Nitrogen Application for Spring Growth of Cool-season Grasses Overseeded in Unimproved Warm-season Pasture

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Abstract
In the southern Great Plains fall overseeding of annual forages into dormant warm-season pasture can increase herbage production in spring and early summer of the following year, but production in early spring, when it is most needed, is usually limited and competition between cool- and warm-season components of mixed pasture may result in only small benefit in total annual yield. The effects of early-producing species, or of stimulation of early growth by nitrogen (N) fertilizer application to the cool-season crop, on early-season availability of herbage and on competition within mixed pasture were evaluated in a series of experiments. Rye (Secale cereale L.), oats (Avena sativa L.), or annual ryegrass (Lolium multiflorum Lam.) were overseeded into dormant unimproved warm-season pasture in fall and provided 22, 45, or 67 lb/acre of N fertilizer in mid-February of the following year. Neither rye nor annual ryegrass showed significant advance in early-season growth (up to early April) resulting from increased N application, and herbage dry matter (DM) yield response was <4.0 lb DM/lb N applied over this period. Over uninterrupted spring growth to a mid-May harvest, DM yield responses to applied N were similar in rye and annual ryegrass and ranged from 9.3 to 32.3 lb DM/lb N. Oats did not tolerate low winter temperatures. Choice of cool-season annual grass species for overseeding and level of N application in spring had little impact on DM yield of the warm-season grass component of mixed cool- and warm-season pasture.

In the southern Great Plains perennial warm-season grasses are dormant, or show only limited activity, during the cooler fall and spring periods, when temperatures are too low for active growth. This prolonged period of low productivity presents problems in lack of continuity of feed supply for livestock (Reuter and Horn, 2002) and increases livestock production costs by obliging producers to find alternative sources of feed (Ramsey et al., 2005). Cool-season grasses can be overseeded into dormant warm-season pasture to provide out-of-season green herbage for grazing that may not only reduce cool-season feed costs, but also increase year-round forage yields (Belesky...
and Fedders, 1995). However, gains in total annual production are frequently less than the production of cool-season grass, because warm-season production may be reduced following overseeding of cool-season grasses (Fribourg and Overton, 1973; Utley et al., 1976). Some increase in early-season and year-round herbage production has been reported on low-productivity marginal land, but gain in cool-season production has been significantly offset by reduction in warm-season forage productivity (Bartholomew and Williams, 2008).

In a low-productivity environment the need for late planting to avoid competition from actively growing warm-season grasses and high temperatures of late summer (early September), combined with declining temperatures in November, provide a narrow window of opportunity for fall growth of overseeded cool-season grasses, and productivity over this period is consequently limited (Bartholomew and Williams, 2009; Evers, 2005). While there is increased production in spring from areas overseeded with cool-season grasses, no substantial yield is available before early April and the bulk of cool-season grass production is achieved in late April and May, as the warm-season grass emerges from winter dormancy (Bartholomew and Williams, 2008). From the perspective of improved feed supply and reduced competition between cool- and warm-season grasses, there may be benefit derived from advancing the growing season and accelerating spring growth of cool-season forages.

Efforts to advance the spring growing season center on selection of forages that offer early-season production or on manipulation of forage growth by fertilizer management. Perennial cool-season grasses are less productive early in the year than annual ryegrass (Bartholomew and Williams, 2008), which is productive later in spring than annual small-grain cereals (Evers, 2005). Among small-grain cereals rye is regarded as the most well adapted for early-season production in low-yield and cold-stress environments (Bruckner and Raymer, 1990; Moyer and Coffey, 2000). Oats are more susceptible to freeze damage than is rye (Webb et al., 1994), resulting in unreliable production over winter (Bruckner and Raymer, 1990). However, oats may offer improved quality forage compared with other small-grain cereals (Bruckner and Hanna, 1990). Nitrogen (N) fertilizer is commonly applied to forage grasses to increase total herbage biomass, but it may also be used to manipulate seasonal distribution of production (Hennessy et al., 2008; van Burg, 1968). The extent to which N fertilizer application may be used to advance production of annual cool-season grasses overseeded into warm-season pasture, and its effects on combined warm- and cool-season herbage production, have not been widely studied. The objectives of the study reported here were to evaluate effects of annual cool-season forages, in combination with different levels of N application in early spring, on seasonal and total annual herbage production of cool- and warm-season grass mixtures.

### SITE AND SOIL TYPE

Field experiments were performed in three successive years, beginning in fall of 2005, at a low-productivity site 4 mi south of Langston, OK (35°53’N, 97°15’W), that had been managed for hay production for >15 yr before the experiment. A different area on the site was used for each experiment. Soil was a Coyle series loam (fine-loamy, siliceous, thermic, Udic Argustoll), with pH 6.1 and available phosphorus and potassium (Mehlich 3) at 10 and 113 ppm, respectively, within the upper 6 inches of the soil profile. The existing perennial warm-season pasture consisted predominantly of sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.), splitbeam bluestem (*Andropogon ternarius* Michx.), little bluestem (*Schizachyrium scoparium* (Michx.) Nash), and big bluestem (*Andropogon gerardii* Vitman).

### PROCEDURES

Annual ryegrass (*Lolium multiflorum* Lam.) cv. Marshall and oats (*Avena sativa* L.) cv. Jerry (in 2006) or rye (*Secale cereale* L.) cv. Elbon (in 2007 and 2008) were overseeded at the end of September or during the first week of October into dormant or nearly dormant warm-season pasture that had been trimmed to a stubble height of approximately 2 inches. A Landpride rotating knife seeder (Landpride, Salina, KS) was used for sowing, with planting depth and seed rates adjusted for the type of seed used. Ryegrass was sown at an average depth of 0.5 inches below the soil surface, and small-grain cereals at approximately 1.5 inches. Seeding rates used were 26, 76, and 83 lb/acre for ryegrass, oats, and rye, respectively. A uniform dressing of 22 lb N/acre was applied in the form of urea (46% N) following emergence of seedlings in fall each year. Plant and tiller counts were made in three 6 by 6-inch quadrats placed at random in each plot in early spring (mid-March) each year.
to measure establishment of sown grasses. Nitrogen application treatments of 22, 45, or 67 lb N/acre were applied at the beginning of the spring growing season (mid- to late February). On each treatment 22 lb N/acre was applied as 19:19:19 compound (N:P2O5:K2O) and the incremental N required for 45 and 67 lb N/acre treatments was provided as urea (46% N). Nitrogen application treatments were combined with initial harvests of cool-season grass at 6 wk after application of spring N (early April) or at 12 wk after application of spring N (mid-May). Treatment effects on cool- and warm-season herbage dry matter (DM) production were measured at the two initial harvest dates and subsequently at harvests of regrowth taken in late July and mid- to late September. At each harvest a sickle-bar mower (Troybilt, Troy, NY) was used to clip an area 2.75 by 20 ft to leave a stubble of approximately 2.5 inches. The material harvested was weighed in the field and a sample of approximately 7 oz of fresh herbage was taken for separation into sown cool-season grass, other grass (warm-season), and forb components. Separated material was dried at 140°F for 72 h and weighed for estimation of component DM content. After weighing, the dried components of each sample were recombined and ground through a 0.04-inch screen before analysis for N concentration by automated flash combustion (varioMacro, Elementar Americas, Inc., Mount Laurel, NJ) to allow estimation of total recovery of N (lb N/acre) at each harvest.

Rainfall and temperature data were taken as means of values recorded at official stations at Guthrie, OK (12 mi west of the site), and Perkins, OK (10 mi east of the site), from Oklahoma Mesonet reported data (OCS, 2012). Accumulated temperature (°F) was calculated as the accumulation of mean daily temperature [(daily maximum {Tmax} + daily minimum {Tmin})/2] above a base temperature of 32°F. In each year, temperature and rainfall accumulations were calculated for the fall establishment period (1 October to 31 December), from 1 January to the date of early harvest and over the period between early and late harvests. Rainfall accumulations were also calculated for mid- and late-summer regrowth periods (mid-May to late July and late July to mid- or late September) in each year.

**STATISTICS**

In each year the experiment was arranged in a split plot layout in which main plots consisted of cool-season grass species and subplots were N application treatment $\times$ initial harvest date treatment. Individual subplots were 4.0 by 20 ft and main plots, comprising six subplots (3 N $\times$ 2 harvest treatments), were 24 by 20 ft. An unharvested strip 1.25 ft wide was left as a discard area between adjacent plots. Each treatment was replicated four times in each experiment. Within each year cool-season forage species, N application level, and initial harvest date were considered fixed effects and replicates were random effects. Statistical analysis was made by ANOVA, using Genstat 11 procedures (Genstat, 2008) and where ANOVA indicated significant differences ($P < 0.05$) among treatments, mean separation was made by least significant difference. Genstat regression procedures were used to estimate marginal responses to applied N of DM yield (increment in DM per unit increase in applied N) and N recovery (increment in N yield in herbage per unit increase in applied N) and to assess the effect of rainfall on herbage DM responses to N application.

### RAINFALL AND TEMPERATURE CONDITIONS

Fall (1 October to 31 December) rainfall in 2005 was less than in the two following years and showed a lower frequency of events with >0.2 inches of precipitation (Table 1). The spring growing season of 2006 was significantly drier overall than that of the two following years, with cumulative rainfall (1 January to date of harvest in May) in 2006 at 54 and 52%, respectively, of the amounts recorded over the equivalent periods in 2007 and 2008 (Table 1). However, rainfall between early April and mid-May in 2006 was greater than that of the same period in 2008 (Table 1). Spring accumulated temperatures between January 1 and date of harvest in May, above a base temperature of 32°F, were greater in 2006 (3132 growing degree-days [GDD]) than in 2007 and 2008 (2693 and 2565 GDD), respectively (Table 1). There were 66, 71, and 94 instances of minimum daily temperatures below 32°F between 1 November and 30 April in 2005 to 2006, 2006 to 2007, and 2007 to 2008, respectively. Minimum temperatures below 27.5°F occurred slightly less frequently between November and April in 2005 to 2006 (41 occasions) than in the two following years (47 and 54 times in 2006–2007 and 2007–2008, respectively). Rainfall over the May to late-July regrowth period was 7.3, 22.4, and 9.9 inches in 2006, 2007, and 2008, respectively. Late-summer
rains, over the late-July to mid- or late-September regrowth were much less variable, with totals of 2.8, 4.7, and 4.6 inches in 2006, 2007, and 2008, respectively.

**STAND ESTABLISHMENT**

Oats planted in fall of 2005 were severely damaged by frosts in early 2006, so that only 29% of emerged seedlings survived (4.6 plants/sq ft) into spring of 2006 and, in consequence, no harvest of oats was made in 2006. In contrast, ryegrass plant stand in spring was 48.4, 47.6, and 30.3 plants/sq ft in 2006 to 2008, respectively, and established populations of rye were 20.9 and 19.1 plants/sq ft in 2007 and 2008, respectively.

**COOL-SEASON GRASS PRODUCTION**

**Effects of Timing of Initial Harvest**

In all years there were large differences in yields of cool-season grasses according to initial harvest date in early April or in mid-May (Fig. 1a, 2a, and 3a). Cumulative yield of sown cool-season grass up to mid-May was also greater in all years with a single harvest taken at the end of the period than with an early harvest followed by a 6-wk regrowth (Fig. 1b, 2b, and 3b).

**Nitrogen Application Effects**

Differences in herbage yields at early and late initial harvests were increased with greater application of N, and in all years this interaction of initial harvest date and N application level was significant ($P < 0.05$) (Fig. 1a, 2a, and 3a). Herbage DM yields up to mid-May harvest showed strong linear relation to applied nitrogen ($R^2$ between 0.85 and 0.96). Marginal DM yield response within the range of 22 to 67 lb applied N/acre with late initial harvest was 21.0 lb DM/lb N (ryegrass only) in 2006, 31.9 and 32.3 lb DM/lb N (ryegrass and rye, respectively) in 2007, and 16.1 (ryegrass) and 9.3 (rye) in 2008. However, responses to N were not significantly different between species in either 2007 or 2008. With early initial harvest, increased N application produced only small gain in yield, and this was reflected in marginal responses that were, in all three years, <4.0 lb DM/lb N applied. Increased N application increased cumulative DM yield of cool-season grass in each year (Fig. 1b, 2b, and 3b), but marginal response was reduced with early harvest followed by regrowth, compared with

![Figure 1](image.png)

Figure 1. Effects of level of spring nitrogen (N) application and timing of initial harvest of cool-season grass (annual ryegrass) on component and total-season dry matter (DM) yields (lb/acre) of mixed cool- and warm-season pasture in 2006: (a) initial harvest yields of cool-season grass, (b) total annual yields of cool-season grass, (c) total annual yields of warm-season grass, and (d) total annual yields of mixed pasture. Least significant differences (LSD) ($P = 0.05$) are indicated for each data set within the respective graphics.
uninterrupted growth to mid-May. There was no significant N \times species interaction in cumulative cool-season herbage yield (Fig. 2b and 3b).

**WARM-SEASON GRASS PRODUCTION**

With the exception of late-harvested ryegrass and early-harvested rye in 2007 (Fig. 2c), N application or species-choice treatments showed little effect on yields of warm-season grass. Early-season production (up to mid-May harvest) of warm-season grass comprised only 15 to 25% of total warm-season yield. The bulk of warm-season grass production was taken in summer and early-fall harvests when there was little or no remaining cool-season crop and there was no significant effect of initial harvest date or N application treatment on warm-season grass yields in harvests taken after mid-May (data not shown).

**TOTAL ANNUAL PRODUCTION OF MIXED COOL- AND WARM-SEASON PASTURE**

Combined total herbage yields from mixed pasture were greater when the cool-season component was ryegrass rather than rye, but marginal yield responses to N were similar in both species. With early initial harvest of cool-season grasses (in early April), total annual herbage yields of mixed pasture were consistently lower than on treatments with initial harvest of cool-season grass taken in mid-May. Nitrogen application up to 67 lb/acre increased the total annual production of mixed cool- and warm-season pasture in two years out of three (Fig. 1d, 2d, and 3d).

**NITROGEN YIELD IN HARVESTED HERBAGE**

In all years only small amounts of N were harvested in herbage cut in early April (Table 2) and marginal increase in uptake with increased N application was small, ranging from 6 to 12% recovery of N applied in
In 2008 there was no significant difference among N treatments in yield of N. Cumulative N yield up to the mid-May harvest increased (P < 0.001) with increased N application in 2006 and with both ryegrass and rye in 2007 but only rye treatments showed significant increase in N yield in 2008. Recovery of N up to mid-May, estimated by regression, ranged from 3 to 32% in ryegrass over 3 yr and from 6 to 24% in 2 yr with rye. Overall N recovery rates were not significantly different between species, with a mean of 19%. Nitrogen yields at July and September harvests, that comprised almost exclusively warm-season grass regrowth, showed no significant differences among spring N application treatments in any year (data not shown).

**SPECIES CHOICE FOR EARLY-SEASON PRODUCTION OF COOL-SEASON ANNUAL GRASSES**

Failure of oats in 2006 was consistent with other reports (Bruckner and Raymer, 1990; Evers, 2005) that have concluded that oats is not sufficiently cold-hardy to overwinter reliably in the southern Great Plains. Other work at the Langston site (Bartholomew et al., 2011) has shown that crop residue can reduce exposure of overseeded crops to low temperatures, but the degree of protection offered by the 2-inch stubble used in the experiments reported here was evidently not sufficient to allow oats to survive, even though conditions in 2005 to 2006 were not untypically cold. Low-temperature exposures over winter 2005 to 2006 (November through February) were, in fact, slightly less frequent and severe than those of the two following years. Rye, in contrast, did not appear to be adversely affected by low winter temperatures but, although sown at recommended seed rate, the established plant stands were marginal (mean 20.0 plants/sq ft) for satisfactory forage production; Boyd et al. (2009), for example, achieved a mean plant stand of 29.9 plants/sq ft with a seeding rate of 80 lb/acre. While it might be possible to increase plant stand and forage production with increased seed rate, this would require additional production cost. Even at recommended seed rates, rye is more expensive to establish than ryegrass (estimated at approximately $22.3/acre, compared with $22.3/acre).
ryegrass at $12.1/acre [Islam et al., 2011]) and it is not clear that the additional cost of increase in seed rate of rye would be compensated by a corresponding gain in forage yield. The results reflect other work (Bartholomew et al., 2011) that has shown the relative ease of establishment of ryegrass by no-till planting, while rye appears to perform relatively poorly in a minimal tillage environment (Moyer and Coffey, 2000).

### NITROGEN MANAGEMENT FOR EARLY-SEASON PRODUCTION OF COOL-SEASON ANNUAL GRASSES

The limited herbage yields and low response rates to applied N of both rye and ryegrass at early harvest emphasize the problem of generating early production of forage in this environment. From the perspective of cool-season forage supply even an early-April harvest is late in the season, and only limited yield was obtained from harvest at this stage. Not only does early harvest offer little benefit in early production, but it may also prejudice the economy of spring-applied N by reducing marginal DM response to N. Although herbage growth rates were increased by an average 21.3 lb DM/acre/d between early April and mid-May, as N application increased from 22 to 67 lb/acre, yield gain or advance in harvest with the higher N use may be of limited value at this time of year, when warm-season grasses begin active growth.

### RAINFALL AND DRY MATTER YIELD RESPONSES TO NITROGEN

Marginal herbage DM yield responses of ryegrass to applied N (lb DM/lb N) were notably variable among years. This variability in response was closely linked to rainfall during the period of active spring growth (early April to mid-May) and over 3 yr showed a linear relation (DM Response [lb DM/lb N] = [4.0 × Rainfall] − 2.1 [R² = 0.96]).

### EFFECTS OF COOL-SEASON GRASS SPECIES AND NITROGEN APPLICATION ON COMPANION WARM-SEASON GRASSES

Effects of cool-season grass species and spring N application treatments on warm-season grass growth later in the season were generally small, though yields in 2007 increased with early-harvested rye and decreased with late-harvested ryegrass, reflecting earlier work (Bartholomew and Williams, 2008) that has shown an inverse relation of cool- and warm-season grass yields. Other studies of N utilization in crop sequences have shown significant scavenging by annual cool-season grasses of residual N remaining after summer cropping (Feyereisen et al., 2006; Kaspar et al., 2007). Here, the cool-season grasses were the primary target of applied N and the warm-season grasses the potential scavenger; the circumstances are analogous, but even though uptake of N by cool-season grasses was, at best, 32%, implying a potential for residual N effect, there was no evidence of any significant effect on warm-season grasses, either as DM yield or N capture. A sequence of cool-followed by warm-season grasses does not appear to increase efficiency of uptake and use of applied N, in spite of a longer season of active growth of the mixture, compared with the separate components.

### CONCLUSIONS

Although spring N application will increase grass growth rate and herbage yield up to mid-May, the low response to N before early April, when increased productivity is most needed, shows that there is only limited potential to advance the growing season of cool-season annual grasses through increased application of N fertilizer. Any early-season production benefit of rye, compared with annual ryegrass, is likely to be offset by less reliable establishment with no-till overseeding and greater seed cost with rye than with ryegrass.

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**Table 2. Nitrogen (N) harvested in annual ryegrass and in cereal rye at early (E) or late (L) initial harvests 2006–2008. Early harvests were made 7 Apr. 2006, 5 Apr. 2007, and 9 Apr. 2008. Late harvests were made 19 May 2006, 18 May 2007, and 21 May 2008.**

<table>
<thead>
<tr>
<th>Year/treatment</th>
<th>Spring N application</th>
<th>LSD P = 0.05</th>
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<tr>
<td></td>
<td>22 lb/acre</td>
<td>45 lb/acre</td>
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<td>2006</td>
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<tr>
<td>Ryegrass E</td>
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</tr>
<tr>
<td>Ryegrass L</td>
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<tr>
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<td>4.6</td>
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</tr>
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<td>Rye E</td>
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</tr>
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</tr>
<tr>
<td>Rye L</td>
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References


