# THE FERTILIZER RECOMMENDATION SUPPORT TOOL (FRST) INITIATIVE: NATIONAL SURVEY ON SOIL FERTILITY RECOMMENDATIONS AND CORRELATION/CALIBRATION DATABASE

**S. E. Lyons[1], J. T. Spargo[2], D. L. Osmond[1], A. W. Pearce[1], N. A. Slaton[3]; D. K. Arthur[4], P. J. A. Kleinman[4], J. M. McGrath[5]**

[1]North Carolina State University, Raleigh, North Carolina
[2]Pennsylvania State University, University Park, Pennsylvania
[3]University of Arkansas, Fayetteville, Arkansas
[4]USDA-ARS, University Park, Pennsylvania
[5]University of Kentucky, Lexington, Kentucky

## ABSTRACT

Soil fertility testing is an integral tool used in nutrient management planning, providing information needed to determine where fertilizers are required and how much to apply. Historically, most soil test correlation and calibration efforts have been led by land-grant universities and recommendations have been developed on a state-by-state or lab-by-lab basis, resulting in limited interstate or regional coordination. Further, not all states have maintained up-to-date correlation and calibration studies, the foundation of fertility assessments and recommendations. The Fertilizer Recommendation Support Tool (FRST) project aims to advance the accuracy of soil-test- and science-based fertilizer recommendations. This presentation will cover two important components of the FRST initiative: a national survey of land-grant university soil fertility recommendations and the FRST database with P and K correlation and calibration studies. The purpose of the survey, conducted in early 2020, was to gain a better understanding of the current status of soil testing across the U.S. to direct collaborative efforts among states and regions, and to identify opportunities to harmonize recommendation guidelines. The support tool will use the FRST database, which contains current and historical data, with trial years ranging from the 1940's to the 2010's. The FRST database is currently populated with over 1,200 P and K response trials for a variety of cropping systems across the U.S. and will continue to grow.

## INTRODUCTION

Fertilizer nutrient recommendations for crops have been developed on a state-by-state basis in the U.S. since the mid 1900's, and continue to be developed and maintained by land grant universities whose scope of inference is defined by state borders. Because soil testing was developed based on political boundaries rather than physiographic regions, soil properties, climatic zones, or cropping systems, inconsistencies exist among states in soil collection and research practices, laboratory methods, terminology, and thus fertilizer recommendations. In addition, much of the foundational research conducted was completed over 30 years ago, with agronomic practices and crop varieties no longer used today. The last national survey to summarize soil fertility recommendations and soil testing was conducted in 1994 by Voss (1998), who reported that only 30% of states based their recommendations on research conducted after 1980, and 25% of states reported not knowing the age of the research undperpinning their recommendations.

In 2018, the FRST effort was initiated with the goal of advancing the accuracy of soil-test-based fertilizer recommendations by establishing a foundational database and an associated decision support tool from which recommendations can be scientifically developed and defended as best management practices (Lyons et al., 2020). FRST is a collaborative and inclusive effort, and is made up of over 80 collaborators from more than 40 institutions. To achieve this, the FRST team: i) created a survey on current practices and recommendations in soil fertility; ii) is defining a minimum dataset requirement for future correlation and calibration trials; iii) is building a database to curate correlation and calibration data; and iv) will develop a user-friendly, searchable decision support tool. Inspired by Australia's Better Fertilizer Decisions for Cropping Systems (BFDC) initiative (Speirs et al., 2013), the decision tool will provide soil test calibration graphs with statistical confidence intervals for the area of interest, and the database will provide data to nutrient management scientists and modelers for in-depth analysis of soil test correlation and calibration.

The objectives of the state fertilizer recommendation survey are to gain a better understanding of the current status of soil testing across the U.S. to direct collaborative efforts among states and regions, and to identify where opportunities exist to harmonize recommendation guidelines. The objectives of the FRST database are to collect, curate, and preserve legacy correlation and calibration trial data as well as current and future data to be used by the decision tool and the soil fertility research community. Here, we discuss selected results from the survey and provide an overview of the database.

## METHODS

### Survey

A national survey was developed that covers land-grant university and state Department of Agriculture soil-test methods and nutrient recommendations, fertilization philosophies, and the provenance of the correlation and calibration data used to support recommendations. The survey included over 80 questions about fertilizer-P and -K recommendations, laboratory methods, soil health considerations, and sampling protocols. The web-based survey instrument was built using Qualtrics (Provo, UT), and was distributed to nutrient management experts at land grant institutions and state departments of agriculture across the U.S in February 2020.

### Database

The FRST database was created in 2019 and includes correlation and calibration data collected from peer-reviewed journal articles, theses and dissertations, extension bulletins, conference proceedings, and unpublished datasets provided by FRST collaborators. The minimum criteria for legacy data includes the trial year, trial location (state), soil test P or K values before fertilization, soil test method and sample depth, replicated fertilizer P or K treatment rates, and crop yield response values. The legacy data criteria are much more inclusive and less strict than the minimum dataset requirements being developed for future research. The database was initially built using Microsoft Excel, and is evolving to a more sophisticated and interactive online database hosted by the USDA-ARS Agricultural Collaborative Research Outcomes System (AgCROS) and cataloged in the USDA National Agricultural Library. Moreover, we will build the database, which currently contains only U.S. P and K data, to have future expandability to include other nutrients, cropping systems, and geographical regions.

## RESULTS AND DISCUSSION

### Survey

By June 2020, over 60 individuals representing 48 states plus Puerto Rico completed the survey — the only two states with no responses were Alaska and Nevada. Respondents included research and Extension faculty as well as soil testing laboratory directors and staff.

A primary goal of this work was to gain a better understanding of resources and capacity available to investigate soil test correlation and calibration among states. The average response to questions about the number of faculty full-time-equivalents (FTE) currently involved in soil test correlation and calibration research and in updating (or validating) recommendations was 1.2 FTEs state$^{-1}$. This is a significant decline from a high of about 3.5 FTEs state$^{-1}$ in the 1950's and 1960's and is consistent with the steady decline in average FTEs state$^{-1}$ reported by Voss through the 1990s (1998) (Fig. 1).

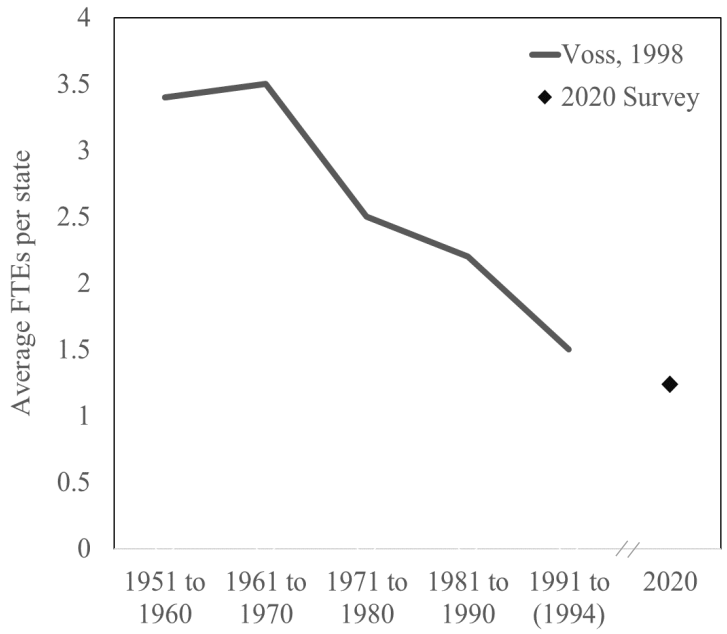


**Figure 1.** Average number of faculty FTEs per state involved in soil test correlation and calibration research. Observations from 1951 through 1994 were reported by Voss (1998).

Respondents were also asked to provide information about the origins of the state's soil test P and K correlation used to interpret results and make recommendations for major crops. These results are summarized in Fig. 2 for grain corn. Only 12% of states responding indicated that their soil test P correlation for corn has been updated or validated in the last decade, and only 14% had updated or validated their soil test K correlation. Almost 80% of states responding are currently using soil test P correlations that are either over 20 years old, or their origins are unknown. Similar reports were made for the age and origins of soil test K correlations. Especially concerning is that about one-third of states reported that the provenance of their soil test P and K correlation was unknown.

The survey also requested information about recommended soil test methods and interpretation of results. Recommended methods generally aligned with regional differences in climate and soil properties. For example, Table 1 summarizes recommended soil test P methods. The Morgan methods are used by New York and most of the New England states. Mehlich 1 is used by a few Southern states while the Mehlich 3 is the predominant method used by states in the mid-Atlantic and Southern regions. The Bray-1 is recommended by several states in the North Central region and Olsen is the predominant method recommended in the Western region.

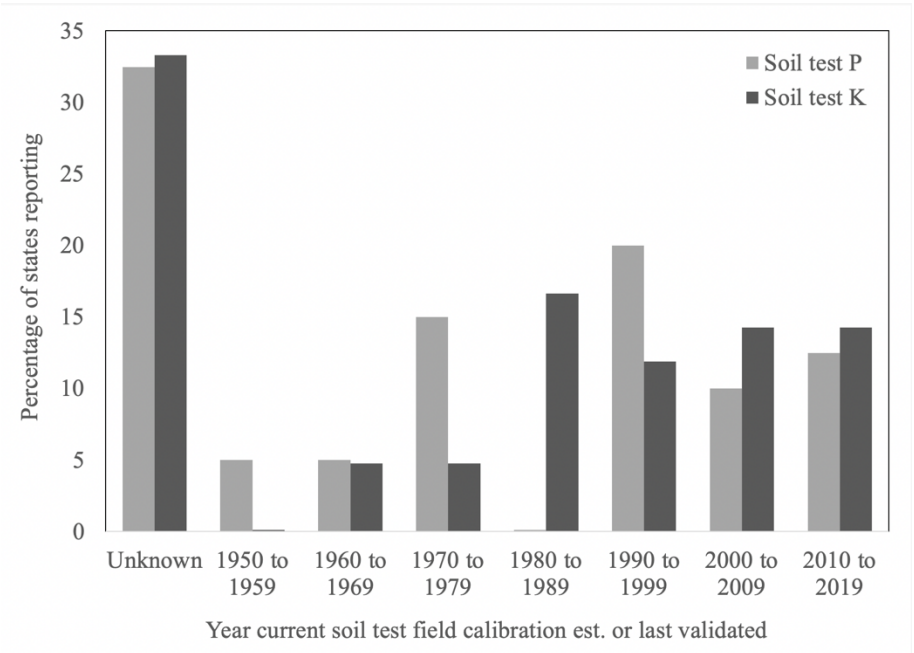


**Figure 2.** The year the soil test P and K field correlation for grain corn was established or last validated. Results expressed as a percentage of forty states responding.

It is widely recognized that soil test interpretation varies among states, both within and among regions, even when the same soil test methods are used. For example, the critical Olsen P level (the soil test level that includes the point of no yield benefit from fertilization), or range, for field corn used by several Western states is summarized in Table 2. The lowest critical range was reported for California, 6 to 12 mg P $kg^{-1}$, and the highest was reported by New Mexico, 25 to 30 mg P $kg^{-1}$. Similar variability was observed within other regions for other soil test P (and K) methods (data not shown). Differences in climate, edaphic factors (e.g., buffering capacity), and cropping systems among and within regions are expected to influence the correlation between soil test level and response to fertilizer nutrients. However, these variables are not generally associated with political boundaries.

| Soil Test P Method | States |
|---|---|
| | *North Central Region* |
| Bray 1 | IL, MI, MO, WI |
| Bray 1, Olsen | MN, NE, SD |
| Mehlich 3 | IN, IA, KS, OH |
| Olsen | ID, ND |
| | *Northeast Region* |
| Mehlich 3 | DE, MD, NH, NJ, PA, WV |
| Modified Morgan | CT, ME, MA, RI, VT |
| Morgan | NY |
| | *Southern Region* |
| Lancaster | MS |
| Lancaster, Mehlich 1 | AL |
| Mehlich 1 | GA, SC, TN, VA |
| Mehlich 3 | AR, FL, KY, LA, NC, OK, TX |
| | *Western Region* |
| Bray 1, Olsen | OR, WA |
| Olsen | AZ, CA, CO, MT, NV, NM, UT, WY |
| Truog | HI |

**Table 1.** Soil test P methods used in each state. Several states specified methods based on regions within the state (or selected soil conditions). In those cases, both methods are listed. Some states have correlation and calibration for multiple methods. In those cases, only the preferred or primary method is listed. Both Iowa and Kansas recommend determining P in the Mehlich 3 extraction using a colorimetric procedure.

**Table 2.** Critical Olsen P concentration or range and minimum soil test P concentration where no fertilizer P is recommended for field corn used by several Western states to make nutrient recommendations.

| State | Critical soil test concentration or range† | Minimum soil test concentration where no fertilizer P is recommended |
|---|---|---|
| | ----------Olsen P, mg $kg^{-1}$---------- | |
| California | 6 to 12 | |
| Colorado | 7 to 14 | |
| Wyoming | 15 to 22 | 23 |
| North Dakota | 15 | 25 |
| Oregon | 15 | 15 |
| Utah | 15 | 15 |
| Montana | 16 | 24 |
| South Dakota | 16 | 16 |
| Idaho | 20 | 25 |
| New Mexico | 25 to 30 | 31 |

†Critical soil test range defined as the soil test level that includes the point of no yield benefit from fertilization.

Soil test critical values or ranges used to determine land grant university nutrient recommendations have primarily been defined using unique datasets, many of which are several decades old, and are exclusive to sites within state boundaries. This approach limits the scope of inference, and results in arbitrary boundaries associated with state lines. This is one of the core issues that FRST will address through access to a wider range of newer, more complete datasets. The FRST decision support tool will allow the database to be queried and selected data analyzed to determine soil-test critical nutrient concentration to be determined for specific regions (independent of political boundaries), crops and soil-test methods.

**Database**

The FRST database currently has over 1200 trials that represent 34 states, 11 crops, and a variety of soil test P and K methods (Table 3). While many states and cropping systems are already represented, there are over 100 articles, dissertations, and bulletins currently on file to be entered. The more than 80 FRST collaborators who are currently on the project have been essential in obtaining relevant data for the database, as they have provided theses, dissertations, station bulletins, fact sheets and other historical documentation.

Due to the nature of field trials and the inconsistencies in correlation and calibration research across the country and over time, building the FRST database comes with challenges. Because we are accepting data in any format (journal articles, extension documents, etc.), there is often a drastic difference in the level of detail provided. Particularly for the older publications, research reports often lack important information such as year, location, laboratory methods, or even units. And while we can contact corresponding authors of more recent publications to request further details, authors are harder or impossible to contact for older reports. Another challenge rests with the technical aspects of the database. As the FRST project grows and evolves, changes to the database are often necessary. Adding, removing, or changing database fields is a tedious

process that risks integrity of previously stored data. Hand-entering data has been necessary in the current database format; however, we plan to develop an online data entry form where FRST team members, as well as researchers, can submit data to be appended to the FRST database.

**Table 3**. Summary of correlation and calibration data currently in the FRST database.

| | | | |
|---|---|---|---|
| Trials | 1227 | Years | 1949-2018 |
| Crops | Corn, soybean, wheat, cotton, rice, cool-season grasses, sugarcane, alfalfa, sorghum, sweet potato, pea | States | AL, AR, CO, CT, DE, FL, GA, IA, KS, LA, MA, MD, ME, MI, MN, MO, MS, MT, NC, ND, NE, NH, NJ, OH, PA, RI, SC, TN, TX, VA, VT, WA, WI, WV |
| P Methods | Mehlich-1 & -3, Bray-1 & -2, Olsen, Morgan, Modified Morgan, Lancaster, acetic acid, Resin, Pi, water, double acid, total P, Oxalate, ammonium acetate, Haney, Truog, sodium acetate | K Methods | Mehlich-1 & -3, ammonium acetate, nitric acid, saturation, rate of release, MS Soil Test, Olsen, Morgan, Modified Morgan, Resin, Tetraphenylboron |

## SUMMARY AND CONCLUSIONS

The FRST project aims to support scientifically based and data-driven fertilizer recommendations across the U.S. The FRST team administered a national survey that clarified current soil fertility management practices, laboratory analysis methods, and nutrient recommendations. In addition, we developed a soil test correlation and calibration database that will support an online, interactive decision support tool. Both the survey and legacy database have shown that more consistent and up-to-date research is needed for efficient and functional soil fertility recommendation systems in the U.S.

## REFERENCES


Lyons, S. E., Osmond, D. L., Slaton, N. A., Spargo, J. T., Kleinman, P. J. A., Arthur, D. K., & McGrath, J. M. (2020). FRST: A national soil testing database to improve fertility recommendations. *Agricultural and Environmental Letters, 5,* 1-5. https://doi.org/10.1002/ael2.20008

Speirs, S. D., Reuter, D. J., Peverill, K. I., & Brennan, R. F. (2013). Making better fertilizer decisions for cropping systems in Australia (BFDC): An overview. *Crop and Pasture Science, 64,* 417-423.

Voss, R. (1998). Fertility recommendations: Past and present. *Communications in Soil Science and Plant Analysis, 29*, 1429–1440. https://doi.org/10.1080/00103629809370040