 37.43 g in Kfardan as produced by Malt-7 to a maximum of 44.72 in Qaa and 53.02 g in Kfardan obtained with Malt-3. Whereas checks recorded in Qaa a minimum of 36.6 for Rihane-3 to a maximum of 40 g for Assi. In Kfardan, thousand grains weights ranged from 36.6 to 78.2 g in Rihane, 42.0 to 58.18 g in Assi, and 39.0 to 70.9 g in Atahualpa (Figure 1).
Yield per m^2. The genotype Malt-9, Malt-10 and Malt-11 had the best average yield in Qaa with 274.4 g/m^2, 232.2 g/m^2, and 231.1 g/m^2 respectively. Whereas in Kfardan trial, Malt-11 and Malt-7 had the highest yields with 245 g/m^2 and 222 g/m^2 respectively. Atahualpa variety produced 244 g/m^2 in Qaa *vs.* 178 g/m^2 in Kfardan overcoming Rihane-3 (172.2 g/m^2 in Kfardane, 200 g/m^2 in Qaa) and Assi (200 g/m^2 in Kfardan, 211 g/m^2 in Qaa).
Traits Validation. Principal Components Analysis revealed the discrimination importance of the traits used in this study in explaining the first two components in both Kfardan (47.52% of the total variation) and Qaa (46.82%) trials (Table 4). The first component in Kfardan is mostly represented by the days to heading, days to maturity, spike length, grains number per spike, grain weight per plant, thousand grains weight, whereas the other traits appeared in the second component. In Qaa trial the first component is represented by all traits studied except the spike number per plant which appeared to in the second component. Although genetic variatibility is a must to carry out selection in any population, yet the study of correlative links between agronomic traits is of a major importance, since the selection for a certain trait may have negative influence on the expression of other traits. In our experiment, strong relationships were established between the different studied traits in both Kfardan and Qaa trials (Table 5). Grain yield/m^2 was negatively correlated with days to heading r= -0.52 in kfardan and -0.66 in Qaa ($p<0.05$). At the same time,

Table 4. Eigen vectors obtained for the agronomic traits according to the first two components.

Traits	Kfardan		Qaa	
	F1	F2	F1	F2
DHE	0.406	0.124	0.366	0.310
DMA	0.392	0.092	0.413	0.130
PH	-0.164	-0.465	-0.265	0.216
S/P	-0.123	0.554	0.013	0.564
SL	0.383	0.145	0.248	0.235
G/S	-0.370	0.300	-0.354	-0.332
G/P	-0.259	0.482	-0.395	0.216
GW/P	-0.358	-0.003	-0.373	0.340
TGW	-0.378	-0.116	-0.271	0.423
Y/m2	-0.132	-0.305	-0.266	-0.127
% Variability	47.523	23.606	46.82	21.595

Table 5. Correlation between the ten traits studied.

Kfardan	DHE	DMA	P H	S/P	S L	G/S	G/P	G W	TGW	Y/m^2
DHE	1	0.773	-0.319	-0.176	0.910	-0.532	-0.330	-0.580	-0.638	-0.514
DMA		1	-0.318	-0.16	0.880	-0.553	-0.368	-0.469	-0.614	-0.369
P H			1	-0.49	-0.267	-0.011	-0.204	0.362	0.554	0.295
S/P				1	-0.115	0.470	0.807	0.049	-0.048	-0.141
S L					1	-0.487	-0.261	-0.442	-0.520	-0.493
G/S						1	0.820	0.741	0.650	-0.036
G/P							1	0.341	0.283	-0.047
GW								1	0.901	-0.117
TGW									1	-0.030
Y/m2										1
Qaa	DHE	DMA	P H	S/P	S L	G/S	G/P	G W	TGW	Y/m^2
DHE	1	0.805	-0.287	0.264	0.575	-0.704	-0.489	-0.384	-0.116	-0.661
DMA		1	-0.541	0.227	0.396	-0.763	-0.651	-0.581	-0.419	-0.466
P H			1	-0.002	0.132	0.327	0.359	0.482	0.657	0.249
S/P				1	0.035	-0.589	0.291	0.417	0.323	0.014
S L					1	-0.552	-0.423	-0.303	-0.076	-0.297
G/S						1	0.52	0.387	0.273	0.281
G/P							1	0.937	0.596	0.429
GW								1	0.696	0.37
TGW									1	0.002
Y/m2										1

At a degree of freedom of 43, absolute values of r > 0.31 are significant at 0.05 level.

grain yield/ m^2 did not reveal any relationship with all other studied quantitative traits, which may indicate the posibility of selectiong for early heading without influencing other yield components. As expected, most of yield components were positively intercorrelated. Thousand grain weight were posetively correlated with grain weight per plant (r= 0.90) in kfardan and (r= 0.69) in Qaa (p<0.05). Grain weight per plant was negatively corelated with days to heading (r= -0.58) in kfradan. As expected, number of grains per plant expressed a strong positive correlation with the number of grain per spike (r= 0.82). Grain per spike was negatively correlated with days to heading (r= -0.53) Kfardan, (r= -0.70) Qaa and maturity (r= -0.55) kfardane (r= -0.76) Qaa. The same patern was notised for the Qaa experimental site. As for other traits, spike length was posetively corelated with days to heading. spike per plant didn't show any significant correlation with any other traits in both sites, wherease plant height was negatively corelated with days to maturity only in Qaa trial.

Relationships between genotypes. A hierarchical classification constructed with Euclidean distance (Ward, 1963) on the basis of the measured traits allowed to distribute the genotypes studied in three mains clusters in both Kfardan and Qaa trials at 2.2 and 2.35 of similarity distance respectively (Figure 2). As to Kfardan trial, Cluster I comprised five malting genotypes, Malt-1, Malt-2, Malt-3, Malt-5 and Malt-8, all presenting low yield per m^2. Cluster II contained Malt-7 and Malt-11 which had the highest yield per m^2. Cluster III is composed of Malt-4, Malt-6, Malt-9, Malt-10 in addition to the three varieties, Rihane-3, Assi, and Atahualpa, all characterized by high days to maturity, high grain weight per plant and intermediate yield per m^2. Both clusters I and III were divided into sub-clusters according mainly to plant height (low to high) and grain weight per plant (low to high). In Qaa trial, Cluster I reassembled Malt-4, Malt-9, Malt-10 and Malt-11 in addition to Assi, Rihane-3 and Atahualpa, which are all characterized by their high yield per m^2. Nevertheless this cluster split in three sub-clusters following days to heading and maturity, and plant stature. Cluster II contained Malt-2, Malt-5, Malt-7 and Malt-8 having late heading and maturity. It was divided in two sub-clusters according to plant height (low to intermediate) and yield/m^2 (lowest to high). Cluster III comprised Malt-1, Malt-3 and Malt-6 all presenting late heading and low yield per m^2. It split in two sub-clusters according to days to maturity (intermediate to late).

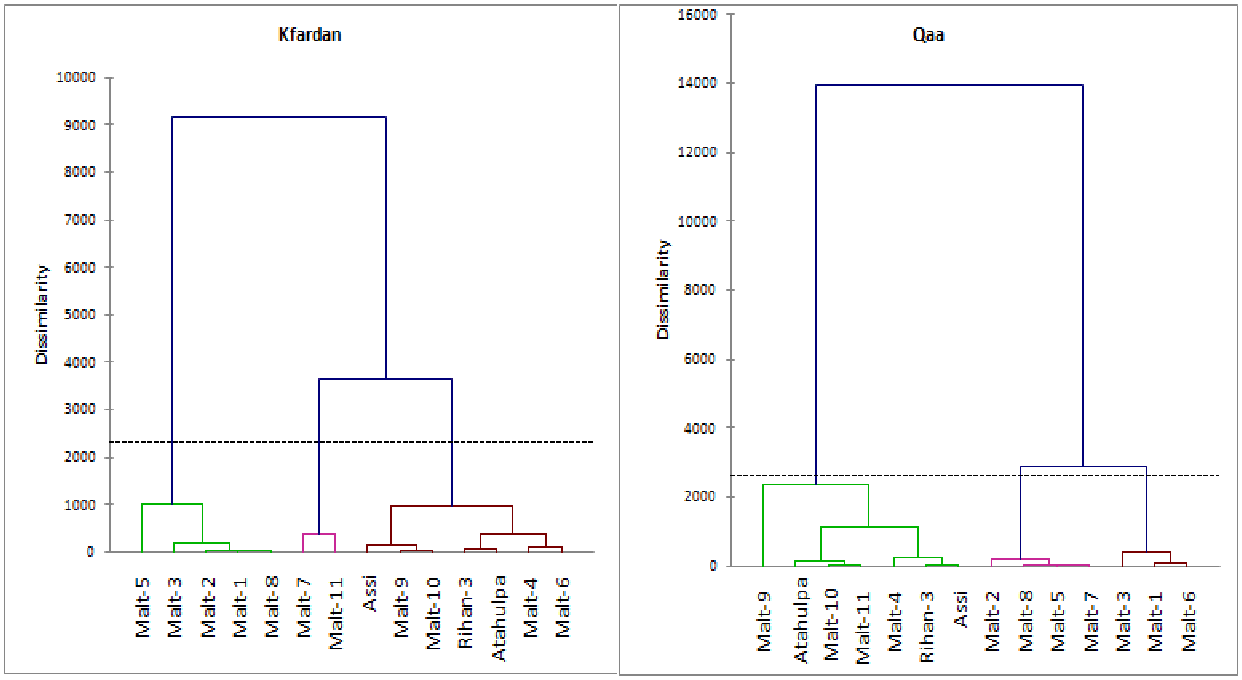

Figure 2. Dendrogram of 11 malting barley genotypes and three varieties constructed on the basis of agronomic traits, using Euclidian distance in both Kfardan and Qaa trials.

Malting quality attributes

The results of traits malting quality assessment for the experimental genotypes together with the common varieties, Rihane-3 and Assi, harvested from Kfardan trial, are presented in (Table 6). Skinned kernels percentage ranked from 0.43% in Rihane-3 and 0.73% in Assi up to 2.5% in Malt 5. With their low percentage of skinned grains, the common varieties ranked best in quality. Together with Malt-3, the controls recorded best percentages of broken grains with 0.1% for Assi, 0.16% for Rihane-3 and 0.23 for Malt-3. Germination capacity percentage was acceptable for all genotypes and controls ranging between 94 to 97%. Moisture content varied from 8.13% in Malt-8 up to 10.78% in Malt-1, and therefore, satisfying the criteria of less than 12% water content required for beer production (Carlsberg, 2008). Malt extract percentage showed a low variability between the genotypes, varying from 63.30 in Malt-8 to 65.73 in Malt-1. When combining the advantages of both moisture percentage and malt extract, Malt-1 is *a priori* the most suitable genotype for beer production. The good malting quality is based on a protein content greater than 9% and lower than 11.5% (Carlsberg, 2008). Malt extract percentage showed a low variability between the genotypes, varying from 63.30 in Malt-8 to 65.73 in Malt-1. When combining the advantages of both moisture percentage and malt extract, Malt-1 is *a priori* the most suitable genotype for beer production. The good malting quality is based on a protein content greater than 9 % and lower than 11.5% (Carlsberg, 2008). Malt-2, Malt 4, Assi and Rihane-3 had the ideal protein percentage for beer production while the other genotypes had high protein content greater than 11.5%. High diastatic power degree was recorded for varied from 50.2903° in Malt-10 to 203.6402° in Malt-7. As to the diastatic power that is referring to the enzymes which convert the starch into maltose, glucose and dextrin, high degrees were recorded for Malt-5 (121.32°), Malt-2 (128.49°), Malt-6 (131.43°), Malt-4 (158.44°), Malt-9 (170.57°) and Malt-7 (203.64°); whereas the common varieties had lower diastatic power with 96° for Assi and 80.88° for Rihane-3. All malt genotypes had β-glucan percentage lower than 4%, ranking between 2.64 in Malt-6 and 3.55% in Malt-8, and therefore are suitable for beer production.

Table 6. Physico-chemical malt attributes of 11 barley malting genotypes.

	Skinned grains %	Broken grains %	Germination %	Moisture %	Malt extract %	Protein %	Diastatic power (°WK)	β-glucan %
Malt-1	1.4	1.2	97	11.0	65.73	11.90	108.54	2.96
Malt-2	2	1.0	96	10.5	65.32	11.37	128.49	2.83
Malt-3	1.13	0.2	96	9.4	64.40	12.77	71.07	2.70
Malt-4	2.0	1.0	94	10.0	65.00	11.37	158.44	2.75
Malt-5	2.5	1.0	94	9.0	64.09	12.42	121.32	2.65
Malt-6	2.4	1.4	94	9.0	64.09	13.65	131.43	2.64
Malt-7	1.2	2.0	94	9.6	64.61	12.25	203.64	2.75
Malt-8	2.2	0.5	94	8.0	63.30	12.07	102.65	3.53
Malt-9	1.5	0.3	95	8.3	63.55	12.25	170.57	3.25
Malt-10	1.0	0.7	95	8.5	63.72	11.72	50.29	3.22
Malt-11	1.6	1.0	96	9.2	64.27	11.72	119.00	2.84
Assi	0.7	0.1	95	9.0	64.10	10.50	96.00	3.29
Rihane-3	0.4	0.2	95	9.0	64.10	10.32	80.88	3.44

Discussion

Despite its potential and market demand, production of barley for malt is not yet practiced in Lebanon. This could be attributed to the lack of information on the effect of genotype, predictable and unpredictable environmental variations and their interaction on yield and quality attributes of the crop. To investigate such variables, 11 malting barley genotypes were assessed rain fed in two locations in the region of northern Bekaa, Lebanon.

The influence of genotype on yield components was highly significant ($p<0.05$) aligning the findings previously reported by Bleidere *et al.* (2013). As expected, a large variability has been observed between genotypes and locations. Similar findings have been reported in malting barley genotypes under diverse agro-ecologies of Ethiopia (Muluken, 2013; Aynewa *et al.*, 2013). The revealed negative relationship between days to heading and yield may serve as an indicator for selecting plants with less days to heading. This allows the plant to escape the harsh conditions of drought and heat during grain filling period. Early heading is more important than days to maturity, since maturity is greatly dependant on environmental factors, especially rainfall, temperature and others (Janusauskaite *et al.*, 2013).

The genotype Malt-11 was the earliest and produced the highest yield per m^2 in Kfardan (245 g/m^2), while Malt-9 had the best average yield in Qaa (274 g/m^2). Both genotypes produced higher yields than our common varieties. Genotypes Malt-7 (221 g/m^2) in Kfardan, Malt-10 (232 g/m^2) and11 (232 g/m^2) in Qaa also produced high yields. Therefore Malt-11 and Malt-9 genotypes are recommended for commercial use and further improvement programs for malt barley production programs in Lebanon, especially in the harsh conditions tested of northern Bekaa.

All agronomic traits showed to have a discrimination potential to differentiate the genotypes. This finding is in line with those of Acevedo *et al.* (1991) and Van Oestrum and Acevedo (1992) who highlighted the effectiveness of these traits for the evaluation of barley genotypes in the Mediterranean areas.

The effect of environment on grain yield was greater than that of the genotype as previously shown in a study of Muluken (2013). Most genotypes performed well in grain yield in Qaa trial while grain weight was with acceptable range in Kfardan, whilst rainfall in both locations didn’t exceed 171 and 119 mm respectively during the barley growth period. The main limitation to obtain higher yield in Mediterranean environment is the restricted water availability (Rizza *et al.* 2004) and, therefore, any superior genotypes 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).

Regarding quality attributes of malting, a preliminary evaluation of foreign genotypes cultivated in Lebanon was carried out to provide minimum functional information to the brewer. To be used in the brewing industry, barley must fulfill the main quality criteria of variety purity of minimum 99%, high germination capacity with minimum of 97% after 3 days, water content of 12.0% (maximum 13.0%), protein content comprised between 9.0 and 11.5%, grading with minimum 90% (> 2.5 mm), β-glucan content of 4% maximum (Carlsberg, 2008).

Comparatively, the studied genotypes had adequate quantities of skinned and broken grains, acceptable germination energy, and moisture content necessary for malting, and therefore meeting the necessary requirements for malt (Agu *et al.*, 2008). On the other hand, a large variability was noticed among the studied genotypes for the diastatic power which ranged from a minimum of 50.29° in Malt-10 to a maximum of 203° in Malt-7. All genotypes produced almost the same amount of malt extract ranging from 63.30 to 65.73%. Most of the brewers consider these levels as close to the required ones. Some studies carried out on hull-less barleys appear to suggest that they contain important brewing qualities, especially with regard to high extract recovery from the malt (Agu *et al.*, 2002; Edney and Langrell, 2004). With its high protein content (13.65%), Malt-6 meets the requirement of fodder barley while our common varieties Rihane-3 and Assi were the best in protein content with respective values of 10.32 and 10.50%. Regarding β-glucan that poses problems for the malting and brewing industry being responsible for reducing the rate of wort filtration and recovery of malt extract, all genotypes studied, including the common varieties, showed percentages lower than 4% and therefore could be considered suitable for brewing purposes (Lewis and Bamforth, 2006).

Based on these preliminary data, it might be concluded that Lebanese common varieties Rihane-3 and Assi could be recommended to be grown for malt, due to their good grain yield performance, protein content and β-glucan rate. Nevertheless, these two varieties may be improved to increase malt extract and diastatic power in further breeding programs.

Acknowledgments

This project is funded by the Grant Research Program-2011 of the National Council for Scientific Research, Lebanon (Ref. 3420). It involves researchers from the Faculty of Agriculture at the Lebanese University, the Lebanese Agricultural Research Institute (LARI) and ICARDA, in addition to Aarzal farmers' cooperative in northern Bekaa.

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