Fall Growth Potential of Cereal Grain Forages in Northern Arkansas


ABSTRACT

In Arkansas, maximizing fall forage production from cereal grains is important for optimizing growth of fall-weaned calves (Bos taurus). Our objectives were to evaluate eight cultivars of wheat (Triticum aestivum L.), oat (Avena sativa L.), rye (Secale cereale L.), and triticale (×Triticosecale Wittmack) for their potential to accumulate fall forage dry matter (DM). At Fayetteville during 2004, triticale and oat cultivars accumulated DM in a cubic (P ≤ 0.01) pattern over time, most likely because growing tillers exhibited stem elongation, and were then susceptible to freeze damage in late December. Wheat and rye cultivars accumulated DM in less complex patterns over harvest dates, but the maximum yield for any wheat cultivar was only 2554 kg ha⁻¹ compared to 4661 kg ha⁻¹ for oat. For Batesville 2004 and Fayetteville 2005, DM yields ranked similarly, but respective mean yields (491 and 988 kg ha⁻¹) averaged over all harvest dates were only 25 and 50% of those for Fayetteville 2004 (1960 kg ha⁻¹), largely due to drought. For Batesville 2005, growing conditions were somewhat unique relative to other site-years, and wheat, rye, and triticale cultivars accumulated an overall mean of 4148 kg ha⁻¹ of forage DM on the final (4 January) harvest date. In contrast, oat cultivars were sensitive to freezing temperatures in November, and ranked last among all cultivars for yield on the final harvest date. Producers can usually improve fall forage production with cultivars that exhibit some stem elongation when planted in early September; however, this trait may make winter survival problematic.

Although its location is adjacent to both Oklahoma and Texas, cereal-grain production in Arkansas is distinctly different from that observed in these neighboring states. Specific differences include (i) predominant use of soft-red winter wheat cultivars; (ii) more favorable climate for forage growth, especially throughout the winter (Daniels et al., 2002); and (iii) geographically segregated regions of livestock and grain production. Within Arkansas, grain-only production of wheat and other row crops occurs primarily within the Mississippi River Delta. In contrast, large portions of the cow-calf and stocker industries are located in the Ozark and Ouachita Highlands; these areas comprise much of the northern and western portions of the state, respectively. As a result of this geographical segregation, the dual-purpose use of wheat to generate income from both grain sales and livestock gains is relatively rare.

Without the need to produce a grain crop, livestock producers may consider a wider range of management strategies that allow them to move weaned stocker calves to high-quality cereal-grain forages as soon as possible in the fall. Maximizing fall growth of these forages also may limit the need for supplemental hay during winter, or provide an emergency source of forage to graze or harvest as silage following extreme summer drought. Previous work seeking to evaluate fall forage production from cereal grains, especially those other than winter wheat, has been limited. In Wisconsin, Maloney et al. (1999) suggested that fall forage yields are maximized by selecting oat or barley (Hordeum vulgare L.) cultivars, rather than those of winter wheat or rye. Contreras-Govea and Albrecht (2006) reported fall forage yields of spring oat in excess of 6 Mg ha⁻¹ when planted in early to mid-August in southern Wisconsin. These forages also contained 10 to 15% less neutral-detergent fiber (NDF) at harvest (77 d from planting) than identical cultivars established during the spring and harvested after a similar growing interval. Several studies (Griggs, 2006; Lyon et al., 2001) also have demonstrated that yields of fall forage improve with earlier planting dates, but rigorous evaluations of diverse cultivars, specifically with fall forage growth as the primary response variable, are (at best) incomplete. To maximize fall growth of winter-animal forages, a wide range of factors need to be evaluated, including: (i) species and varietal selection (including annual ryegrass); (ii) monocultures or mixtures; (iii) sod-seeded, clean-tilled, or no-till establishment; (iv) planting date; (v) fertilization strategies; and (vi) potential for regrowth.

A systematic evaluation of all of these factors is well beyond the scope of a single trial; therefore, this study is confined to evaluations of species, and diverse cultivars within species fol-
lowing establishment with traditional clean-tilled techniques. Objectives for this study were: (i) to evaluate the fall growth potential of eight diverse cereal-grain cultivars representing oat, wheat, triticale, and rye; (ii) to evaluate the regrowth potential for these same forages following an initial harvest in the fall; and (iii) to establish some simple guidelines for estimating forage mass based solely on a simple measurement of canopy height.

**MATERIALS AND METHODS**

**Plot Management**

**Site Preparation**

Sites at both the Livestock and Forestry Branch Station, near Batesville (35°50’ N, 91°48’ W, 141 m above sea level), and at the Arkansas Agricultural Research and Extension Center in Fayetteville (36°05’ N, 94°10’ W, 394 m above sea level) were selected for this project. Respective soil types were a Perigean silt loam (fine-silty, mixed, active, mesic Typic Paleudalfs) and Captina silt loam (fine-silty, siliceous, active, mesic Typic Fragiudults). Each site was clean-tilled and fertilized to meet the soil-test recommendations for P, K, and pH established by the University of Arkansas Cooperative Extension Service (Chapman, 2001). At both sites, 56 kg N ha⁻¹ was applied at planting in the form of ammonium nitrate (34–0–0); no additional fertilizer was applied on any later date during the trial. At each site, cultivars were arranged in a randomized complete block design with four replications (field blocks); individual plot sizes were 9.1 by 7.6 m and 6.4 by 7.6 m at the Batesville and Fayetteville sites, respectively.

**Cultivar Selection**

Eight cultivars were evaluated in the trial. Entries included: (i) ‘Horizon 474’ and ‘Blaze’ oat (Kolb et al., 1999); (ii) ‘GR 9108’, ‘OK 101’, and ‘Prograze’ wheat; (iii) ‘Monarch’ triticale; and (iv) ‘AGS 104’ and ‘Wintergrazer 70’ cereal rye (Table 1). Our goals were to select cultivars that were representative of those used typically for pasture across northern Arkansas (Wintergrazer 70 rye, Prograze wheat), but also to include hard-red (OK 101; Carver et al., 2003) and soft-red (GR 9108; Bacon et al., 2006) wheat cultivars, as well as selections developed under climatic conditions outside of this region (Table 1). Prograze wheat was not available during 2005–2006, and an unstated variety marketed primarily for pasture use was substituted at both sites during the second year of the trial. Since the primary objective of the study was to maximize fall forage production, potential for winter survival, and forage production the following spring or summer were not given consideration during selection of cultivars. There are several reasons for this somewhat unorthodox research approach. Most livestock producers in northern Arkansas would have considerable forage available during the spring from perennial pastures comprised primarily of tall fescue [Lolium arundinaceum (Schreb.) Darbysh.], or other cool-season grasses. Furthermore, if there is adequate availability of fall and winter cereal-grain forage, steers weaned in October might nearly or entirely complete the background phase of development before aggressive growth of wheat or tall fescue occurs during the following spring.

**Establishment**

Plots were drilled into a clean-tilled seedbed at Batesville with a 3.0-m wide John Deere Model 750 (Deere and Co., Moline, IL) drill with 19-cm row spacings, and at Fayetteville with a 2.1-m Marliss Pasture King (Marliss Industries, Jonesboro, AR) drill with 18-cm row spacings. Cereal grains were seeded at rates typical for monocultures throughout the region, which were 134 kg ha⁻¹ for wheat, 125 kg ha⁻¹ for rye and triticale, and 108 kg ha⁻¹ for oat. Planting dates (Table 2) were substantially earlier than recommended normally for production of wheat grain in northern Arkansas (Studebaker et al., 2004; Chapman et al., 2000).

**Harvest Management**

**Initial Growth**

Beginning in mid-October, a single 7.6-m strip was selected at random from each plot and mowed to a 5-cm stubble height with a 0.9-m (width) sickle-bar mower. All (wet) clipped forage was then gently gathered via hand-raking, and weighed on a platform scale in tared 114-L plastic trash cans. Grab samples (1000 g) were dried to constant weight at 50°C to determine the percentage of DM in each forage sample. This value was then used to calculate the yield of DM from each plot. Additional 7.6-m strips from the unharvested areas within each plot were then selected at random and clipped at intervals of approximately 2 wk through the end of December or early January, thereby yielding six harvest dates per forage.

**Table 1. Description of cultivars evaluated for fall forage production at Fayetteville and Batesville, AR, during 2004–2005 and 2005–2006.**

<table>
<thead>
<tr>
<th>Species</th>
<th>Cultivar</th>
<th>Description</th>
<th>Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oat</td>
<td>Horizon 474</td>
<td>winter oat</td>
<td>Florida/Georgia</td>
</tr>
<tr>
<td></td>
<td>Blaze†</td>
<td>spring oat</td>
<td>Illinois</td>
</tr>
<tr>
<td>Wheat</td>
<td>GR 9108‡</td>
<td>soft-red winter wheat</td>
<td>Arkansas</td>
</tr>
<tr>
<td></td>
<td>OK 101§</td>
<td>hard-red winter wheat</td>
<td>Oklahoma</td>
</tr>
<tr>
<td>Triticale</td>
<td>Armor Prograze¶</td>
<td>winter pasture wheat</td>
<td>Arkansas</td>
</tr>
<tr>
<td>Rye</td>
<td>Monarch</td>
<td>winter triticale</td>
<td>Florida/Georgia</td>
</tr>
<tr>
<td></td>
<td>AGS 104</td>
<td>winter rye</td>
<td>Oklahoma</td>
</tr>
<tr>
<td></td>
<td>Wintergrazer 70#</td>
<td>winter rye</td>
<td>Oklahoma</td>
</tr>
</tbody>
</table>

† Kolb et al. (1999).
‡ Bacon et al. (2006). Available through Delta King Seed Company, McCory, AR 72101.
§ Carver et al. (2003).
¶ Armor Prograze wheat (Cullum Seeds, Fisher, AR) was not available for 2005–2006. An unstated (Armor) cultivar, marketed primarily for pasture use, was substituted for 2005–2006.
# Pennington Seed, Madison, GA.

**Table 2. Schedule of field operations for assessment of fall growth potential of cereal-grain forages at Fayetteville and Batesville, AR, during 2004–2005 and 2005–2006.**

<table>
<thead>
<tr>
<th>Field operation</th>
<th>Fayetteville</th>
<th>Batesville</th>
</tr>
</thead>
<tbody>
<tr>
<td>Establishment</td>
<td>8 Sept. 10 Sept. 20 Sept. 20 Sept.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>5 Nov. 4 Nov. 9 Nov. 8 Nov.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>16 Nov. 16 Nov. 18 Nov. 21 Nov.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>2 Dec. 3 Dec. 5 Dec.</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>29 Dec. 3 Jan. 10 Jan. 4 Jan.</td>
<td></td>
</tr>
</tbody>
</table>

† Because of contamination within some plots by volunteer annual ryegrass after the initial harvest, regrowth of cereal grain cultivars was not evaluated at the Batesville site during February 2005.
age cultivar per site-year; however, the specific time intervals between harvests varied slightly due to intermittent periods of wet or inclement weather that made sampling impossible on some scheduled harvest dates. In northern Arkansas, growth of cereal-grain forages slows substantially during a winter period centered generally on the month of January. In practice, this frequently results in shortages of available forage and often forces producers to offer harvested forages on a stop-gap basis until active forage growth resumes during late winter. For this reason, we defined fall growth as that occurring before early January, and then established our sampling procedures on that basis. In addition to DM yield, canopy height was measured immediately before clipping at three locations across each strip. Height was measured (cm) from the ground to the apex of the leaf canopy, but leaves were not extended before making each measurement. Because the growth habits of the cultivars evaluated in this study varied widely, field notes also were recorded on each harvest date. Among these were notations of nodes per plant, as well as counts of elongated or headed tillers per m of drill row. Such observations are reported within the text only to aid in the explanation of results, and are based on simple arithmetic means that were not analyzed statistically.

Regrowth

In addition to initial measurements of canopy height and DM yield, each strip was harvested a second time between 15 February and 1 March to assess the regrowth potential of each cereal grain forage as affected by initial harvest date. Procedures for harvesting forage regrowth and measuring canopy height were identical to those described previously. Evaluation of regrowth was conducted at this time because forage mass often becomes limiting for livestock at some point between the slowing or cessation of fall growth and initiation of spring growth; assessment of regrowth potential for these forages during this critical time period should provide some insight into the potential for late-winter carrying capacity of various cereal-grain forages.

Climatic Data

Thirty-year normals for precipitation and temperature were obtained from published reports (National Oceanic and Atmospheric Administration, 2002) for Batesville and Fayetteville. Monthly means for temperature and precipitation relevant to the 2004–2005 and 2005–2006 evaluation periods were obtained from data compiled daily at each station. Both research stations are regular weather reporting stations that contributed to the published report (National Oceanic and Atmospheric Administration, 2002) summarizing 30-yr normals of climate.

Statistics

Dry Matter Yield and Canopy Height

Initially, site and year were included in the statistical model for the analysis of forage yield and canopy height data. However, all possible interactions of site and year with either cultivar, harvest date, or both were significant (P ≤ 0.03); therefore, data from each site-year were analyzed independently as a split-plot design using PROC MIXED (SAS Institute, 1999). Cereal-grain cultivars served as the whole-plot effect and the six harvest dates were evaluated as subplots. For the whole-plot treatment structure, cultivars were randomly arranged within four complete blocks. For harvests of regrowth, interactions of site-year with either cultivar, harvest date, or both were all highly significant (P < 0.01): therefore, analysis of regrowth data also was conducted by site-year. Within site-year, forage cultivar and harvest date frequently interacted; therefore, single degree-of-freedom orthogonal contrasts were used for each cultivar to test canopy height and DM yield for linear, quadratic, cubic, and quartic effects of harvest date. Because harvest dates were sometimes delayed slightly because of inclement weather, and therefore not equally spaced, PROC IML (SAS Institute, 1999) was used to adjust coefficients for orthogonality before evaluating trends over harvest dates. Before testing each cultivar for trends over time, data was evaluated for heterogeneous variances. Within each site-year, similar variances were grouped on the basis of cultivar or harvest date, depending on which effect provided the best overall fit based on Akaike’s Information Criterion.

Regression of Dry Matter Yield on Canopy Height

A quick, simple estimator of forage mass can be a valuable tool for producers managing grazing livestock. This is especially true when strip-grazing techniques are used because forage must be allotted to grazing cattle on a frequent basis. When simple measurements, such as canopy height, can be used as estimators, the allotment process becomes much easier. Unfortunately, detailed tests for homogeneity of slopes (PROC GLM: SAS Institute, 1999) indicated that linear regressions of DM yield on canopy height were inconsistent (data not shown), and often unique for each specific set of experimental or climatic conditions; therefore, it was inappropriate statistically to pool data into a simple set of linear relationships that are friendly for producer use. However, the statistical standards necessary for formal scientific work are much more restrictive than those needed to establish quick, useful, rule-of-thumb guidelines for daily producer use. Therefore, this lack of homogeneity was ignored, and a simplified analytical approach was conducted using only simple linear regressions (PROC REG; SAS Institute, 1999) of forage mass on canopy height over three broad categories: (i) initial growth at both Fayetteville and Batesville (n = 192); (ii) harvests of forage regrowth (n = 144) for Fayetteville (both years) and Batesville (second year only); and (iii) for all harvested forages combined (n = 336). All linear regressions were conducted using cultivar × harvest date interaction means that were calculated on the basis of four field replications within each site-year. Within each category, independent linear regressions for each cereal-grain species also were determined by identical procedures. Because quadratic relationships are cumbersome, and therefore undesirable for producer use, higher-ordered polynomial regressions were not considered in analysis procedures.

RESULTS

Precipitation

2004–2005

Precipitation was 14% above normal (National Oceanic and Atmospheric Administration, 2002) from July 2004 through February 2005 at both the Fayetteville (Table 3) and Batesville (Table 4) research sites. However, the distribution during specific critical months was poor, particularly at seeding. At Fayetteville, a single 15-mm rainfall event occurred on 6 September, and was the
only precipitation recorded during the entire establishment month. This was enough moisture to support germination following planting on 8 September, but subsequent growth rates were affected adversely. At Batesville, only 1 mm of precipitation occurred from 30 August through 7 October, and no germination was observed until after rains began on 8 October; precipitation then occurred on 19 of 24 d throughout the remainder of the month and totaled 221 mm, which was 223% of the monthly norm for October.

### 2005–2006

Throughout 2005–2006, precipitation was only 45 and 71% of normal for the July through February time period at Fayetteville (Table 3) and Batesville (Table 4), respectively. At Fayetteville, the largest precipitation deficit (87 mm) occurred during October, but deficits also occurred in all other months during this time interval. Although no precipitation was recorded at Batesville during October 2005, distribution during the previous summer months was good, totaling 36 mm above normal for July, August, and September, and this was adequate to support germination and early growth.

### Canopy Height

#### Fayetteville 2004–2005

All cultivars except Monarch triticale and Prograze wheat exhibited cubic ($P \leq 0.04$; Table 5) increases in canopy height across sampling dates, reaching a maximum height on 16 November in all cases. Monarch triticale exhibited a quadratic ($P < 0.01$) pattern over time in which plant height increased rapidly to 49 cm on 16 November, but remained relatively static (44–48 cm) thereafter. Forages that jointed and exhibited at least some stem elongation (Horizon 474 and Blaze oat, Monarch triticale, and AGS 104 rye) reached greater canopy heights, ranging up to 59 cm for Blaze oat, than cultivars that remained vegetative throughout the fall (GR 9108, OK 101, and Prograze wheat, and Wintergrazer 70 rye). Physiological differences were observed across cultivars within all site-years. For Fayetteville during 2004–2005, oat and triticale cultivars exhibited relatively uniform jointing and stem elongation across nearly all tillers. On the (final) 29 December harvest date, Blaze and Horizon 474 oat, and Monarch triticale exhibited an average of four, three, and three nodes per elongated stem. For Horizon 474 and Monarch cultivars, there was an occasional visible seedhead (<0.2 tillers m$^{-1}$ of drill row), which did not occur for Blaze oat. In contrast, only a very low proportion of tillers elongated for AGS 104 rye (20–25 tillers m$^{-1}$ of drill row); of these, most reached boot stage by the final harvest date, but only a few (<1.5 tillers m$^{-1}$ of drill row) exhibited a visible seedhead.

#### Fayetteville 2005–2006

Canopy height increased in complex quartic ($P \leq 0.02$; Table 6) relationships with time for all cultivars except Wintergrazer 70 rye, which did not differ ($P > 0.12$) across harvest dates. In addition to the physiological differences among cultivars described previously, an additional factor contributing to the complexity of these (quartic) polynomial responses was likely related to the 329-mm precipitation deficit that occurred from July through December 2005 (Table 3), as well as the delayed or inconsistent germination and growth that occurred subsequently as a result of this deficit.

#### Batesville 2004–2005

Unlike the Fayetteville site during 2004–2005, soil moisture at Batesville was inadequate for germination immediately after planting, and there was no forage that could be harvested for any cultivar on the initial 20 October harvest date (Table 7). Because of delayed germination, the mean forage canopy height averaged over all cultivars and harvest dates at Batesville (20 cm) was shorter than observed at the companion site at Fayetteville during
the same year (31 cm). Despite the delayed germination, canopy heights for individual cultivars increased over time, primarily in cubic \((P ≤ 0.01)\) patterns, which was consistent with observations for Fayetteville. The lone exception was observed for Blaze, which exhibited a quadratic \((P < 0.01)\) response over time that included a 39% reduction in canopy height between the 16 December and 10 January harvest dates. Because of delayed germination, elongated tillers from oat and triticale cultivars for this site-year were not observed until the 10 January evaluation date, which represented a delayed maturation rate relative to all other site-years.

**Batesville 2005–2006**

Averaged over all forages and harvest dates, the mean canopy height at Batesville during 2005–2006 (25 cm) exceeded that for the previous year (20 cm). Although growth was likely limited during 2005–2006 by the total absence of precipitation during October 2005 (Table 4), greater than normal precipitation (43 mm) in September supported quick germination, which resulted in an improved growth response by the first (mid-October) harvest date. Canopy height for all cereal-grain cultivars increased in curvilinear \((P ≤ 0.03)\) patterns over harvest dates (Table 8), although specific effects varied widely with cultivar. Notably, there were strong declines following the 21 November harvest date for both oat cultivars, while the canopy height for all other forages remained relatively static or increased slightly thereafter.

**Dry Matter Yield**

**Fayetteville 2004–2005**

**Initial growth.** Yields of DM increased across harvest dates in a cubic \((P ≤ 0.01)\) pattern for oat and triticale cultivars (Fig. 1A), all of which exhibited relatively uniform stem elongation across tillers at some point during the sampling period. In contrast, wheat cultivars (Fig. 1B) accumulated DM in simple linear \((P < 0.01)\) relationships over harvest dates; no higher ordered contrasts were significant \((P ≥ 0.09)\). Rye cultivars exhibited sharply contrasting responses (Fig. 1C); Wintergrazer 70 accumulated DM in a quadratic \((P = 0.04)\) pattern, reaching a maximum of 2184 kg ha\(^{-1}\) on the 2 December harvest date. Despite the limited proportion of tillers that elongated, the growth response...
for AGS 104 rye resembled closely those of oat and triticale cultivars; DM accumulation occurred in a strong cubic ($P = 0.01$) relationship with time, and the maximum yield (3776 kg ha$^{-1}$) compared favorably with other cultivars with elongating stems. Overall, stem elongation contributed heavily to fall yield potential. On the 14 December harvest date, the four cultivars that remained vegetative averaged 1731 kg ha$^{-1}$ compared to 4115 kg ha$^{-1}$ for those with at least some developing stems.

Fig. 1. Fall dry matter yield responses for eight cereal-grain cultivars at Fayetteville, AR, during 2004–2005. Yield responses (highest-ordered significant polynomial contrast) for (A) oat and triticale cultivars over time were cubic for Horizon 474 winter oat ($P = 0.01$), Blaze spring oat ($P < 0.01$), and Monarch triticale ($P < 0.01$). For (B) wheat cultivars, responses were linear ($P < 0.01$) over time in each case. Responses for (C) rye cultivars were cubic ($P = 0.01$) for AGS 104, but quadratic ($P = 0.04$) for Wintergrazer 70. Error bars represent the standard error of each interaction mean after adjustment for heterogeneous variances on the basis of cultivar.

**Regrowth.** As expected, accumulation of regrowth for all cultivars declined in curvilinear ($P < 0.05$) patterns as the time interval between the initial and final (15 February) harvest date shortened (Fig. 2). These relationships with time were quadratic ($P < 0.04$) for all forages except Blaze oat and Wintergrazer 70 rye, which exhibited quartic ($P = 0.05$) and cubic ($P = 0.01$) declines over initial harvest dates, respectively. In practical terms, there was no regrowth of Blaze oat (Fig. 2A) if the initial harvest date was on 5 November or later, and all plants (regardless of initial harvest date) appeared to be completely

Fig. 2. Regrowth yield responses for eight cereal-grain cultivars at Fayetteville, AR, during 2004–2005. Regrowth responses (highest-ordered significant polynomial contrast) for (A) oat and triticale cultivars harvested on 15 Feb. 2005 following six initial harvest dates during the previous fall were quadratic for Horizon 474 winter oat and Monarch triticale ($P < 0.01$), but quartic ($P = 0.05$) for Blaze spring oat. For (B) wheat cultivars, responses were quadratic for GR 9108 ($P < 0.01$), OK 101 ($P < 0.01$), and Prograze ($P = 0.04$). Responses for (C) rye were quadratic ($P < 0.01$) for AGS 104, but cubic ($P = 0.01$) for Wintergrazer 70. Standard errors of interaction means after adjustment for heterogeneous variances on the basis of initial fall harvest dates were 334.4 kg ha$^{-1}$ for the 19 October initial harvest date, and 137.7 kg ha$^{-1}$ for all other initial harvest dates, regardless of cultivar.
Yields of DM were reduced substantially relative to the previous year, largely in response to the large precipitation deficit (87 mm) that occurred during October 2005 (Table 3). Averaged across all cultivars, the mean DM yield for 2005–2006 (1514 kg ha\(^{-1}\)) was numerically greatest on the 3 January harvest date, but this was only 52% of that observed on 14 Dec. 2004 (2923 kg ha\(^{-1}\)), which was the harvest date exhibiting the greatest yields during the previous year. Despite the difference between 2004 and 2005 fall growing seasons, cultivars that displayed either uniform (Blaze oat, Horizon 474 oat, and Monarch triticale) or inconsistent stem elongation (AGS 104 rye) yielded 176% more DM than cultivars remaining completely vegetative (2223 vs. 804 kg ha\(^{-1}\)) on the final (3 January) harvest date. Yield responses across harvest dates for individual cultivars varied widely; oat and triticale cultivars accumulated DM in curvilinear \((P \leq 0.03)\) relationships with time (Fig. 3A) that were maximized on the final harvest date between 1976 and 2178 kg ha\(^{-1}\). Yield for wheat cultivars (Fig. 3B) increased linearly \((P < 0.01)\) over time for GR 9108 and OK 101, but a complex cubic \((P = 0.04)\) response was observed for Armor (vns; variety not stated) wheat. In practice, DM yields for Armor wheat were poor throughout the fall, ranging tightly between 234 and 786 kg ha\(^{-1}\) across all harvest dates. Rye cultivars exhibited contrasting responses over harvest dates (Fig. 3C); Wintergrazer 70 exhibited a quartic \((P < 0.01)\) effect, but yields over the final four harvest dates ranged narrowly between 866 and 1098 kg ha\(^{-1}\). In contrast, yield for AGS 104 rye increased in a strong linear \((P < 0.01)\) pattern over time, reaching a maximum of 2752 kg ha\(^{-1}\) that was the greatest numerical yield for any cultivar on any harvest date within this site-year.

Regrowth. Unlike 2004–2005, all forages except Horizon 474 oat exhibited some measurable regrowth following all initial harvest dates. For Horizon 474 oat, there was no measurable regrowth in plots harvested initially on 2 December, but this was the only initial harvest date for which this occurred for this cultivar (Fig. 4A). Yields of regrowth for all oat and triticale cultivars changed in a quadratic \((P \leq 0.03)\) pattern as the time interval between the initial and regrowth harvest dates shortened. Unlike 2004–2005, yields of regrowth for these cultivars reached a minimum following either the 2 or 16 December initial harvest date, but then increased by 374 to 850 kg ha\(^{-1}\) for plots harvested initially on 3 January. For both oat cultivars and triticale, this represented improved winter survival and/or productivity relative to 2004–2005. Regrowth harvested from GR 9108 and Armor wheat cultivars (Fig. 4B) was not affected by initial harvest date \((P \geq 0.18)\), but regrowth from OK 101 wheat declined linearly \((P = 0.02)\) over the same time period. In practice, this represented a 43% decline between the 21 October and 3 January initial harvest dates, but regrowth harvested on 1 March was static following the final four initial harvest dates, which ranged tightly between 702 and 724 kg ha\(^{-1}\). Regrowth harvested from rye cultivars exhibited no relationship \((P \geq 0.07)\) with initial harvest dates.

dead when regrowth was harvested in mid-February. Horizon 474 oat and Monarch triticale responded similarly; both cultivars exhibited little or no regrowth when the initial harvest date was on 2 December or later. However, some live tillers were observed for both cultivars on the regrowth (15 February) harvest date. In contrast, the wheat cultivars (Fig. 2B) consistently exhibited regrowth between the final harvest of initial growth (29 December) and 15 February, accumulating an average of 883 kg ha\(^{-1}\) during this time interval. Winter regrowth responses for cereal-rye cultivars (Fig. 2C) were intermediate between the wheat and oat plus triticale groups, accumulating an average of 502 kg ha\(^{-1}\) between 29 December and 15 February.
However, the yield of regrowth from AGS 104 averaged over all initial harvest dates (2775 kg ha⁻¹) was more than three times that observed for Wintergrazer 70.

Batesville 2004–2005

Initial growth. The overall mean DM yield at Batesville (491 kg ha⁻¹) was only about 25% of that observed for Fayetteville during the same year (1960 kg ha⁻¹); this difference between sites can largely be explained by the 93-mm precipitation deficit that occurred during September 2004 at Batesville (Table 4). Because of this deficit, there was no measurable forage that could be harvested on the initial 20 October harvest date. Otherwise, yields of DM increased in curvilinear (P ≤ 0.04) patterns for all forages over sampling dates. Oat and triticale cultivars exhibited cubic (P ≤ 0.04) responses over time (Fig. 5A), while responses for wheat (Fig. 5B) and rye (Fig. 5C) cultivars were all quadratic (P ≤ 0.03). The higher-ordered responses for oat cultivars may partly be explained by

Fig. 4. Regrowth yield responses for eight cereal-grain cultivars at Fayetteville, AR, during 2005–2006. Regrowth responses (highest-ordered significant polynomial contrast) for (A) oat and triticale cultivars harvested on 1 Mar. 2006 following six initial harvest dates during the previous fall were quadratic for Horizon 474 (P = 0.03) and Blaze (P < 0.01) oat, and for Monarch triticale (P < 0.01). For (B) wheat cultivars, responses were linear for OK 101 (P = 0.02); however, there were no significant contrasts for either other wheat cultivar (P ≥ 0.18). Responses for (C) rye cultivars also were nonsignificant (P ≥ 0.07). Error bars represent the standard error of each interaction mean after adjustment for heterogeneous variances on the basis of cultivar.

Fig. 5. Fall dry matter yield responses for eight cereal-grain cultivars at Batesville, AR, during 2004–2005. Yield responses (highest-ordered significant polynomial contrast) for (A) oat and triticale cultivars over time were cubic for Horizon 474 winter oat (P = 0.04), Blaze spring oat (P < 0.01), and Monarch triticale (P = 0.02). For (B) wheat, responses were quadratic over time for each cultivar (GR 9108, P = 0.03; OK 101, P < 0.01; Prograze, P < 0.01). Responses for both (C) rye cultivars also were quadratic (P ≤ 0.01). Error bars represent the standard error of each interaction mean after adjustment for heterogeneous variances on the basis of cultivar.
the 42 and 56% yield reductions for Horizon 474 and Blaze, respectively, that occurred between the 16 December and 10 January harvest dates.

Following harvests of initial growth, minor contamination was observed within several cereal-grain plots from volunteer annual ryegrass (*L. multiflorum* Lam.). While this had little or no effect on the data for initial growth of cereal-grain forages, contamination levels in some plots were deemed unacceptable for data collection by the regrowth harvest date. Therefore, regrowth of cereal grain cultivars was not evaluated at the Batesville site during February 2005.

**Batesville 2005–2006**

**Initial growth.** Above normal precipitation during September (43 mm) contributed to excellent early-fall growth, and overall yield responses that were unique relative to all other site-years. Horizon 474 oat and Monarch triticale (Fig. 6A), and wheat (Fig. 6B) and rye (Fig. 6C) cultivars all accumulated DM in quadratic (*P* < 0.01) patterns over harvest dates. Excepting Horizon 474 oat, each reached their maximum numerical DM yield on the final (4 January) harvest date. Maximum yields for the six triticale, wheat, and rye cultivars on this date ranged narrowly from 3983 to 4387 kg ha⁻¹; for wheat cultivars (range = 3983–4380 kg ha⁻¹), these growth responses far exceeded the maximums for any wheat cultivar on any harvest date in Fayetteville 2004–2005 (2554 kg ha⁻¹), Fayetteville 2005–2006 (1154 kg ha⁻¹), or Batesville 2004–2005 (778 kg ha⁻¹).

In contrast, both oat cultivars were affected by a freezing temperatures (−7°C) that occurred on 17 and 18 November. Before these dates, the mean high and low temperatures for the first 16 d of November were 22 and 8°C, respectively. After this sudden temperature change, oat cultivars did not continue to accumulate forage mass over the remaining harvest dates. Although Horizon 474 exhibited a quadratic (*P* < 0.01) response over harvest dates, which was consistent with responses for triticale, wheat, and rye cultivars, yields of DM over the final four dates were relatively static (range = 2858–3371 kg ha⁻¹). Yields for Blaze spring oat exhibited a higher-ordered cubic (*P* < 0.01) effect over time, but were affected more severely by freezing temperatures in mid-November; the maximum numerical yield (2461 kg ha⁻¹) occurred on 21 November, and yields declined to 1924 kg ha⁻¹ by the final harvest date.

**Regrowth.** As the time interval between the initial and regrowth harvests shortened, yields of DM from regrowth (Fig. 7A–C) declined (*P* ≤ 0.05) for all cultivars except for GR 9108 wheat (*P* ≥ 0.10); however, specific polynomial effects were inconsistent, but primarily curvilinear. Excepting Armor (vns) wheat, each cultivar exhibited maximum numerical yields of regrowth when plots were harvested initially on 24 October. Consistent with other site-years, Blaze spring oat exhibited the poorest potential for regrowth, producing no measurable regrowth following any initial harvest in November, December, or early January. In contrast, regrowth from Monarch triticale when harvested initially on 24 October (6443 kg ha⁻¹), and for AGS 104 rye following initial harvests on both 24 October and 8 November (6578 and 5846 kg ha⁻¹, respectively) were especially productive; these yield responses exceeded by ≥1185 kg ha⁻¹ those for any other harvest of initial growth or regrowth for any other combination of cultivar, harvest date, site, or year.

**Regression of Dry Matter Yield on Canopy Height**

Regardless of grouping, all linear regressions of DM yield on canopy height (Table 9) exhibited positive slopes that differed from zero (*P* ≤ 0.01). For the analysis of initial growth, slopes for rye, triticale, and wheat were homogenous (*P* = 0.76), and confined within a relatively narrow range (103.4–122.2 kg ha⁻¹ cm⁻¹). Slopes for these species also were homogenous (*P* = 0.75) and confined to a similar, narrow range (105.8–118.3 kg ha⁻¹ cm⁻¹).
cm$^{-1}$) when data for initial growth and regrowth were combined. In both cases, respective slopes for oat (58.6 and 64.9 kg ha$^{-1}$ cm$^{-1}$) differed ($P < 0.01$) from the other three species. This contrast between oat and other cereal grains can be explained largely on the basis of growth habit. Under favorable growing conditions, DM yield for vegetative wheat and rye appeared to increase as a function of both canopy height and tiller density. In contrast, DM yield for oat was more directly a function of upright growth. Previously, the juvenile growth habit of Blaze oat has been described as being erect (Kolb et al., 1999).

Regressions for regrowth alone exhibited greater coefficients of determination ($r^2$) than other groupings; within this context, relationships were especially strong for rye ($N = 36; r^2 = 0.84$), triticale ($N = 18; r^2 = 0.84$), and all regrowth combined ($N = 144; r^2 = 0.70$), but very poor for wheat ($N = 54; r^2 = 0.15$). For regrowth, slopes did not differ ($P = 0.26$) across species (overall range = 101.4–151.5 kg ha$^{-1}$ cm$^{-1}$), while intercepts were heterogeneous ($P = 0.04$).

A distinct contrast was observed between initial growth and regrowth for oat. The slope for regrowth (141.2 kg ha$^{-1}$ cm$^{-1}$) was about 2.4 times that observed for initial growth (58.6 kg ha$^{-1}$ cm$^{-1}$); however, the slope exhibited by regrowth was relatively consistent with slopes exhibited by other species. Procedurally, the evaluation of regrowth for oat also was complicated by sensitivity to cold temperatures; in many cases, plants died or exhibited no measurable regrowth, which did not generally occur for other species. After considering these data and the limitations created by a lack of strict statistical homogeneity, at least two general linear relationships might be suggested for producers to quickly estimate fall and winter forage mass based solely on the basis of canopy height. Rye, wheat, and triticale exhibited relatively common slopes, and potentially could be combined into a common relationship ($Y = 107.7X – 694.1; N = 252; r^2 = 0.48; P < 0.01$). In contrast, the relationship between DM yield and canopy height was very distinct for initial growth of oat, and from a practical standpoint, there was little subsequent regrowth response. Therefore, oat cultivars probably should be estimated independently ($Y = 64.9X – 104.0; N = 84; r^2 = 0.53; P < 0.01$).

**DISCUSSION**

Without the need to produce a grain crop, numerous options exist for clean-tilled cereal grains that will likely exceed the fall forage DM production of a traditional wheat monoculture. In northern Arkansas, coupling an early planting date with selection of cultivars that are likely to exhibit stem elongation will maximize fall yield of DM for most sites and years. Excepting one site-year (Batesville 2005–2006) in which climatic conditions were unique, elongating cultivars produced at least 50% more DM by mid-December than cultivars that remained vegetative. This yield advantage for elongating cultivars agrees with previous reports by Maloney et al. (1999), who found that (elongated) spring cereals harvested during fall in Wisconsin exhibited yield advantages that ranged from two to six times those of winter cereals that remained vegetative. While stem elongation resulted in substantial increases in DM yield, this also was coupled with a concomitant increase in sensitivity to damage by freezing, or by complete winterkill. Generally, these two factors (stem elongation and sensitivity to freeze dam-

![Fig. 7. Regrowth yield responses for eight cereal-grain cultivars at Batesville, AR, during 2005–2006. Regrowth responses (highest-ordered significant polynomial contrast) for (A) oat and triticale cultivars harvested on 17 Feb. 2006 following six initial harvest dates during the previous fall were cubic ($P < 0.01$) for Horizon winter 474 oat, quadratic ($P = 0.02$) for Blaze spring oat, and quartic ($P < 0.01$) for Monarch triticale. For (B) wheat cultivars, responses were linear for OK 101 ($P = 0.01$) and quartic ($P = 0.05$) for Armor (vns); however, there were no significant contrasts for GR 9108 ($P > 0.10$). Responses for (C) rye cultivars were quartic ($P < 0.01$) for AGS 104, but quadratic ($P = 0.01$) Wintergrazer 70. Error bars represent the standard error of each interaction mean after adjustment for heterogeneous variances on the basis of cultivar.
established at Fayetteville and Batesville, AR, during September 2004 and 2005. Height (cm) for initial growth and/or regrowth of eight cereal-grain forages were obtained under near normal precipitation patterns. Harvested 77 d later, immediately before killing frost. These erratic precipitation patterns limited germination and growth.

In contrast, Contreras-Govea and Albrecht (2006) reported yields of 6700 kg ha⁻¹ for several cultivars of spring oat harvested during early August in southern Wisconsin and harvested 77 d later, immediately before killing frost. These yields were obtained under near normal precipitation patterns with soil moisture conditions that did not limit growth. However, yields of oat in our study were generally comparable to those reported by Maloney et al. (1999) for six spring oat cultivars harvested during fall in southern Wisconsin (range = 2900–4000 kg ha⁻¹), but greater than those harvested similarly in central Wisconsin (range = 1100–1800 kg ha⁻¹).

Yield responses for AGS 104 rye were unique; although the vast majority of tillers remained vegetative throughout the fall and early winter, yields for initial growth were comparable to those of oat and triticale cultivars exhibiting relatively uniform stem elongation. This may be explained partly by the 20 to 25 tillers m⁻¹ of drill row that elongated, but also by the aggressive tillering habit of this cultivar. Unlike oat and triticale cultivars, AGS 104 retained the potential for regrowth exhibited by other wheat and rye cultivars that remained completely vegetative throughout the initial fall sampling period. Given these traits, AGS 104 rye offered the best performance with respect to winter survival, and combined yields of DM for initial growth and regrowth. However, the less-erect growth habit of this cultivar during this sampling period, relative to oat, suggests better suitability for grazing applications than for mechanical harvest.

Cultivars of wheat and rye that remained completely vegetative throughout the initial sampling period exhibited the poorest potential for fall growth. However, there was little evidence of winterkill for these cultivars, and the advantages of their use in Arkansas within mixtures or monocultures for spring forage is well documented (Jennings and Coffey, 2006a, 2006b; Daniels et al., 2002; Coblentz et al., 2000). Although not analyzed formally within this study, it is well worth noting that the yield disadvantages observed for these cultivars are reduced considerably if both initial fall growth and winter regrowth are considered in total, and may be eliminated entirely if potential for spring growth also is considered. This suggests that the selection of wheat or rye cultivars that remain strictly vegetative in the fall may become more attractive when producer goals are more general, and include a broader time interval of potential use by one or more livestock groups or classes.

### CONCLUSIONS

Without the need to produce a grain crop, numerous exist for clean-tilled cereal grains that will likely exceed the fall forage DM production of a traditional wheat monoculture. In northern Arkansas, coupling a relatively early planting date with selection of cultivars that typically exhibit at least some stem elongation under expected climatic conditions will maximize fall yield of DM. Unfortunately, this production advantage is coupled with increased sensitivity to freeze damage or winterkill. Therefore, selection of these cultivars should be in response to very specific producer objectives, such as maximizing weight gains of a specific group or class of animals during the fall and early winter, or to provide emergency forage following summer drought. Selection of a wheat or rye cultivar that remains strictly vegetative throughout the fall becomes much more attractive when producer goals are general, and include a broader time interval of potential use by one or more livestock groups or classes.
multiple livestock groups or classes. These results also suggest some additional work may be warranted to evaluate systems using multiple species and/or cultivars in combination, particularly when they are established independently, which could improve both season-long forage production and distribution.

REFERENCES