Emir. J. Food Agric. 2015. 27 (2): 186-199
doi: 10.9755/ejfa.v27i2.19279
http://www.ejfa.info/

REGULAR ARTICLE

Influence of year and sowing date on bread wheat quality under Mediterranean conditions

Ana Sofia Bagulho, Rita Costa, Ana Sofia Almeida, Nuno Pinheiro, José Moreira, Conceição Gomes, João Coco, Armindo Costa, José Coutinho and Benvindo Maçãs

INIAV - National Institute for Agrarian and Veterinarian Research, Estrada Gil Vaz, Ap. 6, 7350-901 Elvas, Portugal

Abstract

Grain quality is an essential component in wheat breeding programs since influences the commercial value of wheat. This study was conducted to determine the effects of genotype, season and sowing date on quality parameters of seventeen bread wheat commercial varieties and three advanced lines from Portuguese Wheat Breeding Program (Plant Breeding Station, Elvas, Portugal) under irrigated Mediterranean systems. Field experiments were conducted at two locations of Southeast Portugal (Elvas and Beja), during two growing seasons. At Elvas, results showed that environment (season) had highest contribution on variation of quality traits. At Beja experiments, the level of environment (season) influence decreased in relation to Elvas experiments: season was the most important factor to explain the variation of protein content and test weight, but for alveograph parameters (W and P/L ratio) it was found that genotype had higher influence. Sowing date was ever the most important factor to explain thousand kernel weight. The results confirmed that genetic potential is crucial to obtain high quality wheat but it is necessary a good environment to promote its expression.

Key words: Bread wheat, Environmental constraints, Genetic improvement, Quality traits, Sowing date

Introduction

Wheat is a major cereal crop in many parts of the world. It belongs to Poaceae family and globally, after maize and rice, is the most cultivated cereal (FAOSTAT, 2013). Researchers can manage wheat cultivars, fertilizer levels, irrigation regime and agricultural practices to maximize wheat crop yield under the current conditions, but environmental constraints still be the main factors affecting wheat productivity in many regions of the world (El-Maaboud et al., 2004). In Mediterranean regions rain occurs mostly during autumn and winter, and the water deficit rises in spring, concurring with anthesis and grain filling period. Thus, drought and heat stress usually reduce yield potential and affect quality during the period of grain formation (Simane et al., 1993; Lloveras et al., 2004).

Wheat quality is complex and depends on flour composition components and the interactions of these components during the mixing and baking process (Mikhaylenko et al, 2000). Quality is an important determinant in wheat breeding since the environment usually less affects its genetic background and sufficiently influences the commercial value of a cultivar (Varzakas et al., 2014). Wheat quality depends on the presence of certain alleles at loci, which are responsible for end product quality. Thus, if a certain cultivar possesses some specific allele combination at crucial loci, then it appears quite possible to exhibit valuable qualitative traits in terms of end product quality (Varzakas et al., 2014). However, production of a cultivar conferring improved quality also require a growing environment that favors expression of this genetic potential in order, for this, to lead to the eventual production of high-quality grain (Yong et al., 2004).

Wheat flour protein is the major component that affects wheat quality. Protein content is strongly influenced by environmental conditions and crop management practices; however, protein quality is genetically determined (Payne et al., 1987; Kasarda, 1989; Cornish et al., 1991; Gupta et al., 1994a; Gupta et al., 1994b; Mikhaylenko et al., 2000).

Received 10 May 2014; Revised 25 June 2014; Accepted 5 July 2014; Published Online 1 February 2015

*Corresponding Author

Ana Sofia Bagulho
INIAV - National Institute for Agrarian and Veterinarian Research, Estrada Gil Vaz, Ap. 6, 7350-901 Elvas, Portugal

Email: ana.bagulho@iniav.pt

Table 1. Trials geographic location, soil type, sowing years and sowing dates.

	Geographic location	Soil	Sowing year	Sowing date
Elvas	38°53'N 7°8'W	Shallow silt loam	2010/11 2011/12	1st: November - December 2nd: December - January
Beja	37º58'N 7º45'W	Deep clay	2011/12 2012/13	1st: October - December 2nd: December - January

Historically breeding programs have emphasized improvement in grain yield, disease resistance and earlier maturity. Currently the emphasis has gradually shifted to the improvement of wheat quality and accordingly multilocation trials, studying genotype and environment effects, have been used to enhance wheat breeding for quality (Yong et al., 2004).

Materials and Methods

Trials location

Trials were conducted during two years at farmers field in two different environments: Elvas (Alto Alentejo region) and Beja (Baixo Alentejo region), representing the most important provinces in Portugal for bread wheat crop. Table 1 shows some important data about the field trial sites.

Wheat germplasm

Among the studied germplasm, seventeen are bread wheat varieties from different origins and the remaining three are advanced breeding lines from Portuguese Wheat Breeding Program of National Institute for Agrarian and Veterinarian Research (Elvas, Portugal). Cultivar name, its origin and its growth cycle are presented in Table 2.

Field experiments

Wheat germplasm was evaluated in two experiments with two different sowing dates and in two locations (Elvas and Beja), under irrigation conditions.

All treatments were conducted with: nitrogen fertilization at sowing time (150 kg ha-1 as 18-46-0) and three top-dressed fertilizations (150 kg ha-1 as Urea 46%; 93,75 kg ha-1 as 32N Solution and 150 kg ha-1 as ammonium nitrate 27%); two weed control (at pre-emergence and post-emergence) and three antifungal treatments (tillering, jointing and heading stages). The experimental design was a randomized complete block design and each plot size had six rows and an area of 6 m2 (5 m X 0.2 m).

Table 2. Origin and growth habit of bread wheat varieties and advanced lines.

Germplasm	Origin	Growth habit
Roxo	Portugal	Very early maturity; Spring
Ardila	Portugal	Very early maturity; Spring
Nabão	Portugal	Very early maturity; Spring
TE 0205	Portugal	Very early maturity; Spring
TE 0206	Portugal	Very early maturity; Spring
Mané-Nick	Spain	Very early maturity; Spring
Pata-Negra	Spain	Very early maturity; Spring
Siena	Spain	Very early maturity; Spring
Badiel	Spain	Early maturity; Spring
Alabanza	Spain	Early maturity; Spring
Nogal	France	Early maturity; Facultative
Flycatcher"s" x …	Portugal	Early maturity; Facultative
Inoui	France	Early maturity; Facultative
Eufrates	Portugal	Late maturity; Facultative
Aguila	France	Late maturity; Facultative
Bologna	France	Very late maturity; Facultative
Ingenio	France	Very late maturity; Facultative
Linha 3	England	Late maturity; Winter
Linha 1	England	Late maturity; Winter
Linha 2	England	Very late maturity; Winter

Quality Evaluation

Grain from each sample was evaluated by test weight (ISO 7971-1) and thousand-kernel weight (ISO 520). Grains were milled in a Falling Number mill (Perten, Sweden) equipped with 0,8 mm sieve to perform whole-wheat protein content (ISO 20483). A grain sample with 800 g of each sample were also tempered to 16% moisture and milled by a Chopin CD1 mill. The flour obtained was used to perform flour protein content (ISO 20483), wet gluten content (ISO 21415-2) and alveograph test (ISO 27971). The variables of alveograph deformation energy (W) and curve configuration ratio (P/L - relation between dough tenacity (P) and extensibility (L)) were measured.

Statistical analysis

Analysis of variance (SAS Institute, Cary, NC) was performed independently for each location with the general linear model procedure and was used to study the effects of different genotypes, crop years (seasons) and sowing dates on technological parameters mean values. Means were compared using Tukey Student's test (significance level $P < 0.05$). The relationship between the quality traits was examined by Pearson correlation coefficients, using the results from the two locations together.

Results and Discussion

A. Elvas experiments

Climatic conditions

Elvas and Beja are located in Alentejo region. In this region, climate is characterized by Mediterranean conditions with high irregularity in precipitation among the seasons.

The 2010/11 season was considered a wet year with 667 mm of total precipitation (Figure 1), distributed by the months with major influence in wheat vegetative and reproductive growth, allowing hydric comfort to plants.

In opposite, 2011/12 season with a total of 270 mm of rainfall was considered a dry year, almost without precipitation from December to March (Figure 2). On November 100 mm occurred allowing early sowing but it was necessary to do additional irrigations in order to minimize the adverse effects of drought stress.

Regarding temperature, it was found that 2010/11 season had a milder winter with minimum temperatures not falling below 5ºC which was verified in 2011/12 with frosts occurring in January and February. In relation to the maximum temperatures during the grain filling period (April-May) it was found a difference of 1.5°C between the two seasons, with 2010/11 showing higher temperatures.

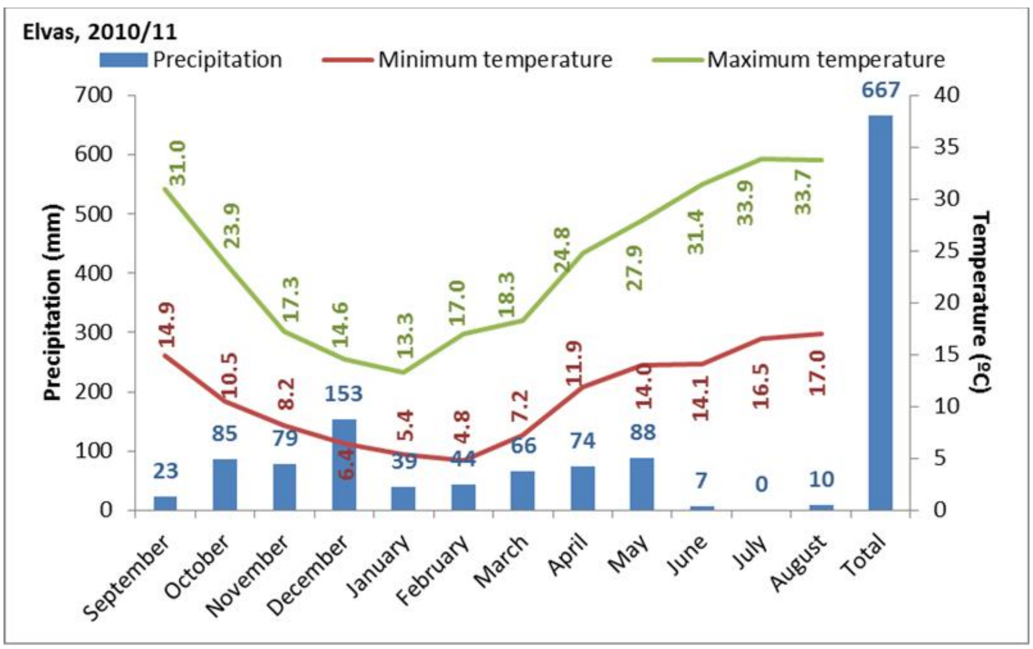


Figure 1. Climatic conditions at Elvas in 2010/11.

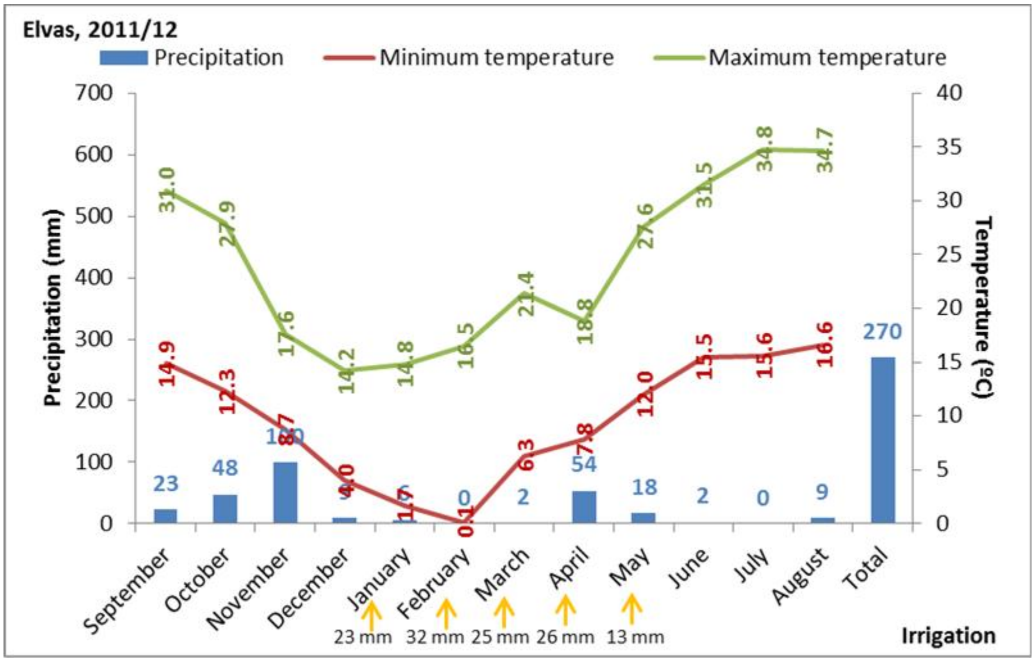


Figure 2. Climatic conditions at Elvas in 2011/12. Yellow arrows indicate irrigation moments with the corresponding quantity (in mm) below.

Table 3. Analysis of variance for flour protein, gluten content, alveograph parameters (W and P/L), test weight and thousand kernel weight of 20 bread wheat sown at Elvas in two dates over two years (seasons).

		Flour Protein (R^2=0.934)		Gluten (R^2=0.957)		W (R^2=0.950)	
Source	df	Mean Square	F	Mean Square	F	Mean Square	F
Genotype (G)	19	2.63	3.38**	58.91	7.28***	45547.18	7.96***
Year (Y)	1	54.45	69.94***	1335.79	165.09***	831544.98	145.35***
Sowing Date (D)	1	20.81	26.73***	225.46	27.86***	18090.11	3.16^{ns}
G x Y	19	1.56	2.00^{ns}	15.29	1.89^{ns}	8540.26	1.49^{ns}
G x D	19	0.48	0.61^{ns}	16.75	2.07^{ns}	6735.09	1.18^{ns}
Y x D	1	45.60	58.57***	134.94	16.68***	68363.12	11.95**
Error	19	0.78		8.09		5721.04	
		P/L (R^2=0.923)		Test Weight (R^2=0.959)		TKW (R^2=0.970)	
Source	df	Mean Square	F	Mean Square	F	Mean Square	F
Genotype (G)	19	0.46	6.65**	65.96	17.92***	124.37	24.09***
Year (Y)	1	0.75	10.76**	39.06	10.61**	166.46	32.25***
Sowing Date (D)	1	0.41	5.84*	43.07	11.70**	270.11	52.33***
G x Y	19	0.14	2.05^{ns}	5.71	1.55^{ns}	9.16	1.78^{ns}
G x D	19	0.17	2.42*	10.41	2.83*	9.03	1.75^{ns}
Y x D	1	0.00	0.02^{ns}	3.49	0.95^{ns}	8.45	1.64^{ns}
Error	19	0,07		3.68		5.16	

*, **; *** stands for significant at the 0.05, 0.01, and 0.001 levels of probability, respectively.

Table 4. Mean values for quality traits of 20 bread wheat grown in Elvas trials over 2010/11 and 2011/12 seasons.

	Flour Protein (%)	Gluten (%)	W ($E^{-4}J$)	P/L	Test Weight (kg/hl)	TKW (g)
2010/11	13.5[b]	31.6[b]	210.2[b]	0.55[b]	76.6[b]	38.0[a]
2011/12	15.1[a]	39.8[a]	414.1[a]	0.75[a]	78.0[a]	35.1[b]

Each value represents the mean (n = 40). Within each parameter, different letters in the same column refer to significant differences between years.

Genotype, environmental conditions (year) and sowing date effects on bread wheat quality

Genotype and environment (year) contributed to variation of all quality traits. For almost the parameters studied, the year variance components were much larger than the variance components from genotype and sowing date, excluding test weight and thousand kernel weight (Table 3). For test weight, genotype was the most important factor and for thousand kernel weight it was the sowing date.

The significance of year effect must be a consequence of two agricultural seasons with climatic conditions completely different (Figures 1 and 2), as frequently occurs in Mediterranean conditions of South Portugal. Grain yield were much lower in 2011/12 (Almeida et al., 2011; Costa et al, 2013) and this affected protein content and almost all quality parameters that were very high in this year (Table 4).

Some authors reported environmental effects larger than genetic effects for protein content (Peterson et al., 1992; Mladenov et al., 2001; Zhu and Khan, 2001; Surma et al., 2012) and for a wide range of other quality parameters including kernel weight, sedimentation value and rheological behavior determined by mixograph (Peterson et al., 1992; Mikhaylenko et al., 2000). Surma et al. (2012) obtained similar importance to both sources of variation in starch content, alveograph W parameter and test weight. Other authors (Yong et al., 2004) reported genotypic effects larger than year and location for almost all the quality studied traits, excluding thousand kernel weight, test weight and falling number.

Sowing date was a very important factor in the variance analysis of almost all quality parameters excluding deformation energy (W, table 3). The results from 1st sowing date originated higher values for P/L ratio, test weight and thousand kernel weight in the two crop seasons (table 5). A significant year x sowing date interaction was found for flour protein content, gluten content and deformation energy, once these three parameters are strongly related. Results revealed that 2nd sowing date was advantageous to these parameters in the 2010/11 crop season, while 1st sowing date was better for protein content and deformation energy in 2011/12 season (Figure 3).

Table 5. Mean values (two crop seasons) for quality traits of 20 bread wheat grown in Elvas trials over two sowing dates.

	Flour Protein (%)	Gluten (%)	W ($E^{-4}J$)	P/L	Test Weight (kg/hl)	TKW (g)
1st sowing date	13.8[b]	34.0[b]	327.2[a]	0.72[a]	78.1[a]	38.4[a]
2[nd] sowing date	14.8[a]	37.4[a]	297.1[a]	0.58[b]	76.6[b]	34.7[b]

Each value represents the mean (n = 40). Within each parameter, different letters in the same column refer to significant differences between sowing dates.

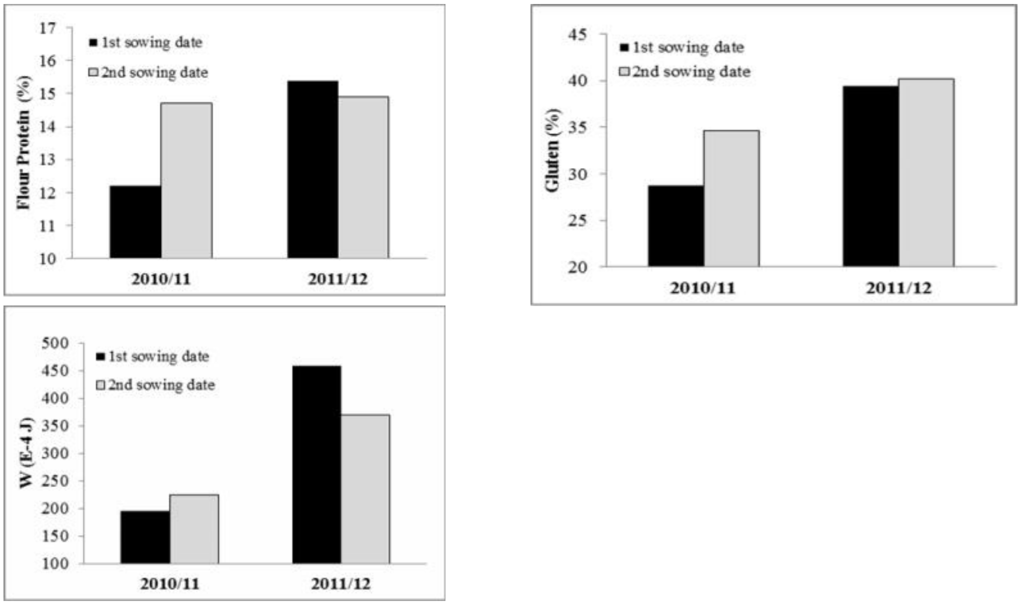


Figure 3. Differences between mean values of flour protein, gluten content and deformation energy (W) for two sowing dates (1st and 2nd) in 2010/11 and 2011/12 seasons.

Table 6. Genotype mean values (averaged over two seasons) for quality traits of 20 bread wheat grown in Elvas.

	Flour Protein (%)	Gluten (%)	W ($E^{-4}J$)	P/L	Test Weight (kg/hl)	TKW (g)
Roxo	15.9^{a}	41.9^{ab}	256.4^{b-e}	0.43^{c-e}	81.0^{ab}	41.1^{a-d}
Pata-Negra	15.5^{ab}	36.5^{a-d}	371.6^{a-d}	0.55^{b-e}	80.7^{ab}	38.9^{a-f}
Alabanza	14.9^{a-c}	38.1^{a-d}	377.5^{a-d}	0.43^{c-e}	80.3^{ab}	43.1^{a-c}
Ardila	14.8^{a-c}	43.8^{a}	205.1^{b-e}	1.59^{a}	79.9^{ab}	37.2^{d-h}
Nabão	14.8^{a-c}	34.0^{b-f}	344.6^{a-d}	0.62^{b-e}	82.4^{a}	33.6^{e-i}
TE0205	14.7^{a-c}	38.1^{a-d}	317.3^{b-d}	0.53^{b-e}	81.5^{ab}	44.9^{a}
Bologna	14.6^{a-c}	37.2^{a-f}	392.3^{a-d}	0.46^{c-e}	78.4^{ab}	30.7^{hi}
Ingenio	14.6^{a-c}	35.6^{a-f}	402.0^{a-c}	0.55^{b-e}	75.9^{bc}	44.4^{ab}
Linha3	14.4^{a-c}	36.5^{a-f}	359.6^{a-d}	0.48^{c-e}	70.3^{de}	28.6^{i}
Mané-Nick	14.4^{a-c}	37.5^{a-d}	418.7^{ab}	0.75^{b-e}	77.0^{ab}	39.7^{a-e}
TE0206	14.3^{a-c}	36.4^{a-f}	177.3^{de}	0.47^{c-e}	79.5^{ab}	45.2^{a}
Eufrates	14.2^{a-c}	38.8^{a-c}	262.1^{b-e}	0.65^{b-e}	80.9^{ab}	31.5^{hi}
Nogal	14.2^{a-c}	33.5^{c-f}	366.1^{a-d}	0.72^{b-e}	78.1^{ab}	32.6^{f-i}
Linha2	14.0^{a-c}	36.0^{a-f}	79.9^{e}	0.19^{e}	69.5^{e}	27.6^{i}
Linha1	14.0^{a-c}	37.3^{a-f}	222.1^{b-e}	0.33^{de}	70.7^{c-e}	32.1^{g-i}
Inoui	13.6^{a-c}	29.2^{f}	345.1^{a-d}	1.12^{a-c}	76.9^{ab}	35.5^{d-h}
Siena	13.5^{a-c}	30.1^{d-f}	389.1^{a-d}	0.60^{b-e}	79.2^{ab}	33.1^{f-i}
Badiel	13.4^{b-c}	29.5^{ef}	537.5^{a}	1.25^{ab}	78.0^{ab}	40.9^{a-d}
Flycatcher"s"x…	12.9^{c}	32.3^{c-f}	221.6^{b-e}	0.34^{de}	75.7^{b-d}	38.2^{b-g}
Aguila	12.5^{c}	32.8^{cd}	197.5^{c-e}	0.95^{a-d}	70.5^{c-e}	31.7^{g-i}

Within each parameter, different letters in the same column refer to significant differences between genotypes.

Anova indicated a significant genotypic effect in all the quality traits studied (Table 3). Genotypes with high protein content usually form a higher gluten network as observed in Ardila and Roxo varieties (Table 6). Deformation energy (W) represents gluten strength. Linha2 obtained the smallest W value and Badiel the highest W value (Table 6). Concerning to P/L ratio, Ardila obtained the highest value and genotypes Linha1, Linha2 and Flycatcher"s"x… obtained the minimum values (Table 6). These genotypes had P/L values unbalanced to bread wheat uses.

Lower results of test weight (Table 6) indicate shriveled grains and were obtained in Linha2, Linha3, Aguila and Linha1, which are mostly winter varieties with low adaptability to Mediterranean environment. These varieties had similarly low thousand kernel weight. Nabão showed the highest result for test weight. For thousand kernel weight highest, values were obtained with the genotypes TE0206 and TE0205. These three genotypes were developed at INIAV-Elvas Wheat Breeding Program.

A significant genotype x sowing date interaction was found for ratio P/L (alveograph) and test weight (Table 3). In most genotypes the P/L ratio decreased or remained approximately from the 1st to the 2nd sowing date, nevertheless P/L value increased for Aguila, Bologna, Nabão (Figure 4). There were no major differences for test weight between the 1st and 2nd sowing date for most genotypes, excluding winter varieties (Linha1, Linha2, Linha3) and some facultative varieties (Aguila, Bologna, Inoui) (Figure 4). For these genotypes 2nd date was disadvantageous. According to Protic et al., (2007) test weight of winter wheat decreased with later sowing.

B. Beja experiments

Climatic conditions

At Beja, the first season, 2011/12 was a quite dry year with 385 mm of total precipitation (Figure 5), occurring only 25 mm during winter (Dec-Jan-Feb). A supplementary irrigation (116 mm) was applied from December through May, during the whole crop cycle.

During 2012/13 season, total rainfall was almost two times higher comparing with season 2011/12 (668 mm) nevertheless, during April and May, the amounts of precipitation were low, consequently two supplementary irrigations were applied with 22 mm each (Figure 6).

Regarding temperatures, the 2012/13 season was milder in winter, than 2011/12 season and presented maximum temperature in April a little higher.

Genotype, environmental conditions (year) and sowing date effects on bread wheat quality

In Beja, trails for almost all quality traits, differences found between seasons (year) were significant, but the magnitude of their influence decreased in relation to Elvas experiments, probably because the climatic differences between the two seasons were not so drastic than in Elvas (Figures 1, 2, 5 and 6). Year was the most important factor to explain the variation of protein content and test weight, however for differences on deformation energy (W) and P/L ratio, genotype was found to be the most important factor (Table 7). Alveograph parameters depend firstly from gluten composition (HMW and LMW glutenin subunits and gliadins) which is a genetic characteristic, besides protein content be an important requirement to these parameters also.

The three interaction effects (genotype x year, genotype x sowing date and year x sowing date) were significant to explain test weight and thousand kernel weight (Table 7).

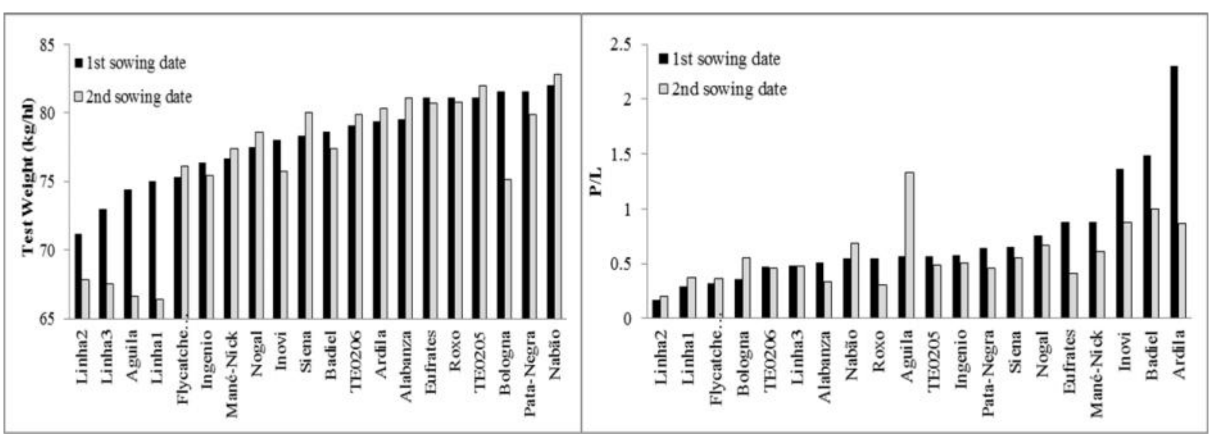


Figure 4. Differences between two sowing dates (1st and 2nd) mean values of P/L ratio and test weight for 20 bread wheat genotypes grown in Elvas trials.

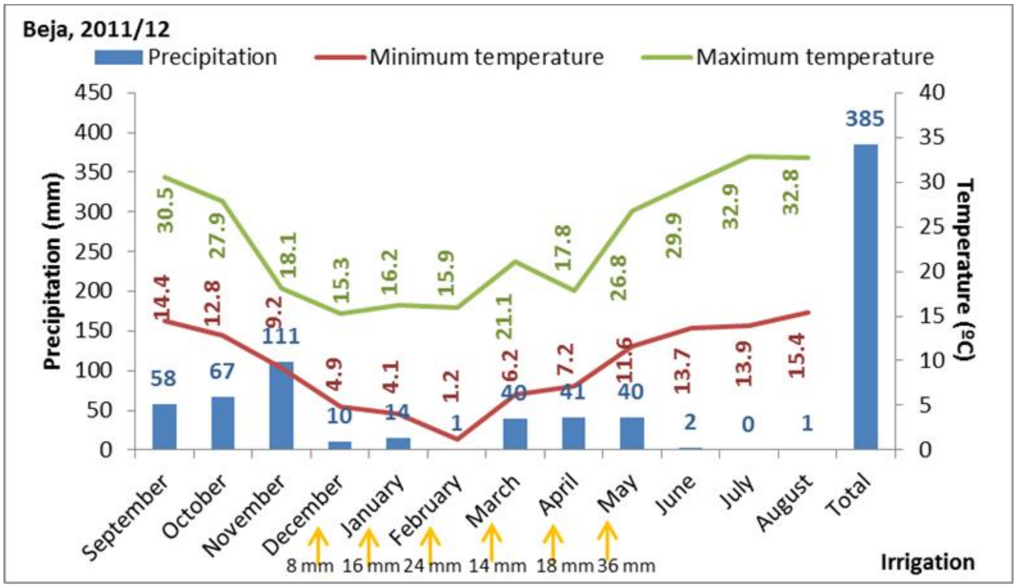


Figure 5. Climatic conditions at Beja in 2011/12. Yellow arrows indicate irrigation moments with the corresponding quantity (in mm) below.

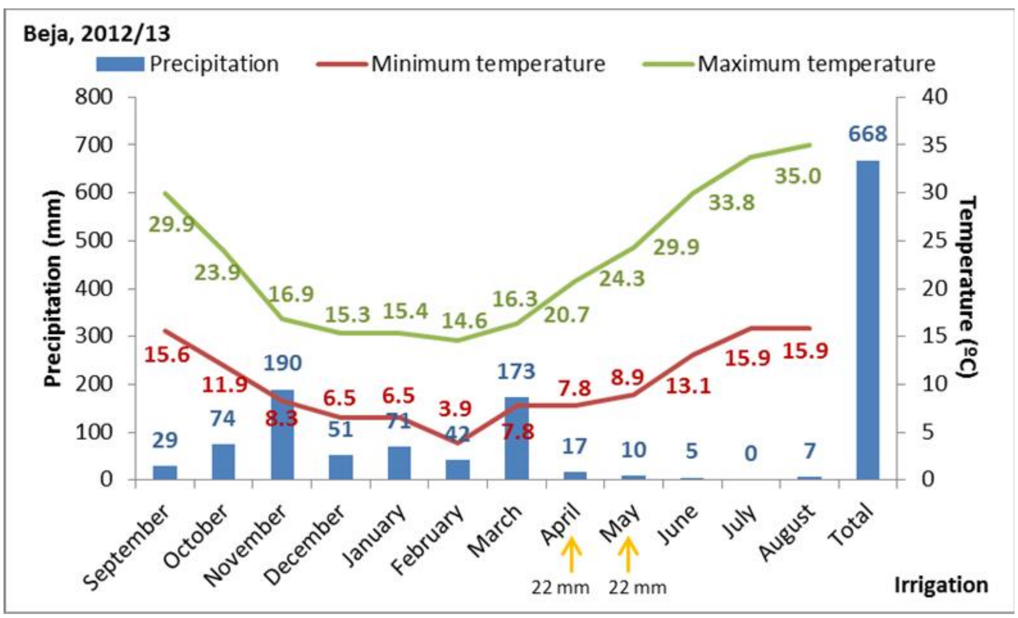


Figure 6. Climatic conditions at Beja in 2012/13. Yellow arrows indicate irrigation moments with the corresponding quantity (in mm) below.

For all quality traits (excluding deformation energy W and gluten) genotypes performed better on 2012/13 season comparing with 2011/12 (Table 8). High temperature and low precipitation during grain filling period observed in 2012/13 season could result on higher grain protein accumulation (Hoseney, 1994; Mikhaylenko et al., 2000) and on superior dough resistance to extension and lower extensibility (Uhlen et al., 1998) that could contribute to increase P/L ratio. Sowing date showed the most significant effect on gluten content and thousand kernel weight. Interaction between year and sowing date was also significant to explain these two parameters and also test weight (Table 7).

Table 7. Analysis of variance for flour protein, gluten content, alveograph parameters (W and P/L), test weight and thousand kernel weight of 20 bread wheat sown at Beja in two dates over two years (seasons).

		Flour Protein (R^2=0.878)		Gluten (R^2=0.877)		W (R^2=0.949)	
Source	df	Mean Square	F	Mean Square	F	Mean Square	F
Genotype (G)	19	3.68	3.00**	23.82	2.38*	31920.07	15.87***
Year (Y)	1	23.11	18.83***	0.95	0.09ns	12839.78	6.39*
Sowing Date (D)	1	13.61	11.09**	388.52	38.75***	8288.56	4.12^{ns}
G x Y	19	1.16	0.94^{ns}	4.08	0.41^{ns}	1136.20	0.57^{ns}
G x D	19	2.03	1.65^{ns}	9.21	0.92^{ns}	3229.05	1.61^{ns}
Y x D	1	0.14	0.12^{ns}	267.55	26.69***	1266.44	0.63^{ns}
Error	19	1.23		10.03		2010.81	
		P/L (R^2=0.975)		Test Weight (R^2=0.990)		TKW (R^2=0,987)	
Source	df	Mean Square	F	Mean Square	F	Mean Square	F
Genotype (G)	19	1.75	35.90***	93.47	78.79***	98.26	52.57***
Year (Y)	1	0.63	13.01**	127.01	107.05***	103.74	55.51***
Sowing Date (D)	1	0.16	3.19^{ns}	89.04	75.05***	393.83	210.71***
G x Y	19	0.09	1.78^{ns}	8.89	7.49***	9.26	4.95***
G x D	19	0.06	1.31^{ns}	5.02	4.23**	8.19	4.38**
Y x D	1	0.00	0.00^{ns}	35.38	29.82***	9.32	4.98*
Error	19	0.05		1.19		1.87	

*, **; *** stands for significant at the 0.05, 0.01, and 0.001 levels of probability, respectively.

Table 8. Mean values for quality traits of 20 bread wheat grown in Beja trials over 2011/12 and 2012/13 seasons.

	Flour Protein (%)	Gluten (%)	W (E^{-4}J)	P/L	Test Weight (kg/hl)	TKW (g)
2011/12	12.3^b	31.7^a	293.1^a	0.89^b	75.1^b	31.8^b
2012/13	13.4^a	31.4^a	267.8^b	1.07^a	77.6^a	34.1^a

Each value represents the mean value (n = 40). Within each parameter, different letters in the same column refer to significant differences between years.

Table 9. Mean values (two crop seasons) for quality traits of 20 bread wheat grown in Beja trials over two sowing dates.

	Flour Protein (%)	Gluten (%)	W (E^{-4}J)	P/L	Test Weight (kg/hl)	TKW (g)
1st sowing date	12.4^b	29.3^b	270.3^a	1.02^a	77.4^a	35.1^a
2nd sowing date	13.3^a	33.8^a	290.6^a	0.93^a	75.3^b	30.7^b

Each value represents the mean value (n = 40). Within each parameter, different letters in the same column refer to significant differences between sowing dates.

For crop season 2011/12 there was no difference for gluten comparing the two sowing dates, nevertheless for 2012/13 season, with a higher protein content, 2nd sowing date conducted to higher gluten content (Figure 7). Test weight and thousand kernel weight showed better results with earlier sowing date during the two seasons, with more evident differences in 2012/13 (Figure 7).

Genotype showed the most significant effect on alveograph parameters (Table 7). Better results of deformation energy were obtained with Badiel (although the high P/L ratio), Mané-Nick, Ingenio, Bologna and Pata-Negra. The smallest values were obtained with Linha2 (Table 10). Data showed the same trend for Elvas experiments, showing stability of these quality parameters across environments. As in Elvas trials, lower test weight values were obtained with Linha2, Aguila, Linha3 and Linha1, which are mostly winter varieties with less adaptability to Mediterranean environment. These varieties showed also low thousand kernel weight. Higher test weight value was obtained by variety Roxo and for thousand kernel weight by genotype TE0205, revealing the adaptability of these genotypes to these environmental conditions (Costa et al., 2013).

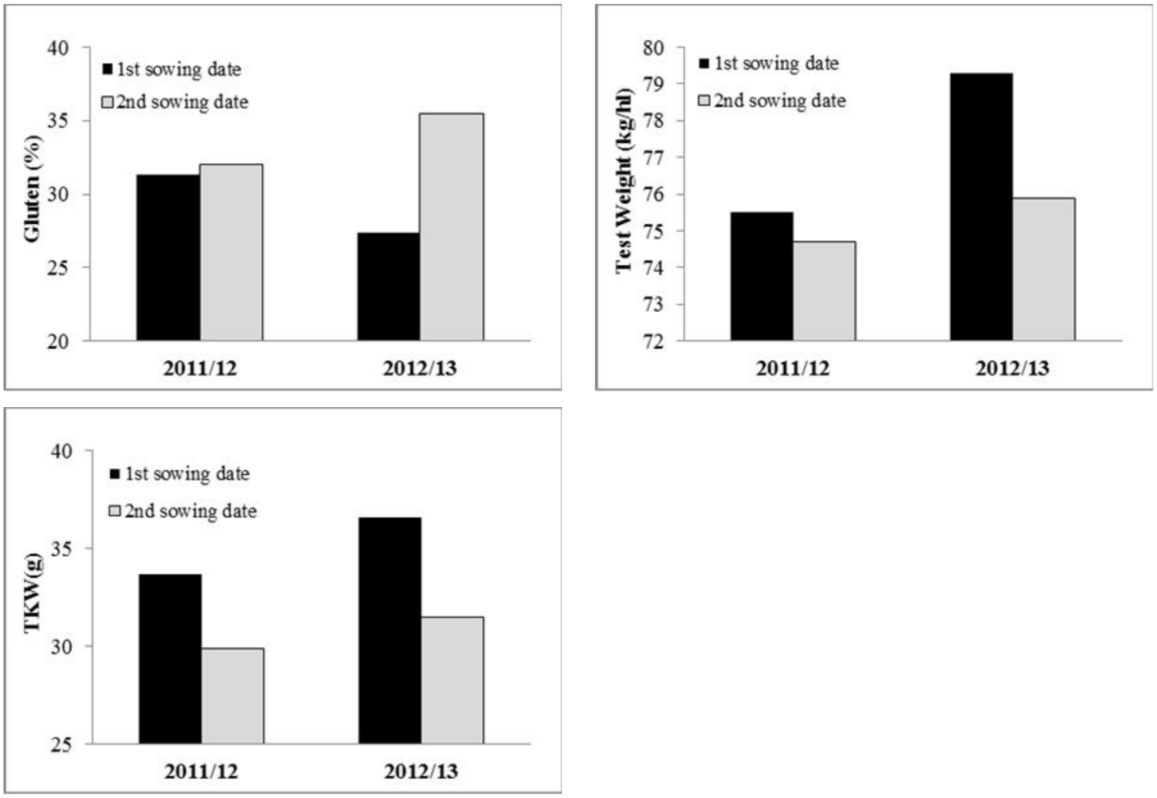


Figure 7. Differences between mean values of gluten content, test weight and thousand kernel weight (TKW) for two sowing dates (1^{st} and 2^{nd}) in 2011/12 and 2012/13 seasons.

Table 10. Genotype mean values (averaged over two seasons) quality traits of 20 bread wheat grown in Beja.

	Flour Protein (%)	Gluten (%)	W (E^{-4}J)	P/L	Test Weight (kg/hl)	TKW (g)
TE0205	14.3^{a}	34.7^{ab}	298.9^{b-d}	0.75^{c-g}	81.5^{ab}	40.9^{a}
Roxo	14.2^{a}	34.2^{ab}	303.3^{b-d}	0.58^{fg}	82.5^{a}	38.2^{ab}
Pata-Negra	13.9^{ab}	33.4^{ab}	349.8^{ab}	0.92^{b-g}	80.6^{ab}	36.4^{bc}
Ardila	13.8^{ab}	36.3^{a}	212.2^{c-f}	3.43^{a}	77.3^{c-f}	33.0^{cd}
Nogal	13.5^{ab}	30.8^{ab}	337.2^{a-c}	1.28^{b-e}	78.8^{b-e}	32.0^{de}
Eufrates	13.4^{ab}	33.0^{ab}	169.6^{ef}	0.87^{c-g}	80.1^{a-c}	27.6^{fg}
Siena	13.4^{ab}	31.0^{ab}	331.9^{bc}	1.02^{b-f}	75.8^{e-g}	28.8^{ef}
Nabão	13.3^{ab}	29.6^{ab}	334.9^{bc}	1.38^{bc}	81.4^{ab}	30.0^{d-f}
Bologna	13.3^{ab}	32.6^{ab}	353.1^{ab}	0.80^{c-g}	79.6^{a-d}	29.4^{d-f}
Alabanza	13.1^{ab}	32.8^{ab}	331.4^{bc}	0.59^{fg}	80.4^{a-c}	38.3^{ab}
Mané-Nick	13.1^{ab}	33.6^{ab}	361.8^{ab}	0.66^{e-g}	76.8^{d-f}	37.1^{ab}
Ingenio	12.7^{ab}	30.5^{ab}	359.5^{ab}	0.86^{c-g}	73.0^{g}	38.0^{ab}
Badiel	12.6^{ab}	27.2^{b}	466.1^{a}	1.53^{b}	77.4^{c-f}	36.4^{bc}
Linha3	12.4^{ab}	32.3^{ab}	259.2^{b-e}	0.61^{fg}	68.7^{h}	26.8^{fg}
Aguila	12.2^{ab}	29.7^{ab}	199.5^{d-f}	0.93^{b-f}	68.5^{h}	27.8^{fg}
Inoui	11.7^{ab}	27.2^{ab}	281.3^{b-e}	1.30^{b-d}	73.0^{g}	30.6^{d-f}
TE0206	11.7^{ab}	30.5^{ab}	198.4^{d-f}	0.72^{d-g}	79.1^{b-d}	38.7^{ab}
Linha1	11.6^{ab}	28.4^{ab}	182.8^{d-f}	0.46^{fg}	69.3^{h}	28.1^{e-g}
Linha2	11.6^{ab}	32.6^{ab}	110.1^{f}	0.29^{g}	67.0^{h}	24.2^{g}
Flycatcher”s”x…	11.0^{b}	30.3^{ab}	167.9^{ef}	0.54^{fg}	75.5^{fg}	36.1^{bc}

Within each parameter, different letters in the same column refer to significant differences between genotypes.

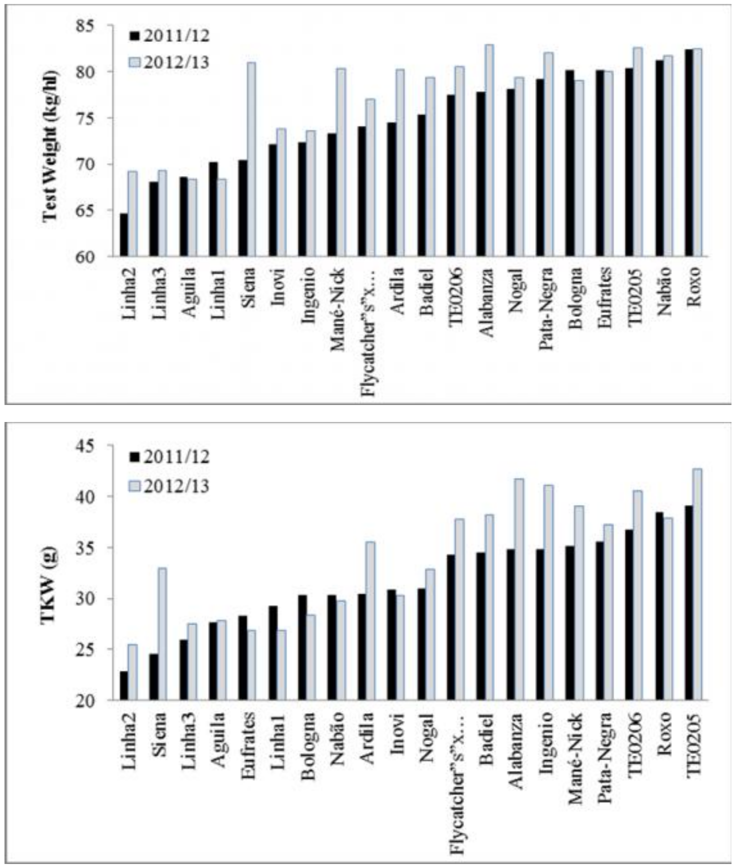


Figure 8. Differences between 2011/12 and 2012/13 seasons mean values of test weight and thousand kernel weight for 20 bread wheat genotypes grown in Beja trials.

Almost all varieties showed better results of test weight and thousand kernel weight on the 2nd year, with more evident differences to some of them. Linha1, Bologna, Eufrates were exceptions to this trend (Figure 8).

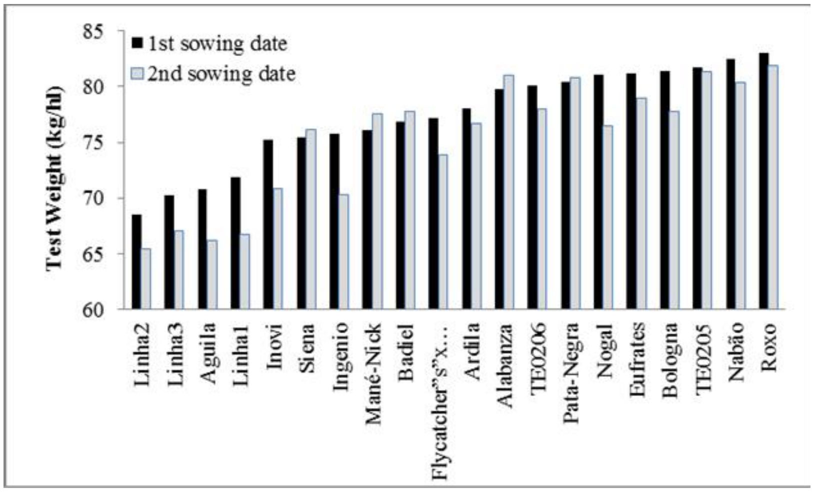
Test weight results of 2nd sowing date were detrimental with the exception of some genotypes with spring growth habit, namely Siena, Mané-Nick, Badiel, Alabanza and Pata-Negra. 2nd sowing date was ever detrimental to thousand kernel weight (excluding Badiel), but in some genotypes difference between two seasons was more accentuated (Bologna, Inoui and Ingenio) (Figure 9).

Relation between quality traits

Correlation analysis also included yield and whole wheat protein content. Quality traits were, in general, significantly correlated, excluding P/L ratio (Table 11).

Protein content (whole wheat and flour), wet gluten content and deformation energy (W) are positively correlated as expected (Mladenov et al., 2001; Surma et al., 2012), since protein fraction (amount and type of proteins) is the determinant of bread wheat quality (Mikhaylenko et al., 2000).

Test weight showed a significant correlation with protein content (Mladenov, et al., 2001) and deformation energy (W). Thousand kernel weight was only positively correlated with test weight and yield (Table 11).



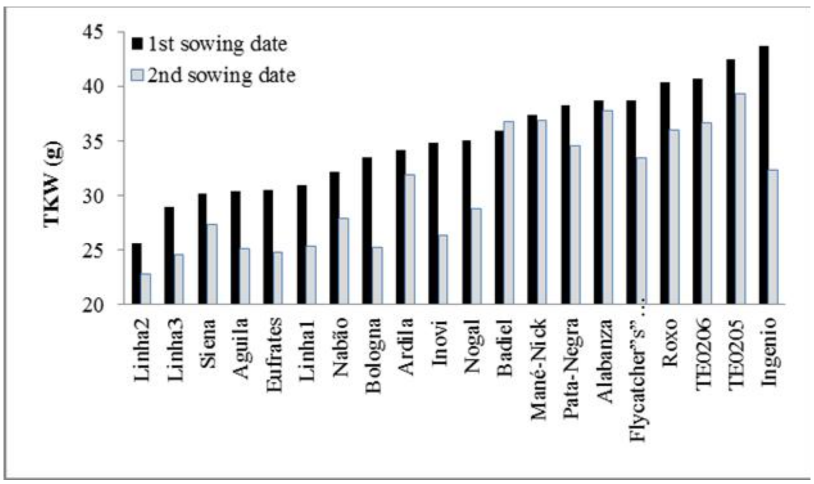


Figure 9. Differences between two sowing dates (1st and 2nd) mean values of test weight and thousand kernel weight for 20 bread wheat genotypes grown in Beja trials.

Table 11. Pearson correlation coefficients among quality parameters obtained with the results of Elvas and Beja experiments (n=160).

	Whole wheat Protein	Flour Protein	Gluten	W	P/L	Test Weight	TKW
Flour Protein	0.842***						
Gluten	0.696***	0.737***					
W	0.344***	0.391***	0.212**				
P/L	-0.031ns	0.002ns	-0.088 ns	0.125 ns			
Test Weight	0.194*	0.265**	0.096ns	0.282***	0.148ns		
TKW	0.046ns	0.101ns	-0.011ns	0.109ns	-0.053ns	0.589***	
Yield	-0.529***	-.534***	-.483***	-0.238**	0.022ns	0.122ns	0.216**

*, **; *** stands for significant at the 0.05, 0.01, and 0.001 levels of probability, respectively.

Correlation coefficients between yield and protein content, wet gluten and alveograph (W) parameter were significantly and negative, confirming the association between those traits (Oury and Godin, 2007; Bordes et al., 2008; Surma et al., 2012), which difficult simultaneous selection in breeding programs for two traits of interest. Breeders should apply breeding strategies to increase one without affecting the other to achieve specific wheat quality classes (Zecevic et al., 2013).

Conclusions

Environmental conditions showed a stronger influence on grain quality due, mainly, to differences in climatic patterns between the seasons. Differences found for genotypes and sowing dates were also significant to almost all quality parameters. Genotype was more associated to variation of alveograph parameters, while sowing date was more associated to variation of thousand kernel weight. Results confirmed that genetic potential is essential to obtain wheat with high quality but it is not enough. Through the years INIAV-Elvas breeding program has been able to provide national germplasm with high-yielding and superior adaptation for Mediterranean conditions. Quality is expected to be, more than ever, an important goal in wheat breeding programs. The difficulty is, still, the known negative correlation between high yield and good quality, but it is an important target for the next coming work efforts at INIAV-Elvas Cereal Breeding Program.

Acknowledgments

E. Dias from Germen – Moagem de Cereais S.A. and P. Cardoso from Ceres A. de Figueiredo & Irmão S.A. by some analytical determinations. This study was supported by PRODER – Medida 4.1."

Author Contributions

J. C. and B. M. designed the study. A. S. B., R. C. and A. S. A. wrote the article and corrected it. C. Figures 1, 2, 5 and 6 are from C. G., N. P., J. Coco and A. C. conducted the field experiments. J. M. collaborated in quality evaluation.

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