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Stability of breeding characters related with bread wheat quality in Southern Spain

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SUMMARY – In 1998 CIMMYT and Agrovegetal SA signed an agreement aimed at developing new wheat varieties adapted to agroclimatic conditions of Southern Spain. To select bread wheat cultivars appropriate for Andalusian market is important to meet high protein and bread making quality requirements. The stability of several characters related with bread quality of a set of five new varieties ('Escacena', 'Ecija', 'Olvera', 'Jerezano' and 'Vejer'), and three checks ('Yecora', 'Cartaya' and 'Pinzon') has been tested in samples collected from trials in quadrate lattice with three replicates in five locations of Andalusia during the 2000-2001 and 2001-2002 crop seasons. The quality testing and statistical analysis of the data were conducted at the Genetics Department of the University of Cordoba, showing that in these typical Mediterranean conditions the main part of quality parameters were highly influenced by the environment. The distribution of phenotypic variance showed that the three quality traits in which the genotype was the main factor of variation in the two-year analysis were SDS-sedimentation, falling number, and alveograph-W. For the rest of traits the environment or the genotype x environment interaction explained, in at least one year, more than 50% of the observed variance.

Introduction

Bread wheat (*Triticum aestivum* ssp. aestivum L. em. Thell), is the third small grain cereal cultivated in the south of Spain, right after durum wheat and barley. The area cultivated to bread wheat has been increasing quickly in the last few years from around 50,000 hectares to more than 100,000 hectares.

The soil and climatic conditions of southern Spain are adequate to produce high quality flours for the bread wheat industry and new cultivars suited for this purpose are being developed by the CIMMYT-Agrovegetal agreement. In a breeding program aiming to select new cultivars with high flour quality and good stability for the most important characters, it is very important to know which of them show a good stability among years and localities and which are the most influenced by the environment.

Materials and methods

The new cultivars 'Escacena', 'Ecija', 'Olvera', 'Jerezano' and 'Vejer', together with the three checks 'Yecora', 'Cartaya' and 'Pinzon', were grown in quadrate lattice with three replicates and plot size of 6 m² in five localities of Andalusia (Spain) during 2000-2001 and 2001-2002: Ecija (Sevilla), Escacena del Campo (Huelva), Jerez de la Frontera, Olvera and Conil (Cádiz). The agronomic practices were according to the standards in each locality. These new cultivars were obtained by the agreement between CIMMYT and Agrovegetal SA.

Yield was measured as kg/ha. The quality traits analysed were test weight and thousand kernel weight, grain and flour moisture content, flour extraction rate, protein concentration, SDS-lactic sedimentation (SDSs) volume measured in ml according to micromethod of Dick and Quick (1983) modified by Peña *et al.* (1990), the gluten index measured in percentage of wet gluten according to Cubbada *et al.* (1992), and the Chopin Alveograph (Tripette & Renaud) parameters (P, L, G, P/L and W), measured according to manufacturer's instructions.

Data were statistically analysed for each locality and all the localities by an analysis of variance (ANOVA). The distribution of phenotypic variance of yield and quality characters in samples collected in five places in 2001and 2002 were determined and compared.

Results and discussion

The distribution of the phenotypic variance (Table 1) showed that the main factor (observed variation above 50%) affecting during the two years the quality traits SDS-sedimentation, falling number and alveograph-W was the cultivar.

$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	Character	haracter Variation factor									Total	
Vield 20011.64E6 69.0^+ $2.92E5$ 12.3 $5.2E5$ 2.2 $3.9E5$ 16.5 $2.3E6$ 100 Yield 2002 $140E+3$ 21.7 $17ZE+3$ 26.8^+ $112E+3$ 17.5 $218E+3$ 34.0^+ $642E+3$ 100 Test weight 2001 2.31 53.8^+ 0.67 15.6 0.66 15.3 0.66 15.3 4.29 100 Test weight 2002 3.96 46.6^+ 2.27 26.7 1.00 11.8 1.27 15.0 8.51 100 1000 kernel weight 2002 9.04 48.6^+ 4.85 26.0 2.32 12.5 2.40 12.9 18.61 100 Grain moisture % 2001 0.34 89.0^+ 0.00 0.0 0.00 0.8 0.04 2.9 1.38 100 Grain moisture % 2001 0.04 4.8 $2E-3$ 1.0 0.02 1.37 $9E-3$ 60.6^+ 0.16 100 Flour moisture % 2001 0.00 4.8 0.00 0.0 0.0 0.8 0.44 2.9 1.38 100 Flour moisture % 2001 0.00 4.8 $2E-3$ 1.0 0.02 13.7 $9E-3$ 60.6^+ 0.16 100 Flour moisture % 2001 0.04 4.8 $2E-3$ 1.0 0.02 13.7 2.17 14.2 15.22 100 Flour extraction % 2001 5.9 5.0^+ $1.6.7$ 36.7 36.1^+ 1.57 100 Spo 2001 <th></th> <th colspan="2">Location (L)</th> <th colspan="2">Cultivar (C)</th> <th colspan="2">Interact. (L x C)</th> <th colspan="2">Error</th> <th>_</th> <th></th>		Location (L)		Cultivar (C)		Interact. (L x C)		Error		_		
Yield 2002140E+321.7172E+326.8"112E+317.5218E+334.0"642E+3100Test weight 20012.3153.8"0.6715.60.6615.30.6615.34.29100Test weight 20023.9646.6"2.773.018.4490.0411.34.2512.63.581001000 kernel weight 20029.0448.6"4.8526.02.3212.52.4012.91.88100Grain moisture % 20021.3194.6"0.021.7"0.100.80.042.9"1.38100Flour moisture % 20010.044.80.000.000.000.008.90.041.0"1.0"Flour moisture % 20010.044.82.531.0"0.001.0"0.0"1.0"		σ^2	%	σ^2	%	σ^2	%	σ^2	%	σ^2	%	
Test weight 20012.3153.8 ⁺ 0.6715.60.6615.30.6615.34.29100Test weight 20023.9646.6 ⁺ 2.2726.71.0011.81.2715.08.511001000 kernel weight 200124.3167.7 ⁺ 3.018.4499.0411.34.5312.635.89100Grain moisture % 20010.3489.0 ⁺ 0.000.00.000.80.0412.91.81010Grain moisture % 20011.3194.6 ⁺ 0.021.70.110.80.042.91.38100Flour moisture % 20021.3490.4 ⁺ 0.021.70.110.80.042.91.38100Flour moisture % 20010.004.80.000.00.000.00.0895.2 ⁺ 0.09100Flour extraction % 20020.4424.82E-31.00.0213.79E-360.6 ⁺ 0.16100Flour extraction % 20023.9526.07.171.420.000.04.7035.713.16100Flour extraction % 20010.162.20.5031.6 ⁺ 0.412.60 ⁺ 0.5736.1 ⁺ 1.52100SDS 20010.9911.05.7864.4 ⁺ 0.070.82.1423.88.98100SDS 20021.6 ⁺ 2.2.41.4013.22.302.164.484.2.0 ⁺ 1.52100Faling num	Yield 2001	1.64E6	69.0†	2.92E5	12.3	5.2E5	2.2	3.9E5	16.5	2.3E6	100	
Test weight 20023.9646.6°2.2726.71.0011.81.2715.08.511001000 kernel weight 200124.3167.7°3.018.4499.0411.34.5312.635.891001000 kernel weight 20029.0448.6°4.8526.02.3212.52.4012.918.61100Grain moisture % 20010.3489.0°0.000.00.880.042.91.38100Grain moisture % 20021.3194.6°0.021.70.010.880.042.91.38100Flour moisture % 20020.042.482E-31.00.021.379E-360.6°0.16100Flour extraction % 20020.942.482E-31.00.021.379E-360.6°0.16100Flour extraction % 20010.5950.1°1.7747.1°1.9312.721.714.215.22100Protein content % 20010.106.20.5031.6°0.4126.0°0.5736.1°1.57100SDS 20010.9911.05.7864.4°0.070.82.1423.88.98100SDS 20021.162.263.0861.1°0.981.80.7114.15.04100Falling number 20012.4723.21.4013.11.4016.63.814.8.6100Fulling number 20012.472.32 <td< td=""><td>Yield 2002</td><td>140E+3</td><td>21.7</td><td>172E+3</td><td>26.8†</td><td>112E+3</td><td>17.5</td><td>218E+3</td><td>34.0†</td><td>642E+3</td><td>100</td></td<>	Yield 2002	140E+3	21.7	172E+3	26.8†	112E+3	17.5	218E+3	34.0†	642E+3	100	
1000 kernel weight 200124.3167,7'3.018.4499.0411.34.5312.635.891001000 kernel weight 20029.0448.6'4.8526.02.3212.52.4012.918.61100Grain moisture % 20010.3489.0'0.000.00.000.80.0410.20.38100Grain moisture % 20021.3194.6'0.021.70.010.80.042.91.38100Flour moisture % 20020.004.80.000.000.000.0895.2'0.09100Flour extraction % 20020.0424.82E-31.00.0213.79E-360.6'0.16100Flour extraction % 20023.9526.07.1747.1'1.9312.72.1714.215.22100Protein content % 20010.106.20.5031.6'0.4126.0'0.5736.1'1.57100SDS 20010.9911.05.7864.4'0.070.82.1423.88.98100SDS 20021.162.263.0661.1'0.091.80.7114.15.04100Falling number 20011.21E410.18358.3469.6'1.4E312.1975.638.11.2E5100Falling number 20022.402.6.81.0'1172.4019.1969.0015.86151.60100 <trr<tr>Wet gluten % 20012.47<!--</td--><td>Test weight 2001</td><td>2.31</td><td>53.8[†]</td><td>0.67</td><td>15.6</td><td>0.66</td><td>15.3</td><td>0.66</td><td>15.3</td><td>4.29</td><td>100</td></trr<tr>	Test weight 2001	2.31	53.8 [†]	0.67	15.6	0.66	15.3	0.66	15.3	4.29	100	
1000 kernel weight 20029.0448,6 ⁺ 4.8526.02.3212.52.4012.918.61100Grain moisture % 20010.3489.0 ⁺ 0.000.00.000.880.041.020.38100Grain moisture % 20021.3194.6 ⁺ 0.021.70.010.80.042.91.38100Flour moisture % 20010.0024.82E-31.00.021.379E-360.6 ⁺ 0.16100Flour extraction % 20016.5950.1 ⁺ 1.871.420.000.04.7035.713.16100Flour extraction % 20023.9526.07.1747.1 ⁺ 1.9312.72.1714.215.22100Protein content % 20010.106.20.5031.6 ⁺ 0.4126.0 ⁺ 0.5736.1 ⁺ 1.57100SDS 20010.9911.05.7864.4 ⁺ 0.070.82.1423.88.98100SDS 20021.1622.63.0861.1 ⁺ 10.91.80.7114.15.04100Falling number 200285.73013.93152.9051.0 ⁺ 1172.4019.1969.0015.86151.60100Falling number 20012.472.321.4013.22.3021.64.4842.0 ⁺ 10.65100Falling number 20012.841.760.2214.10.3622.40.7345.9 ⁺ 1.55100 </td <td>Test weight 2002</td> <td>3.96</td> <td>46.6[†]</td> <td>2.27</td> <td>26.7</td> <td>1.00</td> <td>11.8</td> <td>1.27</td> <td>15.0</td> <td>8.51</td> <td>100</td>	Test weight 2002	3.96	46.6 [†]	2.27	26.7	1.00	11.8	1.27	15.0	8.51	100	
Grain moisture % 20010.3489.0°0.000.000.000.880.041.020.38100Grain moisture % 20021.3194.6°0.021.70.010.80.042.91.38100Flour moisture % 20020.044.80.000.00.000.0895.2°0.09100Flour moisture % 20020.0424.82E-31.00.0213.79E-360.6°0.16100Flour extraction % 20016.5950.1°1.8714.20.000.04.7035.713.16100Flour extraction % 20023.9526.07.1747.1°1.9312.72.1714.215.22100Protein content % 20010.106.20.5031.6°0.1610.70.4730.91.52100SDS 20010.9911.05.7864.4°0.070.82.1423.88.98100SDS 20021.1622.63.0861.1°0.991.80.7114.15.04100Falling number 20011.21E410.1835.3469.6°1.4E312.1975.638.11.2E5100Falling number 20022.402.631.4013.22.3021.64.4842.0°10.6510.5Falling number 20012.472.472.221.4013.22.3021.63.8.14.5.41.5.510.5Falling number 2002<	1000 kernel weight 2001	24.31	67.7 [†]	3.01	8.4	499.04	11.3	4.53	12.6	35.89	100	
Grain moisture % 20010.3489.0°0.000.00.000.880.041.020.38100Grain moisture % 20021.3194.6°0.021.70.010.80.042.91.38100Flour moisture % 20010.004.80.000.00.000.0895.2°0.09100Flour moisture % 20020.0424.82E-31.00.0213.79E-360.6°10.61100Flour extraction % 20016.5950.1°1.8714.20.000.44.7035.713.16100Flour extraction % 20010.106.20.5031.6°0.1426.0°0.5736.1°1.52100Protein content % 20020.4932.4°0.4026.10.1610.70.4730.91.52100SDS 20010.9911.05.7864.4°0.070.82.1423.88.98100Falling number 20011.21E410.1835.3469.6°1.4E312.1975.638.11.2E5100Falling number 20012.472.321.4013.22.3021.64.484.0°1.65100Vet gluten % 20010.2817.60.221.411.4016.63.814.3.4°8.80100Dry gluten % 20010.2817.60.221.411.4016.44.3.4°1.50105Gluten index 20014.8216.3 <td>1000 kernel weight 2002</td> <td>9.04</td> <td>48.6[†]</td> <td>4.85</td> <td>26.0</td> <td>2.32</td> <td>12.5</td> <td>2.40</td> <td>12.9</td> <td>18.61</td> <td>100</td>	1000 kernel weight 2002	9.04	48.6 [†]	4.85	26.0	2.32	12.5	2.40	12.9	18.61	100	
Flour moisture % 20010.004.80.000.000.000.010.0895.2*0.09100Flour moisture %20020.0424.82E-31.00.0213.79E-360.6*0.16100Flour extraction % 20023.9526.07.1747.1*1.9312.72.1714.215.22100Protein content % 20010.106.20.5031.6*0.4126.0*0.5736.1*1.57100Protein content % 20020.4932.4*0.4026.10.1610.70.4730.91.52100SDS 20010.9911.05.7864.4*0.070.82.1423.88.98100SDS 20021.1622.63.0861.1*0.991.80.7114.15.04100Falling number 200285.7313.93152.9051.0*11.4*172.4019.1969.0*15.86151.60100Wet gluten % 20012.442.381.1013.11.4016.63.8143.4*8.80100Wet gluten % 20012.442.681.10*13.1*1.40*16.63.8143.4*8.80100Dry gluten % 20010.281.760.221.410.362.440.7345.9*1.59*10.5*Org gluten % 20010.4431.70.5214.10.362.440.3448.9*1.05*100Dry gluten %	Grain moisture % 2001	0.34		0.00	0.0	0.00	0.8	0.04	10.2	0.38	100	
Flour moisture %20020.0424.82E-31.00.0213.79E-360.6 ⁺ 0.16100Flour extraction % 20016.5950.1 ⁺ 1.8714.20.000.04.7035.713.16100Flour extraction % 20023.9526.07.1747.1 ⁺ 1.9312.72.1714.215.22100Protein content % 20010.106.20.5031.6 ⁺ 0.4126.0 ⁺ 0.5736.1 ⁺ 1.57100Protein content % 20020.4932.4 ⁺ 0.4026.10.1610.70.4730.91.52100SDS 20010.9911.05.7864.4 ⁺ 0.070.82.1423.88.98100SDS 20021.1622.63.0861.1 ⁺ 0.091.80.7114.15.04100Falling number 20011.21E410.18358.3469.6 ⁺ 1.4E312.1975.638.11.2E5100Falling number 2002857.3013.93152.9051.0 ⁺ 1172.4019.1969.0015.86151.60100Wet gluten % 20012.4723.21.4013.22.3021.64.4842.0 ⁺ 10.65100Dry gluten % 20022.402.481.1013.11.4016.63.8143.4 ⁺ 8.80100Dry gluten % 20010.2817.60.2214.10.3622.40.7345.9 ⁺ 1.59100 <td>Grain moisture % 2002</td> <td>1.31</td> <td>94.6[†]</td> <td>0.02</td> <td>1.7</td> <td>0.01</td> <td>0.8</td> <td>0.04</td> <td>2.9</td> <td>1.38</td> <td>100</td>	Grain moisture % 2002	1.31	94.6 [†]	0.02	1.7	0.01	0.8	0.04	2.9	1.38	100	
Flour extraction % 20016.5950.1 ⁺ 1.8714.20.000.04.7035.713.16100Flour extraction % 20023.9526.07.1747.1 ⁺ 1.9312.72.1714.215.22100Protein content % 20020.4932.4 ⁺ 0.4026.10.1610.70.4730.91.52100SDS 20010.9911.05.7864.4 ⁺ 0.070.82.1423.88.98100SDS 20021.1622.63.0861.1 ⁺ 0.991.80.7114.15.04100Falling number 20011.21E410.1835.3469.6 ⁺ 1.4E312.1975.638.11.2E5100Falling number 2002857.3013.93152.9051.0 ⁺ 1172.4019.1969.0015.86151.60100Wet gluten % 20012.4723.21.4013.22.3021.64.4842.0 ⁺ 10.65100Wet gluten % 20022.402.681.1013.11.4016.63.8143.4 ⁺ 8.00100Dry gluten % 20020.4031.70.1512.20.1612.80.5443.2 ⁺ 1.25100Gluten index 20014.8216.38.302.658.913.8546.6 ⁺ 31.00100P 200114.335.417.6766.9 ⁺ 39.7114.934.4012.926.71100P 200114.33 </td <td>Flour moisture % 2001</td> <td>0.00</td> <td>4.8</td> <td>0.00</td> <td>0.0</td> <td>0.00</td> <td>0.0</td> <td>0.08</td> <td>95.2[†]</td> <td>0.09</td> <td>100</td>	Flour moisture % 2001	0.00	4.8	0.00	0.0	0.00	0.0	0.08	95.2 [†]	0.09	100	
Flour extraction % 20023.952.6.07.1747.1°1.9312.72.1714.215.22100Protein content % 20010.106.20.5031.6°0.4126.0°0.5736.1°1.57100Protein content % 20020.4932.4°0.4026.10.1610.70.4730.91.52100SDS 20021.1622.63.0861.1°0.091.80.7114.15.04100Falling number 20011.21E410.18358.3469.6°1.4E312.1975.638.11.2E5100Falling number 2002857.3013.9315.2951.0°1172.4019.1969.0015.86151.60100Wet gluten % 20012.4723.21.4013.22.3021.64.4842.0°10.65100Wet gluten % 20022.4026.81.1013.11.4016.63.8143.4°8.80100Dry gluten % 20020.4031.70.1512.20.1612.80.5443.2°1.55100Gluten index 20014.8216.38.3028.02.658.913.8546.8°29.61100P 20014.8216.38.302.658.913.8546.8°29.61100P 20023.6011.49.7031.33.4011.014.4046.3°31.00100P 200114.335.4178.67	Flour moisture %2002	0.04	24.8	2E-3	1.0	0.02	13.7	9E-3	60.6^{+}	0.16	100	
Protein content % 20010.106.20.5031.6°0.4126.0°0.5736.1°1.57100Protein content % 20020.4932.4°0.4026.10.1610.70.4730.91.52100SDS 20021.1622.63.0861.1°0.091.80.7114.15.04100Falling number 20011.21E410.18358.3469.6°1.4E312.1975.638.11.2E5100Falling number 2002857.3013.9315.29051.0°1172.4019.1969.0015.86151.60100Wet gluten % 20012.4723.21.4013.22.3021.64.4842.0°10.65100Wet gluten % 20022.4026.81.1013.11.4016.63.8143.4°8.80100Dry gluten % 20020.4031.70.1512.20.1612.80.5443.2°1.55100Dry gluten % 20020.4031.70.1512.20.1612.80.5443.2°1.55100Dry gluten % 20020.4031.70.1512.20.1612.80.5443.2°1.55100Dry gluten % 20020.4031.70.1512.20.1612.80.5443.2°1.55100Dry gluten % 20023.6011.49.7031.33.4011.014.4046.3°31.00100Dry gluten % 2002 <td>Flour extraction % 2001</td> <td>6.59</td> <td>50.1†</td> <td>1.87</td> <td>14.2</td> <td>0.00</td> <td>0.0</td> <td>4.70</td> <td>35.7</td> <td>13.16</td> <td>100</td>	Flour extraction % 2001	6.59	50.1†	1.87	14.2	0.00	0.0	4.70	35.7	13.16	100	
Protein content % 20020.4932.4 [†] 0.4026.10.1610.70.4730.91.52100SDS 20010.9911.05.7864.4 [†] 0.070.82.1423.88.98100SDS 20021.1622.63.0861.1 [†] 0.091.80.7114.15.04100Falling number 20011.21E410.18358.3469.6 [†] 1.4E312.1975.638.11.2E5100Falling number 2002857.3013.93152.9051.0 [†] 1172.4019.1969.0015.86151.60100Wet gluten % 20012.4723.21.4013.22.3021.64.4842.0 [†] 10.65100Dry gluten % 20022.4026.81.1013.11.4016.63.8143.4 [‡] 8.80100Dry gluten % 20010.2817.60.2214.10.3622.40.7345.9 [‡] 1.59100Dry gluten % 20020.4031.70.1512.20.1612.80.5443.2 [‡] 1.59100Gluten index 20014.8216.38.3028.02.658.913.8546.8 [‡] 29.61100P 200114.335.4178.6766.9 [‡] 39.7114.934.4012.9267.12100P 200223.9612.893.0049.7 [‡] 49.2526.320.8411.1187.06100L 200136.33 <td>Flour extraction % 2002</td> <td>3.95</td> <td>26.0</td> <td>7.17</td> <td>47.1[†]</td> <td>1.93</td> <td>12.7</td> <td>2.17</td> <td>14.2</td> <td>15.22</td> <td>100</td>	Flour extraction % 2002	3.95	26.0	7.17	47.1 [†]	1.93	12.7	2.17	14.2	15.22	100	
SDS 20010.9911.05.7864.4 [†] 0.070.82.1423.88.98100SDS 20021.1622.63.0861.1 [†] 0.091.80.7114.15.04100Falling number 20011.21E410.18358.3469.6 [†] 1.4E312.1975.638.11.2E5100Falling number 2002857.3013.93152.9051.0 [†] 1172.4019.1969.0015.86151.60100Wet gluten % 20012.4723.21.4013.22.3021.64.4842.0 [†] 10.65100Dry gluten % 20022.4026.81.1013.11.4016.63.8143.4 [†] 8.80100Dry gluten % 20010.2817.60.2214.10.3622.40.7345.9 [†] 1.59100Gluten index 20014.8216.38.3028.02.658.913.8546.8 [†] 29.61100Gluten index 20014.8216.38.3028.02.658.913.8546.8 [†] 29.61100P 200114.335.4178.6766.9 [†] 39.7114.934.4012.9267.12100P 200223.9612.893.0049.7 [†] 49.2526.320.8411.1187.06100L 2001306.3329.6 [†] 32.8132.2 [†] 187.2518.1218.9021.11036.2100L 2002313.61<	Protein content % 2001	0.10	6.2	0.50	31.6†	0.41	26.0†	0.57	36.1†	1.57	100	
SDS 20021.1622.63.0861.1°0.091.80.7114.15.04100Falling number 20011.21E410.18358.3469.6°1.4E312.1975.638.11.2E5100Falling number 2002857.3013.93152.9051.0°1172.4019.1969.0015.86151.60100Wet gluten % 20012.4723.21.4013.22.3021.64.4842.0°10.65100Wet gluten % 20022.4026.81.1013.11.4016.63.8143.4°8.80100Dry gluten % 20020.4031.70.1512.20.1612.80.5443.2°1.59100Dry gluten % 20020.4031.70.1512.20.1612.80.5443.2°1.25100Gluten index 20014.8216.38.3028.02.658.913.8546.8°29.61100Gluten index 20023.6011.49.7031.33.4011.014.4046.3°31.00100P 200114.335.4178.6766.9°39.7114.934.4012.9267.12100P 200223.9612.893.0049.7°49.2526.320.8411.1187.06100L 2001306.3329.6°32.8132.2°187.2518.1218.9021.11036.2100G 20013.6231.0°	Protein content % 2002	0.49	32.4†	0.40	26.1	0.16	10.7	0.47	30.9	1.52	100	
SDS 20021.1622.63.0861.1°0.091.80.7114.15.04100Falling number 20011.21E410.18358.3469.6°1.4E312.1975.638.11.2E5100Falling number 2002857.3013.93152.9051.0°1172.4019.1969.0015.86151.60100Wet gluten % 20012.4723.21.4013.22.3021.64.4842.0°10.65100Wet gluten % 20022.4026.81.1013.11.4016.63.8143.4°8.80100Dry gluten % 20020.4031.70.1512.20.1612.80.5443.2°1.59100Dry gluten % 20020.4031.70.1512.20.1612.80.5443.2°1.25100Gluten index 20014.8216.38.3028.02.658.913.8546.8°29.61100Gluten index 20023.6011.49.7031.33.4011.014.4046.3°31.00100P 200114.335.4178.6766.9°39.7114.934.4012.9267.12100P 200223.9612.893.0049.7°49.2526.320.8411.1187.06100L 2001306.3329.6°32.8132.2°187.2518.1218.9021.11036.2100G 20013.6231.0°	SDS 2001	0.99	11.0	5.78	64.4 [†]	0.07	0.8	2.14	23.8	8.98	100	
Falling number 20011.21E410.18358.3469.6*1.4E312.1975.638.11.2E5100Falling number 2002857.3013.93152.9051.0*1172.4019.1969.0015.86151.60100Wet gluten % 20012.4723.21.4013.22.3021.64.4842.0*10.65100Wet gluten % 20022.4026.81.1013.11.4016.63.8143.4*8.80100Dry gluten % 20010.2817.60.2214.10.3622.40.7345.9*1.59100Dry gluten % 20020.4031.70.1512.20.1612.80.5443.2*1.25100Gluten index 20014.8216.38.3028.02.658.913.8546.8*29.61100Gluten index 20023.6011.49.7031.33.4011.014.4046.3*31.00100P 200114.335.4178.6766.9*39.7114.934.4012.9267.12100P 200223.9612.893.0049.7*49.2526.320.8411.1187.06100L 2001306.3329.6*298.3525.3*300.3025.5*267.4422.8*1179.71100G 20013.6231.0*3.6531.3*1.8315.62.5822.111.67104G 20022.7026.0* <td>SDS 2002</td> <td>1.16</td> <td>22.6</td> <td>3.08</td> <td></td> <td>0.09</td> <td>1.8</td> <td>0.71</td> <td>14.1</td> <td>5.04</td> <td>100</td>	SDS 2002	1.16	22.6	3.08		0.09	1.8	0.71	14.1	5.04	100	
Wet gluten % 20012.4723.21.4013.22.3021.64.4842.0†10.65100Wet gluten % 20022.4026.81.1013.11.4016.63.8143.4†8.80100Dry gluten % 20010.2817.60.2214.10.3622.40.7345.9†1.59100Dry gluten % 20020.4031.70.1512.20.1612.80.5443.2†1.25100Gluten index 20014.8216.38.3028.02.658.913.8546.8†29.61100Gluten index 20023.6011.49.7031.33.4011.014.4046.3†31.00100P 200114.335.4178.6766.9†39.7114.934.4012.9267.12100P 200223.9612.893.0049.7†49.2526.320.8411.1187.06100L 2001306.3329.6†323.8132.2†187.2518.1218.9021.11036.2100L 2002313.6126.6†298.3525.3†300.3025.5†267.4422.8†1179.71100G 20013.6231.0†3.6531.3†1.8315.62.5822.111.67100G 20022.7026.0†2.8026.8†2.6025.2†2.3022.0†10.40100W 2001720.0712.4323.21655.7†	Falling number 2001	1.21E4	10.1	8358.34		1.4E3	12.1	975.63	8.1	1.2E5	100	
Wet gluten % 20022.4026.81.1013.11.4016.63.8143.4†8.80100Dry gluten % 20010.2817.60.2214.10.3622.40.7345.9†1.59100Dry gluten % 20020.4031.70.1512.20.1612.80.5443.2†1.25100Gluten index 20014.8216.38.3028.02.658.913.8546.8†29.61100Gluten index 20023.6011.49.7031.33.4011.014.4046.3†31.00100P 200114.335.4178.6766.9†39.7114.934.4012.9267.12100P 200223.9612.893.0049.7†49.2526.320.8411.1187.06100L 2001306.3329.6†323.8132.2†187.2518.1218.9021.11036.2100L 2002313.6126.6†298.3525.3†300.3025.5†267.4422.8†1179.71100G 20013.6231.0†3.6531.3†1.8315.62.5822.111.67100G 20022.7026.0†2.8026.8†2.6025.2†2.3022.0†10.40100W 2001720.0712.43232.1655.7†960.8816.6891.3815.45804.4100W 20021945.4127.13861.8453.7†	Falling number 2002	857.30	13.9	3152.90	51.0 [†]	1172.40	19.1	969.00	15.8	6151.60	100	
Dry gluten % 20010.2817.60.2214.10.3622.40.7345.9†1.59100Dry gluten % 20020.4031.70.1512.20.1612.80.5443.2†1.25100Gluten index 20014.8216.38.3028.02.658.913.8546.8†29.61100Gluten index 20023.6011.49.7031.33.4011.014.4046.3†31.00100P 200114.335.4178.6766.9†39.7114.934.4012.9267.12100P 200223.9612.893.0049.7†49.2526.320.8411.1187.06100L 2001306.3329.6†323.8132.2†187.2518.1218.9021.11036.2100L 2002313.6126.6†298.3525.3†300.3025.5†267.4422.8†1179.71100G 20013.6231.0†3.6531.3†1.8315.62.5822.111.67100G 20022.7026.0†2.8026.8†2.6025.2†2.3022.0†10.40100W 2001720.0712.43232.1655.7†960.8816.6891.3815.45804.4100W 20021945.4127.13861.8453.7†395.935.5983.8316.77187.01100	Wet gluten % 2001	2.47	23.2	1.40	13.2	2.30	21.6	4.48	42.0 [†]	10.65	100	
Dry gluten % 20020.4031.70.1512.20.1612.80.5443.2†1.25100Gluten index 20014.8216.38.3028.02.658.913.8546.8†29.61100Gluten index 20023.6011.49.7031.33.4011.014.4046.3†31.00100P 200114.335.4178.6766.9†39.7114.934.4012.9267.12100P 200223.9612.893.0049.7†49.2526.320.8411.1187.06100L 2001306.3329.6†323.8132.2†187.2518.1218.9021.11036.2100L 2002313.6126.6†298.3525.3†300.3025.5†267.4422.8†1179.71100G 20013.6231.0†3.6531.3†1.8315.62.5822.111.67100G 20022.7026.0†2.8026.8†2.6025.2†2.3022.0†10.40100W 2001720.0712.43232.1655.7†960.8816.6891.3815.45804.4100W 20021945.4127.13861.8453.7†395.935.5983.8316.77187.01100	Wet gluten % 2002	2.40	26.8	1.10	13.1	1.40	16.6	3.81	43.4 [†]	8.80	100	
Dry gluten % 20020.4031.70.1512.20.1612.80.5443.2†1.25100Gluten index 20014.8216.38.3028.02.658.913.8546.8†29.61100Gluten index 20023.6011.49.7031.33.4011.014.4046.3†31.00100P 200114.335.4178.6766.9†39.7114.934.4012.9267.12100P 200223.9612.893.0049.7†49.2526.320.8411.1187.06100L 2001306.3329.6†323.8132.2†187.2518.1218.9021.11036.2100L 2002313.6126.6†298.3525.3†300.3025.5†267.4422.8†1179.71100G 20013.6231.0†3.6531.3†1.8315.62.5822.111.67100G 20022.7026.0†2.8026.8†2.6025.2†2.3022.0†10.40100W 2001720.0712.43232.1655.7†960.8816.6891.3815.45804.4100W 20021945.4127.13861.8453.7†395.935.5983.8316.77187.01100	Dry gluten % 2001	0.28	17.6	0.22	14.1	0.36	22.4	0.73	45.9 [†]	1.59	100	
Gluten index 20014.8216.38.3028.02.658.913.8546.8†29.61100Gluten index 20023.6011.49.7031.33.4011.014.4046.3†31.00100P 200114.335.4178.6766.9†39.7114.934.4012.9267.12100P 200223.9612.893.0049.7†49.2526.320.8411.1187.06100L 2001306.3329.6†323.8132.2†187.2518.1218.9021.11036.2100L 2002313.6126.6†298.3525.3†300.3025.5†267.4422.8†117.97.1100G 20013.6231.0†3.6531.3†1.8315.62.5822.111.67100G 20022.7026.0†2.8026.8†2.6025.2†2.3022.0†10.40100W 2001720.0712.4323.21655.7†960.8816.6891.3815.45804.4100W 20021945.4127.13861.8453.7†395.935.5983.8316.77187.01100	Dry gluten % 2002	0.40	31.7	0.15	12.2	0.16	12.8	0.54		1.25	100	
Gluten index 20023.6011.49.7031.33.4011.014.4046.3 ⁺ 31.00100P 200114.335.4178.6766.9 ⁺ 39.7114.934.4012.9267.12100P 200223.9612.893.0049.7 ⁺ 49.2526.320.8411.1187.06100L 2001306.3329.6 ⁺ 323.8132.2 ⁺ 187.2518.1218.9021.11036.2100L 2002313.6126.6 ⁺ 298.3525.3 ⁺ 300.3025.5 ⁺ 267.4422.8 ⁺ 1179.71100G 20013.6231.0 ⁺ 3.6531.3 ⁺ 1.8315.62.5822.111.67100G 20022.7026.0 ⁺ 2.8026.8 ⁺ 2.6025.2 ⁺ 2.3022.0 ⁺ 10.40100W 2001720.0712.43232.1655.7 ⁺ 960.8816.6891.3815.45804.4100W 20021945.4127.13861.8453.7 ⁺ 395.935.5983.8316.77187.01100	Gluten index 2001	4.82	16.3	8.30	28.0	2.65	8.9	13.85		29.61	100	
P 200223.9612.893.0049.7†49.2526.320.8411.1187.06100L 2001306.3329.6†323.8132.2†187.2518.1218.9021.11036.2100L 2002313.6126.6†298.3525.3†300.3025.5†267.4422.8†1179.71100G 20013.6231.0†3.6531.3†1.8315.62.5822.111.67100G 20022.7026.0†2.8026.8†2.6025.2†2.3022.0†10.40100W 2001720.0712.43232.1655.7†960.8816.6891.3815.45804.4100W 20021945.4127.13861.8453.7†395.935.5983.8316.77187.01100	Gluten index 2002	3.60	11.4	9.70	31.3	3.40	11.0	14.40		31.00	100	
P 200223.9612.893.0049.7 [†] 49.2526.320.8411.1187.06100L 2001306.3329.6 [†] 323.8132.2 [†] 187.2518.1218.9021.11036.2100L 2002313.6126.6 [†] 298.3525.3 [†] 300.3025.5 [†] 267.4422.8 [†] 1179.71100G 20013.6231.0 [†] 3.6531.3 [†] 1.8315.62.5822.111.67100G 20022.7026.0 [†] 2.8026.8 [‡] 2.6025.2 [‡] 2.3022.0 [‡] 10.40100W 2001720.0712.43232.1655.7 [‡] 960.8816.6891.3815.45804.4100W 20021945.4127.13861.8453.7 [‡] 395.935.5983.8316.77187.01100	P 2001	14.33	5.4	178.67	66.9 [†]	39.71	14.9	34.40		267.12	100	
L 2001306.3329.6 [†] 323.8132.2 [†] 187.2518.1218.9021.11036.2100L 2002313.6126.6 [†] 298.3525.3 [†] 300.3025.5 [†] 267.4422.8 [†] 1179.71100G 20013.6231.0 [†] 3.6531.3 [†] 1.8315.62.5822.111.67100G 20022.7026.0 [†] 2.8026.8 [‡] 2.6025.2 [†] 2.3022.0 [†] 10.40100W 2001720.0712.43232.1655.7 [†] 960.8816.6891.3815.45804.4100W 20021945.4127.13861.8453.7 [†] 395.935.5983.8316.77187.01100	P 2002	23.96	12.8	93.00		49.25	26.3	20.84	11.1	187.06	100	
L 2002313.6126.6 [†] 298.3525.3 [†] 300.3025.5 [†] 267.4422.8 [†] 1179.71100G 20013.6231.0 [†] 3.6531.3 [†] 1.8315.62.5822.111.67100G 20022.7026.0 [†] 2.8026.8 [†] 2.6025.2 [†] 2.3022.0 [†] 10.40100W 2001720.0712.43232.1655.7 [†] 960.8816.6891.3815.45804.4100W 20021945.4127.13861.8453.7 [†] 395.935.5983.8316.77187.01100	L 2001	306.33	29.6†	323.81		187.25	18.1	218.90	21.1	1036.2	100	
G 20013.6231.0 [†] 3.6531.3 [†] 1.8315.62.5822.111.67100G 20022.7026.0 [†] 2.8026.8 [†] 2.6025.2 [†] 2.3022.0 [†] 10.40100W 2001720.0712.43232.1655.7 [†] 960.8816.6891.3815.45804.4100W 20021945.4127.13861.8453.7 [†] 395.935.5983.8316.77187.01100	L 2002	313.61		298.35		300.30	25.5 [†]	267.44	22.8 [†]	1179.71	100	
G 20022.7026.0†2.8026.8†2.6025.2†2.3022.0†10.40100W 2001720.0712.43232.1655.7†960.8816.6891.3815.45804.4100W 20021945.4127.13861.8453.7†395.935.5983.8316.77187.01100	G 2001	3.62						2.58		11.67	100	
W 2002 1945.41 27.1 3861.84 53.7 [†] 395.93 5.5 983.83 16.7 7187.01 100	G 2002	2.70		2.80		2.60	25.2 [†]	2.30	22.0†	10.40	100	
W 2002 1945.41 27.1 3861.84 53.7 [†] 395.93 5.5 983.83 16.7 7187.01 100							-		-			
	P/L 2001	0.05	27.8†	0.06	34.3†	0.02	13.1	0.04	24.8	0.17	100	
P/L 2002 8E-3 17.3 0.01 22.7 0.019 39.0 ⁺ 0.01 21.1 0.05 100								0.01			100	

Table 1.Distribution of phenotypic variance of yield and quality characters in 2001 and 2002

[†]Most important component/s of phenotypic variance for each character.

The influence of location, cultivar and their interaction on all other quality parameters varied with year of testing. For SDS-sedimentation, falling number and alveograph-W, which showed high stability in southern Spain, samples from only two or three trial locations are considered enough for determining the suitability of each new cultivars for industrial purposes. Otherwise for other important traits such as specific weight, protein content, and extensibility (L and P/L), we need samples from at least four or more locations due the low stability of these characters.

The data showed the low screening value of measuring some characters to compare the industrial quality of new cultivars due to the huge influence of locations (specific weight, thousand kernel weight and grain moisture) and errors (flour moisture, wet and dry gluten % and gluten index).

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