UNIVERSITY OF TENNESSEE FERTILIZER RECOMMENDATION DEVELOPMENT

Lori Duncan, Extension Specialist; Hugh Savoy, Associate Professor Emeritus; Forbes Walker, Professor; Michael Essington, Professor; Mike Buschermohle, Professor; Sindhu Jagadamma, Assistant Professor; Shawn Hawkins, Associate Professor; and Don Tyler, Professor Emeritus (Deceased)
Department of Biosystems Engineering and Soil Science

Robert Florence, Lab Director
UT Soil, Plant and Pest Center

Angela McClure, Professor, and Tyson Raper, Assistant Professor
Department of Plant Sciences

Greg Allen, Agent and County Director, UT Extension Lake County; David Qualls, Agent and County Director, UT Extension Lincoln County; John Wilson, Agent and County Director, UT Extension Blount County

Abbreviations or Acronyms: P (phosphorus), K (potassium), N (nitrogen), S (sulfur), Zn (zinc)

Row crop and forage producers, as well as homeowners, should test their soil to determine their crop or garden fertility needs. The University of Tennessee (UT) has a soil testing lab and makes fertilizer recommendations, but is not the only organization in the state that does so. Other organizations and commercial laboratories do not necessarily use the same soil testing procedures or philosophies when making fertilizer recommendations, which can lead to confusion for Tennessee producers and homeowners. The purpose of this document is to describe these differences and ultimately explain how the University of Tennessee determines and updates fertilizer recommendations.

The UT Soil Testing Committee, a subgroup of the Crop Nutrient Stewardship Workgroup, meets annually to review ongoing and completed nutrient management research. This committee is chaired by the UT Extension soil nutrient management specialist and is made up of UT faculty and staff (including, but not limited to, soil scientists, agronomists, biosystems engineers, agricultural economists and county-based Extension agents) conducting applied research in nutrient management for crop production. The committee reviews and discusses ongoing and completed nutrient management studies as presented by the team members. Completed nutrient management project results are used, as agreed upon by the committee, to appropriately update UT's lime and fertilizer recommendations.

UT recommendations are unbiased, local, transparent, research-based and peer-reviewed.

UT Recommendation Development

The University of Tennessee has conducted soil fertility research throughout the state of Tennessee for over a century. This research is conducted based on a statistical design in which a wide range of nutrient (N, P, K, etc.) rates are applied to a specific crop. For P and K research, studies are generally conducted in soils of a low, medium and high soil test value. Generally, these are multiyear and multisite studies to ensure recommendations are relevant throughout various Tennessee soils and climatic conditions. These studies are repeated frequently to verify that recommendations are applicable to newer crop varieties.

The basis of a soil testing program for P and K includes soil test **correlation, calibration** and **interpretation.**

- **Correlation** compares the relationship between soil testing values with a given extract to yield response with fertilizer applied. Correlation answers the question: At what soil test level would a crop probably respond to fertilizer?
- Soil test **calibration** provides information to determine the potential for crop yield response and thus categorize soil test levels as low, medium, high or very high. Calibration helps answer the question: If I need fertilizer, how much do I add?
- Soil test **interpretation** provides a recommended nutrient application rate based on multiyear, multisite studies that apply a range of nutrient application rates (ideally, ≥5 rates including a zero control). This is done at each level of the soil test calibration (low, medium, high) and uses measured yields and the associated changes in soil test values to determine the recommended application rate (Southern Extension and Research Information Exchange Group, SERA-IEG-6).

Nitrogen Fertilizer Recommendations

Nitrogen is taken up by plants primarily in the form of nitrate (NO_3^-) and, to a lesser extent, ammonium (NH_4^+). Nitrate is highly mobile in soils, especially in high-precipitation locations such as Tennessee. This mobility limits the usefulness of a soil test for N. One exception to this is the pre-sidedress nitrate-nitrogen test (PSNT) for corn because it is conducted immediately prior to an in-season application, and the sampling depth is 12 inches. However, this test assumes an ample amount of N was applied pre-season as fertilizer N or as a slower release manure source. This test was designed to evaluate whether an in-season N application is needed where conditions are favorable for loss after initial application.

The N recommendations from the University of Tennessee are based on statistically designed multiyear, multisite studies where a range of N rates are applied to a crop. The recommended N rate is determined to be the rate that maximizes yield. In some cases, such as for corn production, recommended N rates also take into account commodity and fertilizer prices in order to maximize producer profitability. Rates higher than recommended threaten to hurt profitability because of the extra fertilizer expense with no and, in some cases, negative yield response.

Phosphorus and Potassium Fertilizer Recommendations

Different regions have different soils; thus, they use different extracts designed specifically for those soil types. The University of Tennessee, along with the University of Georgia, Auburn University and Clemson University, use the Mehlich-1 extract for P and K soil testing. The initial correlation and calibration for UT recommendations were based on Mehlich-1, which is still used today because it was found to correlate well on Tennessee soils with P and K soil test levels. Another extract used on some Southeastern and North Central soils is Mehlich-3. An initial calibration for Mehlich-3 has been established for West Tennessee soils. These correlations are similar to those reported by Sikora et al. (2005) for Kentucky soils and allow producers who utilize a laboratory using Mehlich-3 to approximate the equivalent Mehlich-1 rating and use UT fertilizer recommendations. Below are the current Mehlich-1 and initial Mehlich-3 calibrations and ratings (low, medium, high and very high) for P and K in Tennessee.

Soil Test Report Values

	Phosphorus (lb/ac) All crops		Potassium (lb/ac) All crops but cotton		Potassium (lb/ac) Cotton	
Rating	Mehlich-1	Mehlich-3	Mehlich-1	Mehlich-3	Mehlich-1	Mehlich-3
Low	0-18	0-30	0-90	0-122	0-140	0-189
Medium	19-30	31-49	91-160	123-216	141-280	190-378
High	31-119	50-196	161-319	217-431	281-319	379-431
Very High	≥120	≥197	≥320	≥432	≥320	≥432

*To convert to approximate ppm divide lb/acre by 2.

These soil test ratings are related to the probability that a crop will respond to an application of the nutrient. Specifically, these test ratings are defined as:

Low (L):
In most cases, plants will respond to the application of that nutrient. If the nutrient is not applied, deficiency symptoms may occur and crops usually yield less than 75 percent of their potential.

Medium (M):
Plants may or may not respond to the application of that nutrient. Deficiency symptoms are not likely and soils can be expected to produce 75 percent or more of their potential without the application of the nutrient.

High (H):
The soil will produce at or near 100 percent of its potential without the addition of the nutrient. Except for tobacco, further applications of the nutrient are not suggested.

Very High (VH):
Supply of the nutrient in the soil is well in excess of the amount needed to produce 100 percent of the soil's potential. Application of the nutrient is not recommended since further additions may create nutrient imbalances (i.e., very high P can induce Zn deficiency).

Common fertility recommendation philosophies are sufficiency or build and maintain. The *sufficiency* concept is based upon filling the gap between the native soil supply of a nutrient and what it takes, on average, to achieve economic optimum yield. This rate is determined in field rate trials on the soils of interest. UT uses sufficiency in conjunction with a slow building philosophy, which has been shown in many studies to be the most profitable approach to manage nutrient inputs into crop production systems (Lessman et al., 1986; Murdock, 1992; Williams, 1999; Savoy, 2003).

The *build and maintain* concept is intended to build low- or medium-testing soil up to a desired level, and once attained, a maintenance recommendation is applied. The build rate is equal to the amount of fertilizer required to optimize yield plus the amount of fertilizer required to raise the soil test level P or K to a desired value. The build rate is dependent upon the soil and the time frame desired to build the soil test level. The maintenance rate is equal to crop removal. Default crop removal values are used in many formulas, but be aware that actual on-farm value may differ. This is where frequent soil testing allows one to track soil trends to see if more or less than removal is being applied.

The University of Tennessee suggested P_2O_5 and K_2O equivalent application rates are research-based and intended to slowly build soil test levels out of the low testing range to the high range. Once the soil is testing high for either P and/or K, no further application is recommended; if the soil is testing at the medium soil test level at a future sampling date, P and/or K are again recommended as appropriate. It is important to note that fertilizer recommendations are given in pounds of P_2O_5 or K_2O equivalent weights. These are English chemical units used to quickly and easily compare the amount of P or K in various fertilizer products.

The exception to the above-described scenario is K fertilization for the production of corn silage or high-yielding hay, such as bermudagrass. Because of luxury uptake and the very high K removal rates by these crops, building soil K is not economically feasible. A minimum (sufficiency level) amount of K found by research to maximize yield is recommended, and this must be added each cropping season with no expectation of building soil test K level.

Environmental Impact

Although UT fertilizer recommendations are based on maximizing profit, there are environmental concerns that should also be addressed. Fertilizer application rates above the recommended rates have the potential to reduce profits as well as have negative impacts on the environment. Currently, there is a large hypoxic zone in the Gulf of Mexico that is caused by excess N and P in the waterways. Models estimate that approximately 71 percent of N and 80 percent of P originate from agricultural production in the Mississippi River Basin and that Tennessee ranks seventh out of 31 states in N and P contributions to the Gulf of Mexico (Alexander et al., 2008).

Within our state, 34 percent (1,314 stream miles) of the nutrient-impaired stream miles and 61 percent (13,937 lake acres) of the nutrient-impaired lake acres are attributed to crop production (TDEC, 2018). Such impairments can cause algal blooms in our freshwater bodies, affecting aquatic life and making our lakes unusable for recreation. It is important for Tennessee producers to be aware of these issues so they can adopt sustainable management practices and avoid potential regulations or legal consequences in the future.

Resources

UT Soil, Plant and Pest Center

https://ag.tennessee.edu/spp

Environmental Impact

Alexander, R. B., R. A. Smith, G. E. Schwarz, E. W. Boyer, J. V. Nolan, J. W. Brakebill. 2008. Differences in phosphorus and nitrogen delivery to the Gulf of Mexico from the Mississippi River Basin. *Environ. Sci. Technol.* 42(3): 822-830.

Tennessee Department of Environment and Conservation (TDEC). 2018. Year 2018 TN 303(d) List. EPA Approved List of Impaired Waters. *https://www.tn.gov/environment/program-areas/wr-water-resources/water-quality.html*

Soil Sampling

Buschermohle, M., L. Duncan, and H. Savoy. Site-Specific Soil Sampling. UT Extension Publication W 306-A.

Savoy, H. J. and D. K. Joines. Soil Testing. UT Extension Publication PB 1061.

Soil Testing

Southern Extension and Research Activity Information Exchange Group – 6. 2014. Soil Test Methods from the Southeastern United States. Southern Cooperative Series Bulletin No. 419.

Essington, M. 2000. Comparison of Mehlich-1 and Mehlich-3 P and K from a West Tennessee field. Personal communication to UT Soil Fertility Committee.

Fertility Recommendations

Duncan, L. A., H. Savoy, and D. Joines. UT Fertility Recommendations for Tennessee Row Crops. UT Extension Publication SP 763.

Lessman, G. M., J. F. Bradley, and L. H. Keller. 1986. Comparison of soil test recommendations on soybean yields. Tennessee Farm and Home Science, Issue 139 p. 3-5.

Murdock, L. 1992. Evaluating fertilizer recommendations. University of Kentucky, Cooperative Extension Service Publication AGR-151.

Parks, W. L., R. D. Freeland, R. Evans, L. Safley, T. McCutchen, and M. Smith. 1991. Effect of residual and fertilizer phosphorus and potassium on yields of corn, soybeans, and cotton growth on several Tennessee soils. UT Agricultural Experiment Station Bulletin 667.

Savoy, H. and D. Joines. Lime and Fertilizer Recommendations for the Various Crops of Tennessee. UT BESS Info #100.

Savoy, H. J. 2003. University of Tennessee Fertilizer Recommendations Are the Most Profitable Tested. Departmental Information Sheet BEES 101. *https://ag.tennessee.edu/spp/SPP%20Publications/BEES101.pdf*

Sikora, F. J., R. S. Mylavarapu, D. H. Hardy, M. R. Tucker, and R. E. Franklin. 2005. Conversion equations for Soil Test Extractants: Mehlich-1 and Mehlich-3. Southern Regional Fact Sheet #5.

Williams, R. 1999. Yield comparisons from different laboratory fertilizer recommendations. Personal communication.

AG.TENNESSEE.EDU

W 795 04/19 19-0124 Programs in agriculture and natural resources, 4-H youth development, family and consumer sciences, and resource development. University of Tennessee Institute of Agriculture, U.S. Department of Agriculture and county governments cooperating. UT Extension provides equal opportunities in programs and employment.