Selection indices for quality evaluation in wheat breeding

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Summary. From multilocation trials involving 125 cultivars of wheat of mainly French and European origin four tests – protein content, Pelshenke, modified Zeleny and the mixograph – were used to establish six selection indices. Three of these indices – IW 1, IW 2 and IW 3 – were calculated in order to evaluate the genetic potentiality of the lines for dough strength as given by the Chopin alveograph. The indices IV 1, IV 2 and IV 3 were established to evaluate loaf volume as measured by the French bread-making standard. A quality index IQ was calculated from the allelic effects of the high-molecular-weight (HMW) subunits of glutenin from 195 cultivars assessed by the Chopin alveograph and the Pelshenke test. Comparison of the relative efficiency of each of the six indices to the individual tests revealed the superiority of the indices over one or several technological parameters. The six selection indices and the quality index were compared using 30 very diverse lines. Their ability to retain the good quality lines is discussed in particular.

Key words: Bread wheat – Technological quality – Loaf volume – Gluten strength – Heritability

Introduction

Breeders use various tests to evaluate wheat quality. These tests are based on the end-use quality objective of the breeding programmes, but there are also one or several indirect technological tests commonly used in a particular country and they must be feasible in the F 3, F 4 or F 5 generations. In addition to the analysis of the allelic composition of the high-molecular-weight subunits of glutenins (HMW-GS) (Payne et al. 1981) and of gliadins (Sozinov and Poperelya 1980) which can be carried out from single kernels, or half grains (Bietz et al. 1975), breeders may have many other technological tests at their disposal. Some tests have been found to be more useful than others for predicting the quality of North American wheats (Baker et al. 1971; Fowler and de la Roche 1975). With respect to European bread wheats, Branlard et al. (1991) compared 17 technological tests for their ability to be both highly heritable and correlated to quality. Some technological parameters, for example, modified Zeleny, Pelshenke test and mixograph criteria, were more suitable for predicting gluten strength or loaf volume than others. As wheat quality is the result of many components, each having different technological properties, which cannot be evaluated by only one indirect test, it appears that a very judicious combination of a few test parameters is necessary for improving the efficiency of wheat quality breeding. Some studies have formed quality indices by combining several technological parameters (Cox et al. 1989). Surprisingly, no selection index has been established for wheat quality as has been for many other agronomic characteristics of plants. The theory of genetic indices first developed by Smith (1936) on wheat was used with success for improving the genetic value of different traits in many crops, such as grain yield in maize (Robinson et al. 1951) grain and straw yield in oats (Eagles and Frey 1974) or yield and protein content in maize (Motto and Perenzin 1982; see Baker 1986 for review).

In the study presented here several indices will be established, six of which were calculated from a limited number of technological tests, each using a small amount of grain, and another from the allelic composition of the allelic composition of the HMW-GS. Their relative efficiency for improving the genotypic value of strength and loaf volume will be calculated and particularly discussed with particular reference to use F 4 offspring.
Material and methods

The six technological indices consisted of IW1, IW2, and IW3, established for improving the genotypic values of strength as evaluated by the Chopin alveograph, and IV1, IV2, and IV3 for bread loaf volume.

Plant material

The six indices IW and IV were established from a total of 125 bread wheat cultivars of European origin and experimentally evaluated for 3 years (1985–1987) in six, seven and five locations, respectively, in France. These multilocation trials enabled us to compare 46 technological parameters (Branlard et al. 1991). Seventy other cultivars of very diverse genetic origins and range of quality were grown each year by the INRA wheat laboratory of Clermont-Ferrand. These seventy cultivars were used to relate gliadin and HMW-GS polymorphism to technological quality (Branlard and Dardevet 1985 a, b) and were added to the previous ones also grown at Clermont-Ferrand. The means of the technological values of these 195 cultivars were used to establish the quality index IQ from their allelic HMW-GS composition.

The relative efficiency and the correlations between the indices IW, IV, and IQ were computed from the 125 cultivars. The indices were compared using 30 F4 lines derived from offspring from several complex crossings including 8 diverse bread wheat cultivars as different combinations between 37 parents. This population was selected during a 3-year breeding programme from 1987 to 1989. In the second year, plants were selected for resistance to disease and for quality using IQ. In the third year these 30 lines were used as experimental material for agronomic purposes at seven locations, and their technological qualities were evaluated from only one location.

Technological tests

From the 17 technological tests previously compared, the following were retained to build the indices of technology IW and IV: protein content (Pro), Pelshenke (Pel), modified Zeleny (Zym) and mixograph (Mixo).

The protein content was estimated on wholemeal flour by Near Infrared Reflectance (NIR). The modification of the mixograph test had seven parameters, consequently the maximum number of parameters used as explanatory variates xj of the strength and loaf volume was ten. The initial variates xj were standardized $x_j = (x_j - m_j)/a_j$ (where $m_j$ and $a_j$ are the mean and standard deviation of xj respectively), before calculating the multiple regression for predicting the strength W or the loaf volume LV. IW1 and IV1 were calculated as functions of three tests: Pro, Pel and Zym. IW2 and IV2 were calculated from Pro, Pel and Mixo, whereas IW3 and IV3 used only Pro and Mixo. The optimum number p of explanatory variates xj introduced in the multiple regression was obtained as previously described (Branlard and Dardevet 1985 a).

The general formula of indices IW and IV is written as follows

$$I_W = \sum_{j=1}^{p} a_j x_j$$

Table 1. Coefficients used in calculating the selection indices: $h^2$, general heritability; $W_i$ and $V_i$, $\beta_j$ coefficients obtained from the multiple regression to explain dough strength W and loaf volume LV, respectively

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Abbreviation</th>
<th>Units</th>
<th>Maximum</th>
<th>$H^2$</th>
<th>W1</th>
<th>W2</th>
<th>W3</th>
<th>V1</th>
<th>V2</th>
<th>V3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>Pro</td>
<td>%db</td>
<td>18</td>
<td>0.247</td>
<td>0.175</td>
<td>0.192</td>
<td>0.255</td>
<td>-0.159</td>
<td>-0.123</td>
<td>0.091</td>
</tr>
<tr>
<td>Pelshenke</td>
<td>Pel</td>
<td>min</td>
<td>305</td>
<td>0.633</td>
<td>0.337</td>
<td>0.299</td>
<td>0.095</td>
<td>0.145</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zeleny modified</td>
<td>Zym</td>
<td>ml</td>
<td>59</td>
<td>0.632</td>
<td>0.526</td>
<td>0.652</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixographe time at maximum</td>
<td>MTM</td>
<td>min</td>
<td>5.7</td>
<td>0.472</td>
<td>-1.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height at maximum</td>
<td>MHM</td>
<td>cm</td>
<td>9.4</td>
<td>0.437</td>
<td>-0.250</td>
<td>1.692</td>
<td>-1.574</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thickness at maximum</td>
<td>MTH</td>
<td>cm</td>
<td>5.6</td>
<td>0.403</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height at 7 min</td>
<td>MH7</td>
<td>cm</td>
<td>7.9</td>
<td>0.546</td>
<td>0.365</td>
<td>0.728</td>
<td>-2.241</td>
<td>2.090</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thickness at 7 min</td>
<td>MT7</td>
<td>cm</td>
<td>3.2</td>
<td>0.565</td>
<td>0.333</td>
<td>0.316</td>
<td>0.193</td>
<td>-0.233</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MTM x MHM</td>
<td>MTM x MHM</td>
<td>–</td>
<td>36.0</td>
<td>0.557</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Index mixo</td>
<td>MIN</td>
<td>–</td>
<td>47.5</td>
<td>0.618</td>
<td></td>
<td></td>
<td></td>
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</table>

$R^2 = 0.75, 0.81, 0.78, 0.43, 0.60, 0.60$

$n = 125$