Conducting On-Farm Biointensive Research

By Steve Moore and John Beeby

Introduction

As farmers we observe our crops, fields and practices season after season. Often we try new things to see if they make a particular part of our food production better. This can be a new crop variety, spacing differences, different multi-cropping practices and so many, many more items that are all part of our day-to-day farming. These trials can be very casual, where we just plant two varieties and see which performs better. This is easy and can be helpful, but, if we want to share our discoveries and conclusions with greater confidence, we need to observe the scientific method of research.

The scientific method involves first asking a specific question, like “What if I try 30-cm spacing for my maize rather than 45-cm spacing? Then, you want to be sure there are no other variables that might cause you to make the wrong conclusion. For example, if the 30-cm spacing produced more food and biomass, but was grown in more fertile soil, you may think 30-cm spacing is better, but you don’t know if it was the 30-cm spacing or the better soil that was the cause. Also, preparing samples according to the standardized methods described in this paper is critical to ensure they are representative and can be compared with other researchers’ data. Another important scientific component is replication of the experiment. These replications need to be sufficient in number (minimally, three and ideally, four) and laid out in a random or equivalent fashion so that the data can be statistically analyzed. These statistics provide the confidence, probability and predictability that our conclusions are indeed supported by the data we have taken. Without the scientific method, results are not often accepted by wider communities of farmers and scientists.

This all sounds complicated, which is why the authors are willing to help you. If you want to have useful research data and outcomes, it is critical that you design your experiment correctly. If your design is robust, you will generate data that can lead to conclusive results, but if your experiment design is weak, you can spend a lot of time and effort only to find that your data cannot be used. Contact us for guidance.

Table of Contents

**Selecting a Research Site pg. 2**

**Soil Sampling Procedure pg. 3**

**Determining Soil Texture pg. 4**

**Collecting Data from a Multi-harvested Crop pg. 6**

**Collecting Crop Residue Data pg. 6**

**Statistical Analysis pg. 9**

**Additional Resources pg. 9**

Selecting a Research Site

Site selection is critical for success for scientific research. Be sure the site has adequate space to allow replication of treatments for statistical analysis. Minimum of triplicate, and quadruplicate is strongly recommended to allow for some errors or unexpected occurrences that cause data to be available only in triplicate.

The site where the beds will be established should be contiguous and as level as possible. The area should be as homogeneous as possible in terms of texture and color, to increase your odds that the area’s soil parameter levels are as homogeneous as possible.

Good research involves identifying and possibly minizing the variations of the natural world, so that the difference we see is a result of the idea (treatment) that we are testing. Below is a check list of some common variations that we might need to identify and work around. Farmers are good observers, so look for other variations that might confuse or confound your experimental results at your research site.

Historical Differences

* Previous crop and soil management
* Previous pests (weeds, insects, nematodes, diseases, wildlife pressures, etc.)

Soil Differences

* Texture
* Color
* Soil analysis (SOM, pH, minerals, salts) if available
* Depth to rock. This should be greater than 2 feet to allow double digging.
* Depth to water table
* Slope (steepness and sloping direction)

Environmental Differences

* Equal access to sunlight (shade)
* Equal access to ground water (a close pond, stream, swale, ditch etc.) No bodies of water should be uphill from the site or within 20 meters.
* Equal effects of wind (increasing or decreasing as a result of buildings, fences, hedges, trees etc. Ideally, there are no trees within 5 meters of the site borders and none within the site where the beds will be established.)

What if you find one or more of these problems in the area you want to or need to use for research? The booklets in the Additional Resource section (pg. 8) can be a help in designing plots around the problem to get the most accurate data. Also, contact agriculture professionals in your area or contact the authors - John Beeby or Steve Moore for additional help.

Soil Sampling Procedure

# Tools needed:

* Spade or shovel
* Trowel or small scoop
* Bucket
* (All of the above equipment should be clean, not made of brass, bronze or soft metal, or galvanized, and free of rust and flaking paint)
* Plastic bag (one quart or one liter in size is ideal)

# Procedure:

1. Soil sampling should be done a few months before you intend to plant your crops. This gives you enough time to adjust your soil’s pH, if necessary, according to your Grow Your Soil recommendation, prior to planting.
2. How many samples do you need to collect? If you are testing your garden soil, typically one sample is sufficient, unless your garden is quite variable in topography or has sections that have been managed quite differently. For example, if one section of your garden has received fertilizers for years, and another section has received no fertilizers, you will want to make two separate samples for your garden.
3. An overview of what you will do to create one sample: For each sample you need, you will dig 10 to 20 holes, take a sample from each hole, mix all the samples together, and take one final sample from the mixture, as described in more detail below. Avoid touching the soil that you will use as a sample.
4. Selecting where to dig the holes: Be sure the site of the hole is fairly representative of the area (and is not a place where chemicals were dumped, or water puddles, or is unique in some way to the rest of the area). Each sample will be taken by first cleaning off any surface debris and then digging a V-shaped hole that is approximately 1 foot (30 cm) deep.
5. Sampling from the hole: Using a trowel or scoop, scrape away a little from one of the sides of the V-shaped hole. Then, use the scoop, starting at the bottom of the hole and moving upward, to gather soil from the scraped side of the hole. Gather the equivalent of about one handful of soil with the scoop from the side and place it in the bucket.
6. Sampling the rest of the holes: Then, repeat steps 4 to 6 for 10 to 20 other locations in the area you are sampling. Put all the samples you collect into the same bucket.
7. Creating the final sample:
   1. Thoroughly mix the soil samples in the bucket, using your spade or trowel (not your hands). Be sure that the soil at the bottom of the bucket is mixed with the soil at the top of the bucket. Then, after very thorough mixing, take small samples from different areas on the surface of the bucket and add them to the plastic bag until there is about 1 to 1.5 pounds (0.5 to 0.7 kg) of soil in the bag. You don’t need to dry the sample.
   2. Determine the soil texture of the final sample. See instructions on page 3.

Optional: you could make a back-up sample in case anything happens to the original sample.

* 1. Seal the bag well, so that there is no chance of the bag opening during transit. You may wish to double-bag your sample, and seal each bag well.
  2. Label the bag very clearly and legibly, with black or blue permanent marker, as specified by the lab to which you are sending the sample.

1. Collect any other samples you need by repeating steps 3 through 7. Then, after all of the samples are collected, well-sealed, and uniquely labeled, complete the lab’s submission form. Be sure to complete all required information in a very clear, legible and permanent manner.
2. Place the labeled sample(s), submission form, and payment method into a sturdy corrugated cardboard box. Do not put the submission form inside the plastic sample bags. Seal the box carefully and ship it to the lab.

Determining Soil Texture

Immediately after making a composite soil sample, and before sending that sample to a lab for testing, determine the soil’s texture by following the flowchart below. You can also watch this video: https:// [www.youtube.com/watch?v=GWZwbVJCNec&list=LL-GhRP\_XBp8D4MgGQJeqVuQ](http://www.youtube.com/watch?v=GWZwbVJCNec&list=LL-GhRP_XBp8D4MgGQJeqVuQ) Note: Any water can be used and a spatula is not essential for this procedure

Diagram

Description automatically generated

Collecting Data from a Multi-Harvest Crop

Be sure that all harvests are done in the same manner. For example, if you are harvesting tomatoes multiple times, fruit should be harvested at the same level of maturity. If harvesting lablab for leaf production, at the expense of compost material production, you must stick with that intention the whole season and not shift to favor compost production by decreasing your leaf harvesting.

Be sure to have a system that will help you to record every harvest accurately and timely.

Collecting Crop Residue Data

Completely drying down of residue biomass is important to accurately determine carbon and nitrogen content. There are several ways to determine this based on the availability of various technologies and techniques.

**Taking a crop residue sample**

1. Harvest the entire crop residue (if possible) or a representative sample of the crop to be dried. If taking a representative sample, determine the percent or fraction of the total growing area in relation to the sample.
2. If the representative subsample is still too large for your drying method (see below for various drying methods), take at least three representative subsamples that will be the right size for your drying method.
3. Dry them and calculate the total dry mass for the area of the bed(s) that you grew to determine the carbon and nitrogen contribution. Remember the sample/subsample is dry when you pull it out of a drying method and it weighs the same in the beginning and the end of a 24-hour period of drying.

Maize as an example - Say your research involves 2 beds (200 sq. ft.) of maize. It would require a lot of time, large equipment and effort to dry all those stalks (residues) down. Cut several representative maize stalks/stovers down, making a note of the area (square feet or meters) of bed space OR if you have spaced the corn accurately the number of stalks/stovers. (Important note: the number of plants in *How to Grow More Vegetables* Master Charts is not accurate for a bed. This chart number represents other additional criteria.) Harvest 4 stalks that were from 4 sq. ft. The stalks [stems, leaves, husks/ear wraps and cobs (after they have been shelled)] are weighed and dried in a cloth bag, if your drying equipment/method allows for this. If not, weigh them, cut them up into pieces small enough to fit into your drying equipment. Take three (or more) of these representative, cut up subsamples and weigh them again. Dry them down until they weigh the same before and after a 24-hour period of drying.

Now do the math.

|  |  |  |
| --- | --- | --- |
| Sample | Wet weight (g) | Dry weight (g) |
| 1 | 101.0 | 8.0 |
| 2 | 90.0 | 7.1 |
| 3 | 120.0 | 8.2 |
| Average (mean) | 103.7 | 7.8 |
| Figure 1. Determining the subsample  average percent dry weight | | |

Take the three samples and average the wet weight and dry weight. Then determine the % (percent) of dry matter by dividing the dry weight by the wet weight and multiplying by 100. See Figure 1, Equation 1.

Equation 1 - (Dry weight) 7.8g / (Wet weight) 103.7g = .075 x 100 = 7.5% dry weight compared to wet weight for the subsample.

This represents the same % for the larger sample. In our example, if the 4 stalks weighed a total of 4.4 kg, the dry weight would equal the % x wet weight.

Equation 2 - 0.075 (7.5 % dry weight) x 4.4 kg (wet weight for 4 stalks / 4 sq. ft.) = 0.33 kg (dried weight for 4 stalks / 4 sq. ft.)

Equation 3 - To calculate the % of area the 4 stalks / 4 sq. ft. represent, divide the sample area (4 sq. ft.) by 200 (2 beds) x 100 (to give percent) = 2% (meaning the % of the total area sampled)

To calculate the dry weight of the entire research plot of Maize divide the sample dry weight by 0.02 (2%)

Equation 4 - 0.33 kg (dried weight for 4 stalks / 4 sq. ft.) / 0.02 (% of bed. Represented in sample = 16.5 kg (dry matter in 2 beds, 200 sq. ft. of Maize)

16.5 kg is the total dry weight of the 200 sq. ft maize research plot. From this number the amount of carbon and nitrogen going into the compost pile can be determined.

**Drying Methods**

**Homemade Drying Equipment -** Many of these ideas are very climate/weather dependent, meaning abundant sun (and wind) are very helpful as are dry evenings so samples do not rehydrate. If you are in an ideal drying location, there are lots of homemade drying equipment that you can make. Here are a few ideas:

* An old pillowcase or a tee shirt sewn up in the arm and neck holes and hug in a dry place - takes time but will dry in the right climate.
* Solar greenhouses and cold frames work well.
* Solar “cookers” can be inexpensively constructed and can also be used for kitchen cooking and purifying water for drinking.
* A Vortex Forage Drier can be built for about US$40 (or less) but does require electricity

https://extension.psu.edu/a-vortex-forage-and-biomass-sample-dryer.

* If you live in temperate or cold climates you have some home heating device (furnace, wood stove etc.) that can be used as well.

Personal note from Steve - we live in a temperate climate and heat our house with wood. We store samples in sewn bags in our shop ceiling. When it gets cold and we start our wood stove we place them near the stove to dry. This is where we also dry down our flour corn for long term storage and get the moisture low enough to grind easily.

Other types of drying equipment can be found at The University of Florida information sheet at <https://edis.ifas.ufl.edu/ag181>. A summary is provided below.

K**itchen Oven -** First, place the forage samples in trays or other oven-safe containers. Do not use paper or plastic because they can burn or melt. Set the oven to the lowest possible temperature, generally around 175°F, and dry for approximately 3 hours. Let the samples cool down to reduce weighing error, then weigh and dry for an extra 30 minutes to see if weight changes. If it does, let the sample dry for another 30 minutes to 1 hour. Repeat the process until constant weight is achieved. When using a regular oven, it is possible to dry more than one sample at a time.

**Microwave Oven -** This is often used for on-farm assessments since it is cheap and fast. It is important to have a dedicated microwave oven, especially if dealing with fermented silage samples. However, this method should not be used if the sample is for nutrient analysis. The high temperatures can alter chemical composition, thus quality and availability, especially for protein.

Procedure

1. Weigh approximately 3.5 oz (100 g) of plant material and place into a microwave-safe dish. Remember to either tare the scale to the dish weight or to record the dish weight so that it can be subtracted from the total weight.
2. Put the sample in the microwave with a 10- to 16-oz glass of water to prevent sample combustion.
3. Set oven to “high” for 2–3 minutes.
4. Allow to cool to room temperature, weigh, and record sample weight.
5. Change the water if boiling and put the sample back into the microwave oven for 2 more minutes. Weigh and record sample weight again.
6. Repeat steps 4 and 5 until sample weight remains unchanged or scorching occurs. If scorching occurs, use previous weight.
7. Subtract the plate weight from the total weight to get the sample dry weight.

For hay, the procedure takes about 10–20 minutes, depending on the initial moisture content of the sample. Silage samples take 15–25 minutes because of coarser particle sizes and grain content.

**Forage Dryers, Air Fryers and Forage Moisture Tester -** These can also be used but are fairly expensive.

**Crop specific guidance on what is edible and residue data** - Each crop can be slightly different in what is measured for edible yield and residue. For edible yield it should only include what you will use to cook or eat. For example, for maize the kitchen useable corn kernels should be weighed and recorded. The husks, cob and inedible kernels should be included in the “residue” data. For cabbage - again the rule of what is going to be used in the kitchen is the important guideline. The outer layer of damaged cabbage head wrapper leaves should not be included in edible data but added to the residue data. For beets- if you eat the beat greens include them in edible. But if they get tough and old and all you are eating is the beet root then count the tops as residue.

Statistical Analysis

Statistical analysis is important to show with confidence the results are from the treatment (i.e. is 30-cm spaced maize more productive than 45-cm spaced maize) and not from any other variables or too few trial areas (plots) to have that needed statistical probability of replicating the results again.

Statistics can be complicated and there are some very sophisticated programs that are both expensive and require specific training to use. That said, there are some simple statistical analyses that a farmer/researcher can perform using traditional math and a hand calculator.

Several publications in the resources section provide a step-by-step method of making those calculations. The authors can provide additional statistical guidance and analyses, and have access to university professors who have expertise in more complex analysis of data.

Additional Resources

Baldwin, K., 2004. A Field Guide for On-Farm Research Experiments. (A 13-page guide by NC A&T State University on basic on farm research) (Retrieved 3/28/2021 from http://biblio.iita.org/documents/U97ManMutsaersFieldNothomNodev.pdf-617e47200debc0424808a278993096cb.pdf)

Baldwin, K., 2004. A Field Guide for On-Farm Research Experiments. (A 13-page guide by NC A&T State University) Spanish Version (see www.growyoursoil.org)

Nielson,R.L. 2008 A practical Guide to On-Farm Research (This is a 10 pg guide from Perdu University) (Retrieved 4/1/2021 from - <https://www.agry.purdue.edu/CCA/2008/Proceedings/NielsenResearch.pdf>)

Mutsaers, H.J.W., Weber, G.K., Walker,G.K., Fischer, N.M., 1997. A Field Guide to On-Farm Experimentation. (This is a downloadable 235 page book that emphasizes research in tropical agriculture especially in Asian Pacific, Africa and the Caribbean) (Retrieved 4/1/2021 from - <http://biblio.iita.org/documents/U97ManMutsaersFieldNothomNodev.pdf-617e47200debc0424808a278993096cb.pdf>)

Reed, D.W. The Scientific Method. (Retrieved 1/5/2018 from <http://generalhorticulture.tamu.edu/LearningCommunity/ScientificMethod.htm>)

SARE Publication, 2007. How to Conduct Research on Your Farm or Ranch. This is a 32-page free downloadable booklet that is very useful. (Retrieved 3/27/2021 from - https://www.sare.org/wp-content/uploads/how-to-conduct-research-on-your-farm-or-ranch.pdf)