Network Management Manual

Research on Agricultural Uses of Gypsum and Other FGD Materials

Sponsors:

Combustion ByProducts Recycling Consortium (CBRC)
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Network web site: http://www.oardc.ohio-state.edu/AgriculturalFGDNetwork

Anyone interested in joining the network to research agricultural uses of FGD materials are requested to contact David A. Kost, The Ohio State University (330-263-3655; kost.2@osu.edu), Warren A. Dick, The Ohio State University (330-263-3877; dick.5@osu.edu) or Ken Ladwig, Electric Power Research Institute (Phone: 262-754-2744; E-mail: keladwig@epri.com).

MANUAL

NETWORK FIELD RESEARCH PROTOCOL: AGRICULTURAL USES OF FGD-GYPSUM AND OTHER FGD MATERIALS

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OVERALL SUMMARY: There are few coordinated efforts to obtain data that tests, in a scientifically accepted manner, the potential benefits of using FGD products for land application uses. The establishment of a national/international network has been proposed to conduct research on agricultural uses of gypsum and other FGD materials. To obtain maximum benefit from such a network, it is important that a common set of research protocols be established. This ensures that valid comparisons can be made not only for treatments at a single site, but also to provide information across a much larger scale (e.g.. national or even international). We have created a brief manual to be used by network participants as they plan their experiments and collect data. The manual cannot cover every possibility or variable that may come up when field research is conducted. Therefore, scientists at The Ohio State University will act as the quality control agents to evaluate and approve specific research plans before they are initiated. The data obtained from the network research sites will be included in the network database. This information will be invaluable in helping determine the best technologies in terms of enhancing crop production, economic return and environmental quality. Anyone interested in more information should contact Dr. David Kost (kost.2@osu.edu) or Dr. Warren Dick (dick.5@osu.edu) at The Ohio State University.

I. First Step

It is important that network participants contact Dr. David Kost or Dr. Warren Dick as soon as possible after a decision has been made to join the research network. We will then initiate the appropriate action required to move the field research plans forward. The most critical decision at this time is whether (1) the research will be conducted in-house with general oversight by The Ohio State University or (2) The Ohio State University will be contracted to do the research for the network participant. A checklist has been developed for each instance and is included on the back page of this manual.

II. Research Objectives

The second most important decision is to carefully define the research objectives. What type of FGD material is to be tested? We assume that in most cases this material will be FGD gypsum. Will the objective be the enhancement of crop performance by increasing nutrient concentrations in the soil? Will the enhancement be indirect by affecting the soil physical properties? Will the application involve improving environmental quality, e.g. by reducing phosphorus runoff to surface waters from soils that have been over treated with animal manures?

Each of the above situations, and others could be added, is really a different research objective and will require different research protocols. Therefore, what follows is a general guideline of variables that need to be controlled, samples that need to be collected, and schedule of when certain tasks need to be done. That is why it is important to contact The Ohio State University before beginning the planning process so that we can help formulate both the research objectives and the specific research plans.

In the material that follows, we provide general information needed as network participants begin to make plans and determine the best approach to take in how to participate in the network.

III. Plot Arrangement

A standard field experiment for the FGD research network would use two materials (an FGD material plus a commercially available substitute) each applied at three rates, plus an untreated control for a total of seven treatments. These treatments will be arranged in a randomized complete block design with four replications as shown below. Other arrangements can be easily accommodated including strip tests in full-scale farm fields.

Figure 1. Randomized Block Field Plot Design

Replicate 1	**Replicate 2**
Replicate 3	**Replicate 4**

In the standard field experiment, combining seven treatments with four replicates requires there be a total of 28 plots. Replicate 1 will have seven plots with each treatment assigned to a plot. This arrangement is repeated for Replicates 2, Replicate 3, and Replicate 4. The seven plots in each block should be as uniform as possible in terms of perceived site conditions such as previous land use history, slope, drainage, soil texture, or other recognizable field characteristics. For example, if the experimental site has a uniform slope in one direction, a block of seven plots should be located across the slope contour at the same slope position to eliminate variation caused by, for example, moisture differences across the slope.

Plot size will vary depending on the crop to be grown, the type of FGD benefit that is being tested, space available and equipment.

IV. Experimental Materials

The choice of FGD material to be tested will depend on the previously defined objectives. Once a material for field research testing has been selected, approximately 1-3 lbs of a representative sample must be immediately sent to The Ohio State University for analyses. This analyses is important for a number of reasons. For example, if the experiment is testing the FGD material as a sulfur source for crop nutrition, the materials must be analyzed for sulfur concentration before appropriate field application rates can be calculated. The analyses also measures concentrations of other required plant nutrients, pH, total alkalinity, salt concentration, and metals concentration.

As much as possible, samples must be drawn from the exact material that will be applied to the field plots. Thus, it is desirable to determine the amount of material that will be needed at the beginning of the experiment. If a synthetic FGD gypsum material is being used as a source of sulfur nutrition to enhance crop growth, assume a sulfur concentration of 10% for estimating the total amount of material to be used in the experiment. If a material contains 10% S, the total mass of material needed for an experiment, using plot sizes of 6 m x 10 m, and testing sulfur rates of 40, 80, and 120 kg/ha would be 57.6 kg (129 lbs), or less than three 50-lb bags. However, it is always prudent to have more material on hand that one may expect to use.

If the field research is meant to test the FGD material as an amendment to enhance soil physical properties, application rates as high as 1200, 1800, and 2400 kg/ha (or higher) may be needed. The total amount of material that is needed, on hand, for such an experiment to go forward would thus need to be calculated based on expected plot size, application rates, and number of replicates.

It is crucial that the material applied in the field be representative of the actual material being tested. The best way to handle this problem is to obtain subsamples from various places within the storage pile and then recombining them into one composite sample. Mixing the material to obtain a composite sample is best accomplished in an open pile on a tarp or in a large container that is less than half full. If variability of material is a matter of concern, or if several different sources of material are being considered for field-testing, several such composite samples should be collected and sent to The Ohio State University. It is possible that this sample would have to be reduced in size for transport to the laboratory. In such case, proper subsampling of the composite sample would be required.

V. Preparation of Experimental Site

Depending on the history of the experimental site, the site may need to be sprayed with herbicides, tilled, treated with fertilizer, etc. to prepare it for application of FGD materials. In general, land preparation should follow the normal procedures that would be used to prepare the soil to grow the crop to be used in the field test.

Fertilizer should be applied according to results of soil tests on the baseline soil samples (see Section VI below). The actual amount of fertilizer to be used will depend on local agronomic recommendations based on the soil tests and the crop to be grown. If the experiment is testing the FGD material as a sulfur source for crop nutrition, fertilizers that contain substantial sulfur, such as ammonium sulfate and ordinary superphosphate, should not be used.

VI. Collection of Baseline Soil Samples Before Applying Treatments

Soil samples for chemical analysis are easily collected with a tube auger (2.5 cm diameter or larger). Collect one composite soil sample from each replicate block of seven plots using the following procedure. Collect two soil cores (0 – 20 cm depth) from each plot. The two cores from each plot should be representative of any variation in the plot. Combine the 14 cores (2 cores/plot X 7 plots) into one composite sample. Mix the composited soil thoroughly. If the entire composited sample is too large to transport, take a representative subsample using a suitable procedure. Immediately air-dry the sample and then send approximately 1-2 lbs to The Ohio State University for analysis of pH, organic C, particle size distribution (i.e. percent of sand, silt and clay), cation exchange capacity, concentrations of plant available nutrients, and Mehlich III extractable metals.

The baseline soil data is important as it provides us with the ability to determine changes due to treatments.

VII. Application of Treatments to Plots

For each replicate block, assign the seven treatments to the seven plots using some random procedure (e.g. draw plot numbers from a hat; use table of random numbers; use statistical software). The amount of FGD material applied to the plots will depend on the objective of the experiment (e. g. whether the experiment will test the FGD material as a sulfur source for crop nutrition or as an amendment to improve soil physical conditions).

It is important that the application rates be calculated, and the amount of material to be applied to each plot, be prepared prior to the time when actual treatments are to be applied. Application rates must account for moisture in the experimental materials. If a material contains 10% moisture by weight, the calculated rate of application for this material must be increased by 10%.

The FGD materials can be applied by hand, a small human-powered spreader, or whatever appropriate equipment may be available. In any case, it must be evenly distributed across the entire plot. If you run out of material before covering the entire plot, the actual rate applied to the covered part of the plot will be greater than desired in proportion to the amount of the plot that is not covered. Also, the smaller the amount of material to be applied to the plots, the more difficult it usually is to obtain a uniform spread across the plot. One way to obtain uniform treatment spread is to divide the total amount of material into several (three or more) roughly equal-sized parts and then use each part to apply a uniform application to the plot.

VIII. Soil Tillage After Treatment Applications

The decision to till the plots after treatments are applied will depend on the general agronomic practice for the crop and region. If the experiment is being done in a region where no-tillage is common or if the purpose of the experiment is to see if the FGD material enhances crop yield in a no-till situation (as on some clay soils), then the experiment should be done without tillage. In other cases the plots might be tilled after treatment application. Material that is broadcast on the soil surface, without follow up tillage, is dependent on rain or other precipitation to move the material into the soil where reaction and equilibration can occur.

IX. Planting

The crop should be planted in accordance with standard agronomic practices in the local region. This would include such variables as planting date, seeding rate, method of seeding, etc.

X. Soil Samples After Treatment Applications

After treatments are applied, there should be a waiting period of at least one month before soil samples are collected from individual plots. Particularly if the plots are not tilled after treatments are applied, movement of the FGD material into the soil and then reaction with the soil will depend upon rain or other precipitation. After a suitable waiting period, collect one sample from each plot (28 total samples total) by combining 5 soil cores (0-20 cm depth) from each plot into one composite sample. The 5 cores should be spaced across the plot so as to include any soil variation in the plot. Air-dry the soil and reduce each sample to an appropriate size for shipping by obtaining a subsample according to standard procedures.

XI. Soil Water Samples Using Suction Lysimeters

Suction lysimeters for soil water sampling at 60 cm depth will be purchased by The Ohio State University and sent to each field research site. They are to be installed in the control plots and in the plots with the highest application rate of each material. A total of twelve lysimeters will be installed (i.e. four lysimeters in the zero treated plots, four in the FGD high application rate plots and four in the high application plots treated with the material to be replaced by FGD). Lysimeters should be installed after treatments are applied and after any tillage operations are completed. Placement of the lysimeters is problematic. The lysimeter should ideally be installed near the central region of each plot but such location would be in the way of mechanical harvesting equipment. It might be possible to locate the lysimeter near the periphery of a plot where it would not interfere with mechanical harvesting equipment, but where a representative water sample can still be obtained.

One lysimeter should be installed in each plot by drilling a 60 cm deep hole with a bucket auger or other suitable soil coring tool that has suitable diameter. Gasoline-powered screw augers should be avoided because they are difficult to control and tend to mix the surface soil down to the bottom of the hole. Care must be used when drilling the hole to minimize the amount of surface or upper horizon soil that falls to the bottom of the hole. This surface soil is preferentially enriched with the experimental material and would “contaminate” the water that percolated down to the lysimeter cup. Any loose material that falls to the bottom of the hole should be removed using the auger or other retrieval procedure before inserting the lysimeter. The bottom of the hole should be covered with a slurry of silica flour and water (approx. 200 mL of slurry) before inserting the lysimeter. Then a ring of bentonite clay (as a slurry in water) should be poured around the lysimeter to seal the lysimeter and prevent water from moving down directly adjacent to the lysimeter. The remainder of the hole to the soil surface should be filled with soil and tamped during filling to seal the hole and prevent water from channeling down to the cup on the lysimeter.

Water is collected from suction lysimeters by pulling a partial vacuum (60 to 70 centibars) on each lysimeter and then waiting at least 24 hours before returning to pump the water into an evacuated flask. The first water that is collected after installing the lysimeters should be discarded. After the initial water is collected and discarded, water samples should be collected on two dates. One date should be early during the experiment and the other date later such as near harvesting time. Sampling is dependent on adequate precipitation to wet the soil profile to the 60 cm sampling depth. To minimize carryover of sample water between samples, the hoses, glass tubing, and collection flask should be flushed with deionized water (supply carried into the field) after each sample is collected from a lysimeter.

XII. Mercury Measurements

Because of the questions raised by regulatory agencies about mercury in FGD samples, especially as new mercury removal technologies are being installed at places where coal is being burned, we will plan to conduct mercury studies. This will involve making measurements of mercury concentrations in the soil, in the plant due to uptake from the soil and of mercury emissions from the surface of FGD treated plots. This work will be done exclusively by personnel from The Ohio State University or by people they designate to do the measurements.

XIII. Harvesting and Plant Sampling

Crops should be harvested when mature consistent with local agronomic practice. Each crop species will have specific procedures for either mechanical or hand harvesting and yield determination at an appropriate moisture level.

XIV. Weather Data

An arrangement must be made to obtain daily weather records for the field site. This would include daily rainfall amounts and daily maximum and minimum temperatures. University field stations routinely collect this type of information. If the field research is not done on university land, the nearest public reporting weather station can be used provided it is within a reasonable distance of the field site. Temperature data is not as variable across the landscape and so an alternative is to install a rain gauge, that must be read on a daily basis, and obtain temperature data from the nearest public site.

XV. Sample Handling and Record Keeping

All samples should be properly labeled with all necessary identifying information. A separate log sheet of samples should be kept. This log should include all sample information as listed on the sample containers and explanations of any abbreviations used.

Samples of experimental materials and soils returned to the lab (or office) will often need to be reduced in size before packaging for shipping to The Ohio State University. If a soil riffle (soil splitter) is available, it can be used to quickly split a sample into successively smaller fractions until a final suitable size is achieved. Otherwise, some other procedure must be used. One way to split a sample in half is to pour the well-mixed material into a circular, conical pile and then splitting the cone in half from the tip of the cone to its base. Keep one half of the material from the cone-shaped pile. Remix the material that is kept and repeat the cone-splitting procedure until the sample is small enough to package for shipping.

Detailed field logs are required to record dates of all sample collection, treatment applications, field operations, observations on crop growth, unusual weather patterns, insect or weed infestations, etc. This information will be included with the actual yield, plant, water, and soil data collected.

ABBREVIATED CHECKLIST

Network Member Level 1 - Work will be conducted by The Ohio State University

- ☐ Contact The Ohio State University about becoming a network member.
- ☐ Work with scientists at The Ohio State University in formulating specific research plans.
- ☐ Select FGD material to be studied and the field site where study will be conducted.
- ☐ Provide all necessary support to scientists from The Ohio State University in conducting field research.
- ☐ Participate in network activities as appropriate.
- ☐ Review data and final report.

Network Member Level 2 – Work will be conducted by network participant

- ☐ Contact The Ohio State University about becoming a network member.
- ☐ Work with scientists at The Ohio State University in formulating specific research plans. Plan must be approved before fieldwork can be initiated.
- ☐ Select FGD material to be studied and send sample to The Ohio State University. Select the field site where study will be conducted.
- ☐ Collect baseline soil samples and send samples to The Ohio State University for analyses.
- ☐ Prepare field, apply treatments, and plant crop.
- ☐ Install lysimeters, collect water samples and send samples to The Ohio State University for analyses.
- ☐ Record all relevant climatic and field observations.
- ☐ Collect post treatment soil samples and send to The Ohio State University for analyses.
- ☐ Make crop yield measurements at harvest and submit plant/grain samples to The Ohio State University for analyses.
- ☐ Provide all necessary support to scientists from The Ohio State University in conducting field research.
- ☐ Participate in network activities as appropriate.
- ☐ Review data and final report.