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Grain yield and baking quality of wheat under different sowing dates

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ABSTRACT. Choosing the right sowing dates can maximize the outcomes of the interaction between genotype and environment, thus increasing grain yield and baking quality of wheat (*Triticum aestivum* L.). The present study aimed at determining the most appropriate sowing dates that maximize grain yield and baking quality of wheat cultivars. Seven wheat cultivars (BRS 179, BRS Guamirim, BRS Guabiju, BRS Umbu, Safira, CD 105 and CD 115) were evaluated at four sowing dates (the 1st and the 15th of June and July) in two harvesting seasons (2007 and 2008). The study was setup in a completely randomized block design with four repetitions. The effects of the year and sowing date when combined explained 93% of the grain yield variance. In 2007, the CD 105 and Safira cultivars had the highest grain yield (GY) for all sowing dates. Only the BRS Guabiju and Safira cultivars possessed high baking quality for all sowing dates assessed. In 2008, the environmental conditions were favorable for superior GY, but the baking quality was inferior. Considering adapted cultivars and sowing dates, it is possible to maximize grain yield and baking quality of wheat.

Keywords: GGE biplot, baking quality, gluten strength, alveograph.

Produtividade de grãos e qualidade industrial de trigo em diferentes épocas de semeadura

RESUMO. A escolha de épocas de semeadura adequadas pode maximizar o aproveitamento da interação genótipo x ambiente e incrementar a produtividade de grãos e a qualidade industrial de trigo (*Triticum aestivum* L.). Objetivou-se com o estudo identificar épocas de semeadura adequadas que maximizam a produtividade de grãos e a qualidade industrial de cultivares de trigo. Sete cultivares de trigo (BRS 179, BRS Guamirim, BRS Guabiju, BRS Umbu, Safira, CD 105 e CD 115) foram avaliadas em quatro épocas de semeadura (01 e 15 de junho, 01 e 15 de julho) durante duas safras agrícolas (2007 e 2008). Utilizou-se delineamento em blocos ao acaso com quatro repetições. Somados, os efeitos de ano e épocas de semeadura explicaram 93% da variância para produtividade de grãos. Em 2007, as cultivares CD 105 e Safira apresentaram a maior produtividade de grãos (GY) em todas as épocas de semeadura. Apenas as cultivares BRS Guabiju e Safira apresentaram elevada qualidade de panificação em qualquer época de semeadura avaliada. Em 2008, as condições ambientais foram favoráveis ao aumento da GY, contudo de menor qualidade industrial. É possível maximizar a GY e a qualidade industrial do trigo com a escolha de cultivares adaptadas e épocas de semeadura mais adequadas.

Palavras-chave: GGE biplot, qualidade industrial, força de glúten, alveografia.

Introduction

Wheat (*Triticum aestivum* L.) is an important and extensively used cereal in human and animal diets worldwide. In Brazil, a significant amount of wheat is imported not only because this country produces only half of its internal consumption but also because the wheat produced has inferior baking quality in some regions of Brazil. Increases in grain yield (GY) and baking quality are crucial for wheat crop competitiveness. Such increases may be accessible based upon the selection of adapted cultivars and adequate management practices.

In wheat, GY and baking quality are dependent on the environment, genetic factors and the interaction between them (YAN; HOLLAND, 2010; COVENTRY et al., 2011). An adequate sowing date positively impacts the GY (SILVA et al., 2011) and baking quality of wheat, causing better adjustment to the physiology, phenology and environmental conditions (WHEELER et al., 1996; RIBEIRO et al., 2009). In addition, the appropriate sowing date also affects the water, temperature and solar radiation available for the crop.

Wheat GY can be increased by 10 to 80% with management of the sowing date, cultivar and environmental conditions (COVENTRY et al., 2011). Similarly, baking quality is also influenced by sowing date (SINGH et al., 2010). Adverse environmental conditions during anthesis and grain filling are important factors in the baking quality classification of wheat (JIANG et al., 2009). Each sowing date determines the baking quality pattern of the wheat (TRIBOI; TRIBOI-BLONDEL, 2002; MOTZO et al., 2007). However, it is difficult to obtain high GY and baking quality due to a negative association between these characteristics (BLANCO et al., 2011).

Thus, the present study aimed at determining the most appropriate sowing dates that maximize grain yield and baking quality of wheat cultivars for the wheat cropping region of central south of the state of Paraná.

Material and methods

The experiment was performed in the municipality of Guarapuava (25°33'S and 51°30'W; altitude of 1,095 m) in the State of Paraná, Brazil. According to the Köppen climate classification system, the predominant climate type in this area is Cfb, which represents a humid subtropical climate with a temperate summer (MAACK, 1968). The experimental site, which is located at the Value of Culture and Use Region 1 (VCU 1), is a region of interest because of the increased yield potential and the occurrence of severe frost.

The experiment was setup in a completely randomized block design with four repetitions in a factorial scheme. The following three bread wheat cultivars were evaluated: BRS Guamirim (early cycle), BRS Guabiju (mid-cycle) and Safira (mid-cycle). The following four soft wheat cultivars were evaluated: CD 105 (early cycle), CD 115 (mid-cycle), BRS 179 (mid-cycle) and BRS Umbu (late cycle). The cultivars were planted on the 1st and 15th of June (E1 and E2) and on the 1st and 15th of July (E3 and E4) during the 2007 and 2008 harvesting seasons. These cultivars were chosen because they are the most representative of that region.

In Brazil, wheat cultivars are classified according to the Normative Instruction No. 7 of the Ministry of Agriculture, Livestock and Food Supply (BRASIL, 2001). The different classes vary according to the alveogramW and falling number (FN) with five classes currently known as follows: soft wheat (W > 50 and FN > 200); bread wheat (W > 180 and FN > 200); improver wheat (W > 300 and FN > 250); wheat for different end uses (W = any and FN < 200); and durum wheat (W = not defined and FN > 250).

The useful area of each plot consisted of six rows (5 m in length with 0.17 m spacing) with a total area of 5.1 m^2. Initially, a basal amount of 300 kg ha^{-1} of NPK 08-30-20 was applied. At the early stages of tilling, 40 kg ha^{-1} of N in the form of urea was applied for fertilization. GY was estimated (kg ha^{-1}) after harvesting the useful area of each plot, and it was corrected to 13% moisture. A thousand kernel weight (TKW) measured in grams (g) was obtained after sampling 250 grains in duplicate. The test weight (TW), which corresponds to the mass of 100 liters of grains (kg hL^{-1}), was determined using a Dalle Molle hectoliter weight balance. The genotypes were characterized using the percentage of pre-harvest sprouting (PHS) with 100 grains randomly collected in each plot. After this, the germinated (rupture of pericarp) and non-germinated grains were counted.

For the analysis of baking quality, individual samples of each treatment were mixed and homogenized resulting in a composite sample. The FN was determined in duplicate using a falling number device from Perten Instruments following method 56-81B of the American Association of Cereal Chemists (AACC, 2000). This test was applied to measure the intensity of the enzymatic activity of the α-amylase enzyme in the grain with the result given in seconds. Low enzymatic activity is associated with elevated values of FN.

The alveogram test (method 54-30A of the AACC, 2000) was performed using a Chopin alveograph. This test refers to the capacity of water absorption by the proteins that comprise gluten and to the capacity to retain carbon dioxide resulting in a quality bread product. Using a manometer, different pressures were recorded, and the alveograph curve was obtained wherein the length, height and a circumscribed area of the curve represent the extensibility (L), tenacity (P) and W-index (W), respectively.

The analysis of joint variance was conducted considering the year effect as random, and the genotype and sowing date were considered as fixed effects. For comparison of mean values, the R computer program was used, and the Scott-Knott test was applied (5%).

To perform the analysis of association between the baking quality parameter of each cultivar and different sowing dates and the association between quality parameters and cultivars, the GGE Biplot methodology was applied (YAN et al., 2000) using the GGE biplot software analysis (YAN, 2001) where the interpretation of the associations is based on the cosine of the angle between the two vectors to be compared. The interpretation rule is: the association is positive if the angle between the vectors is < 90°; it negative if the angle is > 90°; and it is null if the angle is about 90º (YAN; TINKER, 2006). The singular value is entirely partitioned into the entry eigenvectors. Singular value partitioning 1 (SVP 1) is needed for accurate comparison among the entries, while SVP 2 is needed for accurate visualization of the relationship among the testers (YAN et al., 2000).

Results and discussion

The analysis of variance (ANOVA) showed that the effect of the year (Y), sowing date (D), CxY interaction (cultivar x year) and CxYxD (cultivar x year x sowing date) interaction significantly affected the GY (Table 1). The coefficient of variation was 5.2%, which represented good precision of the experiment. The majority of the variation was due to changes in the environment (year = 87% and sowing date = 6%). These results indicated that proportionally, there was a greater variability in the response between years when compared to the sowing dates and cultivars, which can be explained by irregular precipitation, solar radiation and temperature between years and sowing dates; and the frost effects at booting (Figure 1). According to Jalata (2011), there is a greater effect of the environment as compared to the cultivar in such experiments.

Table 1. Mean of grain yield (kg ha^{-1}) of wheat cultivars with different sowing dates and comparison of the effect of sowing date and cultivars in Guarapuava - Paraná State.

Cultivars	Year 2007			
	01 June	15 June	01 July	15 July
BRS 179	4913 b[1]A[2]	5397 bA	5353 bA	5565 aA
BRS Guabiju	4723 bA	5442 bA	5183 bA	5082 bA
BRS Guamirim	5000 bB	5548bA	5775 bA	5816 aA
BRS Umbu	5006 bA	5470 bA	5249 bA	5356 bA
CD 105	5845 aA	6185 aA	6425 aA	6214 aA
CD 115	3924 cB	5557 bA	5445 bA	5280 bA
Safira	5554 aB	6148 aA	6158 aA	6361 aA
Cultivars	**Year 2008**			
	01 June	15 June	01 July	15 July
BRS 179	6441 aB	6721 aB	7402 aA	6940 aB
BRS Guabiju	5715 bB	5968 bB	6590 aA	6501 aA
BRS Guamirim	6190 bB	6330 bB	6739 aA	6864 aA
BRS Umbu	6049 bB	6582 aA	6781 aA	6631 aA
CD 105	6581 aA	6720 aA	6552 aA	6934 aA
CD 115	6237 bB	6828 aA	6995 aA	6773 aA
Safira	6650 aA	6567 aA	6988 aA	6843 aA

[1,2]compare means between cultivars and between sowing dates, respectively. Médias seguidas de mesma letra não diferem entre si pelo teste de Scott Knott a 5%. Means followed by same letter do not differ by testing Scott Knott ($p < 0.05$).

In 2007, the CD 105 and Safira cultivars showed the highest GY in all sowing dates and did not differ from the BRS Guamirim and BRS 179 cultivars in E4 (Table 2). Regarding sowing dates, the CD 115, BRS Guamirim and Safira cultivars showed an inferior GY in E1. In this context, it is important to note that experimental site has a greater occurrence of lower temperatures during anthesis for early sowing dates (GONÇALVES et al., 1998).

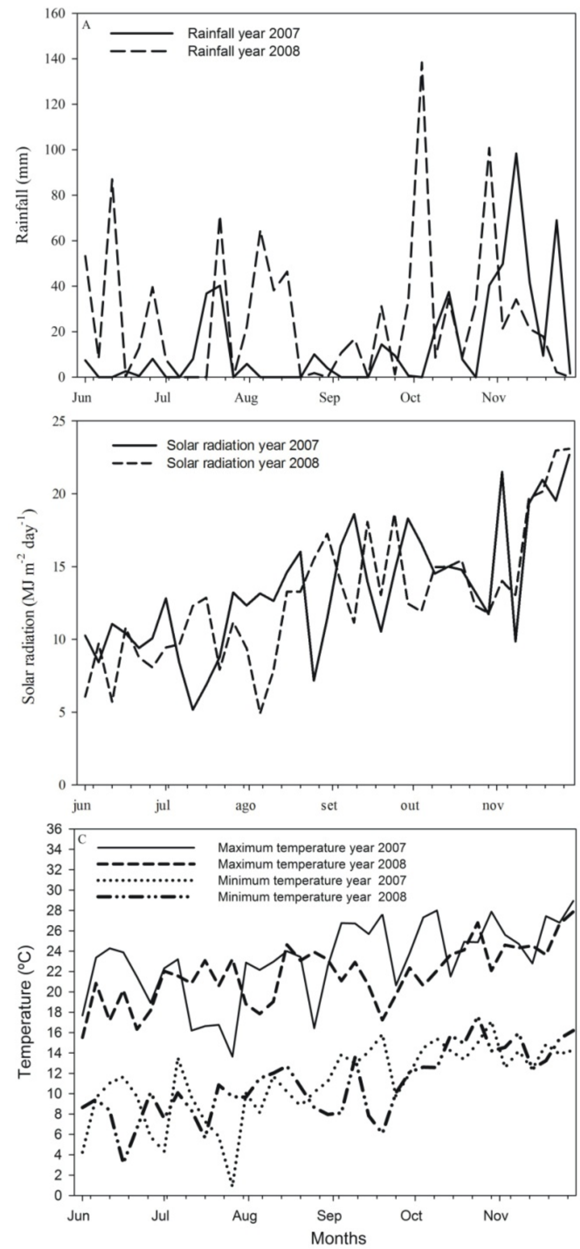

Figure 1. Climate data of rainfall (A), solar radiation (B) and maximum and minimum temperature (C) in Guarapuava-Paraná State for 2007 and 2008 during wheat growth with different sowing dates.

The occurrence of severe frost during the early stages compromises vegetative development and tiller emission and survival. Early cycle cultivars, such as the BRS Guamirim cultivar, must be preferentially planted in the month of July to avoid damages caused by frost. In 2008, the GY was not different between sowing dates, with the exception of the Safira and CD 105 cultivars (Table 2).

Table 2. Mean of grain yield (kg ha^{-1}) of wheat cultivars with different sowing dates in Guarapuava-Paraná State.

Cultivars	01 June		15 June		01 July		15 July	
	2007	2008	2007	2008	2007	2008	2007	2008
BRS 179	4913 B[1]	6441 A	5397 B	6721 A	5353 B	7402 A	5565 B	6940 A
BRS Guabiju	4723 B	5715 A	5442 A	5968 A	5183 B	6590 A	5082 B	6501 A
BRS Guamirim	5000 B	6190 A	5548 B	6330 A	5775 B	6739 A	5816 B	6864 A
BRS Umbu	5006 B	6049 A	5470 B	6582 A	5249 B	6781 A	5356 B	6631 A
CD 105	5845 B	6581 A	6185 A	6720 A	6425 A	6552 A	6214 B	6934 A
CD 115	3924 B	6237 A	5557 B	6828 A	5445 B	6995 A	5280 B	6773 A
Safira	5554 B	6650 A	6148 A	6567 A	6158 B	6988 A	6361 A	6843 A

[1,2]compare mean between cultivars and between sowing dates, respectively. Means followed by same letter do not differ by Scott Knott test ($p < 0.05$).

There was a more favorable GY for all the sowing dates in 2008 than in 2007 (Table 3), which may be a result of a better distribution of precipitation, specifically during the early stages of plant development (Figure 1A). Moreover, the maximum and minimum temperatures in 2007 were superior to those observed in 2008 (Figure 1B). Elevated temperatures accelerate the development of the grain filling stage (GAJU et al., 2009), thereby resulting in a reduced deposition of carbohydrates, accumulation of starch in the grains and GY (TRIBOI; TRIBOI-BLONDEL, 2002; LABUSCHAGNE et al., 2009).

Table 3. Baking quality of wheat cultivars with different sowing dates in Guarapuava-Paraná State in 2007.

Cultivar	ST	TW	TKW	PHS	FN	W	P	L	P/L
BRS 179	E1	83	38	0.1	335	175	85	65	1.31
	E2	83	37	0.1	325	138	69	69	1
	E3	80	41	0.2	309	141	71	70	1.01
	E4	82	41	0.3	356	151	73	70	1.04
BRS Guabiju	E1	84	36	0.1	325	479	119	116	1.03
	E2	83	36	0.1	352	424	98	136	0.72
	E3	82	39	0.1	352	435	98	125	0.78
	E4	84	38	0	354	426	100	132	0.76
BRS Guamirim	E1	82	39	2.3	320	273	108	83	1.3
	E2	85	41	0	452	348	120	93	1.29
	E3	84	39	0	392	321	103	108	0.95
	E4	81	41	0.8	349	299	98	108	0.91
BRS Umbu	E1	83	34	0.1	300	247	54	154	0.35
	E2	81	35	0.3	304	246	51	160	0.32
	E3	83	36	0.5	310	200	45	174	0.26
	E4	82	34	0.6	313	195	44	165	0.27
CD 105	E1	83	44	0.3	301	216	71	110	0.65
	E2	80	44	0.4	310	140	44	128	0.34
	E3	78	45	0.4	317	148	47	126	0.37
	E4	78	45	0.3	323	171	55	118	0.47
CD 115	E1	83	39	0.1	325	205	70	122	0.57
	E2	81	35	0.5	313	171	54	136	0.4
	E3	81	38	0	296	163	60	98	0.61
	E4	82	39	0.3	314	167	59	114	0.52
Safira	E1	85	36	0.1	384	342	130	66	1.97
	E2	83	36	0.1	368	296	100	73	1.37
	E3	83	38	0.1	350	299	79	106	0.75
	E4	84	36	0	364	353	94	105	0.9

The following abbreviations are used: ST, sowing time; TW, test weight (kg hL^{-1}); TKW, thousand kernel weight (g); PHS, pre-harvest sprouting (%); FN, falling number; W, W-index (10^{-4} J); P, tenacity; L, extensibility (mm); and P/L, tenacity/extensibility ratio.

The different sowing dates affected the performance of the studied parameters. The TW varied between 78 and 85 kg hL^{-1} in 2007 (Table 4) and between 75 and 82 kg hL^{-1} in 2008 (Table 4). The evaluated cultivars showed different reduction levels of TW as a result of the sowing date effect where the greatest reduction (7%) was observed for the BRS Umbu cultivar. Bordes et al. (2008) also observed different genotype behavior due to environmental variations. In both years, there was a negative association of TW with PHS and TKW (Figures 2 and 3). Moreover, there was an elevated consumption of the grain reserve and elevated respiration with increased PHS and decreased TKW, TW and GY (GUARIENTI et al., 2003), which resulted in reduced baking quality.

Table 4. Baking quality of wheat cultivars with different sowing dates in Guarapuava-Paraná State in 2008.

Cultivar	ST	TW	TKW	PHS	FN	W	P	L	P/L
BRS 179	E1	81	42	0.5	255	128	57	79	0.72
	E2	80	39	0.4	242	104	48	91	0.53
	E3	79	36	0.5	274	89	40	110	0.36
	E4	80	36	0	292	139	68	78	0.87
BRS Guabiju	E1	82	38	0.4	290	363	103	102	1.01
	E2	82	38	0.2	254	375	90	132	0.68
	E3	82	37	0.6	279	245	54	181	0.3
	E4	82	35	0.1	313	319	72	162	0.44
BRS Guamirim	E1	79	43	1.2	272	214	85	88	0.97
	E2	78	42	2.7	218	149	64	92	0.7
	E3	79	41	7.6	243	168	61	121	0.5
	E4	82	38	0.1	297	206	73	111	0.66
BRS Umbu	E1	81	35	0.6	209	173	42	165	0.25
	E2	82	35	0.4	246	113	36	144	0.25
	E3	82	34	0.2	286	135	35	186	0.19
	E4	76	32	0.3	283	146	34	179	0.19
CD 105	E1	75	47	0.9	287	75	41	77	0.53
	E2	75	44	2.4	209	78	38	89	0.43
	E3	76	43	1.8	268	75	31	122	0.25
	E4	80	40	0	301	114	38	135	0.28
CD 115	E1	78	38	0.3	232	103	46	98	0.47
	E2	79	37	0.7	210	80	32	132	0.24
	E3	79	37	0.6	248	88	35	147	0.24
	E4	80	34	0	285	110	43	120	0.36
Safira	E1	79	36	0.7	316	223	89	66	1.35
	E2	79	35	0.4	273	221	71	92	0.77
	E3	79	33	0.2	295	180	47	137	0.34
	E4	80	30	0	334	217	59	109	0.54

The following abbreviations are used: ST, sowing time; TW, test weight (kg hL^{-1}); TKW, thousand kernel weight (g); PHS, pre-harvest sprouting (%); FN, falling number; W, W-index(10^{-4} J); P, tenacity; L, extensibility (mm); and P/L, tenacity/extensibility ratio.

In 2007, the TKW was superior in sowing dates that maximized the GY (Figure 2; Tables 2 and 4), which indicated a positive association between GY and TKW, except for the CD 115 cultivar (Figure 2). In contrast, TKW was negatively associated with GY in 2008 (Figure 3). The importance of TKW during the formation of GY has been reported in modern cultivars (BORDES et al., 2008).

Wheat with high baking quality must have an elevated W, L and P (BORDES et al., 2008). For the majority of the cultivars, the values of W, P and P/L showed elevated values in E1 and E4 corresponding to 2007 and 2008, respectively (Tables 3 and 4; Figures 2 and 3). For most cultivars, a low L was observed for the flour in E1 and E2, which indicated a negative association with W (Figures 2 and 3).

This result corroborated the study by Scheuer et al. (2011), which reported that high W can result in lower L. However, the BRS Umbu cultivar had a high level of L in all sowing dates (Figures 2 and 3). A high level of L is associated with a low production of flour (MÓDENES et al., 2009).

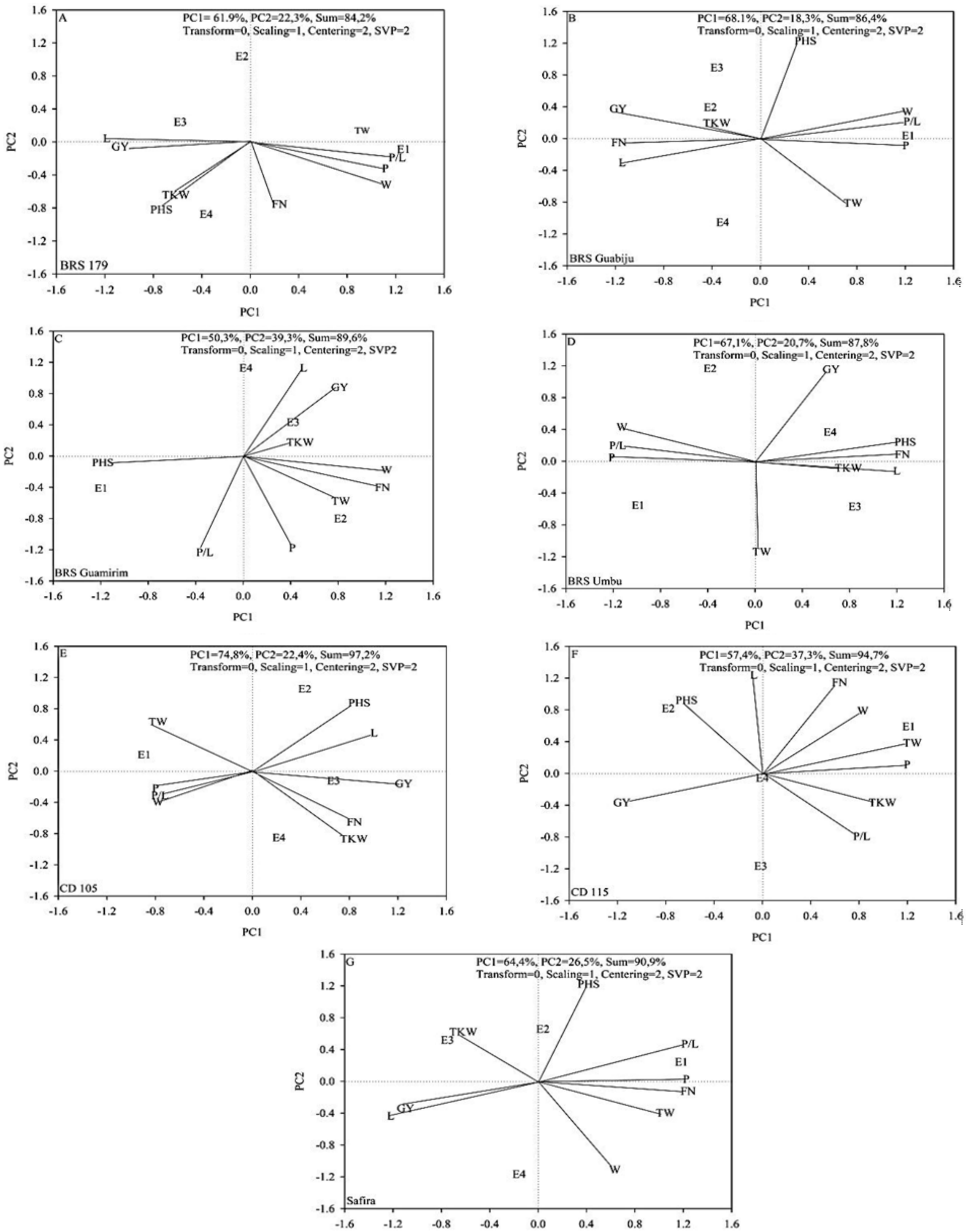

Figure 2. Productivity and baking quality performance of wheat cultivars (A, BRS 179; B, BRS Guabiju; C, BRS Guamirim; D, BRS Umbu; E, CD 105; F, CD 115; and G, Safira) with different sowing dates in 2007 following the GGE biplot methodology. The following abbreviations are used: ST, sowing time; TW, test weight (kg hL^{-1}); TKW, thousand kernel weight (g); PHS, pre-harvest sprouting (%); FN, falling number; W, strength-index (10^{-4} J); P, tenacity; L, extensibility (mm); and P/L, tenacity/extensibility ratio.

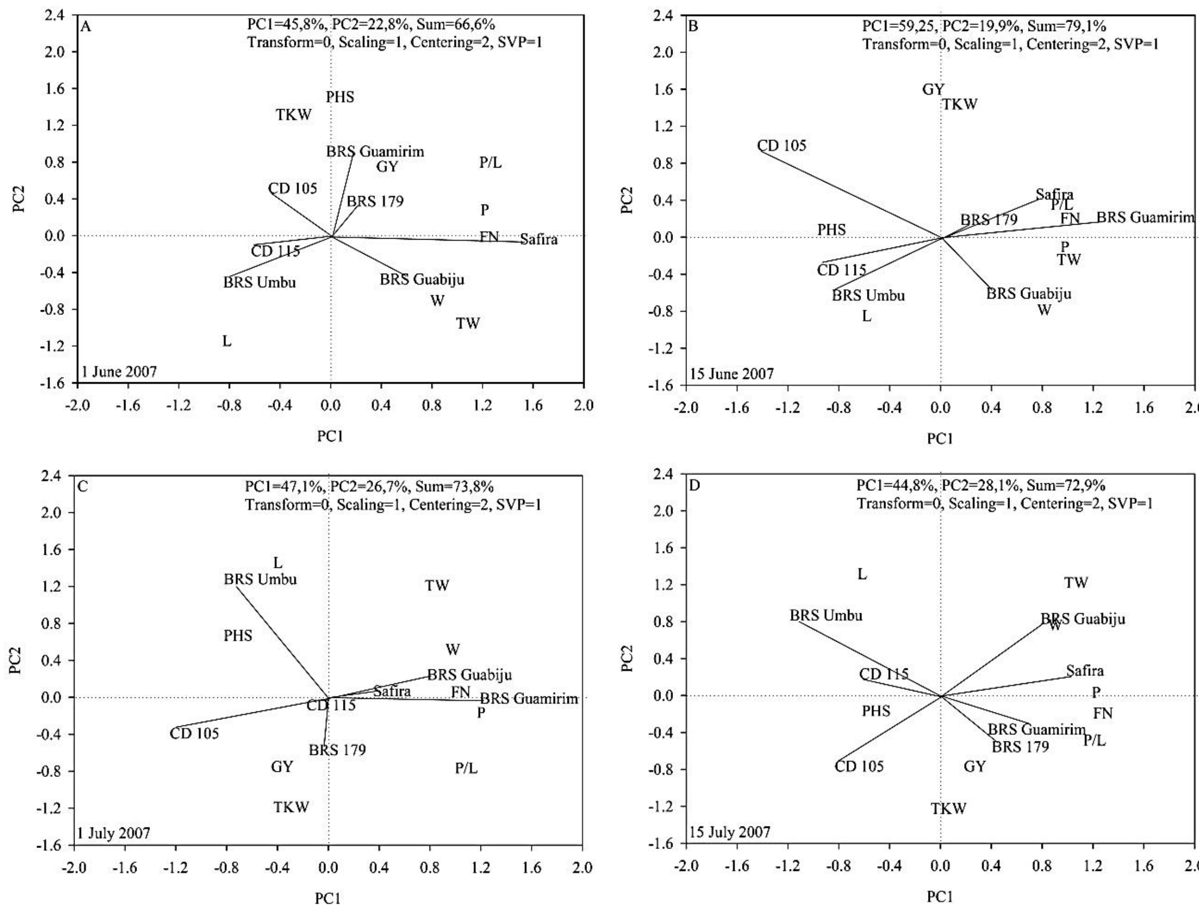

Figure 3. Productivity and baking quality performance of wheat cultivars (A, BRS 179; B, BRS Guabiju; C, BRS Guamirim; D, BRS Umbu; E, CD 105; F, CD 115; and G, Safira) with different sowing dates in 2008 following the GGE biplot methodology. The following abbreviations are used: ST, sowing time; TW, test weight (kg hL^{-1}); TKW, thousand kernel weight (g); PHS, pre-harvest sprouting (%); FN, falling number; W, W-index (10^{-4} J); P, tenacity; L, extensibility (mm); and P/L, tenacity/extensibility ratio.

There was a negative association between W and GY for the majority of the cultivars (Figures 2 and 3), except for the CD 115 (Figure 2F) and CD 105 (Figure 3E) cultivars. Sowing dates subsequent to June specifically promoted GY and reduced W (Figures 2A, 2C, 2F and 3B). Likewise, an elevated W is associated with greater accumulated amounts of proteins (PINNOW et al., 2013), which demands an elevated consumption of carbohydrates. An increased content of proteins causes a decreased accumulation of starch and, consequently, a reduction in GY (RHARRABTI et al., 2001; SCHMIDT et al., 2009).

There was an increase in W during sowing dates in which the period of grain filling occurred simultaneously to the increase in mean, minimum and maximum temperatures (Figures 1B, 1C and 1D; Tables 4 and 5). Moreover, a low magnitude of W was observed in E1 and E2 for the BRS 179, CD 105 and CD 115 cultivars (Figures 3A, 3E and 3F). In the same way, Moldestad et al. (2011) reported that elevated temperatures between the silking and grain filling stage resulted in increased W. However, a temperature increase during this phase leads to a reduction of TKW and GY (RHARRABTI et al., 2003; LABUSCHAGNE et al., 2009; HURKMAN; WOOD, 2011) and promotes a negative association between W and GY. A lower W in E1 and E2 can be attributed to greater precipitation during the grain filling stage (GARRIDO-LESTACHE et al., 2005) and a higher PHS (Figures 2 and 3).

In the grains, PHS results in the degradation of starch and protein. An elevated PHS was observed in E1 for the BRS Guamirim and BRS Umbu cultivars (Figures 2C and 3D) and in E2 for the CD 105, CD 115 and Safira cultivars (Figures 2 and 3). PHS was closely linked to the occurrence of precipitation during the pre-harvest period. The BRS Guamirim cultivar showed a higher value of PHS (7.6) in E3 (2008) as a result of the rainy season preceding maturation (Figure 3C). The extent of the damage caused by PHS in favorable environmental conditions (prolonged precipitation and elevated temperature) depends mainly on the genetic factor (GELIN et al., 2006). The BRS Guamirim cultivar showed the highest PHS among all tested cultivars in both years (Tables 3 and 4).

The falling number method is used to quantify the damages caused by PHS. The FN was elevated in sowing performed in E4 (Tables 3 and 4), which indicated a lower PHS (Figures 2 and 3). A low FN is associated with higher enzymatic activity of α-amylase (elevated PHS). Alterations in PHS and FN can affect the baking quality of wheat, particularly the mass volume, which indicates the amount of end-use flour; thus, an increased FN resulted in greater W (Figures 2 and 3).

In 2007, the BRS Guamirim, BRS Guabiju and Safira cultivars showed high values for baking quality (W, TW, FN, P and P/L) and GY (Figure 4). However, sowing of the BRS Guamirim and Safira cultivars during E1 should be avoided because they exhibited a reduction in GY (Table 2) and a P/L greater than 1.2 (Table 3). The P/L ratio is important as it defines bread volume and structure, which should be between 0.5 and 1.2 for most types of bread (SEBASTIANO et al., 2004). Regardless of sowing date, the BRS Guabiju cultivar showed the lowest PHS (0 to 0.1) and the greatest W (426 to 479) and TW (Figure 4). Independent of sowing date, the BRS Guabiju and Safira cultivars showed improver wheat, and the BRS Umbu cultivar showed bread quality. Moreover, the CD 105 and CD 115 cultivars exhibited a bread quality classification for all sowing dates, except in E1, where they produced soft flour. The BRS Guamirim cultivar was categorized as bread quality in E1 and improver baking quality in the remaining sowing dates (Table 3).

In 2008, the GY was higher than in 2007. The results indicated that it was more difficult to associate elevated grain yield with baking quality independent of the sowing date. Nevertheless, the BRS Guabiju cultivar in E3 and E4 and the Safira cultivar in all sowing dates showed high GY and high baking quality (Table 2 and Figure 5).

The BRS Guamirim and BRS 179 cultivars exhibited high GY and baking quality only in the last sowing date (Figure 5).

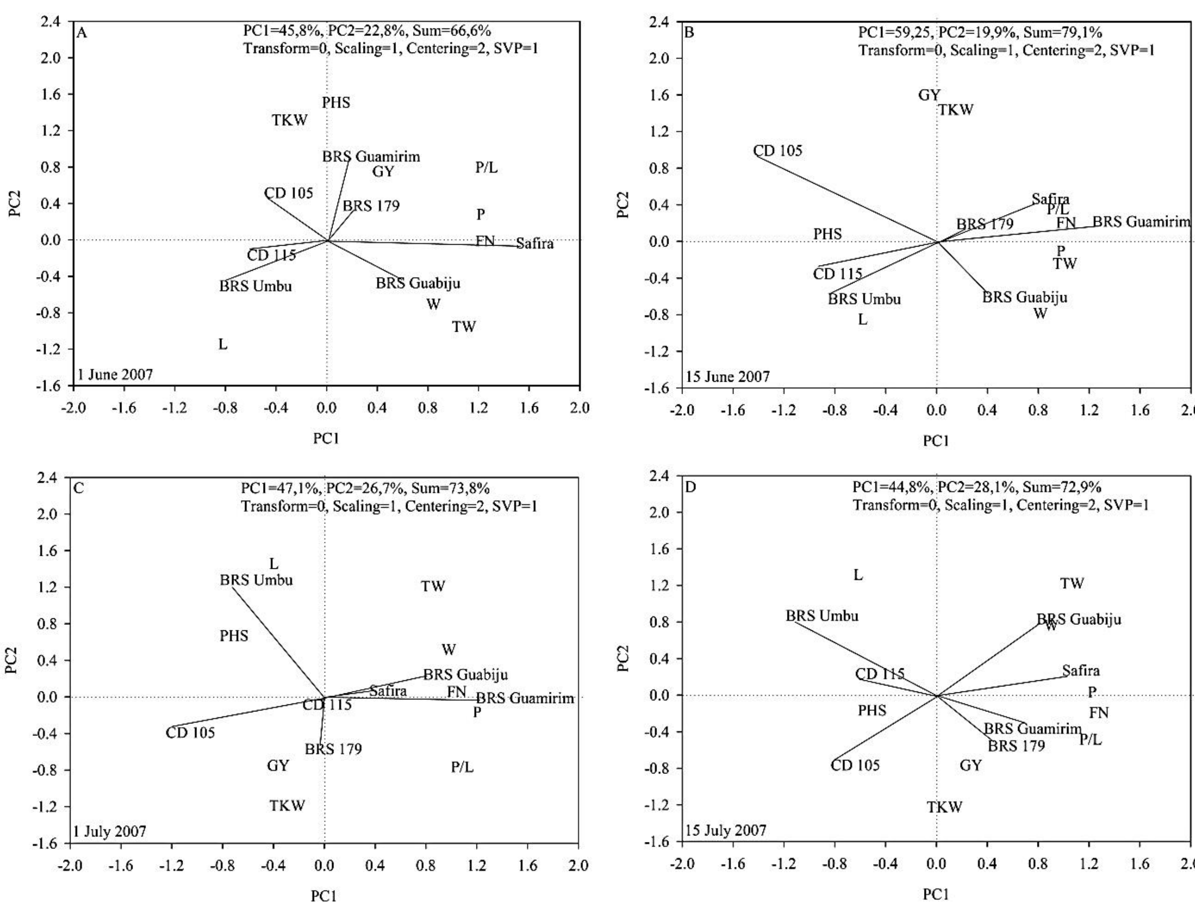

Figure 4. Association among cultivars with different sowing dates (A, 1st of June; B, 15th of June; C, 1st of July; and D, 15th of July) and the quality parameters in 2007 following the GGE biplot methodology. The following abbreviations are used: ST, sowing time; TW, test weight (kg hL^{-1}); TKW, thousand kernel weight (g); PHS, pre-harvest sprouting (%); FN, falling number; W, W-index (10^{-4} J); P, tenacity; L, extensibility (mm); and P/L, tenacity/extensibility ratio.

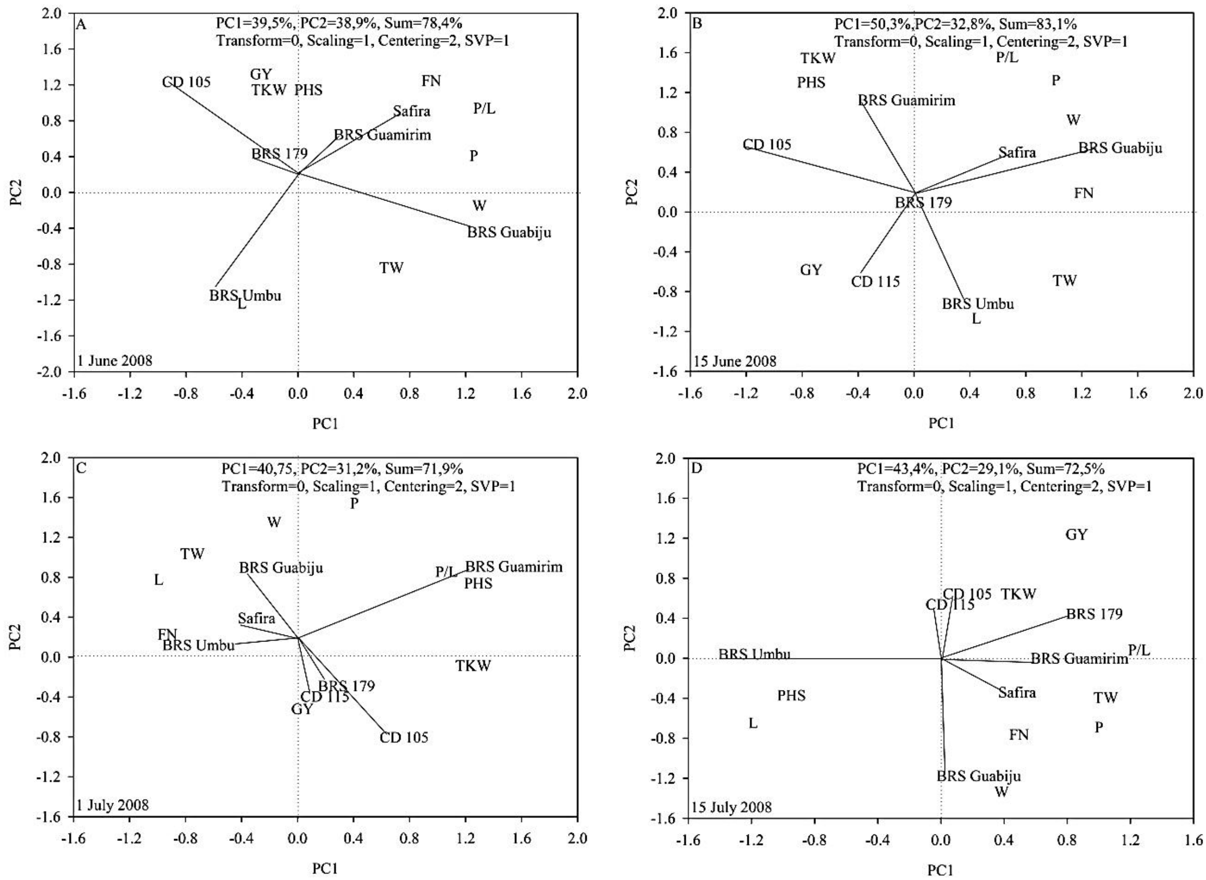

Figure 5. Association among cultivars with different sowing dates (A, 1st of June; B, 15th of June; C, 1st of July; and D, 15th of July) and the quality parameters in 2008 following the GGE biplot methodology. The following abbreviations are used: ST, sowing time; TW, test weight (kg hL^{-1}); TKW, thousand kernel weight (g); PHS, pre-harvest sprouting (%); FN, falling number; W, W-index (10^{-4} J); P, tenacity; L, extensibility (mm^3); and P/L, tenacity/extensibility ratio.

Therefore, the BRS Guabiju and Safira cultivars stood out in regard to their wide adaptability to the sowing date and years evaluated with elevated productive potential and baking quality to meet the bakery industry needs (Figures 4 and 5). In particular, the BRS Guabiju cultivar was the only cultivar that was categorized as improver wheat, and this result was obtained in E1 and E2. The Safira cultivar showed bread quality, and the remaining cultivars were classified as soft wheat (BRS 179, BRS Umbu, CD 105 and CD 115) (Table 4). Schmidt et al. (2009) observed that the Safira cultivar stood out among 28 tested genotypes with respect to TW, W and FN; thus, they classified the Safira cultivar as improver wheat.

Conclusion

The results indicated that there was a differential response of the cultivars with respect to baking quality and grain yield in response to the evaluated sowing dates. Sowing that occurred in July yielded greater productivity. Sowing in June maximized the baking quality of wheat, and early-cycle cultivars should be avoided at this sowing date. Sowing dates in which the grain filling occurred under elevated temperature positively affected the W and negatively affected grain yield. Adapted genotypes and an adequate sowing date can maximize the productivity and the baking quality of wheat.

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