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BREEDING BARLEY FOR QUALITY IN TURKEY

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We evaluated a total of 411 genotypes, including 334 breeding lines with 77 checks from Barley (*Hordeum vulgare* L.) Breeding Program of Turkey (BBPT), based upon their grain yield (GY) and quality traits (namely protein content-PC, acid detergent fiber-ADF, thousand kernel weight-TKW, kernel size-KS and test weight-TW), during the 5 consecutive cropping seasons, from 2007-2008 to 2011-2012. Broad-sense heritability (H) values for quality traits were moderate (0.57-0.65), while it was low (0.43) for grain yield. Accordingly, grain physical features (namely TW, KS and TKW) were positively significantly correlated with GY, but negatively significantly correlated with PC. Results of our study showed that selection for GY and quality traits was less efficient than we expected, due to undesirable multi-variate correlations such as GY vs PC and low to moderate H values. Therefore, we tried to put suggestions forward to the BBPT, by following discussing about our ability to select for high GY and acceptable quality in barley.
Key words: Barley, breeding, correlation, heritability, quality.

INTRODUCTION

Barley (*Hordeum vulgare* L.) is one of the most important cereals in the world, considering its usage specifically for feed and malting. In Turkey, it was cultivated in about 2.7 million hectares with an annual production of 7.9 million tons in 2013. But, its planted area in Turkey gradually decreased from 3.64 million hectares in 2001 to 2.72 million hectares in 2013 (FAOSTAT, 2015). This reduction could be related to lower commodity prices, insufficient subsidies, weaker supply chains and inadequate seed production programs, comparing with those in wheat. Although it is characterized by a lower production cost than other cereals, it can also be adapted to low input environments (YANG *et al.*, 2010; MARINACCIO *et al.*, 2015).

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The major portion, around 90 %, of barley grain annually produced in Turkey is used for feed, while its minor portion, only 2-3 %, is reserved for malting industry. For this reason, simultaneous improvement in grain quality for feed and malting is one of main goals of the current BBPT. But, we believe that breeding for feed quality should be prioritized in the BBPT for the next term, considering the present utilization ratios of barley in Turkey and resources allocated to the BBPT. As for breeding barley for malting quality in Turkey, private sector is currently more interested in developing varieties, exclusively for malting industry, and also handling seed production processes than public sector.

In the 1980s in Turkey, it was noticed that specific varieties should be improved for feed and malting quality. The parental crossings in the BBPT were established upon high yielding capacity, acceptable quality, and resistance to diseases. Although some progress was recorded, breeding for quality was not sufficiently realized due to insufficient quality laboratory infrastructure, equipment and personnel. As a result, landrace-derived varieties, such as Tokak, were able to meet the demand, which represented most of consumption in the 1980s. Recently, improved varieties with acceptable quality, specifically for feed, such as Tarm-92, Karatay-94 and Larende, have become available. Today, more than 80 barley varieties, differing in hullness (hulled vs hull-less), row (two vs six rowed), adaptability (irrigated vs rain-fed), growth habit (winter vs spring or facultative) and quality (feed vs malt or food), are present on the registration list of Turkey (http://www.tarim.gov.tr/BUGEM/TTSM). But, we do not have enough information about feed quality facts of the registered varieties of barley in Turkey, even though most of them have been registered for feed. Regarding malting varieties, their quality characteristics have been well documented because of private sector's interest.

Quality in barley is a complex phenomenon, including several characteristics, and is multi-genic. For instance, the definition of acceptable feed quality is not easy to understand; it depends on its usage aims, including processing techniques (MATTHIES *et al.*, 2014). Barley varieties for feed are specifically developed for good agronomic performance, but also are ones that do not fall into the malting grading standards. They are simply classified as feed varieties, not necessarily possessing desirable feed quality characteristics. Current understanding of true feed quality in barley is somewhat limited. Overall, the feed industry has yet to define quality in any terms that can be used practically for improved breeding selection. Until then, feed varieties will remain second class quality grain (FOX, 2009).

Breeding barley for feed quality has several challenges, including defining what consist of feed quality for the livestock that use barley as feed and being able to efficiently and effectively select for these traits. Another challenge is translating improvements in feed quality into a price premium to the barley producer. While the livestock producer may pay a premium for high TW and KS, he or she may not be getting the best quality product (JUSKIW *et al.*, 2005).

In this study, we have discussed about our ability to select for acceptable quality in barley, by following the results of yield and advanced yield trials conducted in the BBPT, during the cropping seasons, from 2007-2008 to 2011-2012. Also, we have put suggestions forward to the BBPT, by underlining aspects of breeding for quality in barley.

MATERIALS AND METHODS

Field trials

A total of 411 genotypes of hulled two-rowed barley (*Hordeum vulgare* L.), including 334 breeding lines with 77 checks from BBPT, were grown in 14 field trials in Konya, central Turkey, (37°52ʹN, 32°29ʹE, 1016 m above sea level), on a hydromorphic alluvial under the conditions of Mediterranean climate, during the 5 consecutive cropping seasons (from 2007-2008 to 2011-2012) (Table 1). Field trials were designed in completely randomized blocks with three (in Barley Yield Trials-BYTs) to four (in Barley Advanced Yield Trials-BAYTs) replicates. They were sown in October and harvested in July for each cropping season. Sowing was done with an experimental drill in 1.2 m × 7 m plots, consisting of 6 rows spaced 20 cm apart. In rain-fed trials (BYT-RF and BAYT-RF), seeding rate was 550 seeds m^{-2} and fertilizer application was 27 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1} at the planting and 43 kg N ha^{-1} at the stem elongation stage. In supplementary irrigated trials (BYT-SIR and BAYT-SIR), seeding rate was 450 seeds m^{-2} and fertilizer application was 36 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1} at the planting, 42 kg N ha^{-1} at the stem elongation and 42 kg N ha^{-1} at the grain filling stages. Harvesting was done with an experimental combine in 1.2 m × 5 m plots.

Field trials received total annual precipitation varying greatly season to season (232-325 mm), with long term annual average of 289 mm (Table 1). In addition, supplementary irrigation of 100 mm in total (i.e. 50 mm at stem elongation and 50 mm at grain filling stages) was applied to irrigated trials (BYT-SIR and BAYT-SIR), during the 2007-2008 and 2008-2009 cropping seasons.

Quality analyses

Kernel samples for each genotype were individually ground to pass through 0.5 mm screen using a Udy-Cyclone Mill (Ft. Collins). The ground samples were then used for analyses of the protein content (PC) (N × 6.25) with elemental analyzer Leco (LECO, St. Joseph, USA). Acid detergent fiber (ADF) content was determined using an ANKOM 200 Fiber Analyzer (ANKOM Technology Crop., Fairport, NY). Thousand kernel weight (TKW) was determined using grain counter Contador (Pfeuffer GmbH, Kitzingen, Germany). For kernel size (KS), sieve fraction above 2.5 mm on the Sortimat screening machine (Pfeuffer GmbH, Kitzingen, Germany) was used. Test weight (TW) was determined using a Dickey-John GAC2100 (FOX *et al.*, 2007, 2008).

Statistical analysis

Analysis of variance (ANOVA) was conducted in order to determine whether genotype effect was significant for all variables studied. Also correlation analysis was performed to measure the strength of the relationships between the variables.

Broad-sense heritability (H) was estimated directly from the expected mean square of ANOVA for each variable in a single trial. H is the ratio of genetic variance (σ_g^2) to phenotypic variance $(\sigma_g^2 + \sigma_e^2)$, that is H = $\sigma_g^2/(\sigma_g^2 + \sigma_e^2)$, where σ_e^2 is error variance (HOLLAND *et al.*, 2003).

All analyses were done in SAS statistical software (SAS Institute, 2003).

Table 1. Barley yield and advanced yield trials conducted

Cropping season	Trial†	Number of genotype (breeding line + check)	Number of replication	Precipitation + supplemental irrigation (mm)	Trait studied‡
2007-2008	BYT-RF	36 (30 + 6)	3	274	GY, PC, ADF, TKW
	BAYT-RF	25 (20 + 5)	4	274	GY, PC, ADF, TKW
	BYT-SIR	36 (30 + 6)	3	274 + 100	GY, PC, ADF, TKW
	BAYT-SIR	25 (20 + 5)	4	274 + 100	GY, PC, ADF, TKW
2008-2009	BYT-RF	25 (20 + 5)	3	232	GY, PC, ADF, TKW
	BAYT-RF	25 (20 + 5)	4	232	GY, PC, ADF, TKW
	BYT-SIR	25 (20 + 5)	3	232 + 100	GY, PC, ADF, TKW
	BAYT-SIR	25 (20 + 5)	4	232+ 100	GY, PC, ADF, TKW
2009-2010	BYT-RF	30 (24 + 6)	3	267	GY, PC, ADF, TKW, KS
	BAYT-RF	25 (20 + 5)	4	267	GY, PC, ADF, TKW, KS, TW
20010-2011	BYT-RF	42 (35 + 7)	3	325	GY, PC, ADF, TKW, KS
	BAYT-RF	25 (20 + 5)	4	325	GY, PC, ADF, TKW, KS, TW
20011-2012	BYT-RF	42 (35 + 7)	3	258	GY, PC, ADF, TKW, KS, TW
	BAYT-RF	25 (20 + 5)	4	258	GY, PC, ADF, TKW, KS, TW
Total	14	411 (334 + 77)		Mean = 271	

†BYT-RF, Rain-fed barley yield trial BAYT-RF, Rain-fed barley advanced yield trial

BYT-SIR, Supplementary irrigated barley yield trial BAYT-SIR, Supplementary irrigated barley advanced yield trial

‡GY, Grain yield (kg ha^{-1}) PC, Protein content (%)

ADF, Acid detergent fiber (g kg^{-1}) TKW, Thousand kernel weight (g)

KS, Kernel size (> 2.5 mm sieve fraction) TW, Test weight (kg hl^{-1})

RESULTS

Environmental conditions

Comparing with long term averages (289 mm) of precipitation and temperature, lower precipitation (Table 1) and higher temperature (data not shown) were recorded in all cropping seasons except for the 2010-2011 season, from the stem elongation to anthesis stage, while frequent rainfall occurred at the end of grain filling, after the dough stage, although grain filling duration was not prolonged. The precipitation was instead frequent and regular from April to June at the 2010-2011 season, but high temperature led to quick crop maturation. Low precipitation and temperature occurred at the 2008-2009 season, during the stem elongation, booting, heading and grain filling stages. The cooler conditions during the grain filling stage were recorded at the 2011-2012 season, and led to the harvest being delayed till the middle of July.

Analysis of variance

The ANOVA for grain yield and quality traits data indicated that significant differences among genotypes tested in all field trials existed during the all cropping seasons (ANOVA results not shown).

Evaluation of field trials based on genotype means

GY values of barley breeding lines selected from the BYTs and BAYTs conducted over the seasons were superior than those of checks used. Meanwhile, GY means of all trials, ranging 3.11 to 6.87 t ha^{-1}, were higher than barley mean yields of Turkey, ranging 2.17 to 2.66 t ha^{-1}, across the seasons (FAOSTAT, 2015). Consequently, these results showed that our barley breeding program was quite useful to select promising breeding lines with high yielding capacity.

For malting barley, PC should be less than 12 %, specifically between 9 and 11 %, to meet malting industry specifications (VERSTEGEN *et al.*, 2014). However, feed industry has not announced yet any specification for PC. According to YANG et al. (2010), for feed barley, PC should be higher than 12.0 %, usually 13-15 %. In our study, PC values were higher than 12 % for the majority of breeding lines studied. For this reason, we understand that our breeding program was suitable to develop feed barley varieties rather than malting ones.

Despite having the high PC, the high fiber (ADF) content of barley like oats decreases its nutrient and commodity values (STRYCHAR, 2011). ADF values of breeding lines tested varied from 5 to 7 g kg^{-1}. Most of the breeding lines showed promise for commercial purposes, altought the range of ADF for our breeding material was narrower than that, 4-8 g kg^{-1}, reported by BLEIDERE and GAILE (2012).

Heavy kernels are preferred for both feed and malting barley varieties (NEWMAN and NEWMAN, 2008). TKW values measured from our barley breeding trials varied between 38 g and 49 g. According to NEWMAN and NEWMAN (2008), kernels from two-rowed barley varieties were higher TKW values, ranging from 43 g to 50 g with mean of 46 g, than those of six-rowed ones. Although the majority of our barley breeding lines used were hulled two-rowed, their TKW values were slightly lower than those reported by NEWMAN and NEWMAN (2008).

Selection for increased KS (> 2.5 mm) can provide a useful strategy in increasing overall KS. Smaller kernel generally has lower starch and higher protein levels, thus reducing the extract/feed potential. Large kernels, conversely, have increased levels of starch and therefore more potential extract. However, KS ratios (> 2.5 mm) measured in our barley breeding lines were substantially lower than the minimum value, 85 %, for two-rowed barley varieties (FOX *et al.*, 2008). This result suggested that our barley breeding lines, considering their KS values (> 2.5 mm), were more suitable for feed than for malting.

TW is an indicator of large, plump kernels with a greater proportion of starch rich endosperm and a lesser proportion of bran and hull. Higher TW kernels tend to have average PC but a higher metabolizable energy content. Lower TW kernels tend to have slightly higher PC but reduced endosperm size results in substantially lower metabolizable energy concentration (FOX *et al.*, 2008; BLEIDERE and GAILE, 2012). In this study, the kernel samples from the three cropping seasons, from 2009-2010 to 2011 to 2012, were used for measuring TW (Table 1). But, only the breeding lines tested at the 2010-2011 season showed higher TW values than that of the Turkish Grain Board Standard, 64 kg hl^{-1}, (http://www.tmo.gov.tr).

Heritability (H)

H values indicate a ratio of genetic variance when compared to phenotypic variance (HOLLAND et al., 2003). The range in H values is reported in Table 2. H values showed a broad range for each trait across the cropping seasons. For GY, PC and ADF, H values were very high ranging from 0.28 to 0.65 (low to moderate), 0.51 to 0.81 (moderate to high) and 0.52 to 0.78 (moderate to high), respectively. Accordingly, for TKW, TW and KS, H values were moderate, ranging 0.51 to 0.72. In general, H values estimated on the mean basis were above 0.57, with exception of 0.43 for GY, which indicated that a relatively large genetic component was involved in the determination of the observed trait variation.

Table 2. Heritability estimates for traits studied

Cropping season	Trial†	GY‡	PC	ADF	TKW	KS	TW
2007-2008	BYT-RF	0.42	0.69	0.58	0.63		
	BAYT-RF	0.31	0.66	0.64	0.61		
	BYT-SIR	0.42	0.73	0.65	0.69		
	BAYT-SIR	0.58	0.75	0.71	0.62		
2008-2009	BYT-RF	0.38	0.61	0.66	0.71		
	BAYT-RF	0.41	0.64	0.61	0.69		
	BYT-SIR	0.65	0.81	0.78	0.72		
	BAYT-SIR	0.49	0.62	0.63	0.69		
2009-2010	BYT-RF	0.29	0.58	0.52	0.57	0.55	
	BAYT-RF	0.47	0.61	0.59	0.69	0.59	0.63
20010-2011	BYT-RF	0.52	0.51	0.55	0.61	0.51	
	BAYT-RF	0.28	0.57	0.52	0.63	0.57	0.62
20011-2012	BYT-RF	0.39	0.54	0.61	0.57	0.62	0.59
	BAYT-RF	0.45	0.62	0.65	0.71	0.58	0.68
Mean		0.43	0.64	0.62	0.65	0.57	0.63
Min.		0.28	0.51	0.52	0.57	0.51	0.59
Max.		0.65	0.81	0.78	0.72	0.62	0.68

†BYT-RF, Rain-fed barley yield trial BAYT-RF, Rain-fed barley advanced yield trial

BYT-SIR, Supplementary irrigated barley yield trial

BAYT-SIR, Supplementary irrigated barley advanced yield trial

‡GY, Grain yield (kg ha^{-1}) PC, Protein content (%) ADF, Acid detergent fiber (g kg^{-1})

TKW, Thousand kernel weight (g) S, Kernel size (> 2.5 mm sieve fraction) TW, Test weight (kg hl^{-1})

H values were relatively more expressed in the irrigated trials conducted at the 2007-2008 and 2008-2009 seasons, comparing with those in rain-fed trials (Table 2). This could be explained by the fact that seasons and/or sites with better growing conditions are likely to lead to either higher genetic variance relative to lower environmental variance or lower environmental variance relative to higher genetic variance (FOX *et al.*, 2008).

Relationships between traits studied

GY and PC were significantly negatively correlated in ten of fourteen barley trials conducted over five cropping seasons (Table 3). The average correlation was -0.447; individual trial values ranged from 0.009 to -0.776. Conversely, correlations of GY with TKW, KS and TW were significantly positive at most of the trials carried out, indicating that relative ranking of the genotypes remained similar under rain-fed (even under severe drought) and irrigated conditions (Tables 1 and 3). Interestingly, heterogenous correlations, but not significant, were observed between GY and ADF in all field trials.

Table 3. Correlations between grain yield and quality traits studied

Cropping season	Trial†	GY‡ vs PC	GY vs ADF	GY vs TKW	GY vs KS	GY vs TW
2007-2008	BYT-RF	0.009	-0.073	0.518**		
	BAYT-RF	-0.605**	-0.248	0.598**		
	BYT-SIR	-0.614**	0.381	0.634**		
	BAYT-SIR	-0.632**	-0.356	0.765**		
2008-2009	BYT-RF	-0.167	0.224	-0.123		
	BAYT-RF	-0.721**	-0.269	0.543**		
	BYT-SIR	-0.468*	0.113	0.034		
	BAYT-SIR	-0.413*	-0.072	0.573**		
2009-2010	BYT-RF	-0.604**	-0.041	-0.201	0.165	
	BAYT-RF	0.049	0.046	0.098	-0.128	0.478*
20010-2011	BYT-RF	-0.722**	-0.182	0.449*	0.564**	
	BAYT-RF	-0.776**	-0.159	0.498*	0.467*	0.543**
20011-2012	BYT-RF	0.045	0.308	-0.234	0.289	0.267
	BAYT-RF	-0.641**	-0.080	0.386	0.698**	0.454*
Mean		-0.447	-0.029	0.324	0.343	0.436
Max.		-0.776	0.381	0.765	0.698	0.543
Min.		0.009	-0.041	0.034	-0.128	0.267

*, ** significant at P<0.05 and P<0.01, respectively †BYT-RF, Rain-fed barley yield trial

BAYT-RF, Rain-fed barley advanced yield trial BYT-SIR, Supplementary irrigated barley yield trial

BAYT-SIR, Supplementary irrigated barley advanced yield trial ‡

GY, Grain yield (kg ha^{-1}) PC, Protein content (%) ADF, Acid detergent fiber (g kg^{-1})

TKW, Thousand kernel weight (g) KS, Kernel size (> 2.5 mm sieve fraction) TW, Test weight (kg hl^{-1})

For PC, after starch content, being the predominant form of storage compound in barley, a very strong negative correlation, with average of -0.403, ranging 0.026 to -0.789, was observed with TKW under almost all field trials conducted (Table 4). In addition, this adverse relationship existed between PC and KS. On the other hand, there were no significant correlations among PC, ADF and TW. As a result, in cereals, there are apparent negative correlations of GY and TKW with PC, which was the case for our study (MUNIER-JOLAIN and SALON, 2005; ACRECHE and SLAFER, 2009; LACAZE *et al.*, 2009; KALLADAN *et al.*, 2013).

Table 4. Correlations between protein content and quality traits studied

Cropping season	Trial†	PC‡ vs ADF	PC vs TKW	PC vs KS	PC vs TW
2007-2008	BYT-RF	0.134	-0.429*		
	BAYT-RF	-0.284	-0.724**		
	BYT-SIR	-0.313	-0.654**		
	BAYT-SIR	0.229	-0.786**		
2008-2009	BYT-RF	0.049	-0.659**		
	BAYT-RF	0.412*	-0.481*		
	BYT-SIR	-0.381	0.146		
	BAYT-SIR	0.339	-0.469*		
2009-2010	BYT-RF	-0.225	-0.059	-0.421*	
	BAYT-RF	-0.040	0.026	-0.367	0.369
20010-2011	BYT-RF	0.063	-0.437*	-0.659**	
	BAYT-RF	0.248	-0.164	-0.301	-0.263
20011-2012	BYT-RF	-0.086	-0.485*	-0.436*	-0.256
	BAYT-RF	0.224	-0.471*	-0.511**	-0.377
Mean		0.026	-0.403	-0.449	-0.132
Max.		0.412	-0.789	-0.659	-0.377
Min.		-0.040	0.026	-0.301	-0.256

*, ** significant at P<0.05 and P<0.01, respectively

†BYT-RF, Rain-fed barley yield trial BAYT-RF, Rain-fed barley advanced yield trial

BYT-SIR, Supplementary irrigated barley yield trial BAYT-SIR, Supplementary irrigated barley advanced yield trial

‡PC, Protein content (%) ADF, Acid detergent fiber (g kg^{-1})

TKW, Thousand kernel weight (g) KS, Kernel size (> 2.5 mm sieve fraction) TW, Test weight (kg hl^{-1})

In general, correlations of ADF with TKW and KS were slightly low, with values ranging between -0.028 and 0.378. However, ADF was significantly correlated with TW. On the other hand, strong positive correlations were found between TKW and KS (r = 0.543), between TKW and TW (r = 0.412), and between KS and TW (r =0.406).

In summary, GY showed only moderate to high correlations with quality traits (except ADF). Grain physical characteristics, namely TKW, KS and TW, showed high correlations with each other. In constrast, relationships between PC and ADF were loose. Meanwhile, the correlations between ADF and quality traits were low, indicating that the genetic determinants of these quality traits were relatively independent (MATTHIES *et al.*, 2014).

Table 5. Correlations between quality traits studied, except protein content

Cropping season	Trial†	ADF‡ vs TKW	ADF vs KS	ADF sv TW	TKW vs KS	TKW vs TW	KS vs TW
2007-2008	BYT-RF	0.236					
	BAYT-RF	-0.110					
	BYT-SIR	0.389					
	BAYT-SIR	-0.213					
2008-2009	BYT-RF	-0.156					
	BAYT-RF	-0.108					
	BYT-SIR	0.059					
	BAYT-SIR	-0.169					
2009-2010	BYT-RF	-0.310	-0.123		0.734**		
	BAYT-RF	0.204	-0.052	-0.411*	0.468*	0.449*	0.441*
20010-2011	BYT-RF	0.239	-0.378		0.356		
	BAYT-RF	0.087	-0.007	0.303	0.587**	0.412*	0.537**
20011-2012	BYT-RF	-0.305	0.025	-0.266	0.523**	0.299	0.171
	BAYT-RF	-0.240	-0.323	-0.423*	0.590**	0.487*	0.475*
Mean		-0.028	-0.143	-0.199	0.543	0.412	0.406
Max.		0.389	-0.378	-0.423	0.734	0.487	0.537
Min.		0.059	-0.007	-0.266	0.356	0.299	0.171

*, ** significant at P<0.05 and P<0.01, respectively

†BYT-RF, Rain-fed barley yield trial BAYT-RF, Rain-fed barley advanced yield trial

BYT-SIR, Supplementary irrigated barley yield trial BAYT-SIR, Supplementary irrigated barley advanced yield trial

‡ADF, Acid detergent fiber (g kg^{-1}) TKW, Thousand kernel weight (g)

KS, Kernel size (> 2.5 mm sieve fraction) TW, Test weight (kg hl^{-1})

DISCUSSION

Results of our study showed that barley breeding lines developed in the BBPT had the potential to increase barley production of Turkey. In recent years, barley facts of Turkey have revealed that GY has increased gradually, accompanying with world trend (FAOSTAT, 2015). However, its cropping area in Turkey has contantly diminished at the same time. Since 1963, 80 barley varieties in total have been released in Turkey, most of which, 42, have been put into the list of registration (http://www.tarim.gov.tr/BUGEM/TTSM), during the last decade (2006 to 2015), indicating that BBPT, together with private sector, have made a great effort to enhance the barley production of Turkey. However, we believe that even if Turkey allocated more resourses than ever before to the BBPT, decreasing trend in barley production and its cultivated land of Turkey would countinue in the years to come. To be honest, we recognize that there are several reasons why barley facts of Turkey have been trending downward recently. The first reason is related to commodity price of barley grain in domestic market. For instance, barley grain has been sold at $ 250 per ton, comparing with that, $ 330 per ton, of wheat grain (*T. aestivum* L.) in commodities exchanges of Turkey, during the fourth quarter of 2015 (http://www.ktb.org.tr). The second reason is related to competitiveness or productivity of barley against wheat. For a long time we have experienced that in rain-fed conditions of Turkey, barley can be more competitive against or more productive than wheat, mainly due to its escape mechanism (i.e. earliness) from the terminal drought stress, frequently occurred in the mandate area of our barley breeding program (BLUM, 2009; KALLADAN *et al.,* 2013; AYRANCI *et al.,* 2014; GOUS *et al.,* 2015). The third reason is related to subsidy for cereals. Necessarily, farmers prefer high yielding barley varieties to grow in rain-fed areas. However, they have recently faced the fact that wheat cultivation is economically more subsidized than barley cultivation under both rain-fed and irrigated conditions of Turkey. After all, we understand that drought tolerance mechanism or having high yielding capacity under dryland conditions does not provide any more advantage to barley. Instead, it needs something else rather than high GY potential to be attractive to farmers.

Today, under the irrigated conditions of Turkey, unfortunately, barley is less competitive against or productive than wheat. Obviously, there is no collected data about how much irrigated area is annually cultivated with barley in Turkey. But we are quite sure that a very limited part, less than 1 %, of irrigated agricultural land of Turkey is annually designated for barley cultivation, while its one quarter, 25 %, is occupied by wheat cultivation. In recent years, Turkey has become an importer for quality wheat. Therefore, to meet domestic demand for quality wheat, irrigated wheat cultivation has been specifically subsidied by the government. For the time being, we clearly understand that barley is unlikely to replace the crops, such as wheat, maize and sugar beet, predominantly grown in irrigated land of Turkey. All things considered, at the 2009-2010 season, we took a decision about the BBPT, exclusively for the irrigated barley breeding program, conducted for developing varieties to irrigated land, and then we discontinued it to allocate more resources to the rain-fed barley breeding program. On the other hand, from the breeding perpective of barley, the present study showed that selection for GY under the irrigated conditions would be more successful than that under the rain-fed conditions, because H values estimated for all traits studied under the irrigated conditions were slightly higher than those under the rain-fed conditions.

BBPT primarly targets to develop varieties superior feed quality with high PC and ones high malting quality with low PC, as well as ones with high yielding. Given the goals of BBPT, they seem to be very impressive on the project text due to their exact definitions. On the contrary, putting them in practice are so complicated that they can hardy ever be achieved indeed. We obviously believe that there are several reasons why breeding for quality in the BBPT is less successful than we expected. Firstly, we should inquire about why H values of quality traits presented in this study are moderate, but not high. Secondly, some of the correlations among the traits studied are very strong. Again we should determine which correlations would be desirable or undesirable for selecting barley breeding lines with high feed or malting quality in the BBPT. As far as we know, correlations involved usually make the barley breeding cycles more complicated, since most of the agronomic or quality characteristics are undesirably correlated (KAYA and AKCURA, 2014). This was the case for our study. The phenomenon of different traits co-localizing to a QTL, namely correlation, is observed in a variety of crops, including barley. Such co-localization can be due either to tight linkage of genes underlying a particular QTL with nearby genes or to the pleiotropic effect of the gene/genes underlying a QTL. It is crucial to be aware of these relations to understand the tradeoffs implied in the optimization of breeding lines (KALLADAN *et al.*, 2013; MATTHIES *et al.*, 2014).

We believe that a simultaneous selection for feed and malting quality is not feasible, although it is included among the objectives of BBPT. According to VERSTEGEN *et al.* (2014) there are many specific requirements for feed and malting barley. For instance, high PC (13-15 %), TKW, TW and KS and low ADF are essential for feed barley, while high TKW, TW and KS and low PC (9-11 %) and ADF are prerequisites for malting barley. At this point only have we mentioned about quality traits studied. But we know that there are also many specific traits expressing feed and malting quality in barley (see VERSTEGEN *et al.*, 2014).

To make BBPT more successful, we suggest that its objectives should be reestablished more specifically. In other words, BBPT should be separated into two programs. The first program could target only to develop feed barley varieties. The second program might specifically focus on breeding barley varieties for malting. For now, we recommend that the first program, based on feed barley breeding, should be commenced, because more than 90 % of barley grain produced annually in Turkey is used for feed. On the other hand, barley usage for malting is very limited, only 2-3 % of the annual production. Since 1998, private sector in Turkey has been conducting a self-sponsored breeding program of barley, specifically for malting quality. Up to now, 29 varieties have been released by private sector, most of which are suitable for malting (http://www.tarim.gov.tr/BUGEM/TTSM). Above all, we believe that private sector resources for financing the malting barley breeding in Turkey are quite sufficient for the time being.

As far as we know, one of the challenges facing our barley breeding program is the lack of quality data of parents using in crossing block. Unfortunatley, we have not yet evaluated the entire set of parents on the basis of quality traits especially for feed. For the development of barley breeding lines, the most important step is to choose promising parents, usually called elite breeding lines, and then cross them in order to find in their progeny such lines that combine the parents' quality and performance characteristics and ideally surpass the parents' performance in at least one of the traits of interest (VERSTEGEN *et al.*, 2014). Therefore, we urgently need quality data of parents in order to use them for making crossings more efficient.

Another challenge to the BBPT is related to the breeding method, which is currently being applied for selection in successive generations. We follow the bulk method so that we can reduce labour cost, since selections are not made for quality or agronomic traits in early generations (F2 to F5) (VERSTEGEN *et al.*, 2014). In our program, selection for agronomic traits starts at the F5 generation (i.e. head rows) and continues at the following generations, namely, observation nurseries (F6 generation) and preliminary yield trials (F7 generation). However, we do not conduct quality analysis for evaluation up to the F8 generation (i.e. yield trials). On regular basis we just select barley breeding lines for quality at yield (i.e. F8 generation) and advanced yield (F9 generation) trials. For the moment, quality analysis is not conducted at F6 and F7 generations in our barley breeding program. Judging from the results of the barley breeding method currently applied, we understand that advanced generation (F8 and F9) selection for quality possibly results in promoting some barley breeding lines with unacceptable quality, since they are not able to be discarded from the F6 and F7generations, in which quality analysis is not conducted yet. To drop the barley breeding lines with unacceptable quality from advanced generations, we should start to carry out quality analysis at the F6 (i.e. observation nurseries) and F7 (i.e. preliminary yield trials), and continue at further generations, F8 and F9 (BAENZIGER *et al.*, 2001; KAYA and SAHIN, 2015).

Barley grain is graded on the basis of TW, soundness, color, moisture, foreign material, damage and hullness in several countries such as Canada (https://www.grainscanada.gc.ca), Australia (www.graintrade.org.au) and USA (http://www.gipsa.usda.gov). In addition, PC is used as a grade factor for malting barley only in Australia. As for Turkey, the entire mentioned above have been using in barley grading system, since 2010 (https://www.tmo.gov.tr). We believe that barley grading system of Turkey is now effectively used in the purchasing operations of barley grain. On the other hand, the list of quality criteria, only including PC, KS, TKW and TW, currently used in the variety registration procedure for feed barley in Turkey should be updated immediately. For malting barley variety registration procedure, the quality criteria concerned are quite sufficient to determine whether a barley variety or candidate is suitable for malting or not. As for the quality criteria essential for feed barley variety registration, we believe that new criteria should be added into the current list, because present criteria are fully inadequate for determining feed qualiy in barley. Therefore, we suggest that physical (namely kernel hardness, kernel color and hull content), chemical (namely ADF, NDF, beta-glucan, starch, lipids, pentosans and lysine) and animal nutritional quality criteria (namely digestibility and energy) should be added into the list currently used for feed barley variety registration (BOWMAN *et al.*, 2001; JUSKIW *et al.*, 2005; BLEIDERE and GAILE, 2012). Given the quality criteria already suggested, they should also be implemented to the BBPT in order to develop barley varieties better in feed quality.

CONCLUSION

We have taken the messages, given below, from the current study.

1. Barley is more competitive against or more productive than wheat under the rain-fed conditions of Turkey. But, commodity price of barley grain is lower that of wheat in domestic market. Meanwhile, wheat is more subsidized than barley by the Government of Turkey. Therefore, there is little incentive for farmers to grow barley.

2. For selecting barley breeding lines with high feed or malting quality in the BBPT, undesirable correlations between quality traits can be broken or heritability values for quality traits can be increased by means of targeted crossing programs. Therefore, we urgently need quality data of parents in order to use them for making crossings more efficient

3. A simultaneous selection for feed and malting quality is not feasible, because there are many specific requirements for feed and malting barley. Thus, we should divide BBPT into quality oriented programs. The first program could target only to develop feed barley varieties. The second program might specifically focus on breeding barley varieties for malting.

4. In BBPT, to discard the barley breeding lines with unacceptable quality from advanced generations, we should start to carry out quality analyses at the F6 (i.e. observation nurseries) and F7 (i.e. preliminary yield trials), and continue at further generations, F8 and F9.

5. For quality traits essential for feed or malting barley variety registration, novel quality traits should be added into the present list, because it is incapable of determining feed or malting quality in barley. Also, the aforementioned quality traits should immediately be used in the BBPT to improve barley varieties better in feed or malting quality.

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OPLEMENJIVANJE JEČMA NA KVALITET U TURSKOJ

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Izvod

Ispitano je ukupno 411 genotipova ječma (*Hordeum vulgare* L.), uključujući 334 selekcione linije sa 77 konrole iz oplemenjivačkog programa Turske (BBPT), na osnovu prinosa (GY) i svojstva kvaliteta (sadržaj proteina - PC, kiselih deterđent vlakana - ADF, mase 1000 zrna –TKW, veličine semena – KS, i test težine – TW tokom 5 uzastopnih sezona od 2007-2008 do 2011-2012. Vrednosit za heritabilnost za svojstva kvlaiteta su bile umerene (0.57-0.65), dok su za prinos bile niske (0.43). Fizička svojstva zrna (TW, KS and TKW) su pozitivno značajno korelisana sa prinosom, ali negativno značajno sa sadržajem protiena. Rezultati naših ispitivanja pokazuju da selekcija za prinos zrna i svojstva kvaliteta su bila manje uspešna od očekivanog, usled neželejne multivarijetne korelacije kao prinosa i sadržaja protiena i niske do umerene heritabilnoisti.

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