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REGULAR ARTICLE

Effect of sowing date and seeding rate on bread wheat yield and test weight under Mediterranean conditions

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Abstract

Yield and test weight are attributes of particular economic importance in wheat production systems and are strongly affected by environmental conditions. This study was conducted to determine the effects of sowing date and seeding rate on grain yield and test weight of fifteen bread wheat varieties and five 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, during 2011/2012 growing season. Two seeding rates were compared (200 and 350 seeds.m^{-2}) in two different sowing dates in each location. Results showed that sowing date and seeding rate affects yield and test weight under irrigation field conditions, for Mediterranean region of Southeast Portugal, but only sowing date had significant effects among the varieties. At Elvas, higher yield was obtained with the 2nd sowing date (21 December) for most of the varieties studied. In opposite, in Beja trials, the highest values for yield were found when varieties were sown earlier (1st sowing date - 26 October). Test weight had a similar performance in the two sites, though top values for this trait were found with the 1st sowing date. Comparing the results obtained in the two studied locations, Beja showed, for the majority of the varieties, 3t/ha higher average yield than Elvas.

Key words: Bread wheat, Sowing date, Seeding rate, Yield, Test weight, Environmental constraints

Introduction

Wheat (*Triticum aestivum* L.) is a major cereal crop in many parts of the world and it is commonly known as the king of cereals. 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 the US, for instance, unfavorable environments account for over 94% of the difference between average and record yield, and less than 6% of the disparity is attributable to diseases, insects and weeds (Boyer, 1982). In Mediterranean regions rain falls mostly during autumn and winter, and the water deficit rises in spring, coinciding with the anthesis and grain-filling period. Thus, drought and heat stress usually reduce yield potential during the period of grain formation (Simane at al., 1993; Lloveras et al., 2004). The challenge to increase wheat yield is even more difficult by projected climate changes, particularly higher temperatures and changes on rainfall distribution and amount (Parry and Hawkesford, 2010; Lobell et al., 2011). Even at a single location, in addition to variation due to agronomic and genetic factors, there is often considerable year to year variation reflecting different weather patterns. It is important to recognize that for farmers, maximizing yield is not their sole objective; profitability and managing risk are the most important criteria. Test weight is especially important for several food grain crops, particularly for those on which this trait is compulsory measured. The test weight is the first measurable/weighable qualitative trait of grain cereals mentioned in history, from the 19th century. Since then a great attention has been paid to it. Although it was introduced into regulations during the 20th century, it is hardly mentioned in the seed

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legislation. Protic et al. (2007) defines seed test weight using its dependence on seed density, shape and size, highlighting the fact that test weight is an important quality trait and that it can be used to estimate the amount of grain in a warehouse. They also state that test weight increased in time as a contribution of plant breeding. It is used by breeders to evaluate variety adaptation to the specific local conditions. The main goal of this study was to evaluate the effect of sowing date and seeding rate on grain yield and test weight of bread wheat under irrigation, in farmers field conditions.

Materials and Methods

Trials location

Trials were conducted during the 2011/2012 cropping season 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

Cultivars choice was based on its growth cycle and origin. Among the studied germplasm, fifteen bread wheat varieties are from different origins and the remaining five are advanced breeding lines from Portuguese Wheat Breeding Program of National Institute for Agrarian and Veterinarian Research (Elvas, Portugal). Table 2 presents origin and growth habit of the germplasm used in the experiments.

Table 1. Geographic location, soil type, sowing and harvesting dates of the trials.

Location	Geographic Location	Soil	Sowing date	Harvesting Date
Elvas	38°53'N 7°8'W	Shallow silt loam	1st: 05-12-2011	28-06-2012
			2nd: 21-12-2011	29-06-2012
Beja	37º58`N 7º45'W	Deep clay	1st: 26-10-2011	06-07-2012
			2nd: 29-11-2011	06-07-2012

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

Table 3. Location, sowing date and sowing rate of field experiments.

Location	Sowing date	Seeding rate
Elvas	5 December 2011	200 seed m^{-2}
		350 seed m^{-2}
	21 December 2011	200 seed m^{-2}
		350 seed m^{-2}
Beja	26 October 2011	200 seed m^{-2}
		350 seed m^{-2}
	29 November 2011	200 seed m^{-2}
		350 seed m^{-2}

Field experiments

Wheat germplasm was evaluated in four experiments with two different sowing dates and two seeding densities, in two locations (Elvas and Beja), under irrigation conditions (Table 3).

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%; 937 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 with four replications using a split plot treatment arrangement. Each plot size area was 6 m^2 (5 m long and and six rows, 20 cm apart). Details of the meteorological conditions and irrigation supply, in both environments, are presented in Figure 1.

Statistical analysis

Statistical analysis was performed on SPSS software (IBM, version 17.0). Means were compared using Tukey Student's test (significance level $P < 0.05$). Analyses of variance were done across sowing date and seed rate for each location.

Results and discussion

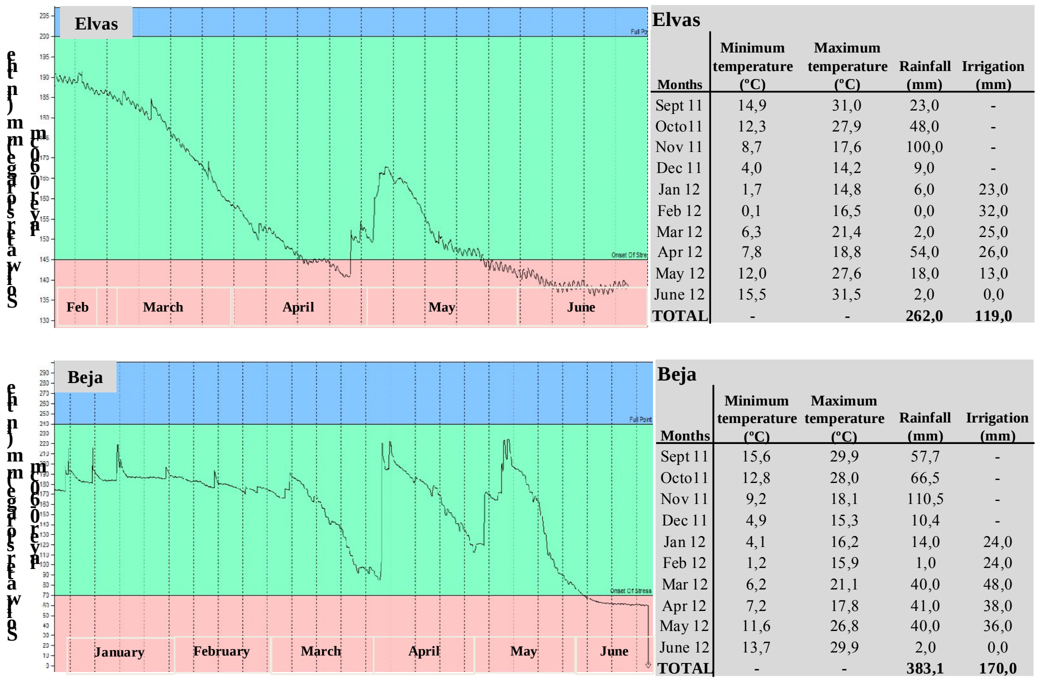
Evolution of soil water availability and climatic conditions

The evolution of water stored in the soil differed between the two studied locations. At Elvas, a shallow silt loam soil with about 50 cm of deep and with infiltration problems, applied irrigations were of low allocation to avoid losses by flooding. The irrigation had an effect only on the first 10 cm of soil deeper. With raising temperatures in March, it was observed an intensification of water consumption by plants and, consequently, a reduction of its availability on the soil (Figure 1). This situation was slightly reversed due to rainfall occurred during April and May. At Beja, with a deep and clay soil, irrigation had a visible effect in the 20-30 cm of soil deep, allowing a better "hydric comfort" to plants during the growth cycle. Only in March (when the maximum temperature increased), water consumption augmented due to crop evapotranspiration and water evaporation from the soil surface, resulting in a decrease on the amount of available water to the crop. This situation was quickly reversed by the occurrence of precipitation at the end of March (Figure 1). The soil differences of the two sites were of great importance in the wheat development. The higher water holding capacity of the soil at Beja allowed genotypes to grow under hydric comfort during grain filling period, as it can be seen in general on yield and test weight values.

Elvas experiments

Variety, sowing date and seeding rate affected yield significantly (Table 4). A significant variety x sowing date interaction for grain yield was found result of the cultivars different growth habits (winter/facultative/spring).

Significant differences were found for grain yield among varieties, when sowed with different seeding rates and at different sowing times. This experiment also showed an overall yield advantage for the late sowing time (Table 5). Ingenio and Flycatcher"s" obtained the highest values for yield in the 2nd sowing date differing significantly from other varieties. Linha 2 obtained the smallest yield value for both sowing times and seeding rates with a significant difference from others. The greatest increase on yield between the 1st and the 2nd sowing date was observed in Ingenio, Inoui and Aguilla. These results are in disagreed with other authors (Cutforth et al., 1990, Ozturk et al., 2006) who reported that delaying sowing date leads to a decrease in wheat yield. Our results revealed that facultative and winter wheat varieties showed an advantage for grain yield when sown later as, in this specific crop season (2011/2012), temperatures during the grain filling period (April and May) where moderate as shown in Figure 1. Thus, it was possible for the varieties to elongate the cycle and increase the individual thousand grain weight with a positive response on yield. Nevertheless, spring wheat varieties (Ardila and Badiel) showed a decrease in grain yield for 2nd sowing date, data that are in accordance with several authors (Cutforth et al., 1990; Lloveras et al., 2004; Ozturk et al., 2006).



Elvas

Months	Minimum temperature (°C)	Maximum temperature (°C)	Rainfall (mm)	Irrigation (mm)
Sept 11	14,9	31,0	23,0	-
Octo11	12,3	27,9	48,0	-
Nov 11	8,7	17,6	100,0	-
Dec 11	4,0	14,2	9,0	-
Jan 12	1,7	14,8	6,0	23,0
Feb 12	0,1	16,5	0,0	32,0
Mar 12	6,3	21,4	2,0	25,0
Apr 12	7,8	18,8	54,0	26,0
May 12	12,0	27,6	18,0	13,0
June 12	15,5	31,5	2,0	0,0
TOTAL	-	-	**262,0**	**119,0**

Beja

Months	Minimum temperature (°C)	Maximum temperature (°C)	Rainfall (mm)	Irrigation (mm)
Sept 11	15,6	29,9	57,7	-
Octo11	12,8	28,0	66,5	-
Nov 11	9,2	18,1	110,5	-
Dec 11	4,9	15,3	10,4	-
Jan 12	4,1	16,2	14,0	24,0
Feb 12	1,2	15,9	1,0	24,0
Mar 12	6,2	21,1	40,0	48,0
Apr 12	7,2	17,8	41,0	38,0
May 12	11,6	26,8	40,0	36,0
June 12	13,7	29,9	2,0	0,0
TOTAL	-	-	**383,1**	**170,0**

Figure 1. Evolution of water stored in the soil at Elvas and Beja.

Table 4. Analysis of Variance for yield of 20 bread wheat sown at Elvas (Alto Alentejo, Portugal).

Variation Source	Yield			
	df	Mean Square	F value	Sig. (p)
Variety	19	2061981,027	12,714	***
Sowing date	1	$1{,}025E^{7}$	63,183	***
Seeding rate (seed m^{-2})	1	3245180,582	20,009	***
Variety x Sowing date	19	611466,257	3,770	***
Variety x Seeding rate	19	51106,681	0,315	ns
Sowing date x Seeding rate	1	127884,471	0,788	ns
Variety x Sowing date x Seeding rate	19	156759,565	0,967	ns
Error	240	162187,048		

***, **, *: Significant at P<0.001; P<0.01 and P<0.05, respectively; ns: no significant

Grain yield increased with an increase in seeding rate (Table 5). Similarly, Ozturk et al. (2006) found that an increasing seeding rate up to 525 seeds m^{-2}, increased spikes per square meter at harvest, resulting in increased grain yield. Seeding rate effect was less important than sowing date in maximizing grain yield in Mediterranean environments.

Table 6 shows great differences between minimum and maximum yield values obtained at Elvas. The minimum yield value was obtained with Badiel with the lower seeding rate and at the 2nd sowing data. In opposite, the maximum was obtained with Ingenio with the higher seeding rate and also at the 2nd sowing data. An high coefficient of variation confirm this finding.

Table 5. Yield differences between two sowing dates with two seeding densities for 20 varieties/advanced lines of bread wheat in Elvas trials.

Variety/advanced line	Yield (kg/ha) 1st sowing date		Yield (kg/ha) 2nd sowing date	
	Seed rate 200 seed.m^{-2}	Seed rate 350 seed.m^{-2}	Seed rate 200 seed.m^{-2}	Seed rate 350 seed.m^{-2}
Flycatcher “s”	2783^{abc}	3275^{d}	3460^{f}	3382^{b-f}
Ingenio	2844^{abc}	3165^{d}	3712^{f}	4054^{f}
Nabão	2619^{abc}	3066^{cd}	2811^{a-f}	3060^{a-f}
Alabanza	2435^{abc}	3025^{bcd}	3204^{def}	2726^{a-e}
Badiel	2949^{bc}	3012^{bcd}	1904^{a}	2477^{a-d}
Pata-negra	3039^{c}	2974^{a-d}	3176^{c-f}	3450^{b-f}
Inoui	2327^{abc}	2970^{a-d}	3529^{f}	3575^{def}
Eufrates	2781^{abc}	2898^{a-d}	2934^{b-f}	3116^{a-f}
Mané-Nick	2375^{abc}	2794^{a-d}	2908^{a-f}	2966^{a-f}
Ardila	2315^{abc}	2706^{a-d}	2178^{abc}	2406^{abc}
Aguilla	2568^{abc}	2690^{a-d}	3130^{b-f}	3697^{ef}
TE0206	2681^{abc}	2678^{a-d}	2757^{a-f}	3017^{a-f}
Linha1	2343^{abc}	2640^{a-d}	2887^{a-f}	3149^{a-f}
Bologna	2492^{abc}	2601^{a-d}	3233^{ef}	3493^{c-f}
Nogal	2274^{abc}	2531^{a-d}	3055^{b-f}	2943^{a-f}
TE0205	2342^{abc}	2528^{a-d}	2930^{b-f}	2748^{a-e}
Siena	2590^{abc}	2491^{a-d}	2869^{a-f}	3129^{a-f}
Linha3	1891^{ab}	2119^{abc}	2377^{a-e}	2677^{a-e}
Roxo	1945^{ab}	2070^{ab}	2197^{a-d}	2212^{a}
Linha2	1817^{a}	2005^{a}	2118^{ab}	2323^{ab}
Range	1817-3039	2005-3275	1904-3712	2212-4054
Mean	2471	2712	2868	3030
SE	45,59	42,29	43,51	48,47

Varieties are listed in yield decreasing order of 1st date and usual seed rate (350 seed.m-2). Different letters in the same column indicate significant difference (P<0.05).

Table 6. Descriptive statistics values of yield in 20 bread wheat at Elvas.

	n	Mean ± SE	Minimum	Maximum	CV (%)
Yield (kg/ha)	320	2770±32,42	812	5430	20,94

Table 7. Analysis of Variance for test weight of 20 bread wheat sown at Elvas (Alto Alentejo, Portugal).

Variation Source	Test weight			
	df	Mean Square	F value	Sig. (p)
Variety	19	335,961	426,584	***
Sowing date	1	281,4	357,306	***
Seeding rate (seed.m^{-2})	1	22,113	28,078	***
Variety x Sowing date	19	12,924	16,410	***
Variety x Seeding rate	19	2,148	2,727	***
Sowing date x Seeding rate	1	0,367	0,466	ns
Variety x Sowing date x Seeding rate	19	1,184	1,504	ns
Error	240	0,788		

***, **, *: Significant at P<0.001; P<0.01 and P<0.05, respectively; ns: no significant.

Table 8. Test weight differences between two sowing dates with two seeding densities for 20 varieties/advanced lines of bread wheat in Elvas trials.

Variety	Test weight (kg/hl) 1^{st} sowing date		Test weight (kg/hl) 2^{nd} sowing date	
	Seed rate 200 seed.m^{-2}	Seed rate 350 seed.m^{-2}	Seed rate 200 seed.m^{-2}	Seed rate 350 seed.m^{-2}
Nabão	82,67^{j}	83,31^{j}	81,66^{i}	82,30^{h}
TE0205	82,74^{j}	82,88^{ij}	81,46^{hi}	82,09^{gh}
Siena	81,90^{hij}	82,81^{hij}	80,86^{ghi}	82,46^{h}
Pata-negra	82,56^{ij}	82,73^{hij}	81,06^{hi}	81,52^{fgh}
Ardila	80,47^{ghi}	82,38^{hij}	78,73^{efg}	80,16^{e-h}
Bologna	81,53^{g-j}	82,10^{g-j}	79,26^{e-h}	80,02^{e-h}
Roxo	82,38^{hij}	82,05^{g-j}	80,36^{ghi}	80,69^{fgh}
Eufrates	81,99^{hij}	81,99^{g-j}	80,70^{ghi}	80,94^{fgh}
Badiel	80,38^{gh}	81,21^{f-i}	77,08^{de}	80,18^{e-h}
Alabanza	80,92^{g-j}	80,86^{fgh}	80,33^{ghi}	80,56^{fgh}
TE0206	80,46^{ghi}	80,35^{efg}	79,53^{f-i}	79,39^{efg}
Mané-Nick	79,57^{fg}	79,80^{def}	80,48^{ghi}	80,50^{e-h}
Nogal	78,16^{f}	78,64^{cde}	77,39^{def}	78,69^{def}
Inoui	77,95^{ef}	78,24^{cd}	75,34^{cd}	75,36^{c}
Flycatcher “s”	75,61^{cd}	77,07^{c}	75,59^{cd}	77,65^{cde}
Ingenio	75,95^{de}	76,95^{c}	74,59^{c}	76,39^{cd}
Aguilla	74,81^{cd}	74,36^{b}	69,19^{b}	70,06^{b}
Linha1	73,68^{bc}	74,01^{b}	68,69^{b}	67,70^{b}
Linha3	71,92^{b}	72,03^{a}	67,60^{a}	67,31^{b}
Linha2	69,16^{a}	70,22^{a}	66,06^{a}	63,86^{a}
Range	69,16-82,74	70,22-83,31	66,06-81,66	63,86-82,46
Mean	78,74	79,20	76,80	77,39
SE	0,092	0,083	0,095	0,123

Varieties are listed in test weight decreasing order of 1st date and usual seed rate (350 seed.m-2). Different letters in the same column indicate significant difference ($P<0.05$).

Test weight was significantly affected by variety, sowing date and seeding rate. Furthermore, interactions between variety and sowing date and variety and seeding rate were found to be statistically significant for test weight (Table 7).

Test weight depends on grain size, shape and density and indicates the adaptability of a variety to environment. Nabão, TE0205, Roxo and Pata-Negra, showed the highest value for test weight and reveal remarkable stability across the two sowing times (Table 8).

A test weight advantage with the 1^{st} sowing date was observed when compared with the 2^{nd} date (Table 8). These results are in accordance with Protic et al. (2007) who concluded that test weight of winter wheat decreased with later sowing, as a consequence of compensatory effects among yield components (Borghi et al., 1995). Portuguese variety Nabão and advanced line TE0205, both developed at Wheat Breeding Program (INIAV-Elvas), had the highest test weight values. Linha2, Linha3 and Linha1 had the lowest values for this trait (Table 8), with non-significant differences between seeding rates neither sowing dates. Genetics has an important role in regulating test weight but it can be affected also by climatic and edaphic factors.

Results of the whole data set showed that, test weight ranged from 61,84 to 83,62 kg.hl^{-1} at Elvas with a coefficient of variation showing low data dispersion (Table 9).

Beja experiments

Variety, seeding rate and sowing date showed a significant effect on yield. Interaction between sowing date and variety was also statistically significant for grain yield (Table 10).

Average yield of the top 5 varieties/ advanced lines in the 1^{st} sowing date was almost 2 t/ha higher than the 2^{nd} sowing date. Table 11 shows that in Beja trials, the higher yielding varieties increased grain yield when sown earlier. Results showed that sowing with a higher seeding rate did not outcome higher yield. Grain yield obtained with higher seeding rate was slightly superior (Table 11). Moreover, under favorable edafoclimatic conditions (irrigation, soil, etc.) a higher seed density results in high-biomass production, high number of spikes per square meter though with smaller spikes and consequently with no increase in grain yield. Peltonen-Sainio (1991) showed that a higher seed rate usually produces high-biomass and the genotypes often mature late, which is usually undesirable.

For the 1st sowing date, the higher values for yield were obtained with Nogal, Inoui, Bologna, Flycatcher"s", Eufrates, Aguilla and Linha1 (Table 11), cultivars with facultative growth cycle (excepting Linha1) for which heading time occurred after April's 10 (data no shown). In Mediterranean conditions of Portugal the optimum heading time must occurred ± 10 days around April 1st. For this facultative or winter wheat, the earlier sowing date (26 October) promoted a higher expression of grain yield potential. These results are according with Malcolm et al. (2013) who reported that in many countries where only spring wheat is cultivated, the highest wheat yield of over 15 t/ha have been achieved for winter wheat grown with a long growing season at higher latitudes. Woodruff et al. (1983) also reported that the large differences on the yield of genotypes having different development cycles, within a group and from a given sowing date, were primarily due to the interactions between growth duration, water use and evaporative demand conditions around anthesis. For 1st sowing date, the lowest yield varieties were Pata-Negra, Alabanza, Mané-NicK, Ardila, Siena and Linha2 (Table 11). Except for Linha2 (winter variety), other varieties have short growth cycles, with earlier heading time, before April´s 1st. Consequently, the late sowing date, on November 29th, showed to be an advantage for grain yield of these spring wheat varieties. Ingenio, Roxo, Nabão, TE0206, Badiel and TE0205 revealed remarkable yield stability concerning sowing date with an optimum heading time around April 1st, as referred. However, yield of these varieties was always below the trial average mean.

Table 12 shows a large gap between the minimum and maximum yield values. This is in accordance with the big coefficient of variation found. The minimum yield value was obtained with Linha2 with the higher seeding rate and for the 2nd sowing date. This performance points out the importance of duration of growth cycle, indicating that this variety is not adapted, once is a very late variety (data not shown). The maximum value was obtained with Nogal with the higher seeding rate and for the 1st sowing date (Table 11).

Wheat variety, sowing date and seeding rate affected significantly test weight. Interaction between variety and sowing date was also found to have a significant effect on this trait (Table 13).

Table 9. Descriptive statistics values of test weight in 20 bread wheat on Elvas.

	n	Mean ± SE	Minimum	Maximum	CV (%)
Test weight (kg/hl)	320	78,03±0,27	61,84	83,62	6,08

Table 10. Analysis of Variance for yield of 20 bread wheat sown at Beja (Baixo Alentejo region, Portugal).

Variation Source	Yield			
	df	Mean Square	F value	Sig. (p)
Variety	19	$1,297E^7$	35,148	***
Sowing date	1	$1,552E^7$	42,082	***
Seeding rate (seed.m^{-2})	1	2271623,395	6,158	**
Variety x Sowing date	19	8064707,629	21,862	***
Variety x Seeding rate	19	542237,996	1,470	ns
Sowing time x Seeding rate	1	542238,187	1,470	ns
Variety x Sowing date x Seeding rate	19	924877,6	2,507	***
Error	240			

***, **, *: Significant at P<0.001; P<0.01 and P<0.05, respectively; ns: no significant

Table 11. Yield differences between two sowing dates with two different seeding densities for 20 varieties/advanced lines of bread wheat in Beja trials.

Variety	Yield (kg/ha) 1st sowing date		Yield (kg/ha) 2nd sowing date	
	Seed rate 200 seed m^{-2}	Seed rate 350 seed m^{-2}	Seed rate 200 seed m^{-2}	Seed rate 350 seed m^{-2}
Nogal	8585^{g}	9099^{f}	6830^{fg}	6787^{gh}
Inoui	7392^{fg}	7638^{ef}	5381^{b-f}	5758^{c-g}
Bologna	7022^{c-g}	7601^{ef}	5917^{d-g}	6348^{e-h}
Linha1	7191^{d-g}	7379^{de}	4276^{abc}	4938^{bcd}
Flycatcher "s"	5600^{a-e}	7071^{cde}	6049^{d-g}	5978^{d-g}
Ingenio	5949^{b-f}	6968^{cde}	5647^{c-f}	5535^{c-f}
Eufrates	7349^{efg}	6801^{cde}	5421^{b-f}	5179^{cde}
Aguilla	7431^{fg}	6681^{b-e}	4870^{bcd}	5626^{c-g}
Linha3	5111^{ab}	6195^{a-e}	3826^{ab}	3821^{ab}
Roxo	6242^{b-f}	6177^{a-e}	6222^{d-g}	6153^{efg}
Nabão	6914^{c-g}	6154^{a-e}	5759^{c-g}	6123^{d-g}
TE0206	5941^{b-f}	5672^{a-d}	5211^{b-e}	6416^{fgh}
Badiel	6074^{b-f}	5447^{abc}	6219^{d-g}	7445^{h}
TE0205	5453^{a-d}	5040^{ab}	5795^{c-g}	5866^{d-g}
Pata-negra	4648^{ab}	5024^{ab}	6763^{efg}	6116^{d-g}
Alabanza	5378^{abc}	4964^{a}	6621^{efg}	6838^{gh}
Mané-Nick	5692^{a-f}	4813^{a}	7319^{g}	6825^{gh}
Linha2	4164^{a}	4762^{a}	2851^{a}	2619^{a}
Ardila	4481^{ab}	4507^{a}	5416^{b-f}	6355^{e-h}
Siena	4143^{a}	4492^{a}	3911^{ab}	4597^{bc}
Range	4143-8585	4492-9099	2851-7319	2619-7445
Mean	6038	6124	5515	5766
SE	75,79	72,96	68,51	51,80

Varieties are listed in yield decreasing order of 1st date and usual seed rate (350 seed.m-2). Different letters in the same column indicate significant difference ($P<0.05$)

Table 12. Descriptive statistic values for test yield in 20 bread wheat varieties at Beja.

	n	Mean ± SE	Minimum	Maximum	CV (%)
Yield (kg/ha)	320	5861±72,35	1873	9492	22,08

Table 13. Analysis of variance for test weight of 20 bread wheat sown at Beja (Baixo Alentejo region, Portugal).

Variation Source	Test weight			
	df	Mean Square	F value	Sig. (p)
Variety	19	401,032	115,78	***
Sowing date	1	48,875	14,110	***
Seeding rate (seed m^{-2})	1	6,962	2,010	***
Variety x Sowing date	19	36,970	10,673	***
Variety x Seeding rate	19	2,939	0,848	ns
Sowing date x Seeding rate	1	2,938	0,848	ns
Variety x Sowing date x Seeding rate	19	4,310	1,244	ns
Error	240			

***, **, *: Significant at $P<0.001$; $P<0.01$ and $P<0.05$, respectively; ns: no significant

Table 14. Test weight differences between two sowing date with two seeding densities for 20 varieties of bread wheat in Beja trials.

Variety	Test weight (kg/hl) 1st sowing date		Test weight (kg/hl) 2nd sowing date	
	Seed rate 200 seed m^{-2}	Seed rate 350 seed m^{-2}	Seed rate 200 seed m^{-2}	Seed rate 350 seed m^{-2}
Roxo	$83{,}01^{g}$	$82{,}70^{i}$	$82{,}20^{i}$	$81{,}83^{h}$
Bologna	$81{,}40^{fg}$	$82{,}23^{hi}$	$78{,}59^{f\text{-}i}$	$78{,}64^{gh}$
Nabão	$82{,}35^{g}$	$81{,}27^{hi}$	$79{,}99^{f\text{-}i}$	$81{,}19^{h}$
Eufrates	$80{,}73^{efg}$	$80{,}91^{ghi}$	$80{,}30^{ghi}$	$79{,}01^{gh}$
Nogal	$79{,}83^{efg}$	$80{,}46^{ghi}$	$75{,}87^{e\text{-}h}$	$76{,}52^{fgh}$
TE0205	$80{,}03^{efg}$	$79{,}82^{f\text{-}i}$	$81{,}14^{i}$	$80{,}89^{h}$
TE0206	$77{,}52^{def}$	$77{,}90^{e\text{-}h}$	$76{,}09^{e\text{-}h}$	$78{,}72^{gh}$
Pata-negra	$77{,}41^{def}$	$77{,}87^{e\text{-}h}$	$80{,}57^{hi}$	$81{,}09^{h}$
Alabanza	$76{,}42^{de}$	$76{,}60^{efg}$	$79{,}33^{f\text{-}i}$	$79{,}16^{gh}$
Badiel	$73{,}20^{cd}$	$75{,}62^{ef}$	$75{,}20^{ef}$	$77{,}56^{gh}$
Ingenio	$74{,}67^{cd}$	$75{,}43^{def}$	$70{,}12^{bcd}$	$69{,}53^{b\text{-}e}$
Flycatcher “s”	$74{,}56^{cd}$	$74{,}63^{de}$	$72{,}54^{cde}$	$74{,}57^{efg}$
Ardila	$74{,}15^{cd}$	$74{,}51^{cde}$	$75{,}41^{efg}$	$73{,}98^{d\text{-}g}$
Inoui	$74{,}30^{cd}$	$74{,}46^{cde}$	$70{,}03^{bcd}$	$70{,}03^{b\text{-}e}$
Linha1	$71{,}00^{bc}$	$73{,}39^{b\text{-}e}$	$67{,}85^{abc}$	$68{,}80^{bcd}$
Linha3	$67{,}43^{ab}$	$70{,}89^{a\text{-}d}$	$68{,}05^{abc}$	$66{,}12^{ab}$
Mané-Nick	$71{,}71^{bc}$	$69{,}90^{abc}$	$76{,}10^{e\text{-}h}$	$75{,}51^{fg}$
Aguilla	$71{,}16^{bc}$	$69{,}58^{ab}$	$65{,}85^{ab}$	$67{,}73^{bc}$
Siena	$67{,}82^{ab}$	$68{,}93^{ab}$	$73{,}58^{de}$	$71{,}84^{c\text{-}f}$
Linha2	$65{,}79^{a}$	$67{,}13^{a}$	$63{,}88^{a}$	$62{,}04^{a}$
Range	65,79-83,01	67,13-82,70	63,88-82,20	62,04-81,83
Mean	75,22	75,71	74,63	74,74
SE	0,189	0,199	0,213	0,229

Varieties are listed in test weight decreasing order of 1st date and usual seed rate (350 seed.m-2). Different letters in the same column indicate significant difference ($P<0.05$)

Table 15. Descriptive statistic values for test weight in 20 bread wheat varieties at Beja.

	N	Mean ± SE	Minimum	Maximum	CV (%)
Test Weight (kg/hl)	320	75,08±0,30	60,14	83,74	7,21

Data showed that the higher and steady test weight values (including two sowing dates) were obtained with Ardila, Roxo, Nabão, Eufrates, TE0205 and TE0206, with an increase when sowed later (Table 14). Varieties with longer growth cycle presented a significant reduction on test weight in 2nd sowing date. Spaner et al. (2000) and Ozturk et al. (2006) reported that a delayed in sowing tends to decrease test weight in facultative wheat.

Maximum test weight was recorded Roxo, Bologna, Nabão, Eufrates, Nogal, TE0205 and TE0206, in the 1st sowing date (October 26th) with a significant decrease in the 2nd sowing date (November 29th) as shown in table 14. This behaviour is similar to the observed with the grain yield at Beja. This performance reflects an important adaptation of these varieties to Mediterranean conditions predominant in Portugal. In opposite, varieties developed in different environmental conditions (longer growth cycles) showed worse adaptation resulting on lower test weights.

Results showed that test weight ranged from 60,14 to 83,74 $kg.hl^{-1}$ in Beja with a small coefficient of variation indicating low dispersion of the data.

Conclusions

Results clearly confirmed that intrinsic genetic yield potential is not enough to obtain high wheat yield. Overall, in Beja, with the same varieties, the average wheat yield was around 3t/ha higher than in Elvas (Tables 6 and 12). This fact indicates that several limitations to the expression of yield potential exist, related with agronomy (i.e., depth and physical structure of the soil and crop management practices) and climate such as frost during flowering and high temperatures during grain filling, which could cause irreversible damage to wheat crop yield. In this context, the fastest and most practical ways to increase yield are to improve agronomy in conjunction with continuing genetic improvement (Costa et al. 2012). At Beja, the highest value for grain yield was obtained by Nogal with 7,8 t/ha and heading time at April 1st. On the other hand, Linha2 showed the lowest performance with 3,6 t/ha and heading time out of adequate window (May 1st). At Elvas, Flycatcher"s", an advanced breeding line, was the best genotype with 3,2 t/ha and Linha2 revealed the end of the varieties ranking with 2 t/ha. The highest test weight was obtained with the 1st sowing date, in both locations. Increasing sowing rate did not significantly influenced test weight at Elvas and Beja, for the majority of cultivars. These results showed that both sowing date and seeding rate influence grain yield and test weight in the majority of cultivars, but the effect of sowing date was greater than that of seeding rate. Results also indicated that according with the climatic conditions occurred during 2011/2012 season in both places (Elvas and Beja), where a strong Mediterranean pattern drives wheat development, the germplasm evaluation and selection is paramount to better determine and characterize the ideotype wheat plant that breeders should strive to develop. New advanced breeding lines like Flycatcher"s", TE0205, TE0206, obtained by Cereal Breeding Program in Plant Breeding Station (Elvas, Portugal) are excellent examples resulting from this kind of approach.

References

Abd El Maaboud, M. S., A. F. Abou-Hadid, M. Edriss and M. A. Medany. 2004. Climate change and productivity of some wheat cultivars under rainfed and supplementary irrigation conditions. In: C. Cantero-Martínez and D. Gabiña (Eds.), pp. 139-146. Mediterranean rainfed agriculture: Strategies for sustainability. Zaragoza: CIHEAM. (Options Méditerranéennes: Série A. Séminaires Méditerranéens; n. 60).

Borghi, B., M. Corbellini, M. Ciaffi, E. Lafiandra, E. Stefanis, D. Sgrulletta, G. Boggini and N. Fonzo. 1995. Effect of heat shock during grain filling on grain quality of bread and durum wheats. Aust. J. Agric. Res. 46: 1365-1380.

Boyer, J. S. 1982. Plant productivity and environment. Science 218:443-448.

Costa, R., N. Pinheiro, A. S. Almeida and B. Maçãs. 2012. Influence of enhanced UV-B radiation on wheat production in relation with abiotic, biotic and socioeconomics constraints. Emir. J. Food Agric. 24(6):565-575.

Cutforth, H. W., C. A. Campbell, S. A. Brandt, J. Hunter, D. Judiesch, R. M. DePauw and M. Clarke. 1990. Development and yield of Canadian western red spring and Canada prairie spring wheats as affected by delayed seeding in the brown and dark brown soil zones of Saskatchewan. Can. J. Plant Sci. 70:639-660.

FAOSTAT 2013. Available in http://www.faostat.fao.org

Hawkesford, M., J. L. Araus, R. Park, D. Calderini, D. Miralles, T. Shen, J. Zhang and M. Parry. 2013. Prospects of doubling global wheat yields. Food Ener. Sec. 2(1):34–48.

Lloveras, J., J. Manent, J. Viudas, A. López and P. Santiveri. 2004. Seeding rate influence on yield and yield components of irrigated winter wheat in a mediterranean climate. Agron. J. 96:1258-1265.

Lobell, D. B., W. Schlenker and J. Costa-Roberts. 2011. Climate trends and global crop production since 1980. Science 333:616-620.

Ozturk, A., O. Caglar and S. Bulut. 2006. Growth and yield response of facultative wheat to winter sowing, freezing sowing and spring sowing at different seeding rates. J. Agron. Crop Sci. 192:10-16.

Parry, M. A. J. and M. J. Hawkesford. 2010. Genetic approaches to reduce greenhouse gas emissions: increasing carbon capture and decreasing environmental impact. In: M. P. Reynolds (Ed.) pp. 139-150. Climate change and crop production. CABI International, Wallingford, U.K.

Peltonen-Sainio. 1991. Productive oat ideotype for northern growing conditions. Euphytica 54:27-32.

Protic, R., M. Miric, N. Protic, Ž. Jovanovic and P. Jovin. 2007. The test weight of several winter wheat genotypes under various sowing dates and nitrogen fertilizer rates. Rom. Agric. Res. 24:43-36.

Simane, B., J. M. Peacock and P. C. Struik. 1993. Differences in development plasticity and growth rate among drought-resistant and susceptible cultivars of durum wheat (*Triticum turgidum* L. var. *durum*). Plant Soil. 157:155-166.

Spaner, D., A. G. Todd and D. B. McKenzie. 2000. The effect of seeding date, seeding rate and N fertilization on winter wheat yield and yield components in eastern Newfoundland. Can. J. Plant Sci. 80:703-711.

Woodruff, D. R. and Tonks, J. 1983. Relationship between time of anthesis and grain yield of wheat genotypes with differing developmental patterns. Aust. J. Agric. Res. 34:1-11.