Fall Forage Biomass and Nitrogen Composition of Winter Wheat Populations Selected from Grain-Only and Dual-Purpose Environments

Charles T. MacKown* and Brett F. Carver

ABSTRACT

Winter wheat (Triticum aestivum L.) is the foundation of many agricultural enterprises in the southern Great Plains and is grown primarily as either a grain-only (GO) or a dual-purpose (DP, grazing plus grain) crop. Traditionally, cultivars are developed in GO systems. Because of genotype × system interactions, the DP environment may compromise gains in grain yield accrued in GO-developed cultivars. Forage traits for 24 sets of populations (each with unique pedigree) were used to test benefits of tailoring breeding programs for DP wheat. Each set came from the same F2 source and contained a base (B) F2 bulk population and F3 bulk populations mass selected from the F2 within either a GO or DP system. Forage biomass and forage total N and nitrate were measured at the start of fall grazing. Nearly always, the effect of selection environment was consistent across genetic backgrounds. Effect of selection environment on forage biomass of each nursery was significant at \( P = 0.09 \) and \( P = 0.07 \). In 2001, DP-derived populations produced about 5% less than GO-derived populations; in 2002, the selection effect was not significant \( (P = 0.38 \) and 0.30). Selection environment had a significant effect on forage total N, but not nitrate levels. Total N in DP selections was slightly greater \((2.5\%, P < 0.05)\) than those from B and GO selections. Forage nitrate was affected by genetic background; mean nitrate-N among the 24 backgrounds ranged from 1.3 to 3.1 mg g\(^{-1}\) in 2001 and 0.4 to 1.3 mg g\(^{-1}\) in 2002. Selection in the DP system appears to offer equal or slightly less fall forage biomass without greatly changing forage total N and nitrate concentrations.

Hard winter wheat grown in Oklahoma and the surrounding areas of the Texas Panhandle, southern Kansas, eastern New Mexico, and southeastern Colorado is managed as GO, grazing-only, grazing plus grain (DP), and as a hay or silage crop. Wheat pastures in the southern Great Plains have a pivotal role in the U.S. beef (Bos taurus L.) industry by providing the link for millions of fall stocker calves received annually that pass from more than 500,000 farms across the southern USA to feedlots located in the Great Plains. Because grasslands in the southern Great Plains are dominated by warm-season species, the predominative source of cool-season forage is wheat. Consequently, as much as 80% of the total wheat acreage in the southern Great Plains is grazed (Pinchack et al., 1996). Typically in Oklahoma, about 40% of the wheat acreage is grown as a DP crop (Hossain et al., 2004). Wheat producers choosing a DP management system have greater flexibility and additional economic advantages compared with those choosing to grow wheat as a forage-only or GO crop (Redmon et al., 1995), but they need to follow a recommended set of management practices to optimize returns.

When market conditions favor the forage value more than the grain value of wheat intended for DP, the crop should be planted earlier (Hossain et al., 2003) and seeded more densely (Epplin et al., 2000) than GO wheat. To assure early fall growth, fertilizer N needed to achieve a desired grain yield plus additional N to account for N removal in consumed forage is usually applied at planting (Krenzer, 1994; Zhang et al., 1998). These DP management practices may add certain risks. An early planting date in the southern Great Plains favors the incidence and severity of soil-borne and insect transmitted disease (Hammon et al., 1996; Hunger et al., 2002; Piccinni et al., 2001) and insect herbivory (Royer et al., 1997) and can reduce grain yields by variable amounts depending on the year or cultivar (Epplin and Peeper, 1998; Carver et al., 2001). These disease risks are necessary, however, when the goal is to produce a sufficient base of fall forage that is well anchored in the soil. Another potential risk arises from additional N fertilizer applied in the fall. The extra N can increase the nitrate levels in wheat forage (Raun and Westerman, 1998, 2000). Wheat producers growing wheat primarily as a forage crop (Redmon et al., 1995), but they need to follow a recommended set of management practices to optimize returns.

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Table 1. Genetic background of winter wheat bulk subpopulations used to evaluate fall forage traits in two nurseries (Nursery 1 and Nursery 2) in 2001 and 2002.

<table>
<thead>
<tr>
<th>Set</th>
<th>Nursery 1</th>
<th>Nursery 2</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>2180/Ccy2/2Cyta-3/Ogallala</td>
<td>Oro Blanco/Custer</td>
</tr>
<tr>
<td>2</td>
<td>Tkw/Kitf 92/2Cyta-3/Heckok</td>
<td>Betty/TAM 302</td>
</tr>
<tr>
<td>3</td>
<td>Plat/ks537-337/Wakefield</td>
<td>OK9619E8/OK97G605</td>
</tr>
<tr>
<td>4</td>
<td>Plainsman V/OK79256 seln//</td>
<td>Oro Blanco/ks58w663-11-6</td>
</tr>
<tr>
<td>5</td>
<td>FL302/3/Jagger</td>
<td>KS94WGRC32/OK93P735</td>
</tr>
<tr>
<td>6</td>
<td>Castler/FL302/TAM 302</td>
<td>KS94WGRC33/TAM 302</td>
</tr>
<tr>
<td>7</td>
<td>Jagger*2/FL302</td>
<td>OK93P735/OK94P512</td>
</tr>
<tr>
<td>8</td>
<td>2137/SW76-117C-4</td>
<td>OK91P648/2137</td>
</tr>
<tr>
<td>9</td>
<td>OK95G702/OK91F648</td>
<td>OK93P634/TAM 302</td>
</tr>
<tr>
<td>10</td>
<td>OK95G703/2137</td>
<td>N44/OK94P455</td>
</tr>
<tr>
<td>11</td>
<td>OK95G703/OK92403</td>
<td>2174 Bulk 4</td>
</tr>
<tr>
<td>12</td>
<td>OK95G704/OK91P648</td>
<td></td>
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</table>

MATERIALS AND METHODS
Development of Experimental Materials

Released and experimental genotypes of winter wheat were hybridized in single-cross and three-way-cross combinations to form 23 populations (Table 1). These combinations constituted a representative sample of crosses routinely made in the winter wheat cultivar development program at Oklahoma State University. From the F1 generation grown in the greenhouse, each F2 seedlot was divided and planted in field plots assigned to GO and DP systems at the Wheat Pasture Center in Noble, OK, 56 km east of the Wheat Pasture Center. This single-generation increase offered a reasonable compromise for producing sufficient seed for field testing and maintaining genetic variability present in the original F1 population, while restricting natural selection in a field environment to one year.

An additional set of three subpopulations was generated for a total of 24 sets, by treating a foundation-seed source of the hard red winter wheat cultivar 2174 in the same way as the hybridized populations. Though considered to be an F1-derived highly homozygous line, 2174’s appearance in this way as an heterozygous line lent itself to treatment as a bulk population. Hence, 24 sets of three subpopulations comprised the experimental materials used in this study. System-derived subpopulations were evaluated as F3 bulks, whereas the base subpopulations were evaluated as F2 bulks.

Agronomic practices followed during the generation-advance stages (F1–F3) were consistent with those used by wheat producers in the southern Great Plains (Krenzer, 1994). The corresponding cropping seasons were 1997–1998, 1998–1999, and 1999–2000. The two management systems were established in the same 9- to 10-ha pasture, separated by an electrical fence to contain grazing cattle in the DP area. Stocker cattle grazed the wheat pasture as part of stocking rate or supplementation studies conducted at the Center, with a target stocking rate of 2 steers ha$^{-1}$. Stocking rate was adjusted within the grazing season according to forage availability. Grazing commenced during late October to late November. Grazing termination occurred in late February to early March, as determined by the appearance of hollow stems in nongrazed plants of an early maturing cultivar planted on the same day as the DP plots.

Field Testing of Experimental Materials

The 24 triplicate sets of subpopulations were arbitrarily divided into two nurseries of 12 sets each (Nursery 1, Nursery 2) to accommodate replicated field testing. Using a split-plot design with three complete blocks, the 12 sets were assigned.
to main plots, while the subpopulations within sets were assigned to split-plots. Because each set represented a unique cross, they are hereafter referred to as genetic backgrounds. Three commonly grown hard red winter wheat cultivars with different juvenile growth habits were included as checks. These included Custer (semierect to erect), and 2174 (erect). To maintain balance of field design, each check was assigned to a set of three split-plots and randomized along with the 12 sets of experimental genetic backgrounds in each Nursery, though differences among them were considered strictly environmental.

The two nurseries were maintained as separate but contiguous experiments in the field. Experiments were established in the 2001–2002 and 2002–2003 cropping seasons at the Wheat Pasture Center near Marshall, OK, as described above. Plots were established in a DP management system in the same 9- to 10-ha pasture in which the materials were derived. Dual-purpose management practices in this population testing phase for Nursery 2 in 2001, biomass of the base populations were managed as DP wheat crops in 2001 and 2002. Each subplot was 3 m long with five rows spaced 23 cm apart. Forage Biomass

Biomass mean bars having the same letter within a year-by-nursery combination are not significantly different (\( P > 0.10 \)).

**RESULTS AND DISCUSSION**

The ANOVA results for forage traits are summarized in Table 2. Nearly always, the genetic background × selection environment effect was not significant. Effect of selection environment on biomass of each nursery was significant at \( P = 0.093 \) and 0.068 in 2001; in 2002 the effect of selection environment was not significant. Selection environment was a significant effect for total N but not nitrate levels.

Forage Biomass

In 2001, bulk populations selected from a DP management environment had mean fall forage biomass that tended to be less (Nursery 1, \( P = 0.093 \); Nursery 2, \( P = 0.068 \)) than the GO and base populations (Fig. 2). For both nurseries, biomass of the DP selected bulk populations averaged about 5% less fall biomass than the bulk populations selected from the GO production system. For Nursery 2 in 2001, biomass of the base populations averaged about 3% greater than those selected from the GO system.

The trend for less forage biomass among the populations selected from a DP system may be associated with a more pronounced prostate growth habit than among plants in the bulk populations derived from the GO

![Fig. 2. Forage biomass of base (B) and selected (grain-only, GO; dual-purpose, DP) bulk subpopulations of two nurseries (Nursery 1 and Nursery 2) managed as DP wheat crops in 2001 and 2002. Biomass mean bars having the same letter within a year-by-nursery combination are not significantly different (\( \alpha = 0.10 \)).](image)
Table 4. Cumulative rainfall, total solar radiation, and calculated growing degree-days (GDD, base temperature of 0°C) for data from the Marshall Oklahoma Mesonet site located at the Marshall Wheat Pasture Center.

<table>
<thead>
<tr>
<th>Climate variable</th>
<th>10 September to 5 November</th>
<th>24 September to 12 November</th>
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<tbody>
<tr>
<td>Rainfall, cm</td>
<td>14.6</td>
<td>10.9 (−25)†</td>
</tr>
<tr>
<td>Total solar radiation, MJ m⁻²</td>
<td>822</td>
<td>931 (13)</td>
</tr>
<tr>
<td>GDD, °C</td>
<td>983</td>
<td>980 (−0.3)</td>
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</table>

† Numbers in parentheses are the percentage difference from the 1994 to 2000 growth period means.
total biomass as leaf blades with high N concentration were probably greater than the other subpopulations. To confirm this, additional research comparing biomass partitioning and N concentrations between leaf blades and sheaths of fall wheat forage is needed. Among the bulk populations, total N concentrations ranged from 40.9 to 44.3 g kg\(^{-1}\) dry weight in 2001 and from 39.5 to 45.4 g kg\(^{-1}\) dry weight in 2002 (data not shown). These total N concentrations were comparable with those of the check cultivars (Table 3). The genetic background \(\times\) selection environment interaction effect for total N was not significant (\(P > 0.05\)) except for Nursery 2 in 2001 (Table 2). Some of the genetic backgrounds of Nursery 2 in 2001 had forage total N concentrations that were similar among the three selection environments (Sets 1, 3, and 12), while in others total N of the DP subpopulation was slightly greater than that of the GO selection but not the base subpopulation (Sets 5, 7, and 10) or greater than only the GO selection (Sets 4, 6, 9, and 11) (data not shown). In all cases, however, the level of total N (protein equivalent > 200 g kg\(^{-1}\)) is more than adequate to support high rates of weight gain (up to 1.36 kg d\(^{-1}\) for 135- to 225-kg steers) for stocker calves (Torell et al., 1999), so the slight difference in total N created by selection system should not affect stocker performance. Unfortunately, the energy content and low dry matter (high water content) of wheat limit average daily gains to <1.0 kg d\(^{-1}\) when supplement energy is not provided (e.g., Mader et al., 1983; Phillips et al., 1995, 2001; Pinchack et al., 1996).

Selection environment of the bulk populations did not affect forage nitrate concentrations, but differences among genetic backgrounds were significant (Fig. 4). Overall, mean nitrate levels of fall forage from 2001 (2020 \(\mu\)g NO\(_3\)\(-\)N g\(^{-1}\) dry wt.) exceeded the levels in 2002 by about threefold (661 \(\mu\)g NO\(_3\)\(-\)N g\(^{-1}\) dry wt.).

Similarly, the average forage nitrate levels of the check cultivars in 2001 exceeded the levels in 2002 by about threefold (Table 3). In both 2001 and 2002, a few of the same genetic backgrounds within a nursery had nitrate concentrations that ranked \(\geq 75\%\) quartile (Nursery 1, Sets 5 and 10; Nursery 2, Sets 1 and 8). At the lower range of nitrate levels, other genetic backgrounds had concentrations that ranked consistently \(\leq 25\%\) quartile (Nursery 1, Set 6; Nursery 2, Set 5). In 2001, at least 50% of the 24 genetic background sets had NO\(_3\)\(-\)N levels exceeding the check 2174 (1790 \(\pm\) 120 \(\mu\)g NO\(_3\)\(-\)N g\(^{-1}\) dry wt.; highest level among the check cultivars), while only one (Fig. 3; Nursery 1, Set 9) was less than Custer, the lowest check cultivar. In 2002, nearly all sets had NO\(_3\)\(-\)N levels that fell within the range of NO\(_3\)\(-\)N levels of the check cultivars, except for Set 9 in Nursery 2 (1280 \(\mu\)g NO\(_3\)\(-\)N g\(^{-1}\) dry wt.), which exceeded the highest check NO\(_3\)\(-\)N level by 62% (cf. Fig. 3 and Table 3). Because all of the entries in 2001 had nitrate concentrations \(> 1125 \mu\)g NO\(_3\)\(-\)N g\(^{-1}\) dry weight (\(> 5000 \mu\)g NO\(_3\)\(-\)N g\(^{-1}\) dry wt.) that is considered...
ACKNOWLEDGMENTS

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REFERENCES


