FARMERS GUIDE TO CONDUCTING ON-FARM RESEARCH

ORGANIC FARMING RESEARCH FOUNDATION

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Transition to Organic Partnership Program

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INTRODUCTION

About OFRF

OFRF is a national non-profit organization founded in 1990 to advance organic agriculture through scientific research. The organization fosters the improvement and widespread adoption of organic farming systems by cultivating organic research, education, and federal policies that bring more farmers and acreage into organic production. For over three decades, OFRF has collaborated with land grant universities and organic researchers, awarding over $3M in research grants across the United States.

One of OFRF's core capacities is adapting science-based information for practical and sustainable on-farm applications. Providing free educational and technical resources to support organic farmers has always been essential to OFRF's mission. The organization maintains an extensive research database with hundreds of organic research articles, and has published many educational guidebooks, factsheets, instructional videos, and webinars that are available to transitioning and organic farmers.

Who is this guide for?

Organic farmers and ranchers like you are always testing and experimenting with new ideas to improve their farming operations. You probably have some ideas every day that you would like to try. Incorporating a few scientific steps in your experiments will generate more reliable results that you can trust.

This guide was specifically created for you, the organic farmer or rancher who is curious about conducting some type of trial or experiment on your farm in a more structured way. Whether you are looking at reducing the use of off-farm inputs, minimizing disease pressure, trying out new crop varieties or animal feed, or testing new cover crop techniques or irrigation sensors, this practical guide was created to assist you along the way.

If you are a farmer recipient of OFRF funding to conduct your on-farm research trial, OFRF staff will provide you in-depth technical support throughout your entire farm trial.

The benefits of farmer-led research

Research studies have shown that farmers greatly benefit when they lead on-farm research trials at their farms. Conducting your own research allows you to address your farm-specific questions, and has historically supported the adoption and innovation of sustainable agricultural practices across the world (Wettasinha, et al. 2014). A recent study of farmers involved in the farmer-led research program of the Ecological Farmers Association of Ontario found that farmers who learned to conduct their own scientific research were more "knowledgeable, confident, motivated, and inspired to adopt and/or improve ecological" farming practices (Nelson et al., 2023, p. 2).

"On-farm trials represent a powerful way for farmers to gain agency and support in solving our most pressing challenges."

~Farmer April Thatcher
April Joy Farm, WA

How to use this guide

This guide will walk you through seven major steps needed to conduct a simple on-farm trial, from the original theory you want to test all the way through to drawing conclusions from your results.

For each of these steps, this guide will provide you with practical information, examples from other farmers and ranchers, additional ideas and resources, and the chance for you to put your own ideas down on paper using farmer worksheets.

The appendix section provides additional resources to dive deeper into research design and implementation, as well as farmer profiles that walk through each of the research steps.

USDA photo

Time and resources needed

Conducting on-farm trials requires strong commitment. It will take dedication to establish, maintain, and complete your on-farm trial successfully. An idea that sounds great in mid-winter might feel overwhelming in August, so thinking through the timeline of the research trial and how it will fit into the workflow of the farm is a useful step.

The time needed to complete a trial varies depending on what your trial is about. If you are focusing on seed germination, your trial may take only weeks or a few months and you may take all your data early in your cropping season. On the other hand, you may want to carry out a multiple year trial where you collect data throughout multiple seasons, which is likely to create competing demands with your regular farming activities.

Having stated the above, an on farm-trial also gives you the opportunity to test something new and feel confident about your results. Undoubtedly, the experience gained from conducting trials on your farm will help you improve your farming operation in the long run.

ORGANIC CERTIFICATION REMINDER

If you are a certified organic producer and your trial involves using a new input, variety or practice, make sure that it complies with organic certification standards and the farm plan you currently follow. It is also important for you to notify your certifying agency of such changes before you start your trial.

STEPS OF AN ON-FARM TRIAL

This guide will walk you through seven steps to complete your on-farm trial. For an overview of these seven steps and how they fit together, see **Figure 1**.

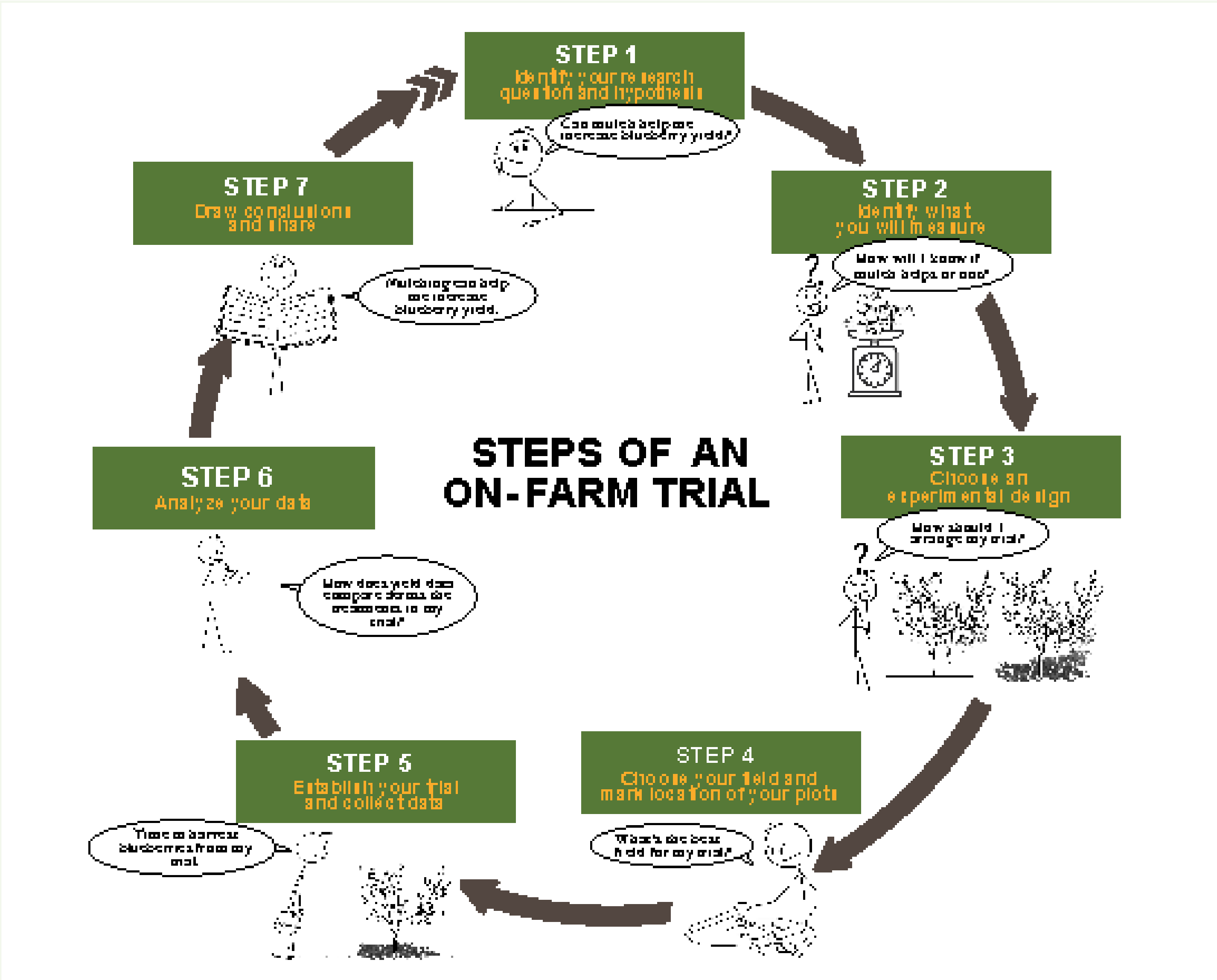


Figure 1. Steps of an on-farm trial.

For examples of farmers going through the seven steps of this guide, see the Farmer Researcher Profiles at **Appendix 1**. Each farmer profile has a summary of each step from planning the trial to drawing conclusions.

"On-farm research has provided me with the foundation for improved long term soil health at my farm. I have eliminated several off-farm inputs while fine tuning my cover cropping and rotation practices." ~April Thatcher, Farmer, April Joy Farm, WA

Step 1: Identify your research question and hypothesis

Framing good research questions and hypotheses is critical to the entire on-farm trial process. Your question and hypothesis are like your vision and mission statements, every action that comes after should be guided by these. They can provide you with a good roadmap to follow.

Before framing your question and hypothesis, and in case you have not done so already, spend some time learning about what research has been conducted in the past related to your question. This may help you see if someone else has tried your ideas in the field, and could help you refine your own research question. See **Sources of research information** for a good list of sources you can search.

SOURCES OF RESEARCH INFORMATION

- **Sustainable Agriculture Research and Education (SARE).** This USDA program site has hundreds of publications and searchable reports of on-farm research conducted by producers themselves across the country. Type in your keywords in their search box.
- **ATTRA Publication Library.** A good compilation of resources for sustainable and organic agriculture.
- **Organic Farming Research Foundation (OFRF).** Publications, online courses and a searchable organic research grants database.
- **Practical Farmers of Iowa (PFI)** runs the Cooperator's Program, a farmer-led research initiative since 1987. See examples of farmer-led research protocols and reports in their searchable database.
- **Ecological Farmers Association of Ontario (EFAO)** runs a farmer-led research program since 2016. Their Research Library database contains farmer-led research protocols and reports.
- **e-Organic Extension** Hundreds of technical resources for organic farming developed by a coalition of USDA and state Extension programs.
- Trade Magazines such as **Growing for Market** and **ACRES USA** may have some research articles on organic farming.
- Look to your state's university extension system for publications relevant to organic farming. Additionally, reach out to researchers and extension agents who have organic farming experience in your region.
- **Google Scholar**. Good source for research journal publications. If you can't access the full journal articles, your local extension agent may be able to obtain them for you.

Identify your research question

What idea have you wondered about that could really benefit your farm operation? All farms have aspects that can be improved, and perhaps there are one or two challenges that you have been struggling with for some time and would really like to find solutions. These issues could be related to yield, input or water savings, disease, weed and/or pest management, food safety, or anything else impacting your farm.

A GOOD RESEARCH QUESTION SHOULD:

- Be clear and provide specific information about what you want to answer
- Be focused in its scope and narrow enough to be addressed in the trial
- Be precise and complex enough that it does not simply answer a closed "yes or no" question
- Be testable

Perhaps you have a few ideas that you would like to tackle. Write them all down and think about them for some time. Which of these ideas is worth taking a good look at? What questions could be answered by setting up a small, simple experiment at your farm? Do any of these ideas seem practical and doable?

"Understanding what the question is that you are trying to answer is important… that's the bottom line."

~Farmer Jeremy Barker-Plotkin, Simple Gifts Farm, Amherst, MA.

Find a few farmer colleagues, an extension agent, or someone with experience who can listen to you and discuss these ideas. Then prioritize and identify one or two good research questions. Good research questions are clear, concise and testable statements that guide and focus your research. Do not be afraid to ask for support to refine your questions. See **Table 1** for some examples of "not-so-great" research questions, tips and advice to revise them and potential revised questions. See some examples of good research questions in **Table 2**.

Table 1. Getting to a good question.

Original question	Comments/advice	Revised question
What's the best cover crop I can use, at what rate and when to incorporate it into the soil?	Too many questions asked, and need to be more specific. Get advice from other farmers and extension agents.	When is the best time to incorporate sunn hemp cover crop to maximize nitrogen addition to the soil?
Will adding native vegetation improve pest suppression in eggplants?	Not specific enough. Unclear what and how much native vegetation will be introduced. Pest suppression includes all pests, focus on 1 or 2 species only.	Can I increase populations of thrips' natural enemies by planting native wildflower vegetation rows? And will this translate into increased pest suppression for my eggplant crop?
Where can I find heat-tolerant lettuce varieties?	This is not really a question you can answer with an on-farm trial. Get more advice from farmers and extension agents. Once you find potential varieties you may want to test them in an on-farm trial.	What are the best heat-tolerant lettuce varieties that can allow me to extend my season over the summer?

Identify your hypothesis

While a research question is the focused question your study hopes to answer, a hypothesis is the statement the study sets out to prove or disprove. The hypothesis comes directly from your research question, but it is more specific and testable - that is, with good certainty, you can prove it true or false. Having a hypothesis is helpful because it frames your trial by making explicitly clear what you are testing.

For example, let's say you want to reduce the number of fertilizer applications in the field to reduce labor demands without impacting yield in a bell pepper crop. You wonder if you can use the same amount of total nitrogen over the course of the growing season, but reduce the number of times you apply fertilizer.

Your research question could be:

> **Can I reduce the number of nitrogen fertilizer applications in my bell pepper crop from 4 times per season to 3 times per season without reducing yield?**

And your potential hypotheses could be:

- **Reducing fertilizer applications from 4 to 3 in my summer bell pepper crop will result in higher yields**
- **Reducing fertilizer applications from 4 to 3 in my summer bell pepper crop will result in similar yields**
- **Reducing fertilizer applications from 4 to 3 in my summer bell pepper crop will result in lower yields**

In this example, we have three hypotheses that provides us enough guidance to know:

a) we are comparing two different fertilizer schedules (3 or 4 fertilizer applications, with the total sum of fertilizer applied remaining equal),

b) what you are going to measure (yield) to compare these two fertilizer schedules, and

c) what you think the outcome will be (higher yields, similar yields or lower yields).

See **Table 2** for examples of questions and hypotheses.

> For some research inspiration and ideas, see **Appendix 4** for a list of 30 farmer-led on-farm trials conducted through the assistance of the Sustainable Research and Education Center (SARE), Practical Farmers of Iowa (PFI) and the Ecological Farmers Association of Ontario (EFAO).

Table 2. Examples of good research questions and their related hypotheses

Research questions	Hypotheses
When is the best time to incorporate my sunn hemp cover crop to maximize nitrogen addition to the soil?	Incorporating sunn hemp cover crop at 12 weeks of growth provides the maximum nitrogen addition to the soil that can be taken up by the next crop.
Do trap crops minimize stink bug damage in my tomatoes and peppers? If trap crops are effective, how much additional pest suppression do they provide when compared to my current management?	When planting a combination of sunflower and grain trap crops, pest incidence is reduced in my pepper and tomato crops compared with my current management.
Does mulching my garlic with straw affect winter survival, growth rates, and/or yield?	Mulching with straw will reduce winter kill. Mulching with straw will improve growth rates. Mulching with straw will increase yield in my garlic.
How does a pre-plant application of composted manure affect my spring wheat yield and/or protein content?	A pre-plant application of composted manure will increase my spring wheat yield and/or protein content.
What is the best planting date to achieve early harvest, high yield and optimal quality in my sweet corn?	Different planting dates will result in differences in sweet corn harvest date, yield, and/or quality.

Farmer Worksheet

Step 1 - Identify your research questions and hypothesis

Use the space below to brainstorm 3-5 ideas or questions that you would like to explore to improve your farming operation. Is there an amendment, cover crop or any other practice that you would like to try at your farm? See Table 2 for some examples of good questions.

Idea/question 1 ______________________________

Idea/question 2 ______________________________

Idea/question 3 ______________________________

Idea/question 4 ______________________________

Idea/question 5 ______________________________

Now take a few minutes or more time to reflect on these ideas. Then choose, from the ideas above, 1 or 2 ideas or questions that you think are the most important for your operation and that can lead to a simple and doable on-farm trial. Remember, this does not have to be your final question. You will have time to think about this and very possibly change or refine your ideas.

Refined idea(s), or question(s):

Now, let's try writing your hypothesis. Remember that the hypothesis is more specific than your question and states what you believe will be the outcome of your trial. For some examples of questions and hypotheses, see Table 2. Most questions and hypotheses are refined over time, so don't feel pressured to have all this figured out the first time. This worksheet space is just to get you started. You can always revisit this section and refine your question and hypothesis.

Step 2: Identify what you will measure

Your question and hypothesis will help you identify what you need to measure. Ask yourself, what do I need to measure to test my hypothesis? In the previous example, the farmer would need to measure yield to compare the two fertilizer schedules. It is common for certain types of on-farm trials to require measuring yield, however you may need to measure other parameters to test your hypothesis. For example, you may need to measure fruit quality and size if you are comparing varieties or disease treatments. You may need to measure soil temperature, organic matter or soil moisture if you are comparing new irrigation systems or cover crop mulches. Other data you may want to take are fruit sugar levels, weed counts, plant height, leaf number, pest pressure counts, etc.

Regardless of what you are measuring, make sure that it helps you test your hypothesis and answer your question. **See Table 3** for some examples of potential measurements based on what you are testing.

Take into account the time, frequency and resources required to take these measurements. It is really important to think ahead about the possible tools or equipment you may need, as you may have to buy or borrow some. There is more practical guidance on data collection on Step 5 below, but for now, it is essential to identify what measurements are needed to answer your question and support a hypothesis.

Table 3. Examples of potential measurements based on what you are testing.

If you are testing:	Potential measurements based on type of trial (highlighted in green)														
	Yield	Produce quality	Produce size	Disease incidence	Pest populations	Cost	Weed count / weight	Germination rate	Water saving	Soil organic matter	Soil nutrients	Bio-mass	Soil Moisture	Soil temp	Stem/ root length or weight
Pest treatments	■	■	■		■	■									■
Disease treatments	■	■	■	■		■		■				■			■
Fertilizer / soil amend.	■	■	■	■	■	■				■	■	■	■		■
Weed suppression	■	■	■			■	■				■				■
Pruning	■	■	■	■	■	■									
Varieties	■	■	■	■	■	■	■	■	■		■	■			■
Seeding / germination	■			■	■	■	■	■	■			■	■		■
Irrigation systems	■			■		■		■	■				■	■	
Cover crops	■			■	■	■	■	■	■	■	■	■	■	■	

Farmer Worksheet

Step 2 - Identify what you will measure

Take a look at the questions and hypotheses you came up with in Step 1. In your opinion, what do you need to measure in order to test your hypothesis? What measurements are needed to know what treatment is better for your farm? Yield data is commonly measured, but measuring other parameters could be useful as long as it helps you answer your question and hypothesis. Remember that it will take time and resources to take these measurements. This exercise will get you started thinking of your idea and help you refine your process.

Use the space below to brainstorm on possible measurements for your trial. Make a short list if needed.

Possible measurement 1

Possible measurement 2

More measurements

Step 3: Choose an experimental design

Based on the guidance from your question and hypothesis, you will need to choose from a few simple experimental designs to set up your on-farm trial. An experimental design provides guidance on how to set up your trial based on the number of treatments with the goal of minimizing variation and bias. Using an experimental design will make your farm testing more structured and its results more reliable.

The three most common types of designs used for on-farm trials are:

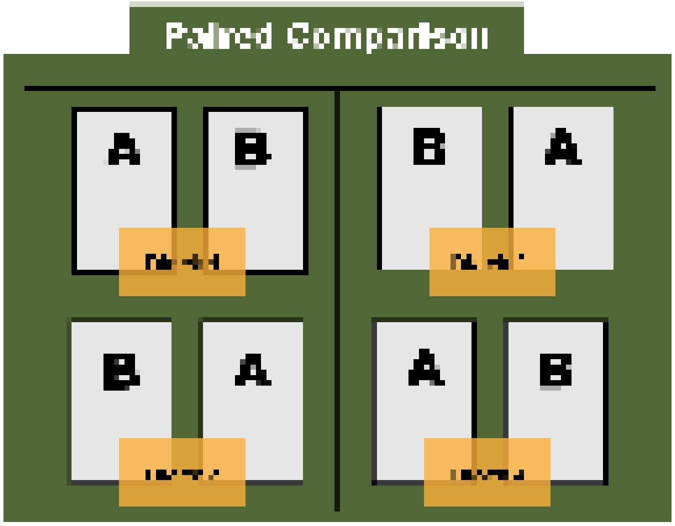
a) Paired Comparison: When you only need to compare one different practice at your farm (treatment) with what you generally do (control). You only have two treatments you are comparing in this design, your control (business as usual) and the new treatment you are testing. Examples: two varieties, two fertilizers, two pesticides, two pest management strategies, or two types of irrigation, etc.

b) Comparison of 3 or more treatments (Commonly known as Randomized Complete Block Design): Very similar to the paired comparison, except that you have more than 2 treatments. You have 3 or more treatments that you are comparing and one of them is your control.

c) Split Plot: This design is more complex, and it is used when you want to compare two different things at your farm, such as two new varieties of carrots (1st Level of treatments) with three types of fertilizers (2nd Level of treatments). Instead of conducting two separate trials, -one trial to test the carrot varieties and another one to test the fertilizers- you put them together to see how they interact. For example, it is possible that one of the varieties of carrots respond better to one of the three types of fertilizer used. Another example could be that you want to test grafting tomatoes (1st Level of treatments) and 3 new tomato varieties (2nd Level of treatments) to minimize disease and improve yield and flavor. This type of design will require significant space for you to set up enough replications for each treatment.

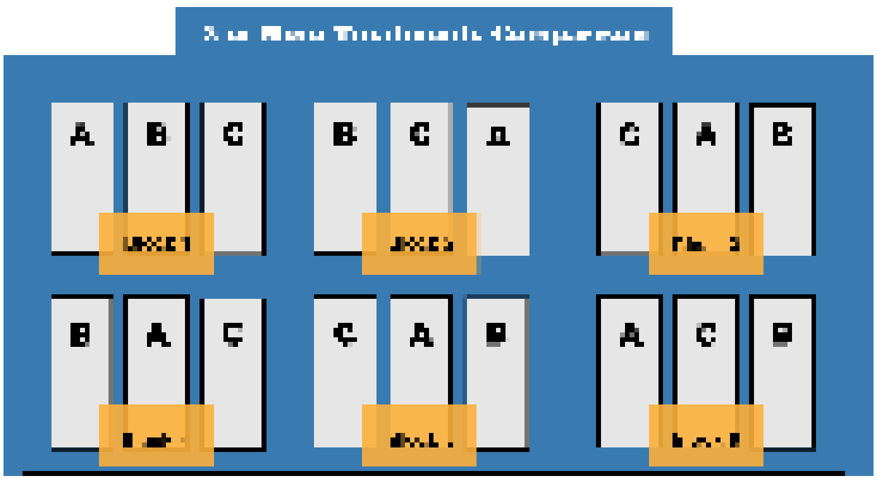
See **Figure 2** for a graphical representation of these three types of experimental designs.

USDA photo by Lance Cheung.



Paired Comparison:

Comparing fertilizers A and B on 4 blocks.



3 or more Treatments Comparison:

Comparing 3 fertilizers, A, B, and C, on 6 blocks.

Split Plot Design:

Comparing 3 fertilizers, A, B, and C plus the use of Mulch and No mulch control on 4 blocks. Mulch and no mulch are used as the main plots, while the fertilizer treatments are the subplots.

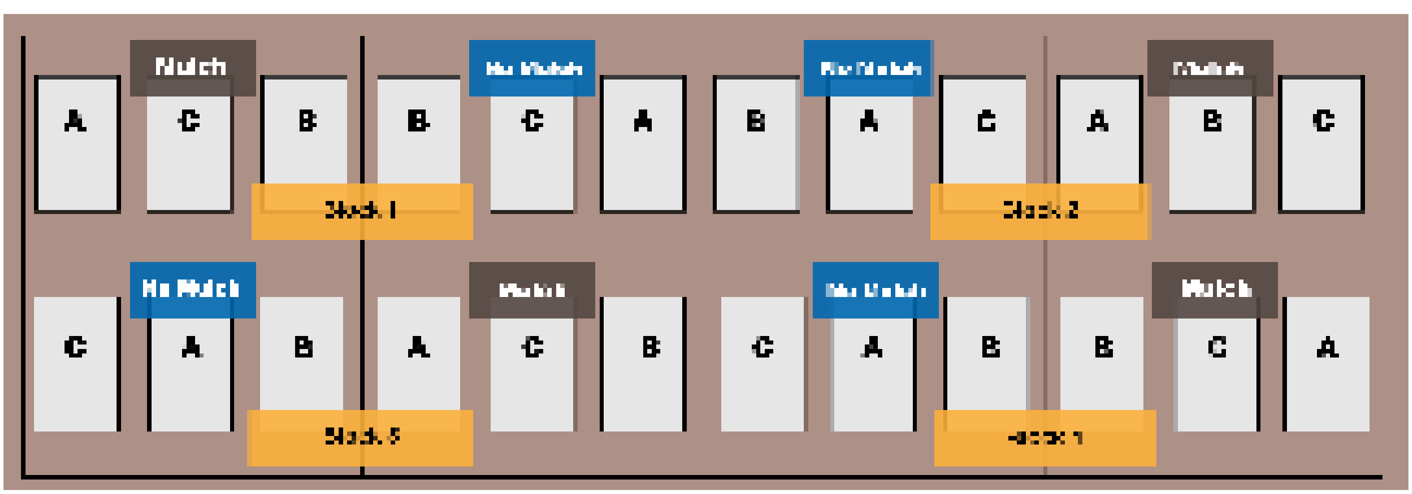


Figure 2. Comparison of the three most common experimental designs.

Elements of experimental design

Following are definitions of a few key elements of experimental design. See **Figure 3** for a graphical representation of these concepts.

a) Treatment is the name of the farm practice you are comparing. For example, if you are comparing a cover crop mulch with plastic mulch for weed control, you have two treatments: Treatment A: plastic mulch, Treatment B: cover crop mulch.

b) Control is the treatment that you currently use at your farm and the one you are comparing with a new way of doing things. In the example above, if you routinely use plastic mulch, that is your control. Treatment A (Control): plastic mulch, Treatment B: cover crop mulch. In order to know if cover crop mulch is better or the same for weed control than plastic mulch, you must include your control in your trial.

c) Plot is the smallest unit of area on your on-farm trial that contains one of your treatments. For example, Treatment A is assigned to one plot, while Treatment B is assigned to another plot.

d) Replication is the number of repetitions or times you will compare your treatments. It is recommended to have a minimum of 4 replications. Having 6 or more replications is ideal. The more replications you have, the more successful you will be in minimizing variation and bias in your trial. This is usually accomplished by arranging your treatments in **Blocks** or groups.

e) Randomization is used to minimize variation within a replication or block so that they are not always placed in the same order. This allows for the existing variation to affect all treatments more equally.

The three experimental designs recommended here are classified as block experimental designs due to the use of blocks. Following the mulch example from above, the farmer had 6 replications or blocks. Each block has both Treatment A and Treatment B. So in total, we have 6 Treatment A plots and 6 Treatment B plots.
See **Figure 3** for a representation of all these elements.

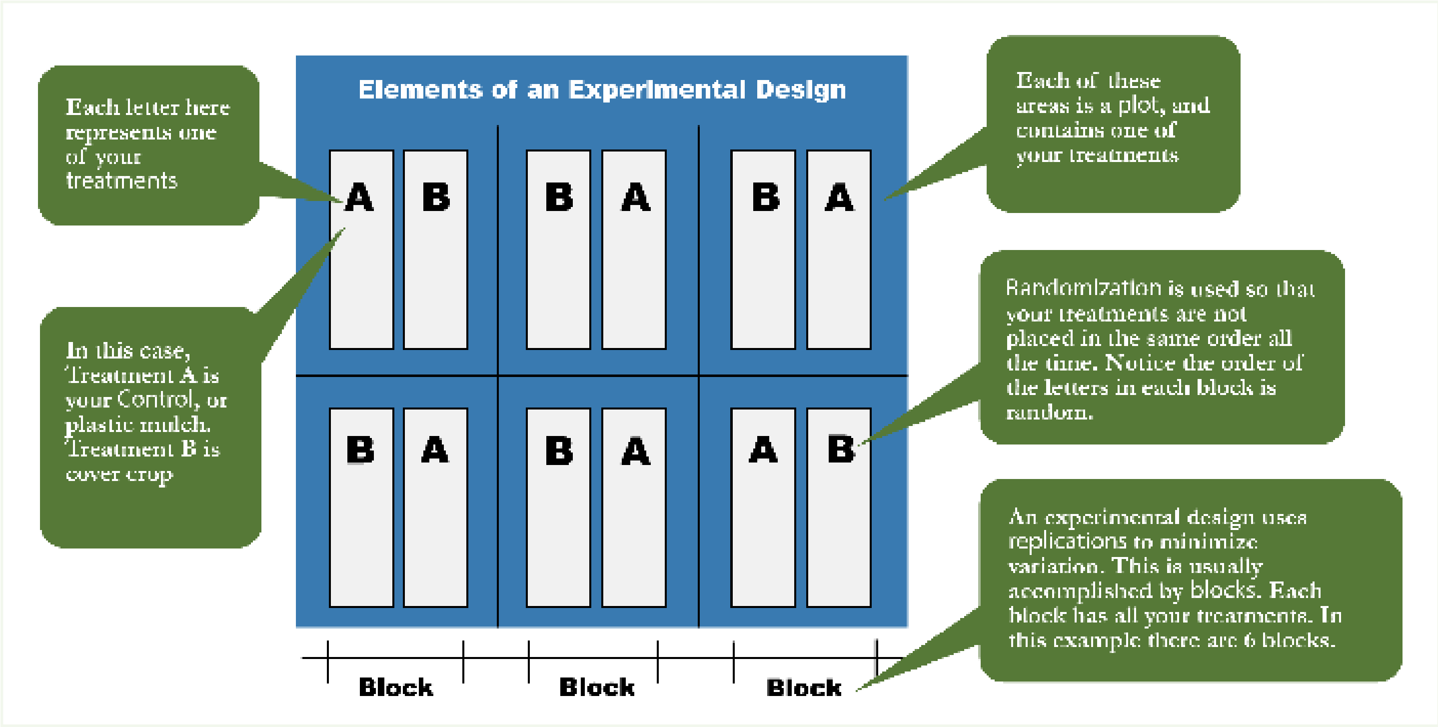


Figure 3. Elements of an experimental design

WATCH OUT FOR BIAS

Bias is the unintentional tendency of favoring one treatment over another. In this case, you may be rooting for one treatment over another, and so you may subconsciously decide to put the treatment you favored on the most fertile land. Your results may reflect this difference in soil fertility, rather than the actual treatment difference.

Photo by PavloBaliukh on Istock.

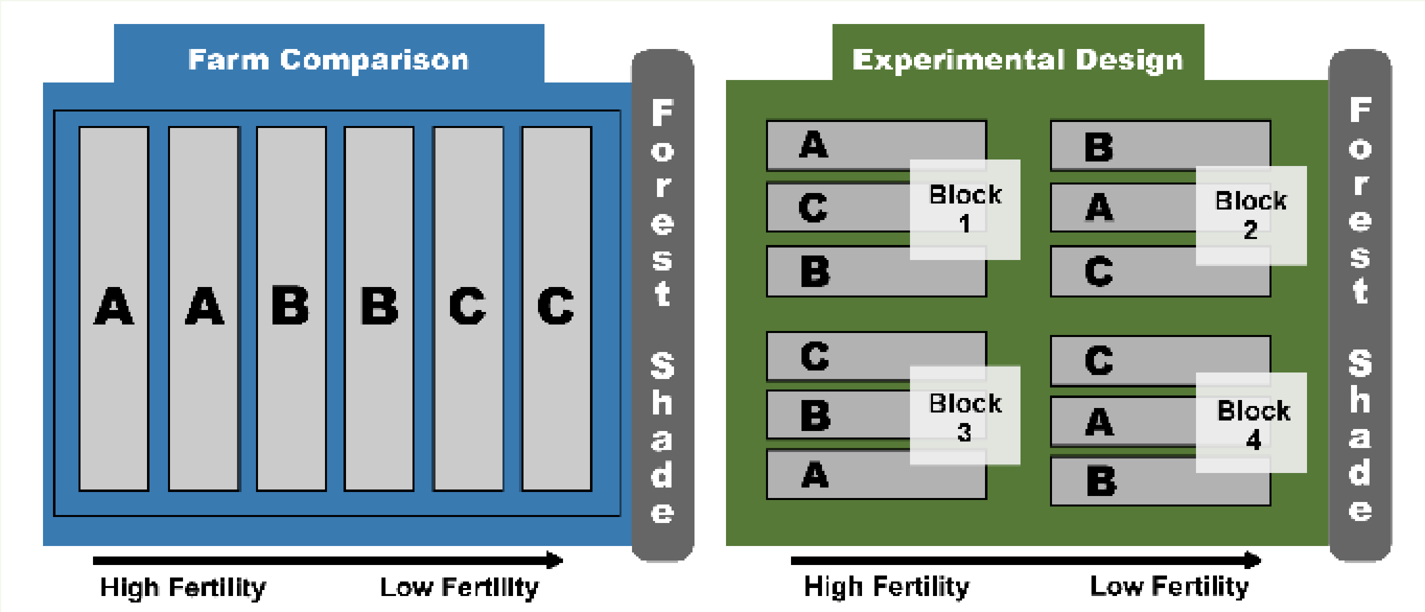


Figure 4. Advantages of using experimental design principles in farm trials

Comparison of a typical farm trial with a farm trial using an experimental design. By using randomization and blocks or replications, the experimental design minimizes sources of variation such as the fertility gradient in the field and forest shade on the east side. In this case the typical farm comparison would favor treatment A due to the higher fertility in that side of the field and unfavor treatment C due to shade. In the experimental design these two factors are affecting all three treatments more equally.

Managing variation

Variation is the difference of naturally occurring conditions in various areas of your field. That is to say, conditions change naturally depending on what section of your field you are located in. For example, there could be a moisture, slope, or fertility gradient in your field and that will affect the outcome of your trial. Other sources of variation include field history, other fields nearby, shade, etc. Your goal as a farmer-researcher is to try to minimize variation by taking these factors into account so that they affect your treatments equally.

For example, let's say that you are testing 2 different varieties of kale to the one you currently grow, so in total you have 3 varieties of kale in your trial, or 3 treatments. However, the field you have available for this trial is known for having a fertility gradient and some shade from the forest nearby. By following an experimental design with replications and randomization of each block, you minimize the chance of favoring any of the 3 varieties. You give the 3 varieties the same chances to show how well they can grow.

See **Figure 4** for a comparison between a farm trial that uses an experimental design and a farm trial that does not use it. This comparison is based on the kale example above.

For examples of farmers going through the seven steps of this guide, see the 3 Farmer Profiles located on **Appendix 1**. Each farmer profile has a summary of each step from planning the trial to drawing conclusions.

Farmer Worksheet

Step 3 - Choose an experimental design

Remember that the experimental design is chosen based on the number of treatments you have and if you are testing more than one practice at your farm. See Figure 3 for a graphical representation of these three designs.

- **Paired Comparison:** Comparing 2 treatments of one practice. Examples, 2 fertilizers, 2 varieties, 2 mulches.
- **Comparison of 3 or more treatments:** Similar to the paired comparison, except that it has 3 or more treatments.
- **Split plot:** In this case you are testing two different things at your farm. For example, you may want to test 2 fertilizers and 3 varieties at the same time.

Try your best to choose an experimental design. Given your number of treatments and what you are comparing, what is the most likely design for your trial? Write out your different treatments.

Remember to ask for help from a local extension agent, non profit farming organization or researcher.

Step 4: Choose your field and mark location of your plots

Choosing a field for your trial is an important step. For example, the field you choose should be easily accessible or in a location that you visit frequently, so that you can keep an eye on it throughout the season. Another critical factor is the natural variation found within your field. Remember that differences in things like soil slope, texture, moisture, fertility, or field history will impact the results of your trial.

So, try your best to choose a field that is as uniform as possible so as to minimize variation. At the same time, pay attention to any external factors that may influence your trial, such as your neighbor's field, prevailing winds, typical insect migrations, or a nearby patch of forest, etc. Depending on the type of trial you have, you may need to use buffer zones around and within your trial, especially where the possibility of pesticide or input drift or runoff could occur.

Using an experimental design with replications and randomization will help you minimize any field variation. As a farmer, you have an intimate knowledge of your fields and can possibly point out each of your field's "temperament," or their strengths and challenges. Use this knowledge when deciding what field to use for your trial and how to lay out your treatments to minimize variation. For example, if you have a field where fertility goes from low to high, make sure that your blocks fall across this gradient. See Figure 5 for more examples.

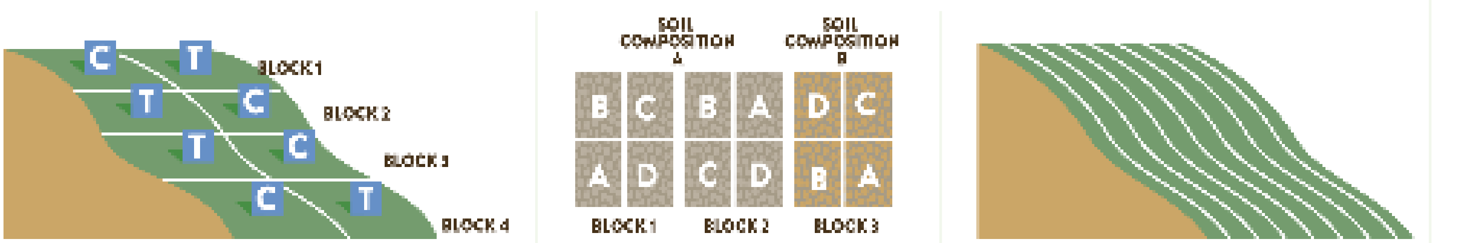


Figure 5a Figure 5b Figure 5c

Figure 5. Addressing field variability with blocking

Agricultural research should usually be blocked because of field variability. If your field has a known gradient, such as a fertility or moisture gradient, it is best to place blocks so that conditions are as uniform as possible within each block.

- Figure 5a: On a slope, for example, each whole block should occupy about the same elevation. Treatments are randomized and run across the slope within each block.
- Figure 5b: Place whole blocks within different soil types.
- Figure 5c: If blocks cannot be used to account for variability, then each treatment should run across the whole gradient, as in all the way down the slope or all the way across the field.

Figure credit: Sustainable Agriculture Research and Education (SARE). Used with permission.

Draw your map

Once you have decided what field you will use for your trial and your experimental design, you are ready to draw your plot map on paper. Given the number of treatments you have and the number of replications (minimum 4), decide how big your plots and whole trial will be. The size of an on-farm trial varies, and can be determined using practical criteria, such as the length of the field and the width of your tractor pass. Ideally, you should use the same bed and field dimensions as you generally do at your farm, using the same implements. Decide what size your plots will be and start drawing a plot map, starting with drawing each block, which will contain all your treatments.

IDEAS FOR RANDOMIZATION

- If you only have two treatments, you can flip a coin.
- If you have between 3 and 6 treatments, roll a dice, assigning each treatment to one dice number.
- Use a random number calculator or generator online. You write what letter or numbers to draw from and the calculator provides one random letter or number every time you want.

When you label each of your plots on paper and in your field, they need to be placed randomly rather than in order. This can be easily done by pulling papers from a hat. For example, if you have 3 treatments: A, B, and C; you write down each of these letters and fold them in small pieces of paper. Then you put them inside a hat and pull them out one at a time. This assures that they will be placed randomly for each of your blocks. So block 1 may look like this: C, A, and B. Block 2 may look like B, C, A.; block 3 may look like A, C, B., and so forth. See **Ideas for randomization.**

Finish drawing a map of your on-farm trial plots, clearly labeling all your treatments and repetitions as well as all the measurements. Make sure you specify what each treatment letter represents, and any other details you may need later on, such as important dates for data collection or application rates per treatment.

Create copies of this map for future reference and keep at least one copy in a safe place. See **Figure 6** for a plot map example.

Remember that your crops will grow and may cover the flags and labels you put before planting.
Keep a copy of your plot map - with all your treatments and plots clearly identified - in a safe place for future reference.

Figure 6. Plot map example with an experiment in Field 2. The experiment shown here is comparing three treatments (A, B, and C) and the treatments are repeated in 6 blocks.

Mark your plots

Next, it is time to lay out your plots in the field based on the map you have created. Using measuring tape, carefully identify and mark where each plot and repetition will be located. You may need at least 2 people to do this. Use irrigation flags or tall stakes and weather-resistant labels to clearly mark and identify each repetition and each treatment.

Remember that your crops will grow and may cover the flags and labels you put before planting. Train all your staff about what you are testing in your trial and to be careful around the trial plots, especially when using heavy machinery that may knock down the flags and treatment signs. Monitor the trial on a regular, scheduled basis to make sure that all your flags and labels remain in place.

Remember that all your plots need to be managed in the same exact way (irrigation, fertilization, weeding, pruning, planting date, etc.), except for the treatment you are testing. For example, if you are comparing the use of a new cultivation implement versus an old one, make sure that all other crop activities remain exactly the same for all of your plots.

Farmer Worksheet

Step 4 - Choose your field and mark location of your plots

Think about the best possible field you can place your trial. Remember that it should be as uniform as possible and keep in mind any sources of variation within and outside the field. Based on your available land and equipment, think about the size of your plots and entire trial. Think about the possible number of replications (minimum 4, ideally 6. The more replications, the better, but it is also more work). Then below, draw your field and surrounding areas, indicating any source of variation (fertility, soil, slope, moisture, etc.). You can also print out a Google satellite map of your farm and start your plot map there. Then draw the potential location of each block or replication of your trial. For examples of these, see **Figure 6**.

In addition to your map, it is time to identify your treatments using letters or numbers.

Treatment A ________________________ Treatment B ___________________________
Treatment C ________________________ Treatment D ___________________________
Treatment E ________________________ Treatment F ___________________________

Then, use one of the randomization ideas to start labeling each of your plots per block. Remember that you can always change or refine these ideas.

Step 5: Establish your trial and collect data

It is time to start your trial in the field. Remember that all your farm activities need to remain exactly the same for all your treatments, except for the one or two things that you are testing. In Step 2 you identified what you would measure to answer your hypothesis and question. It is time to make decisions about how you would take these measurements.

Depending on your experiment, you may need to collect data from your trial several times during the season. For example, if you are interested in weed, pest or disease pressure, it will be important to monitor the field over time and collect data 2-3 times before harvest. It is recommended to create a calendar for your trial where you keep track of the important dates. For example, if you are testing input application rates, it is important to spell out in detail the dates, treatments and application rates. This way, you don't have to remember what you have to do with each treatment, since you have planned and specified this in advance.

> Remember to have a data collection plan in place before starting your trial in the field. This will help you to make sure that you have all the equipment and tools you need when you start collecting data.

Yield data is commonly collected for on-farm trials by measuring harvest totals. In addition to, or instead of, yield, you may be interested in other traits, such as germination rate, fruit quality and flavor, weed pressure, or soil improvements, etc. In order to take these measurements, make decisions on what tools, equipment, and standard procedures you will use. That is, you have to make a plan for how you will take these measurements. You may need to borrow some tools or equipment from your local extension agent or researcher to collect your data. See some advice, tips and resources for data collection on **Table 4**.


Photo by deyangeorgiev on Istock.

Collecting data

It is usually not practical to measure the entirety of your plots; instead, sampling some sections of your plots will be enough. Collecting soil samples in your plots in a zig-zag pattern, or placing a sample frame or a hula hoop randomly in your plot a few times and measuring the weeds that fall inside the frame are examples of random sampling. Even for yield data, you may want to harvest some samples only, which can be accomplished by hand if it is difficult to harvest an exact area when harvesting mechanically.

For yield data, make sure that you document the plot area you harvested so that you can calculate pounds per acre. If your trial has the potential to be influenced by different factors at field edges like drift, prevailing winds, or runoff, it is recommended to conduct the sampling in the middle rows of your beds, to minimize such influence. Finally, have sampling bags or containers labeled in advance by repetition and treatment to avoid any mistakes. See a few examples of strategies to collect sample data randomly in **Table 4.**

Table 4. Examples and resources for sampling strategies

Measure stand establishment by counting the number of emerged seedlings in several rows or use a square sample frame. For germination tests off the field, check out this test guide from Southern Exposure Seed Exchange.
Measure soil organic matter or other soil properties by sampling soil randomly in your beds in a zigzag pattern. The overall goal of soil sampling is to collect a sample that is representative of the conditions you would like to measure. Follow your local soil lab's recommendations for sample collection as some tests require more soil than others. The Haney soil test is often recommended to estimate food available for the soil biological community. This NCAT/ATTRA publication provides an in-depth discussion of soil tests and labs recommended to measure soil health.
Measure yield by harvesting from a carefully measured area. In some cases, farmers who usually harvest mechanically may need to consider harvesting measured treatment areas by hand. Make sure that the scale you use measures down to the weight units that are helpful to you. Conversions can always be made to make your measurements more meaningful, for example, going from lbs/plot to bu/ac.
Measure biomass by placing a sample frame or hula hoop randomly in your beds. Then cut all the cover crops or forage growing in the area at soil level and place it on a labeled cloth bag to measure weight. For an example of biomass sampling and dry weight calculation, see this video and publication from the University of Georgia Extension. Another example is this guide for biomass sampling from USDA-NRCS.
Measure weed suppression by doing weed counts based on a sample frame or hula hoop placed randomly in your beds once or twice per season. You can also cut the weeds at soil level and place them in a paper bag for fresh weight measurement. If you cut the weeds, make sure you mark this location so as not to sample in this area twice. Calculate dry weight based on the microwave method included in this University of Georgia publication.
Measure pest or disease presence by sampling for pest numbers in your beds using traps, or visual observation of randomly chosen plants. You can also use a frame to sample multiple plants found in the frame area. This should be done at least twice during the season. See this video from Penn State for pest and disease scouting techniques, which can be used for sampling. See another video on scouting in vegetable crops created by eOrganic. For more in-depth information on disease sampling, see this video lecture by Alison Robertson from Iowa State University.
Measure fruit quality by weighing, measuring diameter, disease and pest presence, or send to a laboratory for fruit sugar content, dry matter content, firmness, color, and acidity. A hand-held and relatively inexpensive brix refractometer can also be used to measure sugar content.
Measure flavor by doing a blind produce test to rate size, shape, color, flavor, aroma, texture and overall quality. More information on how to conduct consumer tasting panels and a good example of flavor evaluation datasheets, consult The Grower's Guide to Conducting On-farm Variety Trials.

USDA photo by Peggy Greb.

Data sheets

It is important to collect research data using data sheet templates to minimize the risk of data entry errors. Make sure to collect data per plot, do not lump together the yield or data from all the plots of one treatment to find their average. See **Appendix 2** for a few recommended data sheets and other sources of data sheets you can use. When possible, get help when collecting and entering data, as it is easy to make mistakes with these tasks. Finally, store your data sheets in a safe place and take pictures of these as a back up.

Field observations

Make sure to write observations about your trial throughout the season. This should include observations on weather, pest, disease, crop growth, and any other observations you find interesting. These notes can be very helpful when it is time to interpret your trial results. Additionally, take pictures of your on-farm trial as frequently as possible, especially if you can easily observe differences among treatments.

Farmer Worksheet

Step 5 - Build out your data collection plan

See what you wrote on Step 2 and explore how you will go about taking the measurements you identified using the following questions. It is ok if you don't have all the details on your data collection plan at this point. These questions are just to get you started. You can always revisit these questions later on when you are ready to make decisions about your trial. Remember that you will need to use a datasheet template to enter your data. See examples of datasheets in **Appendix 2**.

Measurement 1 ______________________________

Explain how you will measure this, what are the steps?

____

____

List what you will need to measure it (people, tools, bags, equipment, time)?

____

____

How many times and when will you collect this data? ______________________________

What procedure will you use to collect samples randomly?

____

____

If needed, who can you contact to help you develop the sampling procedure? __________________

Measurement 2 ______________________________

Explain how you will measure this, what are the steps?

____

____

List what you will need to measure it (people, tools, bags, equipment, time)?

____

____

How many times and when will you collect this data? ______________________________

What procedure will you use to collect samples randomly?

____

____

If needed, who can you contact to help you develop the sampling procedure? __________________

Measurement 3 ______________________________

Explain how you will measure this, what are the steps?

____

____

List what you will need to measure it (people, tools, bags, equipment, time)?

____

____

How many times and when will you collect this data? ______________________________

What procedure will you use to collect samples randomly?

____

____

If needed, who can you contact to help you develop the sampling procedure? __________________

Step 6: Analyze your data

You have done all this hard work and collected data from your trial. It is time to use statistics to help you find your results. Rather than just simply using an average and drawing conclusions from any difference, statistical tests help us have more certainty that the difference we see is the actual difference among treatments, rather than due to chance or any other external factor.

Before you conduct your statistical test, you need to make sure that your data follows a normal distribution. If you sample the weight of 100 wheat plants in your field, it is very likely that some will be in the lower values, some in the upper values and the majority will be in the middle range. That would be a normal distribution, often called a bell-shaped curve or bell-shaped distribution. Before running statistical analysis, 'normality tests' are used to make sure that your data follows a normal distribution. The statistical tests recommended in this guide are appropriate for data that follows a normal distribution. If that is not the case, and your data does not follow a normal distribution then you will have to rely on other statistical tests called Non-parametric, which we will not discuss here, but you can find more information in Appendix 3.

The statistical tests recommended here use a value called 'Levels of Confidence' which help determine trust if a difference among treatments is valid or not. Levels of confidence of 90% or 95% are common. You get to choose the level of confidence you want, but most farm trials use a 95%. A level of confidence of 95% means that there is still a 5% chance that our results may be wrong, but you can be 95% certain of your results. In science, you can't be 100% certain of anything, but by having a 95% level of confidence, you can safely view your results as trustworthy.

The statistical test you choose for your trial depends directly on the experimental design you have.

- For a **Paired Comparison**, use a t-Test.
- When **comparing 3 or more treatments**, use an Anova test
- For **Split Plot design**, use an advanced type of Anova test.

All three of these tests make similar calculations with your data. We won't get into the details of how these tests work here, for more information on these statistical tests and how they work see **Appendix 3**.

Don't worry if you feel overwhelmed in this section, there are free online tools that will do the statistical analysis for you. You just have to enter your data. See below for guidance on how to use a few recommended online tools.

Each of these tests calculates the Least Significant Difference value or LSD, which is a value calculated based on the mean and variation of your data plus the level of confidence. The LSD value tells you the smallest significant difference between treatment averages. When the average differences among your treatments are higher than the calculated LSD, then you can safely trust that your results are indicating a statistically valid difference. This means that one or more of your treatments indeed produced higher values than the other treatments. On the other hand, if the average differences among treatments are lower than the LSD value, then there are no statistically significant differences among your treatments. See an **Example of data analysis** below.

Example of data analysis

Farmer-Researcher David conducted an on-farm trial to compare two types of postharvest pruning or hedging treatments in blueberries. Some of the farmer's peers recently recommended a more aggressive pruning than the farmer currently does, removing about 50% more plant material. The farmer implements an on-farm trial to test this idea and determine what is best for the farm. The trial had 2 treatments: A: Control (or the current pruning program), B: More aggressive pruning. The farmer's hypothesis is: Pruning an additional 50% plant material during post-harvest will negatively affect yield in blueberry crop.

Given that the study is comparing 2 variations of one practice (pruning), the farmer uses a Paired Comparison design with 6 replications in randomized blocks. See **Figure 7** for a graphic representation of the trial design.

The farmer conducts the on-farm trial and then harvests and weighs total pounds per plot yield for the entire experiment. The yield data (lbs/plot) is entered into a datasheet as follows in **Table 5**.

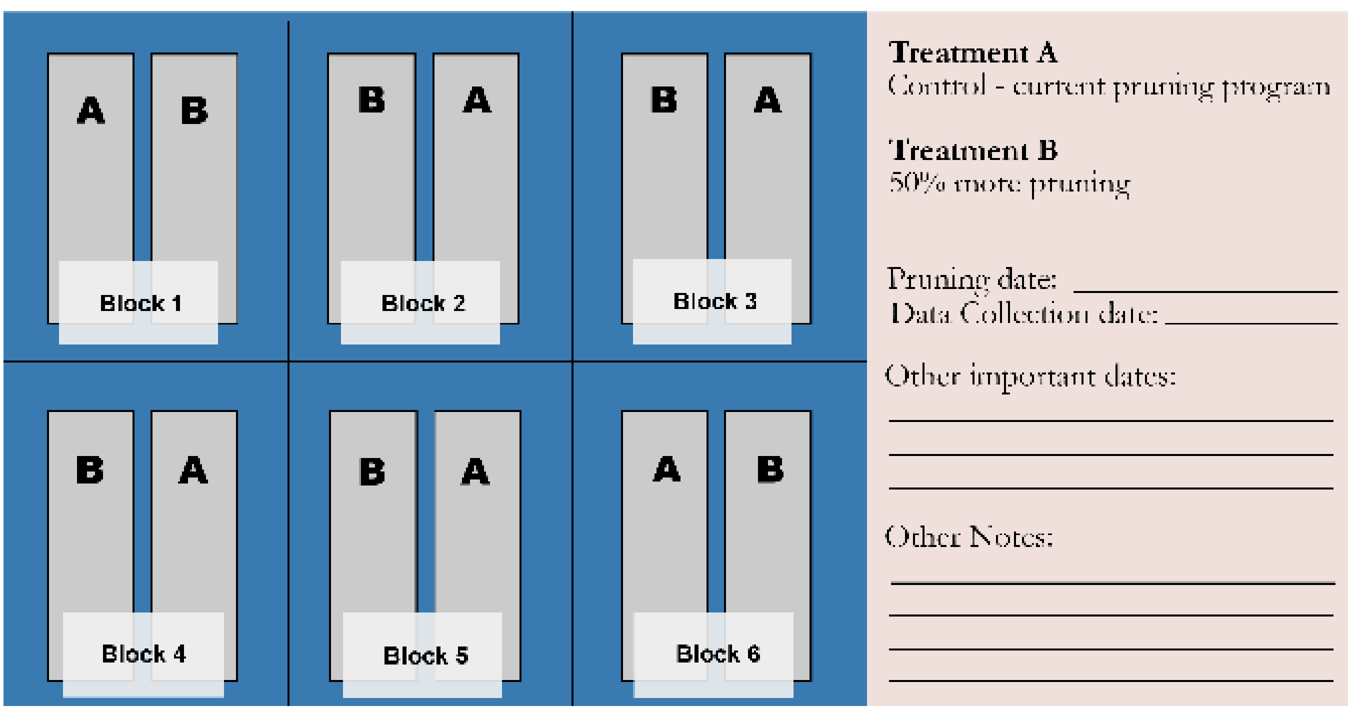


Figure 7. Paired comparison with 6 replications in randomized blocks

Based on the averages alone, it would appear that there were small differences among treatments. This may indicate that the more aggressive pruning treatment increased yield, rather than lowered it, as the farmer suspected. But before jumping to conclusions, the farmer used a statistical test to analyze their data and feel more confident about the results.

The farmer chose the standard 95% of confidence interval and used an T-Test on FarmStat online tool from the University of Nebraska-Lincoln to analyze the data. The Least Significant Difference value (LSD), or sometimes called the Fisher's LSD, was calculated as 6.6. Then the farmer compared the LSD value to the differences among averages for the two treatments.

Treatment B (149.83) – Treatment A (147.67) = 2.16. This value is lower than the LSD value of 6.6, therefore we can say that pruning 50% more plant material post harvest in the blueberry crop did not affect yield either positively or negatively. Yield remained the same for both pruning treatments.

Table 5. Yield data per plot

	Treatment A (control) lb/plot	Treatment B lb/plot
Block 1	150	145
Block 2	145	155
Block 3	140	150
Block 4	151	149
Block 5	153	152
Block 6	147	148
Average	**147.67**	**149.83**
Range	140-153	145-155

The farmer-researcher can draw good information from this trial. There was no yield difference between the two pruning treatments. The recommendation from other farmers for more aggressive pruning did not help to increase yield. On the other hand, pruning this additional plant material didn't lower yield, as the farmer suspected. When it comes to blueberry yield, the farmer can use any of the two treatments going forward. Other considerations, such as pruning costs come into play when deciding what to do. The farmer is considering conducting the trial again using a different blueberry variety.

USDA photo by Preston Keres.

How do you go about conducting these tests?

There are various free statistical analysis tools on the internet that you can use to analyze your data. You have to enter all your data but the online tools will do the analysis for you. If you have access to Microsoft Excel or Google Sheets you can also conduct the analysis yourself. See **Free online tools for statistical analysis** for a list of recommended statistical sites that can help you run the statistical test for your trial.

Finally, don't be discouraged if you struggle with statistics. Most of us do. Ask for help from your local extension agent or researcher. If you are a recipient of OFRF funding for your research trials, OFRF staff will assist you with this.

Free online tools for statistical analysis

FarmStat from the University of Nebraska-Lincoln. It's a simple tool for paired comparison and 3 or more treatments comparison designs. There is a tutorial video you can view for reference.

Jamovi. This is a free open source software tool that you can use online. You may need to create a free account so that you can use the tool for 45 minutes per session. You can run a T-test for paired comparison designs, Anova tests for 3 or more treatment comparison; or Anova test for a split plot design. See a Jamovi video tutorial from Idaho State University.

Organic Seed Variety Trial Tool - This tool, developed by the Organic Seed Alliance, can help you plan and view results for your on-farm trial. It was designed specifically to help farmers do trial varieties for organic farming. Using this tool you can conduct t-test for paired comparison designs and Anova tests for a 3 or more treatment comparison. See a tutorial video on how to use this tool.

Microsoft Excel or Google Sheets. You can conduct t-test and Anova analysis in these tools. Anova tests in these tools will only tell you if there were significant differences among treatments

*Note: See **Appendix 3** for more specific guidance on how to use these online tools.*

Step 7: Draw conclusions and share

Once you have statistically analyzed your results, it is time to ask, do these results appear to agree with your hypothesis? What about your original question? Take some time to reflect on your trial and your results and think about what these mean for the rest of your farm.

Depending on your results, is it time to expand the practice you tested to the rest of your farm? Or do you need to conduct more testing or find additional information to make this decision? Perhaps you may consider running the same experiment next year, as weather conditions change. Discuss this with a trusted farmer colleague or extension agent and use your field observation notes to help you interpret your results. Often, trial results lead to even more refined or helpful ways to ask questions to improve your practices.

> When drawing conclusions from your trial, remember to take into account the differences in cost among your treatments. An increase in yield may not look so good after all if you had to double the amount of labor used for the new agricultural practice. If your treatments will vary in cost, it is recommended that you keep track of them so that you can use this information to make informed decisions.

It is important to keep your results in context. Whatever the outcome, it does not mean that these results should apply to all farms in the country where the same crops are grown. Your results are more likely to apply to your local farm and your local farming community. Feel free to share your experience conducting an on-farm trial and your results with your peers and friends. It is likely you learned a lot from the entire process and that you may want to continue tinkering with on-farm testing to improve your operation. Share your learning and excitement with others. They can learn a lot from you; farmers learn best from other farmers!

Don't be discouraged if your results are not statistically significant, as that is a valid result. Conducting on-farm trials takes hard work and sometimes you don't get the outcomes you expected. Keep in mind that even not statistically significant results are good information for your farm. For example, your results may let you know that a specific practice you were very excited about does not really work and it is not worth investing more of your energy and resources. This is good guidance for your farm management.

> ***"As farmers, we are generally people who wonder what's going on… we have some thoughts, we observe things. Diving a little bit more on some questions is something that a lot of farmers would benefit from."***
>
> ~Farmer Jeremy Barker-Plotkin
> Amherst, MA


USDA photo by Preston Keres.

Finally, **stay curious!** Use the information you obtained from your on-farm trial and keep asking questions that have the potential to improve your operation. In science, as in a farming operation, new questions keep coming up. We encourage you to use these guidelines to continue conducting on-farm trials at your farm. The most relevant and impactful research for your farm may well be the one you design and lead.

For examples of farmers going through the seven steps of this guide, see the **Farmer-Researcher Profiles** located in **Appendix 1**. Each farmer profile has a summary of each step from planning the trial to drawing conclusions.

Appendix 1 - Farmer-Researcher

Farmer-Researcher Profile 1: Galo's Grains

Background
Galo's Grains is a fictional 100-acre organic grain farm located in the state of Michigan, USA. The farmers specialize in small grain production such as barley, oats, and wheat. Their main buyers are the high-quality flour and the artisanal brewing industries. One of their main buyers, a brewery, recently approached the farmers to try a new variety of barley. The farmers are unsure if this new variety will grow well at their farm, as it was bred specifically for another region of the country.

Step 1- Identify your research question and hypothesis
Questions: Can this new variety of barley adapt and grow well in my fields? Will it produce good yields when compared to the variety currently grown?
Hypothesis: The new barley variety will not produce the same or more yield per acre as the variety grown at the farm for years.

Step 2 - Identify what you will measure
The farmers will measure grain yield per acre during harvest time.

Step 3 - Choose an experimental design
Based on the number of new varieties compared, the farmers will have 2 treatments. Treatment A: control (the variety currently grown). Treatment B: new barley variety. The experimental design used will be a Paired Comparison.

Step 4 - Choose your field and mark location of your plots
The farmers have chosen to use a 0.5 acre field located on the west side of their property. This field has been used to grow barley and wheat in the past few years. The field is flat and uniform and borders the neighbor's conventional corn and soybean production. To protect from possible drift, the farmer will establish a 25' buffer to protect the trial. The farmers have decided to use 6 replications or blocks. Plot size is 2 tractor passes of the entire field length. Placement of the treatments in each repetition is decided randomly by drawing pieces of paper from a hat. The farmers use measuring tape, flags, waterproof labels and stakes to mark the field. **Figure 8** shows the plot map for this trial.

Step 5 - Establish your trial and collect data
The farmers plant the 2 varieties on the same day. Yield data will be measured by harvesting each plot individually and stopping to weight harvest totals for each plot. The farmers ensure that the harvest area on each plot is the same in all treatments by trimming the plots perpendicular to the beds. The harvest data is entered in a datasheet for further analysis. See Appendix 2 for a yield datasheet sample.

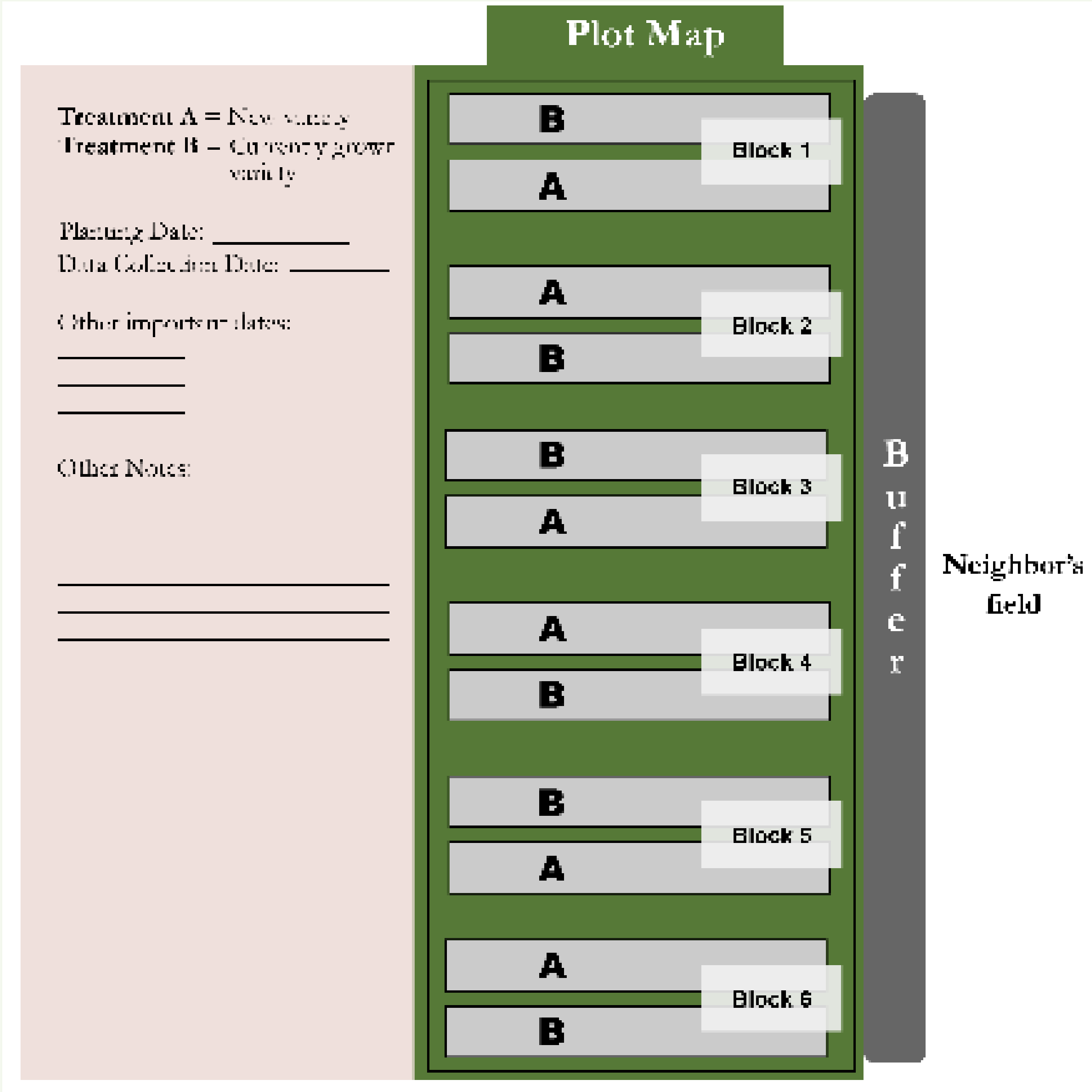


Figure 8. Plot map example for Galo's Grains with two treatments (A and B) repeated in 6 blocks.

Step 6 - Analyze your data

The farmers use a T-test in FarmStat, a free online statistical tool from the University of Nebraska-Lincoln, to enter and analyze their data. See more information on available online free tools for statistical analysis on Step 6. See **Table 6** for a summary of the data collected. The farmers run the statistical T-test, which provided the Least Significant Difference value (LSD). They compare the LSD value to the average differences among treatments to see if there is a statistically valid difference among treatments. **The farmers found that the LSD value is lower than the average differences between treatments.**

Table 6. Yield data per acre

Blocks	Treatment A (Control) bushels/acre	Treatment B (new barley variety) bushels/acre
Block 1	52.52	55.02
Block 2	53.01	55.45
Block 3	53.21	55.33
Block 4	52.11	54.95
Block 5	55.03	55.52
Block 6	52.86	56.87
Average	**53.12**	**55.52**
Range	**52.11 - 55.03**	**54.95 - 56.87**

Calculated LSD value: 1.198
Average difference between treatments: Treatment B (55.52) minus Treatment A (53.12) = 2.4

Step 7 - Draw conclusions and share

Given that the LSD test value is lower than the average difference between treatments, the farmers conclude that this new barley variety produces a higher yield than the currently grown variety. There is a significant statistical difference between yield of the two varieties. The farmers compare their results with their original research questions and hypotheses. Their suspicion that this new barley variety will not perform well at their farm did not come to pass. The farmers decide to slowly increase acreage of the new barley variety to sell to their client, while continuing to monitor yields. They share with their farmer peers about their trial and feel more confident about the barley varieties grown at their farm. The farmers at Galo's Grain decide their next test should be a taste test of the new beer!

Farmer-Researcher Profile 2: Trisha's Green

Background
Trisha's Green Thumb is a fictional 20-acre organic vegetable farm located in the state of Georgia, USA. The farmers grow a wide variety of vegetables, including greens, roots, tomatoes, peppers, strawberries, blueberries and some peaches. They are located near two urban centers where they sell most of their produce through farmers markets, a large CSA program and wholesaling to local restaurants and community grocery stores. For years they have used sunn hemp as their default cover crop, but they are now looking for alternatives due to high seed prices. They would like to test sorghum sudan, pearl millet, lab lab, and also try a mix of sorghum sudan and cowpeas. When using cover crops, the farmers' primary objectives are to obtain sufficient weed suppression and produce as much organic matter as possible to benefit the soil. These concerns are critical to the success of the following fall and winter crops.

Step 1- Identify your research question and hypothesis
Questions: Can other cover crop alternatives provide better weed suppression and add more organic matter than sunn hemp currently does? Given increasing seed prices, what is the most affordable way to keep weeds down and add as much organic matter to the soil as possible?
Hypothesis: **The mix of sorghum sudan and cowpea cover crop will be the most affordable, provide the best weed suppression, and add more organic matter than all the other cover crops.**

Step 2 - Identify what you will measure
The farmers will measure weed suppression and the amount of organic matter (biomass) produced by each treatment. The farmers are also concerned with the cost of cover crop seeds.

Step3 - Choose an experimental design
Based on the number of cover crops compared, the farmers will have 5 treatments. Treatment A is sunn hemp (control), Treatment B is sorghum sudan, Treatment C is pearl millet, Treatment D is lab lab, and Treatment E is a mix of sorghum sudan and cowpeas. The experimental design used will be **Comparison of 3 or more treatments** (also known as Randomized Complete Block Design).

Step 4 - Choose your field and mark location of your plots
The farmers have chosen to use 1/4 of an acre field located on the north side of their property. This field has been used intensely to grow tomatoes and green vegetables within the last 5 years. The soil in this field is relatively uniform but it tends to keep more moisture towards the north edge. The farmers have decided to use 4 replications or blocks, which will be laid out across the moisture gradient. The farmers decided on the size of their plots by dividing the field in 4 replications and each replication by 5 treatments. Placement of the treatments in each repetition is decided randomly by drawing pieces of paper from a hat. The farmers use measuring tape, flags, waterproof labels and stakes to mark the field. See **Figure 9** for the trial plot map.

Step 5 - Establish your trial and collect data
The farmers decide to plant the cover crops by hand given the small plot size. Planting for all plots occurs on the same day. The farmers decide to collect weed pressure data twice, at 30 and 60 days after planting, using a hula hoop as a sample frame. The sample will be taken twice from each plot and the frame will be placed randomly. Weeds will be counted, placed in labeled paper bags and fresh weighted. Total biomass produced will be measured at the same time as the 2nd hula hoop weed sampling. All the cover crop grown above the soil will be cut and freshly weighted. The farmers will use a measuring scale, labeled paper bags (for weeds) and labeled cloth bags (for cover crops) to make these samplings. Dry weight will be calculated using the microwave method explained in this University of Georgia publication.

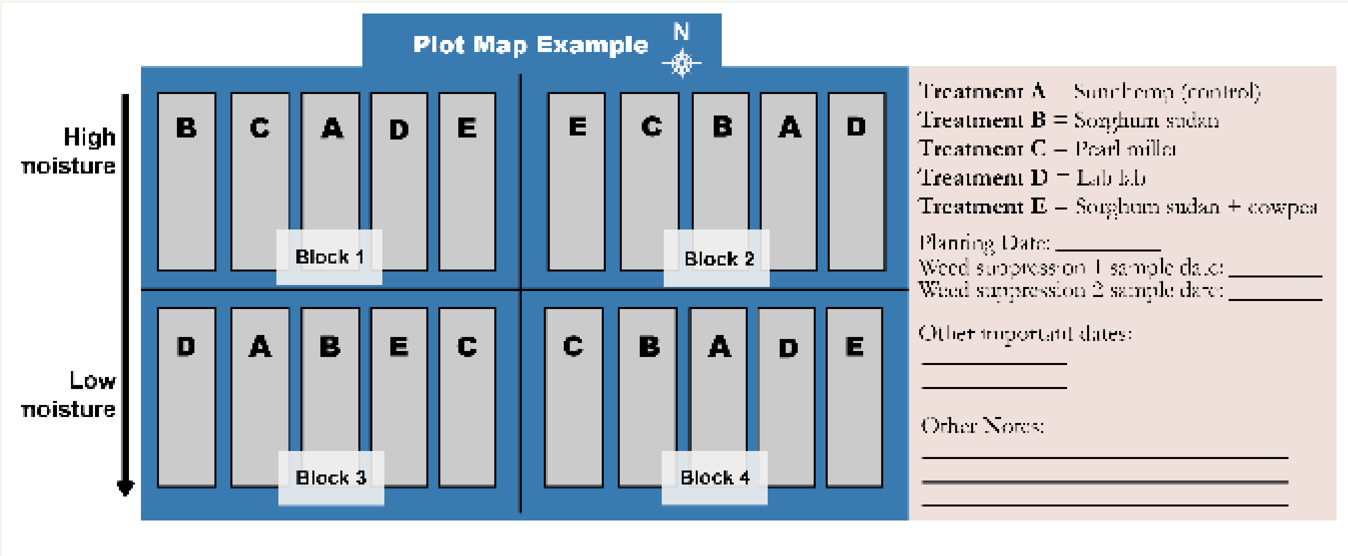


Figure 9. Plot map example for Trisha's Green Thumb showing five treatments (A through E) repeated in four different blocks that are arranged across a moisture gradient.

Step 6 - Analyze your data

The farmers use an **Anova test** in FarmStat, a free online statistical tool from the University of Nebraska-Lincoln. See more information on available online free tools for statistical analysis on Step 6. They compare the Least Significant Difference (LSD) value to the average differences among treatments to see if there is a statistically valid difference among treatments. See **Tables 7, 8 and 9** for a summary of weed pressure data and total biomass yield.

Table 7. Weed data in grams/square feet at 30 days

Blocks	**Treatment A (Control)** Sunnhemp	**Treatment B** Sorghum sudan	**Treatment C** Pearl Millet	**Treatment D** Lab lab	**Treatment E** Sorghum sudan + cowpeas
Block 1	10.2	9.2	8.8	7.2	9.5
Block 2	8.2	10.1	10.2	9.5	8.6
Block 3	7.9	8.5	12.3	5.6	10.4
Block 4	10	9.9	9.5	10.1	8.8
Average	**9.07**	**9.42**	**10.2**	**8.1**	**9.32**
Range	**7.9 - 10.2**	**8.5 - 10.1**	**8.8 - 12.3**	**5.6 - 10.1**	**8.6 - 10.4**

Calculated LSD value: No LSD value generated
No significant differences among treatments.

Table 8. Weed data in grams/square feet at 60 days

Blocks	Treatment A (Control) Sunnhemp	Treatment B Sorghum sudan	Treatment C Pearl Millet	Treatment D Lab lab	Treatment E Sorghum sudan + cowpeas
Block 1	19.5	25.1	23.5	20.1	17.5
Block 2	18.2	24.8	22.5	21.3	20
Block 3	17.8	20.1	21.6	22.6	16.5
Block 4	20.1	22.3	24.7	19.5	15.9
Average	**18.9**	**23.07**	**23.07**	**21.2**	**16.6**

Calculated LSD value: 2.38

Average difference between treatments: Treatment B (23.07) minus Treatment A (18.9) = 4.98, higher than the LSD value

Average difference between treatments: Treatment B (23.07) minus Treatment E (16.6) = 6.47, higher than the LSD value

Average difference between treatments: Treatment D (21.2) minus Treatment E (16.6) = 4.6, higher than the LSD value

Average difference between treatments: Treatment C (23.07) minus Treatment A (18.9) = 4.98, higher than the LSD value

Table 9. Total biomass data in dry weight tons/acre

Blocks	Treatment A (Control) Sunnhemp	Treatment B Sorghum sudan	Treatment C Pearl Millet	Treatment D Lab lab	Treatment E Sorghum sudan + cowpeas
Block 1	2.57	2.58	2.53	2.4	2.51
Block 2	2.55	2.63	2.46	2.36	2.41
Block 3	2.49	2.57	2.51	2.39	2.39
Block 4	2.53	2.59	2.31	2.34	2.61
Average	**2.53**	**2.593**	**2.45**	**2.37**	**2.48**
Range	**2.49 - 2.57**	**2.57 - 2.63**	**2.31 - 2.53**	**2.34 - 2.40**	**2.39 - 2.61**

Calculated LSD value: 0.11

Average difference between treatments: Treatment A - (2.53) minus Treatment D (2.37) = 0.16, higher than the LSD value.

Average difference between treatments: Treatment B - (2.593) minus Treatment C (2.45) = 0.14, higher than the LSD value.

Average difference between treatments: Treatment B - (2.593) minus Treatment D (2.37) = 0.22, higher than the LSD value.

Average difference between treatments: Treatment B - (2.593) minus Treatment E (2.48) = 0.113, higher than the LSD value.

Step 7 - Draw conclusions and share

The farmers use the statistical results to make conclusions about their trial. At first sight, Treatment D (Lab lab) appears to provide more weed suppression than the other treatments. However, the statistical test found no statistical significant differences among the cover crop treatments. On the other hand, sunnhemp and the mix of sorghum sudan+cowpeas showed better weed suppression at 60 days. There were statistical significant differences between sunnhemp and sorghum sudan+cowpeas mix and the other treatments. In terms of biomass production, Sorghum sudan monocrop (Treatment B), showed higher biomass production than the rest of the treatments, except for Sunn hemp (Treatment A). Sunnhemp showed higher biomass production than Lab lab (Treatment D), but no statistical differences were found with the other treatments.

The farmers obtained a lot of good information from this trial. They compared their results with their original research questions and hypotheses. They also use seed costs to calculate costs per lbs of biomass produced. They decided to incorporate sorghum sudan into their regular cover crop use, alternating it with sunn hemp every other season. Whenever sunn hemp seed was expensive or hard to find, they relied on sorghum sudan. They sometimes use the mix of sorghum sudan and cowpeas whenever weed suppression is the main objective. Finally, the farmers shared their experience with their peers and felt more confident about what cover crops work well for their farm system.

Farmer-Researcher Profile 3: Brianda's Blooms

Background
Brianda's Blooms is a fictional small organic urban farm located in the state of Massachusetts, USA. The farmers grow high-end edible flowers, greens and tomatoes for restaurants and some catering companies. They grow all their crops under greenhouse conditions. They have recently been struggling with fungal diseases among the violas, a type of popular edible flower. They are looking for solutions to this problem by trying 3 new varieties and 2 foliar fungal sprays. The farmers suspect that some of the new varieties will respond better to at least one of the fungal sprays, so instead of conducting two separate experiments, they put them together.

Step 1- Identify your research question and hypothesis
Questions: Do any of these foliar fungicidal sprays provide enough disease suppression in violas? Do any of these other viola varieties present any natural resistance to fungal disease?
Hypothesis: Among the three new varieties and 2 foliar sprays, at least one of the new viola varieties will show better resistance to disease but the fungal foliar sprays will not be more effective than no spray at suppressing disease.

Step 2 - Identify what you will measure
The farmers will measure disease incidence twice during the season to capture how the varieties and foliar sprays perform in early and late growth stages.

Step3 - Choose an experimental design
The farmers are testing two different things: 3 new varieties and 2 fungicidal foliar sprays. This is a Split Plot Design. There will be 4 variety treatments: Varieties 1, 2, 3, and 4; in this case, variety 4 is the control (the variety they normally grow). There will be 3 foliar spray treatments: A, B, and C; in this case, treatment C will be the control, or no spray.

Step 4 - Choose your field and mark location of your plots
The farmers have chosen to use a small section of the greenhouse to conduct the trial. There will be 4 blocks of replications. The variety level will be used as the larger plots, while the foliar spray will be considered the subplots. See **Figure 10** for the plot map of this trial. Each plot will be a small flower bed. Placement of the treatments in each repetition is decided randomly by drawing pieces of paper from a hat. The farmers use measuring tape, flags, waterproof labels and stakes to mark the plots.

Step 5 - Establish your trial and collect data
Planting for all the treatments takes place on the same day. Disease incidence is measured twice (at 30 and 60 days after planting) by using a small circular frame (hula hoop) placed randomly twice in the center of the plot to minimize drift effects. The plants located in the middle rows will be examined for the presence of disease. Severity of disease will be measured for each plant in the sample using a rating scale from symptomless (1) to extremely diseased (5). Then an average for the whole sample will be calculated by adding all the numbers and dividing by the number of plants in the sample.

Step 6 - Analyze your data
The farmers use an **Anova test** in Jamovi online tool to enter their data and analyze their trial. See **Table 10** for a summary of this data. For their analysis, they use two "fixed factors," as the variety and fungicidal spray are the two different levels of treatments they compared. The statistical analysis showed significant differences among both treatments, varieties and fungicidal sprays, but no interaction between these two. For more information on Jamovi, see Step 6 **- Free online tools for statistical analysis**.

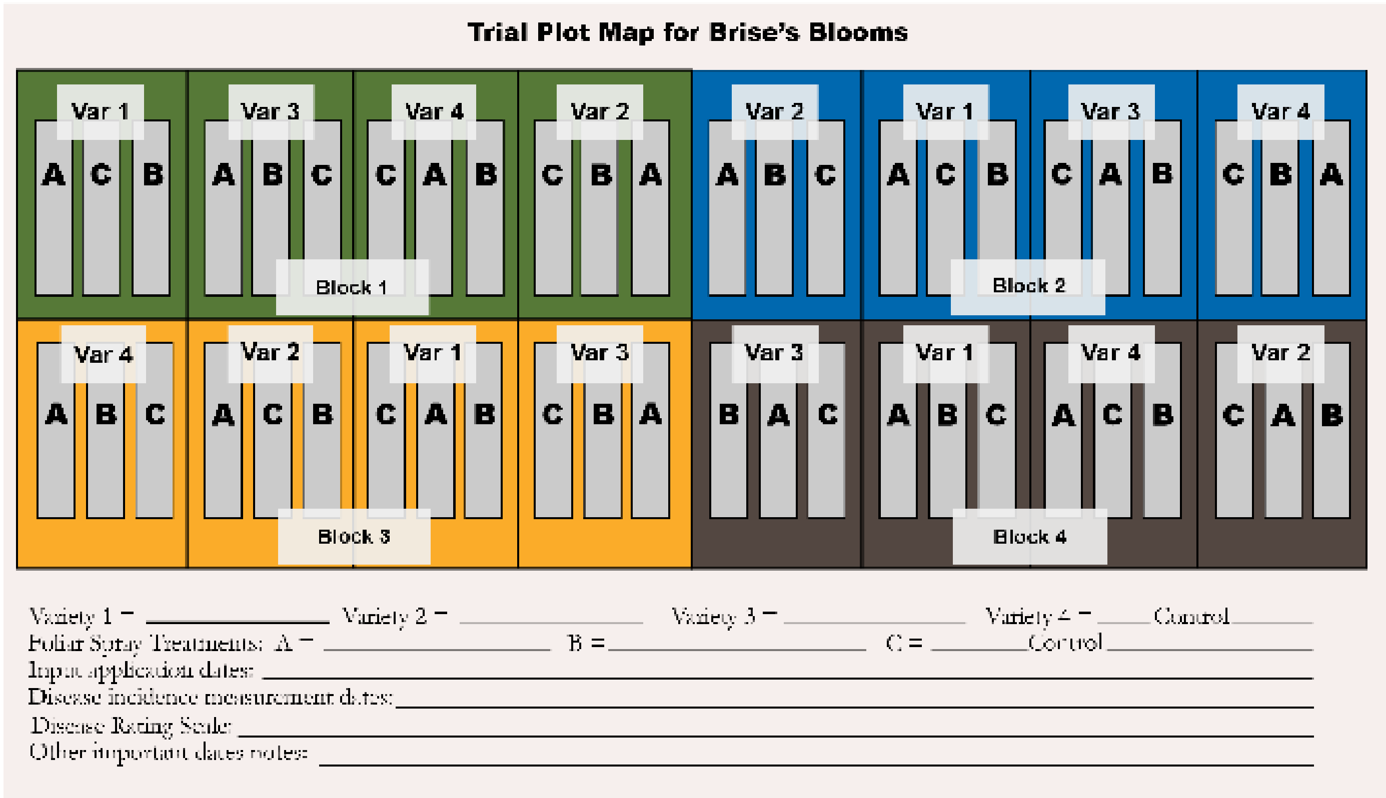


Figure 10. Trial plot map for Brianda's Blooms showing three foliar spray treatments (A, B, and C) and four varieties (1, 2, 3, and 4) in four blocks.

Table 10. Disease incidence data at 60 days

	Var 1			Var 2			Var 3			Var 4 (control)		
	A	B	C	A	B	C	A	B	C	A	B	C
Block 1	1.84	1.8	1.78	1.59	1.6	1.98	1.78	2.08	2.05	1.75	1.73	1.98
Block 2	1.66	1.92	1.84	1.88	1.78	2	1.88	2.1	2.01	1.65	1.96	1.66
Block 3	1.74	1.8	1.69	1.62	1.94	1.91	1.91	2.02	1.99	1.7	1.94	1.77
Block 4	1.5	1.91	1.8	1.85	1.66	2.02	2.1	2.01	1.89	1.91	1.8	1.91

Mean values for each treatment

Var 1 = 1.77	Var 2 = 1.82	Var 3 = 1.98	Var 4 (control) = 1.82
A = 1.77	B = 1.88	C (control) = 1.89	

The statistical results showed that:

- Variety 1 (1.77) is significantly different from Variety 3 (1.98)
- Variety 2 (1.82) is significantly different from Variety 3 (1.98)
- Variety 4 (control) (1.82) is significantly different from variety 3 (1.98)
- Fungicidal treatment A (1.77) is significantly different from fungicidal treatments B (1.88) and C (1.89, control).

Step 7 - Draw conclusions and share

The farmers use the statistical results to make conclusions about their trial, taking into account seed and input prices. The farmers compare their results with their original research questions and hypotheses. The farmers discovered that Varieties 1, 2 and 4 (control) had a significantly lower disease severity than variety 3. On the other hand, the results show that fungicidal spray A had a significantly lower disease severity than fungicidal spray B and C (no spray control). The farmers decided to continue the use of fungicidal spray A, and continue the use of the new varieties (except for Variety 3), as they showed good aesthetic qualities. They share information about their trial with their peers, and feel more confident about what strategies to use to minimize fungal disease incidence for viola production. They are hoping to do another trial the following season with additional varieties.

Appendix 2 - Datasheet examples and sources

Yield Sample Datasheet

Farmer Name: ______________________ Crop(s):__________________________
Planting date: ____________________ Harvesting Date: ______________________
Area harvested per sample __________ Area of sample frame (if applicable): __________
Scale units: __________________ Container/bag weight (if applicable): _____________
Samples collected by: ____
Note taker: ____

Block Number	Treatment ID	Weight units ________	Calculate yield (lb or tons/acre)	Observations

Biomass Sample Datasheet

Farmer Name: ______________________ Crop(s): __________________________
Planting date: ____________________ Sampling Date: ______________________
Area of sample frame: _______________ Scale units: __________________
Container/bag weight (if applicable): _____________
Samples collected by: ____
Note taker: ____

Block Number	**Treatment ID**	**Sample Number** (if applicable)	**Fresh weight** (units) ________	**Estimated Dry Weight** (units) ________	**Calculate total biomass** (lb or tons/acre)

Observations

Notes: A column for "Sample Number" is included here in case you collect more than one sample per plot. Guidance on estimating dry weight samples is found on Table 4.

Weed Sample Datasheet

Farmer Name: ________________________ Crop(s):_____________________________

Planting date: _____________________ Sampling Date: ________________________

Area of sample frame: _______________ Scale units: ___________________

Container/bag weight (if applicable): ______________

Samples collected by: ____

Note taker: ____

Block Number	**Treatment ID**	**Sample Number** (if applicable)	**Weed count**	**Fresh weight** (units) ________	**Observations**

Notes: A column for Sample Number is included here in case you collect more than one sample per plot.

Stand Establishment Sample Datasheet

Farmer Name: ________________________ Crop(s):_____________________________

Planting date: _____________________ Sampling Date: ________________________

Area or length of sample: ________________ Samples collected by: ____________

Note taker: ___________________________

Block Number	Treatment ID	Plants germinated	Average (Add plants germinated and divide by number of samples taken in the same plot)	Calculate plants per square foot	Observations

Other datasheet resources

For great examples of **variety trial and flavor datasheets**, consult Appendix G of The Grower's Guide to Conducting On-farm Variety Trials developed by the Seed to Kitchen Collaborative.

A great example and discussion of **insect sampling datasheet** is found in this eOrganic article titled Overview of Monitoring and Identification Techniques for Insect Pests by Geoff Zehnder, Clemson University.

Great biomass calculation instructions and an example for **biomass sampling datasheet** developed by the USDA NRCS in Iowa in this Estimating Cover Crop Biomass publication.

Appendix 3 - Guidance and resources on statistical analysis

Guidance to run statistical analysis for free online tools.

FarmStat from the University of Nebraska-Lincoln.
Use the "Randomized Complete Block Design" option. Enter your data directly or copy from Excel. For the analysis, use the Fisher's LSD option. Then, identify the LSD critical value to compare with the differences in average among your treatments. The tool also provides you with concluding statements from the analysis.There is a tutorial video you can view as well.

Jamovi
You can run a T-test for **paired comparison** designs, Anova tests for **3 or more treatment compariso**n; or Anova test for a **split plot** design. Enter your data by rows, so that each row is one observation. For example, 1st. Column = Treatment A, 2nd. Column = Block 1, and 3rd. Column = the data for this treatment. To run the analysis, enter the "Dependent variable," which will be the data you are comparing (yield, germination rates, etc.), and the "Fixed Factors" (names of the treatments you are comparing, represented by treatment letters. In a split plot design you will have 2 fixed factors. The test will tell you if there are statistical significant differences among treatments. Use the "Tukey Post Hoc Test" to figure out where exactly these differences are among treatments. Any result below 0.05 can be considered statistically significant. See a Jamovi video tutorial from Idaho State University.

Organic Seed Variety Trial Tool
Using this tool you can conduct a T-test for a paired comparison design and Anova tests for a 3 or more treatment comparison. By entering the number of treatments and repetitions, this tool can help you design your trial by automatically placing your treatments randomly. The tool asks you to upload your data in a ".csv" file type. If you have your data on Google Sheets or Microsoft Excel, you can "Save As" and choose .csv as the format. Make sure that your file matches the number of columns and column headers as the template for RCBD example found in the "upload your data tab." Analyze your data by running a "Means Table" analysis. It will provide you the mean results, identifying statistically significant differences among treatments by the letters next to your results (a, b, c,... where each letter is statistically different from the other letters). You can also visualize your data in plots. See a tutorial video on how to use this tool.

Microsoft Excel or Google Sheets.
You may have to download statistical add-ons (XL Miner Analysis Tool Pack in Google sheets and Add ins - Analysis Tool Pack in Microsoft Excel). For a t-test, enter the code "=Ttest" in any cell and it will then ask you for the data for each treatment (called range), the type of test (choose type 2, two sample equal variance), and tails (choose 2 tailed distribution). The resulting number will tell you whether the difference you see is statistically significant or not. If the number is equal or lower than 0.05, then the difference shown in your treatments is statistically significant. See a T-test tutorial using Microsoft Excel here and an Anova test tutorial here using the same software.

More In-depth resources on Statistical Analysis
How to Conduct Research on Your Farm or Ranch is a Sustainable Agriculture Research and Education (SARE) publication that contains in-depth information on on-farm research experimental design, statistical analysis and practical advice to conduct an on-farm trial.
OFRF's On-Farm Research Guide for more tips and another example of statistical analysis.

Appendix 4 - Examples of farmer-led on-farm research trials

Sustainable Agriculture Research and Education (SARE) producer projects summaries (chosen randomly). Find more farmer-led reports here.

- Effects of using ducks as biological control to manage weeds and pests within an orchard crop system. Golden Sun Farm & Nursery LLC. Oregon. See summary here.
- Optimizing No-Till Methods for a Direct-to-Market Organic Vegetable Farm. Whitewater Gardens Farm. Minnesota. See summary here.
- Interseeding cover crops and grazing cattle to improve soil health, water infiltration, and profitability within an Organic transition. Getting Farms LTD. Iowa. See summary here.
- Sustainable Biofungicide for Organic Farms. Cannivera. Wisconsin. See summary here.
- Investigating best practices for efficient minimal heating of high tunnels with modular heaters and row covers. MIllsap Farms LLC. Missouri. See summary here.
- Effects of Vermicast Extract and Cover Cropping on the Soil Food Web and Crop Health as Compared to Beds Treated with Conventionally Applied Compost. Samaritan Community Center. Arkansas. See summary here.
- Breeding and Evaluation of Butternut Squash Varieties for Southeast Organic Farms. Common Wealth Seed Growers / Twin Oaks Seed Farm. Virginia. See summary here.
- Reduction of Water Use On Peony Crops By Using Shade Cloth. Cherry Petals Flower Farm. Utah. See summary here.
- Efficacy of insect-exclusion nettings and shade cloth combinations on diversified vegetable production in the Southwest. Highwater Farm. Colorado. See summary here.
- Ginger Spacing in High Tunnels for Maximum Yields. Rustic Roots Farm. Maine. See summary here.

Practical Farmers of Iowa - Cooperators Program. Summary reports of farmer-led on-farm trials (chosen randomly). Find more farmer-led reports here.

- Fine-Tuning Fertility for Better Broccoli. Humble Hands Harvest, Wild Woods Farm, and Scattergood Friends Farm. Iowa. See summary here.
- Flame Weeding Organic Soybeans. Iowa. See summary here.
- Living Mulch for Pathway Weed Management in Bell Peppers. Iowa. See summary here.
- Clover Cover Crop Termination Date for a Rye-Corn System. Iowa. See summary here.
- Annual Flowers as Pollinator Resource for Cucurbits. Iowa. See summary here.
- Economic and Soil Health Impact of Grazing Different Cover Crop Mixes. Iowa. See summary here.
- Potting Soil Comparison for Vegetable Seedling Quality. Iowa. See summary here.
- Planting Corn in 60-in. Row-Widths for Interseeding Cover Crops. Iowa. See summary here.
- Replacing Corn with Hybrid Rye in Feeder Pig Rations. Iowa. See summary here.
- Organic Control of Squash Vine Borer in Winter Squash. Iowa. See summary here.

Ecological Farmers Association of Ontario - Farmer-Led Research Program. Summary reports of farmer-led on-farm trials (chosen randomly). Find more farmer-led reports here.

- Iceberg Lettuce variety trial. Ontario. See summary report here.
- Alternative to traditional peat moss starter mixes. Paper Kite Farm. Ontario. See summary report here.
- Efficacy of mycorrhizal inoculants on vegetable transplants. Grenville Farms. Ontario. See summary report here.
- Effects of liquid and biological amendments on emergence and yield of no-till planted spring cereals. Orchard Hill Farm. Ontario. See summary report here.
- Assessing methods for nutrient application to prevent chlorosis in chestnuts. Summergreen Tree Crops & Mushrooms. Ontario. See summary report here.
- No-till tomatoes 3-ways. Jones Family Greens. Ontario. See summary report here.
- Pasture-raised chicken breed comparison. Burdock Grove. Ontario. See summary report here.
- Does planting timing of green mulches affect yield of garlic and labor? Eva Mae Farm - East. Ontario. See summary report here.
- Okra variety trial for southern Ontario and southern Quebec. Ontario. See summary report here.
- Performance of Chantecler chickens on a reduced protein grower ration. D&H Newman Farm. Ontario. See summary report here.

Appendix 5 - Other on-farm research resources

- The USDA Sustainable Agriculture Research and Education (SARE) has many resources related to on-farm research. How to Conduct Research on Your Farm or Ranch is a SARE publication that contains in-depth information on on-farm research experimental design, statistical analysis and practical advice to conduct an on-farm trial. This publication also covers on-farm research on pasture and livestock systems. SARE also runs a Producer Grant program where farmers can apply for grants to conduct research on their farms. These grants are administered by regions, so each region will have their own application deadlines and application priorities.
  Finally, SARE keeps a searchable database of all their grants conducted by farmers, researchers and graduate students.

- Practical Farmers of Iowa runs the Cooperator's Program, a farmer-led research initiative, since 1987. Farmers conduct on-farm trials and share their results through reports and through an annual conference. See examples of farmer-led research protocols and reports in their searchable database.

- Ecological Farmers Association of Ontario (EFAO) runs a farmer-led research program since 2016. Their Research Library database contains farmer-led research protocols and reports.

- For more in-depth information and practical tips check out our very own OFRF's On-Farm Research Guide.

- The B. C. Forage Council produced a Guide to On-Farm Demonstration Research specifically created for forage producers. The guide provides guidance and worksheets to assist you in your on-farm forage trial.

- Organic Seed Alliance publication: The Grower's Guide to Conducting On-farm Variety Trials.

- The University of Georgia Extension publication Designing Research and Demonstration Tests for Farmers' Fields.

- Oregon State University publication Experimenting on the Farm: Introduction to Experimental Design.

References

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Wettasinha C, Waters-Bayer A, van Veldhuizen L, Quiroga G and Swaans K. 2014. Study on impacts of farmer-led research supported by civil society organizations. Penang, Malaysia: CGIAR Research Program on Aquatic Agricultural Systems. Working Paper: AAS-2014-40.

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