Phosphorus Fertilization of Annual Ryegrass

By T.J. Butler, J.P. Muir, T. Provin, and W.M. Stewart

Annual ryegrass is an important forage crop in the southern U.S. It has good yield potential and excellent nutritive value. This central Texas study has demonstrated the importance of both nitrogen (N) and phosphorus (P) fertilization in ryegrass production. The optimal rate of P fertilization was either 40 or 60 lb/A, and optimal N rate was 200 or 300 lb/A, both depending on seasonal rainfall distribution. Interestingly, there was relative agreement between removal of P in forage and optimal P fertilizer rate. These results demonstrate, and further confirm, the importance of balancing nutrient inputs in forage production to optimize yield, quality, and grower profit.

Annual ryegrass provides highly nutritious herbage in the southeastern U.S. during a critical time of the year when both forage availability and quality are limiting. Depending on latitude, ryegrass is planted or allowed to self-reseed where it is naturalized from September to October and then grazed during the winter and spring. Ryegrass responds well to N fertilizer. However, that response may be limited by insufficient P. This is particularly true on soils that are low in P, such as those that occur in much of northcentral Texas and south-central Oklahoma.

Our objectives in this study were to: 1) evaluate annual ryegrass yield response to annual applications of various rates of N and P fertilizer, paying particular attention to interaction between nutrients and application rates and, 2) evaluate the accuracy of two soil test-P methods: Mehlich-3 and ammonium acetate (NH_4OAc)-EDTA (formerly called the Texas A&M method).

This study was initiated in September 2001 on a Windthorst sandy loam soil (Udic Paleustalf) in northcentral Texas near Stephenville. Initial soil tests indicated these results: soil pH, 5.1; nitrate (NO_3)-N, 6 parts per million (ppm); P, 6 ppm (low, NH_4OAc-EDTA extractant); and potassium (K), 205 ppm (high). A split-plot randomized complete block design with four replications, six main treatments, and two sub-treatments was established. Main plots received annual applications of 0, 20, 40, 60, 80, and 100 lb P_2O_5/A/year. Phosphorus from triple superphosphate (0-46-0) was preplant-incorporated 6 to 8 in. deep. Subplots received annual split applications of 200 or 300 lb N/A/year. Nitrogen (34-0-0) applications were split-applied, with half applied at planting and the remainder in February. Ryegrass was planted at 30 lb seed/A each year to ensure adequate stands.

Balanced fertilization of annual ryegrass optimizes yield, quality, and profitability.

Plots were harvested four times on monthly intervals (February through May) during 2001-02, 2002-03, and 2003-04. Ryegrass yield for each harvest was determined for each treatment and samples were analyzed for N, P, neutral detergent fiber (NDF), and acid detergent fiber (ADF). Nitrogen concentration was multiplied by 6.25 and reported as crude protein (CP).

Soil samples (6 in. depth) were taken from each plot at the end of each growing season to determine treatment differences. Soils were analyzed for pH using a 1:2 ratio of soil to deionized water, NO_3-N by cadmium (Cd) reduction, and sodium (Na), magnesium (Mg), sulfur (S), K, calcium (Ca), and P based on two soil-extractant methods: acidified NH_4OAc-EDTA and Mehlich-3. After the 2002-03 growing season, 1.5 tons/A ECCE (effective calcium carbonate equivalent) dolomitic limestone was added to all plots to adjust the average soil pH from 4.9 to 5.8.

Total seasonal (September through June) rainfall differences were relatively small. Precipitation in the first growing season totaled 29.2 in., 30.5 in. for the second season, and 31.0 in. during the third season. Although total seasonal rainfall among the 3 years was similar, the difference in distribution among growing seasons was substantial (**Figure 1**). The second growing season (2002-03) had the best early and midseason moisture…45% of the season total fell by the end of January 2003 (i.e., midseason). During the first and last seasons (2001-02 and 2003-04) 36% and 25%, respectively, of the season totals fell by the end of January. Overall, seasonal rainfall distribution was superior for ryegrass production in the second season.

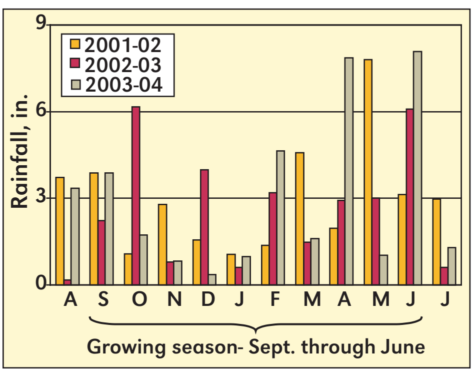

Figure 1. Monthly precipitation, August to July, during 3 years at Stephenville, Texas.

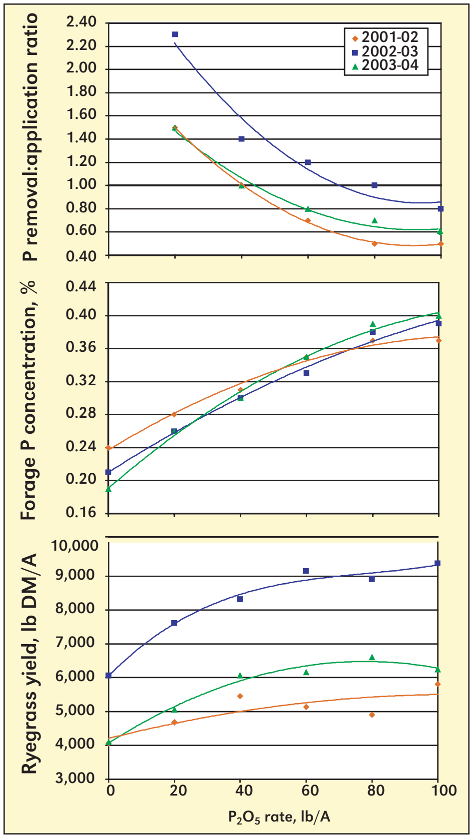

Figure 2. Response of TAM90 annual ryegrass dry matter forage yield, P concentration, and removal to application ratio to rates of P at Stephenville, Texas.

Ryegrass dry matter (DM) yields were greatest in the 2002-03 growing season, while the 2001-02 and 2003-04 seasons were similar (**Figure 2**). Increasing yearly N fertilizer rates from 200 to 300 lb significantly increased ryegrass yields only in the 2002-2003 season (**Table 1**) when yield potential was higher due to superior rainfall distribution.

In 2001-02, ryegrass yields increased 34% from the zero P control to the optimal rate of 40 lb P_2O_5/A (**Figure 2**). Yield

Table 1. Nitrogen rate effect on annual ryegrass yield and crude protein content.

N rate, lb/A	Parameter		
	2001-02	2002-03	2004-05
	----- Dry matter yield, lb/A- ----		
200	4,842	7,877	5,632
300	5,176	8,593	5,780
LSD, p=0.05	NS	536	NS
	------ Crude protein, % ------		
200	23.1	21.6	18.6
300	25.8	25.8	22.2
LSD, p=0.05	0.9	0.7	0.7

at the 40 lb P_2O_5/A rate did not differ from the 60, 80, or 100 lb P_2O_5/A rates. In 2002-03, ryegrass yields increased 26% from the addition of 20 lb P_2O_5/A, 37% with 40 lb P_2O_5/A, and 51% at optimal production with 60 lb P_2O_5/A. The 60 lb rate did not differ from the 80 or 100 lb P_2O_5/A rates. In 2003-04, ryegrass yields increased 23% from the application of 20 lb P_2O_5/A and 48% with the optimal rate of 40 lb P_2O_5/A, which did not differ from 60, 80, or 100 lb P_2O_5/A rates.

The 300 lb N/A/year treatment increased CP concentration over the 200 lb N treatment (**Table 1**). Forage N concentration in the 200 lb N/A plots was well over the critical N concentration (11.3% CP) required to produce over 90% of maximum yield (Robinson and Ellers, 1996). Therefore, it is assumed that N was not limiting at the lower rate.

Phosphorus fertilizer rate did not affect CP levels in the ryegrass. However, P fertilizer increased total CP yields up to the 40 lb P_2O_5/A/year treatment (data not shown). This total CP increase was a direct result of forage yield increase from P fertilizer and reached 60% over the control plots during the year with the best rainfall distribution (2002-03).

The addition of P fertilizer increased P concentration in the ryegrass throughout the study (**Figure 2**). The average concentrations were 0.21, 0.27, 0.30, 0.34, 0.38, and 0.39% P for the 0, 20, 40, 80, and 100 lb P_2O_5/A rates, respectively. Similar results have been reported for ryegrass grown in other soils (Hillard et al., 1992; Rechcigl, 1992; Robinson and Ellers, 1996). Phosphorus yields in the forage were greatest at the highest forage yield (2002-03). Apparent P fertilizer recovery efficiency was greatest at the lower P fertilizer rates (18 to 31% at the 20 lb P_2O_5/A vs. 12 to 22% at the 100 lb P_2O_5/A rate). It is important to note that apparent P fertilizer efficiency can be misleading and is commonly greatest at low levels of input in low testing soils. In this case, apparent efficiency should be distinguished from sustainable efficiency (Dibb et al., 2003). Annual ryegrass forage ADF and NDF did not differ among P or N treatments.

An interesting aspect of forage fertilization is the evaluation of nutrient uptake and removal compared to fertilizer application rate. Where forage crops are harvested and biomass removed from fields (e.g., hay and silage production) nutrient uptake is practically equal to nutrient removal. An instructive way to evaluate the relationship between nutrient removal and nutrient application with relatively immobile elements such as P and K is through the removal:application ratio. If the removal:application ratio is less than 1 then more of the nutrient in question is being applied than is being removed. Where this is the case with elements such as P and K, soil test levels should increase over time. On the other hand, where the ratio is greater than 1, more is being removed than applied and soil test levels should decline.

Figure 2 also shows the P removal: application ratios for each P application rate from each year of the study. It is worth noting that the optimal rates of P application for years 1 and 3 (40 lb P_2O_5/A) coincided with a removal:application ratio of 1 (i.e., the point where removal equals addition). The removal:application ratio at the optimal rate of P application in year 2 (60 lb P_2O_5/A) was 1.2.

Stepwise multiple regression analysis was used to evaluate the impact of extractable soil P from both the Mehlich-3 and NH_4OAc-EDTA methods on annual ryegrass yield. Each annual plot yield was

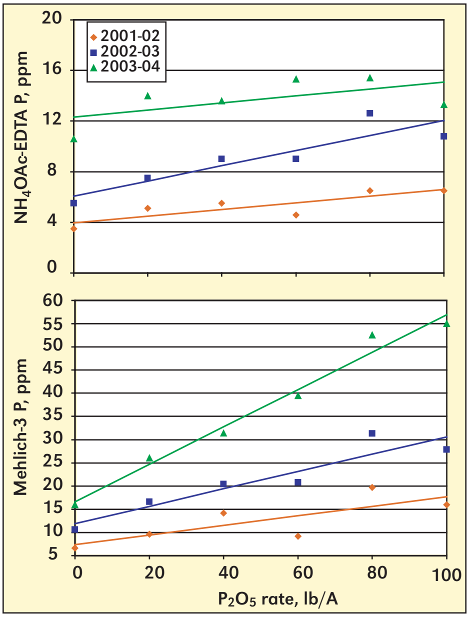

Figure 3. Soil P levels from two methods of extraction after the 2002, 2003, and 2004 growing seasons at Stephenville, Texas.

normalized against relative yield (%RY) potential. Soil test P data obtained from the NH_4OAc-EDTA method was not correlated to %RY. The multi-variant equation representing %RY, developed using the Mehlich-3 soil test P data, included P fertilizer rate (lb P_2O_5/A), soil pH, and Mehlich-3 P (ppm) soil test data. The equation is as follows:

%RY=108.95+0.174*P rate–10.471*pH+0.175 Mehlich-3 P
$r^2=0.484$ $P<0.001$.

There was a trend towards greater soil-P concentration over years for both methods evaluated (**Figure 3**). This was apparent even in plots where no fertilizer P was applied. Although soil pH certainly had an effect on soil-P availability following the application of lime in 2003-04, other factors were involved in the 2002-03 increase since pH levels tended to decrease that year compared to 2001-02. Perhaps organic P from native organic matter and forage materials incorporated prior to the initiation of this study contributed to the increase in extractable P.

Ryegrass response to P fertilizer rates was independent of the two N fertilizer rates used in this study. The optimal fertilizer rates for annual ryegrass production were 40 lb P_2O_5/A/year and 200 lb N/A/year in the 2001-02 and 2003-04 growing seasons. However, in the 2002-03 season, when rainfall distribution was superior to the other years, the optimal rates were 60 lb P_2O_5/A and 300 lb N/A. Where P fertilizer was applied, the average removal of P_2O_5 in ryegrass forage was 51 lb/A. Interestingly, there was relative agreement between removal of P in forage and optimal P fertilizer rate. These results confirm the importance of balancing nutrient inputs in forage production. BC

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PPI/FAR Research Project 48-F.

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