# Building Soil Phosphorus and Potassium in a Low-Testing Fescue Field

By Gene Stevens, David Dunn, and Steve Hefner

**The objective of this long-term study is to evaluate the effects of P and K build-up periods on tall fescue hay yield and to validate the build-up equations used in the University of Missouri (MU) fertilizer recommendation program.**

The MU soil test laboratory recommendations for P and K fertilizer are based on three components: target level, crop removal, and build-up. Target level is the amount of extractable nutrient found in a soil at which point applying more fertilizer containing the nutrient will probably not increase crop yields. Crop removal is how much the nutrient is reduced in the soil annually from harvested forage, grain, or fiber. Build-up is the additional fertilizer needed above crop removal to increase low- and medium-testing soil P and K to the target fertility levels for crop production.

Soil P and K build-up can be slow or fast depending on the economic situation of the farmer. Total fertilizer applied in slow and fast build-up programs is about the same amount, but the cost may be spread out over more years in slow build-up periods. The current soil test recommendation system used by MU allows growers to select the number of years over which to build-up soils. This decision has a large effect on the amount of fertilizer that a farmer will purchase and apply in a given year. If a grower does not select a build-up period, the soil test lab uses an 8-year default build-up time to calculate fertilizer recommendations.

Research has not been conducted to determine which build-up strategy is the most profitable to manage crop nutrients in fescue forage production. Long build-up programs help farmers manage their financial resources by spreading fertilizer costs over several years. However, growers need information concerning the magnitude of yield loss that may occur early in an 8-year build-up as compared to a shorter build-up (1 to 4 years).

A field experiment in a non-renovated fescue hay field was begun in 2004 and is currently mid-way through an 8-year evaluation. The study location is on a Tonti-Hogcreek complex (Typic Fragiudult) soil in the Ozark Highlands near Mountain View, Missouri. The experimental design is a randomized complete block with four replications. Initial soil test levels in the test area averaged 8 lb Bray-1 P/A and 162 lb ammonium acetate-extractable K/A. Cation exchange capacity was 6.5 meq/100g soil and organic matter content was 1.5%.

**Table 1.** Annual fertilizer application rates based on soil tests for soil P and K build-up programs beginning in 2004 (Year 1) in an Ozark Highland hay field.

| | Year 1 | | Years 2, 3, 4 | | Years 5, 6, 7, 8 | |
|---|---|---|---|---|---|---|
| Build-up program | $P_2O_5$ | $K_2O$ | $P_2O_5$ | $K_2O$ | $P_2O_5$ | $K_2O$ |
| | lb/A | | | | | |
| Untreated check | 0 | 0 | 0 | 0 | 0 | 0 |
| N only | 0 | 0 | 0 | 0 | 0 | 0 |
| 1-year build | 404 | 156 | 18[1] | 681 | 18[1] | 68[1] |
| 4-year build | 115 | 90 | 115 | 90 | 18[1] | 68[1] |
| 8-year build | 66 | 79 | 66 | 79 | 66 | 79 |

[1] Only crop removal P and K applied.

Each spring before fertilizer applications are made, 0 to 6-in. composite soil samples are collected from each plot and analyzed for Bray-1 P and ammonium acetate-extractable K at the MU- Delta Center Soil Laboratory at Portageville, Missouri. Hay yield from each plot is determined by harvesting forage (typically two or three cuttings per year) using a lawnmower with a bagging attachment. Forage subsamples are collected from each plot and oven dried to calculate moisture content and analyzed for N, P, and K content, crude protein, and acid and neutral detergent fiber (ADF and NDF, respectiviely).

Fertilizer treatments used in the experiment were an untreated check, a N only check, and 1-year, 4-year, and 8-year P and K build-up programs (**Table 1**). The treatments were designed so that at the end of 8 years, the total amount of fertilizer applied to each plot would be close to equal. Triple superphosphate (0-46-0) and muriate of potash (0-0-60) were used as P and K sources. Each plot except the untreated check was fertilized with 80 lb N/A as ammonium nitrate and ammonium sulfate each year (50 lb N and 9 lb S/A in late March, 30 lb N/A in early September).

Shown below are the equations used at MU to calculate the P and K build-up component of soil test recommendations.

$$\text{Build-up } P_2O_5 = \frac{110\,(X_d^{\frac{1}{2}} - X_o^{\frac{1}{2}})}{\text{Years}} \qquad \text{Build-up } K_2O = \frac{75.5\,(X_d^{\frac{1}{2}} - X_o^{\frac{1}{2}})}{\text{Years}}$$

$X_d$ = target soil test level in lb P or K per acre
$X_o$ = observed soil test level in lb P or K per acre
Years = desired time period for build-up

The MU Bray-1 P target for fescue is 40 lb P per acre. Target ammonium acetate-extractable lb K/A is 160 + (5 x CEC). The soil CEC of the test field was 6.5 so the calculated K target was 193 lb K/A. When farmers submit soil samples to Missouri labs for testing, they are asked to provide a crop yield goal to be used to calculate additional fertilizer needed to compensate for crop removal. For the test field at Mountain View, the farmer selected a 2 t/A yield goal. Current MU recommendations estimate fescue hay nutrient removal at 9 lb $P_2O_5$ /ton and 34 lb $K_2O$ /ton. Thus, the 2 t/A yield goal used for this study resulted in the crop removal fertilizer component in the build-up treatments being 18 lb $P_2O_5$/year and 68 lb $K_2O$ /year (**Table 1**).

After 3 years, fertilizer treatments increased soil test P levels in plots compared to the untreated and N only checks, with soil test levels for plots with 1-year build-up being above the target 40 lb Bray-1 P/A (**Table 2**). The 4 and 8-year build-up

**Abbreviations and notes for this article:** P = phosphorus; K = potassium; N = nitrogen; S = sulfur; t = tons (2,000 lb); CEC = cation exchange capacity.

P treatments were below the target levels; however, they are on track to be above the target level by the end of their respective build-up periods. Soil K levels for all treatments, including the one year build-up program, were below the original 162 lb K/A levels measured in 2004 (**Table 2**).

Tissue P and K contents in first cutting hay from 2004 through 2006 are shown in **Table 3**. Converting % K into pounds $K_2O$ per ton, the average observed K removal across treatments and years was 54 lb $K_2O$/t compared to the MU removal estimate of 34 lb $K_2O$/t. This difference was a contributing factor to the failure of the one year build-up program to raise soil test K values above the target level. The highest K removal occurred in the first year (2004) with the 1-year build-up program (75 lb $K_2O$/t).

**Table 2.** Soil test P and K levels after 3 years of P and K build-up treatments. Samples were collected in March 2007 before spring fertilizer treatments were applied.

| Build-up program[1] | Soil test levels after 3 years | |
|---|---|---|
| | P | K |
| | lb/A | |
| Check | 13 | 108 |
| N only | 14 | 97 |
| 1 yr build-up | 50 | 149 |
| 4 yr build-up | 35 | 110 |
| 8 yr build-up | 26 | 108 |

[1] Targets are 40 lb Bray-1 P/A and 193 lb ammonium acetate-extractable K/A.

Converting % P in hay to pounds $P_2O_5$/t shows that the MU removal value for P (9 lb $P_2O_5$/t) is close to the observed average across three years in this study (7 lb $P_2O_5$/t). The highest P removal also occurred in the first year (2004) with the 1-year build-up program (14 lb $P_2O_5$/t). These results suggest that luxury plant consumption of P and K may occur when large amounts of fertilizer are applied at one time to correct low soil test levels.

Crude protein in the harvested forage was significantly lower in untreated check plots compared with the average crude protein in fertilized treatments (**Table 4**). Crude protein in hay from N only plots was not different from plots receiving P and K; however, hay from N only plots contained lower ADF and NDF than hay from plots receiving P and K fertilizer. This result suggests that farmers with high fertility fescue fields should cut hay earlier and more often to maximize quality.

Rainfall at the test site was unusually low in July and August of 2005 and 2006. In 2006, N fertilizer alone increased fescue dry matter yields 33% compared to the untreated check (**Table 3**). Applying P and K fertilizer with N increased hay yields an additional 35%, suggesting that P and K fertilizer helped produce fescue plants with healthy root systems that withstood drought better than plants in low fertility plots. In good rainfall years, local hay prices are usually around $30/t. However during drought years, hay has to be shipped in from other regions of the country and hay price can reach more than $100/t. Thus, even in dry years, P and K fertilization for fescue hay production on low-testing soils may be economically favorable.

We concluded that a 4-year soil P and K build-up program can be used by farmers without sacrificing hay yields in the first 3 years. No significant fescue hay yield increase was observed when using a 1-year build-up program compared to the 4-year build-up program (**Table 3**). However, in 2004, hay yield was significantly higher with 1-year build-up P and K applications than the 8-year build-up program. Cumulative costs of fertilizer build-up programs for the first 3 years are shown in **Table 4**.

The most expensive program for the first 3 years was the 1-year build-up program. However, most of this cost occurred in 2004 and for the rest of the study, the only fertilizer that will be applied according to the 1-year build-up program will be to off-set crop removal. By the end of the study, the total P and K fertilizer costs, not including interest, should be about the same for 1, 4, and 8-year programs. However, a farmer could have part of the large up-front money used to purchase fertilizer in the 1-year program earning interest in the bank or invested in some other enterprise on the farm. BC

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**Table 3.** Annual dry matter hay yields and P and K content in first cutting hay in 2004, 2005, and 2006.

| Build-up program | 2004 | | | 2005 | | | 2006 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Hay | P | K | Hay | P | K | Hay | P | K |
| | t/A | —%— | | t/A | —%— | | t/A | —%— | |
| Check | 1.5 | 0.08 | 2.0 | 0.9 | 0.08 | 2.2 | 0.7 | 0.05 | 1.8 |
| N only | 2.1 | 0.13 | 2.4 | 1.3 | 0.07 | 1.6 | 1.0 | 0.09 | 1.9 |
| 1-year | 3.0 | 0.31 | 3.1 | 2.0 | 0.18 | 2.2 | 1.6 | 0.18 | 2.2 |
| 4-year | 2.8 | 0.25 | 2.7 | 2.0 | 0.16 | 2.2 | 1.6 | 0.18 | 2.0 |
| 8-year | 2.6 | 0.19 | 2.7 | 1.9 | 0.15 | 2.3 | 1.5 | 0.15 | 2.3 |
| $LSD_{.05}$ | 0.4 | 0.07 | 0.8 | 0.3 | 0.05 | 0.5 | 0.2 | 0.05 | n.s. |

N.S.= not significant at the 0.05 probability level.

**Table 4.** Cumulative effect of build-up programs (2004+2005+2006) on total fertilizer cost and fescue hay yield.

| Build-up program | Cumulative for 3 years | | | | | Mean across years[2] | | |
|---|---|---|---|---|---|---|---|---|
| | N | $P_2O_5$ | $K_2O$ | Cost[1] | Hay yield | CP | ADF | NDF |
| | lb/A | | | $/A | t/A | | | |
| Check | 0 | 0 | 0 | 0 | 3.1 | 9.0 | 34.5 | 63.6 |
| N only | 240 | 0 | 0 | 89 | 4.4 | 11.6 | 33.2 | 62.5 |
| 1-year build | 240 | 441 | 291 | 282 | 6.6 | 10.8 | 35.3 | 64.2 |
| 4-year build | 240 | 351 | 270 | 251 | 6.4 | 10.8 | 34.9 | 64.0 |
| 8-year build | 240 | 195 | 237 | 197 | 6.1 | 12.8 | 35.2 | 63.9 |
| $LSD_{.05}$ | | | | | 0.4 | 2.3 | 1.1 | 1.2 |

[1] Costs are based on $0.37/lb N, $0.30/lb $P_2O_5$, $0.21/lb $K_2O$.
[2] Mean hay analyses values from subsamples collected at first cutting each year.
CP=crude protein, ADF= acid detergent fiber, NDF= neutral detergent fiber.