

## STEPS IN CONDUCTING A RESEARCH PROJECT OR EXPERIMENT

When you are involved in conducting a research project, you generally go through the steps described below, either formally or informally. Some of these are directly involved in designing the experiment to test the hypotheses required by the project. The following steps are generally used in conducting a research project.

1. Review pertinent literature to learn what has been done in the field and to become familiar enough with the field to allow you to discuss it with others. The best ideas often cross disciplines and species, so a broad approach is important. For example, recent research in controlling odors in swine waste has exciting implications for fly and nematode control.

2. Define your objectives and the hypotheses that you are going to test. You can't be vague. You must be specific. A good hypothesis is:

- a. Clear enough to be tested
- b. Adequate to explain the phenomenon
- c. Good enough to permit further prediction
- d. As simple as possible

3. Specify the population on which research is to be conducted. For example, specify whether you are going to determine the P requirements of papaya on the Kauai Branch Station (a Typic Gibbsihumox), or the P requirements of papaya throughout the State, or the P requirements of papaya in sand or solution culture. The types of experiments required to solve these problems vary greatly in scope and complexity and also in resource requirements.

4. Evaluate the feasibility of testing the hypothesis. One should be relatively certain that an experiment can be set up to adequately test the hypotheses with the available resources. Therefore, a list should be made of the costs, materials, personnel, equipment, etc., to be sure that adequate resources are available to carry out the research. If not, modifications will have to be made to design the research to fit the available resources.

5. Select Research Procedure:

a. Selection of treatment design is very crucial and can make the difference between success or failure in achieving the objectives. Should seek help of a statistical resource person (statistician) or of others more experienced in the field. Statistical help should be sought when planning an experiment rather than afterward when a statistician is expected to extract meaningful conclusions from a poorly designed experiment. An example of a poor selection of treatments is the experiment which demonstrated that each of three treatments, Scotch and water, Gin and water, and Bourbon and water taken orally in sufficient quantities, produce some degree of intoxication. Will this experiment provide information on which ingredient or mixture causes intoxication? Why? How can this experiment be improved? An example related to agriculture is an experiment with 2 treatments, Ammonium Sulfate and Calcium Nitrate, selected to determine whether or not maize responds to N fertilizer on a Typic Paleudult soil. Will this experiment provide the desired information? What is lacking? What sources of confusion are included in the treatments?

b. Selection of the sampling or experimental design and number of replicates. This is the major topic of this course so this will not be discussed further other than to comment that in general one should choose the simplest design that will provide the precision you require.

c. Selection of measurements to be taken. With the computer it is now possible to analyze large quantities of data and thus the researcher can gain considerably more information about the crop, etc. than just the effects of the imposed variables on yield. For example, with corn, are you going to measure just the yield of grain, or of ears, or of grain plus stover? What about days to tasseling and silking? Height of ears, kernel depth, kernel weight, etc. What about nutrient levels at tasseling, or weather conditions, especially if there are similar experiments at other locations having different climates? With animal experiments, you can measure just the increase in weight or also total food intake, components of blood, food digestibility etc.

d. Selection of the unit of observation, i.e., the individual plant, one row, or a whole plot, etc? One animal or a group of animals?

e. Control of border effects or effects of adjacent units on each other or "competition". Proper use of border rows or plants and randomization of treatments to the experimental units helps minimize border effects. Proper randomization of treatments to the experimental unit is also required by statistical theory so be sure this is properly done.

f. Probable results: Make an outline of pertinent summary tables and probable results. Using information gained in the literature review write out the results you expect. Essentially perform the experiment in theory and predict the results expected.

g. Make an outline of statistical analyses to be performed. Before you plant the first pot or plot or feed the first animal, you should have set up an outline of the statistical analysis of your experiment to determine whether or not you are able to test the factors you wish with the precision you desire. One of the best ways to do this is to write out the analysis of variance table (source of variation and df) and determine the appropriate error terms for testing the effects of interest. A cardinal rule is to be sure you can analyze the experiment yourself and will not require a statistician to do it for you--he might not be there when you need him. Another danger in this age of the computer and statistical programs, is to believe that you can just run the data through the statistical program and the data will be analyzed for you. While this is true to a certain extent, you must remember that the computer is a perfect idiot and does only what you tell it to do. Therefore, if you do not know what to tell the computer to do and/or if you don't know what the computer is doing, you may end up with a lot of useless output-garbage!! Also, there is the little matter of interpreting all the computer output that you can get in a very short time. This is your responsibility and you had better know what it is all about.

6. Selection of suitable measuring instruments and control of bias in data collection: Measuring instruments should be sufficiently accurate for the precision required. Don't want a gram balance (scale) to weigh watermelons or sugarcane. Experimental procedure should be free of personal bias, i.e., if treatment effects must be graded (subjective evaluation) such as in

herbicide, or disease control experiments, the treatments should be randomized and the grader should not know what treatment he is grading until after he has graded it. Have two people do the data collection, one grade and the other record.

7. Install experiment: Care should be taken in measuring treatment materials (fertilizers, herbicides, or other chemicals, food rations, etc.) and the application of treatments to the experimental units. Errors here can have disastrous effects on the experimental results. In field experiments, you should personally check the bags of fertilizer or seed of varieties which should be placed on each plot, to be certain that the correct fertilizers or variety will be applied to the correct plot before any fertilizer is applied or any seed planted. Once fertilizer is applied to a plot, it generally cannot be removed easily. With laboratory experiments or preparation of various rations for feeding trials, check calculations and reagents or ingredients, etc., and set up a system of formulating the treatments to minimize the possibility of errors.

8. Collect Data: Careful measurements should be made with the appropriate instruments. It is better to collect too much data than not enough. Data should also be recorded properly in a permanent notebook. In many studies data collection can be quite rapid and before you know it you have data scattered in 6 notebooks, 3 folders, and 2 packs of paper towels!! When it is time to analyze the data, it is a formidable task, especially if someone has used the paper towels to dry their hands. Thus a little thought early in the experiment will save a lot of time and grief later. Avoid recording data on loose sheets at all costs as this is one good way to prolong your stay here by having to repeat experiments because the data were lost. Avoid fatigue in collecting data as errors increase as one gets tired. Also avoid recopying data as this is a major source of errors in experimental work. If data must be recopied, check figures against the originals immediately. It is better to have two people do the checking, one read the original data and the other read the copied data. When one person is making measurements and another recording, have the person recording repeat the value being recorded. This will minimize errors.

9. Make a complete analysis of the data: Be sure to have a plan of analysis, e.g., which analysis and in what order will they be done? Interpret the results in the light of the experimental conditions and hypotheses tested. Statistics do not prove anything and there is always the possibility that your conclusions may be wrong. One must consider the consequences of drawing an incorrect conclusion and modify the interpretation accordingly. Do not jump to a conclusion just because an effect is significant. This is especially so if the conclusion doesn't agree with previously established facts. The experimental data should be checked very carefully if this occurs, as the results must make sense!

10. Finally, prepare a complete, correct, and readable report of the experiment. This may be a report to the farmer or researcher or an extension publication. There is no such thing as a negative result. If the null hypothesis is not rejected, it is positive evidence that there may be no real difference among the treatments tested.

In summary, you should remember the 3 R's of experimentation:

1. Replicate: This provides a measure of variation (an error term) which is used in evaluating the effects observed in the experiment. This is the only way that the validity of your

conclusions from the experiment can be measured.

2. Randomize: Statistical theory requires the assignment of treatments to the experimental units in a purely random manner. This prevents bias.

3. Request Help: Ask for help when in doubt about how to design, execute or analyze your experiment. Not everyone is a statistician, but should know the important principles of scientific experimentation. Be on guard against common pitfalls and ask for help when you need it. Do this when planning an experiment, not after it is completed.