Productivity and adaptive capacity of winter wheat landraces and modern cultivars grown under low-fertility conditions

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Abstract

In recent decades, most winter wheat (Triticum aestivum L.) breeding in the United States has been done in field nurseries in which the soil receives ample fertilization. To determine the effects of these breeding efforts on productivity under low-fertility conditions, we evaluated twenty-nine winter wheat genotypes (seven Asian landraces; thirteen standard-height U.S. cultivars released between 1874 and 1971; and nine semidwarf cultivars released between 1977 and 1988) under severe fertility stress at three Kansas, USA locations. Experiments included fertilized and unfertilized treatments. The modern, semidwarf cultivars yielded 18% and 20% more, on average, than landraces and standard-height cultivars under low and high fertility, respectively; however, only the latter difference reached the 5% significance level. At only one location (Hays) was there a significant genotype X fertility interaction: there, 89% of the semidwarf cultivars, only 8% of the standard cultivars, and 57% of the landraces responded to fertilization. The regression coefficient of mean grain yield (unfertilized) on year of introduction or release for standard and semidwarf cultivars was zero, indicating that a century of breeding has produced no genetic improvement in performance under these low-fertility conditions. Although we found that the usual yield advantage of modern cultivars is not expressed under very low fertility, we saw no evidence that older cultivars are superior under those conditions.

Introduction

Severe biotic and abiotic stresses result in relatively low grain yields of hard red winter wheat (Triticum aestivum L.) in the southern Great Plains of the United States. From 1900 until 1951, Kansas winter wheat yields averaged only 1079 kg ha⁻¹ (Kansas Agricultural Statistics, 1990). But over the past 15 years, with the advent of semidwarf cultivars and increased nitrogen use, yields have more than doubled to more than 2300 kg ha⁻¹ (Kansas Agricultural Statistics, 1990). Cox et al. (1988) reported that breeding efforts alone had increased grain yields of hard red winter wheat in the Great Plains of the United States by about one percent of the baseline yield per year between 1919 and 1987. In reviewing the literature, Austin et al. (1989) concluded that genetic improvement in winter wheat yields across several countries around the world ranged from 0.4 to 0.8% per year.

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In a review of breeding for environments with differing intensities of management, Bramel-Cox et al. (1991) concluded that (i) continued selection in high-input environments could reduce gain in low-yielding environments and (ii) genetic gain can be achieved under stress or with low inputs, if selections are made in such environments. Goodman (1993) stated that 'there is little doubt that today's cultivars have not been selected for low-input farming and are unlikely to be optimal for such use'.

Muruli & Paulsen (1981) reported that one maize (Zea maize L.) population that was selected in a low-nitrogen environment outyielded another population selected in a high-nitrogen environment by nearly 30% when both were compared at 0 kg N ha⁻¹. In the Philippines, Evans & De Datta (1979) found that a tall rice cultivar derived from traditional germplasm, H-4, performed better than IR8, a modern semidwarf variety, when no nitrogen was applied to the soil. Ceccarelli & Grando (1991) reported that under low-yielding conditions, barley genotypes selected for high grain yield in adverse environments outyielded genotypes selected in optimum environments. One private wheat breeder in Kansas has made selections in low-nitrogen environments and has released two cultivars – 'Kleopatra Red' and 'Kleopatra White' – to farmers (Leo Schrader, Pharoah Seeds, Timken, KS, USA, personal communication).

Agricultural extension personnel in Kansas often hear from producers that older wheat cultivars will perform as well as or better than newer cultivars in stressed or low-input environments. Austin et al. (1989) proposed the same idea in the United Kingdom. It is indeed evident that most modern breeding programs have expended considerable selection effort in high-fertility environments but less at low-fertility sites. The objective of this research was to determine whether breeding efforts during this century have affected performance of hard red winter wheat cultivars under low-fertility conditions.

**Materials and methods**

Twenty-nine winter wheat genotypes were evaluated: (1) seven landraces, collected in southwestern Asia and held in the U.S. Small Grains Collection; (2) thirteen standard-height cultivars, introduced or released between 1874 and 1971, and once grown commercially in large areas of the U.S. Great Plains; and (3) nine semidwarf cultivars released and grown commercially in the U.S. Great Plains since 1977 (with the exception of one genotype – KS831957 – that was not released as a cultivar). The seven landraces had been grown and observed at Manhattan, Kansas, USA, for two years and were known to have adequate winter hardiness and earliness to survive in Kansas conditions.

The wheat genotypes were evaluated in four field environments: near McCune, in southeastern Kansas, in harvest year 1989; at Manhattan, in northeast Kansas, in 1990 and 1991; and near Hays, in west-central Kansas, in 1991. Soil at all three locations contained low levels of nitrogen [less than fifteen parts per million (ppm)] and inorganic phosphorus (from 2 to 6 ppm).

The previous years' crops in the fields in which the experiments were sown were grain sorghum [Sorghum bicolor (L.) Moench] at McCune, oat (Avena sativa L.) at Manhattan in 1990, and wheat at Manhattan in 1991 (experiments conducted on the same site in both years). The field at Hays had lain fallow the previous year. Before sowing, 23 kg ha⁻¹ phosphorus and 20 kg ha⁻¹ nitrogen were applied in the form of diammonium phosphate to one-half of the experimental area with commercial equipment.

Because fertility treatments (fertilized and unfertilized) within environments were not randomized, each fertility-environment combination was an experiment. Experiments were in randomized complete-block designs with 29 genotypes tested in two replicates. Plots as sown were 12.2 m long and 1.4 m wide and contained six rows, seeded at a rate of 67 kg/ha in October. There was a separation of at least 6 m between fertility treatments. Approximately two weeks before harvest, ends of plots were trimmed, shortening them to a length of 7.6 m. Following end-trimming, the two outer rows of each plot were cut with a hand-sickle and removed, so that four rows of each plot were harvested. The distance between harvested plots within a replicate was 0.6 m.