

Genetic improvement trends in agronomic performances and end-use quality characteristics among hard red winter wheat cultivars in Nebraska

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Received 1 September 2004; accepted 20 April 2005

Key words: bread wheat, genetic gain, grain yield, GXE, *Triticum aestivum*

Summary

Evaluation of wheat cultivars from different eras allows breeders to determine changes in agronomic and end-use quality characteristics associated with grain yield and end-use quality improvement over time. The objective of this research was to examine the trends in agronomic and end-use quality characteristics of hard red winter wheat cultivars grown in Nebraska. Thirty historically important and popular hard red winter wheat cultivars introduced or released between 1874 and 2000 were evaluated at Lincoln, Mead and North Platte, Nebraska in 2002 and 2003. An alpha lattice design with 15 incomplete blocks of two plots and three replications was used at all locations. Agronomic (days to flowering, plant height, spike length, culm length, grain yield and yield components, and grain volume weight) and end-use quality (flour yield, SDS-sedimentation value, flour protein content, and mixograph time and tolerance) traits were measured in each environment. Highly significant differences were observed among environments, genotypes and their interactions for most agronomic and end-use quality characteristics. Unlike modern cultivars, older cultivars were low yielding, and less responsive to favorable environments for grain yield and yield components. Semidwarf cultivars were more stable for plant height than traditional medium to tall cultivars. All cultivars had high grain volume weight since it is part of the grading system and highly selected for in cultivar release. Modern cultivars were less stable than older cultivars for SDS-sedimentation and mixing tolerance. However, the stability of older cultivars was attributed to their having weak mixing tolerance and reduced SDS-sedimentation values. The reduced protein content of modern cultivars was offset by increased functionality, as measured by mixograph and SDS sedimentation. In conclusion, breeders have tailored agronomic and end-use quality traits essential for hard red winter wheat production and marketing in Nebraska.

Hard red winter wheat (*Triticum aestivum* L.) is the largest wheat class produced and exported from the U.S.A. It is mainly produced in the Great Plains for grain, though in the Southern Great Plains, it is often grazed as forage prior to stem elongation (Khalil et al., 2002a). Though there is decreasing hectareage, the average production and yield of winter wheat has consistently increased in the U.S.A.. From 1909 to 2003, the average winter wheat yield in Nebraska increased six-fold from 0.5 to 3.2 tonnes per ha (NASS, 2003) due to cultivars with improved agronomic characters and

appropriate management practices (Cox et al., 1986; Baenziger et al., 2001).

The merits of genetic improvement and its cost necessitate periodical evaluation of its benefits. This evaluation is useful both to demonstrate the importance of plant breeding and as way of identifying traits or target environments that may require increased efforts by breeders (Cox et al., 1988). Furthermore, genetic gain assessment is vital for evaluating selection efficiency and identifying associated traits as criteria for future selection.

Various approaches have been used to estimate genetic gain in agronomic and end-use quality characteristics in wheat. For example, progress has been evaluated from the differences between historic check cultivars and the mean yield of highest yielding lines from multi-environment cultivar trial data. Schmidt & Worrall (1984) estimated genetic gain as the grain yield of the highest yielding lines in regional breeders' nurseries as percentages of long-term checks from 3-year means. They found 0.75% and 1.5% increase per year in grain yield from 1960 to 1980 in the hard red winter wheat Northern and Southern Regional Performance Nurseries, respectively. Feyerherm et al. (1984), who used differential yielding ability computed as the differences between high yielding cultivars and the check cultivars, reported up to 31% yield advantage of the top five entries over the long-standing checks in a Great Plains hard red winter wheat nursery from 1920 to 1979. Genetic gain estimated from the difference between checks and top-yielding cultivars are biased by the genotype by environment interactions (GEIs), especially where crossover interactions occur and older cultivars are grown under modern cultural practices. Studies of genetic gain that use check cultivars depend on the assumption of non-significant GEI involving the checks and other cultivars to avoid confounding environmental effects (Cox et al., 1988). They recommended evaluation of cultivars from different eras in common environments to evaluate the genetic gain. Using regression analysis, the genetic gain of grain yield was 0–1.4% in 38 hard red winter wheat cultivars released from 1874 to 1987 in Kansas (Cox et al., 1988) and 0.2% in 12 cultivars from 1969 to 1993 in Oklahoma (Khalil et al., 1995). Donmez et al. (2001) reported mean genetic gains of 0.15% (for cultivars released in the 1940s compared to 'Turkey' which was listed as being released in 1873, though its release date has also been reported as 1874 [Cox et al., 1989]) and 0.63% (for cultivars released in the mid to late 1990s compared to Turkey) per year for 12 hard red winter wheat genotypes in Kansas.

Estimates of genetic gain also can identify the underlying causes of yield improvement and be used to design indirect selection strategies (Morrison et al., 2000). The increase in grain yield was largely associated with the improvement of harvest index and lodging resistance with only small changes in total dry matter weight of crops (Slafer & Andrade, 1989; Bell et al., 1995). The harvest index increase, resulting mainly from larger numbers of kernels per square metre (Calderini et al., 1995; Sayre et al., 1997) was

obtained by combining genes for reduced height and resistance to lodging, diseases, insects, and environmental stresses. Modern wheat cultivars tend to be shorter, earlier flowering and produce more tillers than their ancestors (Austin et al., 1989).

Hard red winter wheat is primarily used to produce yeast-leavened bread (Smith, 1995) and cultivars have been selected for high milling and baking potential. Grain characteristics used as indicators of milling quality include grain volume weight, kernel weight, and flour yield; whereas indicators of baking quality include wheat or flour protein content, Mixograph mixing time, Mixograph mixing tolerance, water absorption, loaf volume and crumb grain and color (Finney et al., 1987). As with agronomic characteristics, end-use quality characteristics of a wheat genotype will vary with the environment (Peterson et al., 1992). Hence estimates of genetic gain must be from multiple environments.

Despite their importance, studies on the genetic gain in agronomic and end-use quality traits of hard red winter wheat have not been done in Nebraska using designed experiments. End-use quality genetic gain estimates are important to investigate if improvements in grain yield affected end-use quality (Cox et al., 1989). Wheat breeders try to select lines responsive to favorable environments for grain yield and yield components, with consistent or stable performance for end-use quality. The objectives of this study were to 1) measure in Nebraska agronomic performance and end-use quality characteristics of thirty hard red winter wheat cultivars released from 1874 to 2000 and 2) examine the phenotypic stability and the genetic gains in agronomic and end-use quality characteristics among the same cultivars.

Materials and methods

Plant materials

Thirty hard red winter wheat cultivars, introduced or released between 1874 and 2000, were used in this study (Table 1). Information about each cultivar was obtained from the Germplasm Resource Information Network (GRIN) website (<http://www.ars-grin.gov>). The cultivars were carefully selected to represent many historically important and currently widely grown hard red winter wheat cultivars in Nebraska. Turkey was introduced from Russia and is the oldest ancestral line. It was the foundation cultivar for hard red winter wheat in the