From: *Plant Nutrient Management in Hawaii's Soils, Approaches for Tropical and Subtropical Agriculture*
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Chapter 8

Collection of Calibration Data for Interpreting Soil and Plant Tissue Analyses

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Correct diagnosis of soil and plant analyses values is difficult without local field calibration data. Without local calibration, diagnoses of nutrient deficiencies are merely a best guess, and recommendations to correct nutrient deficiencies are questionable.

Calibration data have been obtained on some of Hawaii's soils for some crops, but for many crops that are unique to Hawaii, only approximate levels of nutrient adequacy are being used. These are levels that were determined for crops similar to the crop in question. In the computer program used by the CTAHR Agricultural Diagnostic Service Center (the Fertilizer Advice and Consulting System, or FACS), data are currently available only for the following 17 crops: avocado, banana, beans, bermudagrass, Chinese cabbage, coffee, corn, cucumber, kikuyu grass, lettuce, macadamia, papaya, dryland taro, wetland taro, tomato, vegetables, and watermelon.

Another category, "other crop," results in a generic recommendation, which will probably suffice to keep the crop from suffering from a great lack of nutrients, but it might result in fertilizer applications that are too high, wasting fertilizer and possibly causing environmental pollution. Therefore, it is important to collect field calibration data to allow correct diagnoses and recommendations to be made.

The goal of calibration is to relate available soil nutrient levels and plant nutrient content levels with crop growth to identify the minimum levels ("critical" levels) of nutrients required for normal growth in the particular soil. The *critical level* is the concentration of a nutrient above which the crop is adequately supplied and below which the crop is deficient in the nutrient.

Calibration also relates amounts of fertilizer applied to the resulting soil test values to allow appropriate fertilizer recommendations to be made. This answers the question, "How much fertilizer must be applied to result in the desired increase in the level of available nutrient in this soil?"

When a sample is analyzed for a nutrient (phosphorus, for example), the number reported from the analysis means very little until it is compared to the critical level for that nutrient. Say, for example, that a soil sample extracted with the Modified Truog extractant has a phosphorus value of 28 ppm. What does this mean? Is this high, low, or adequate? Once the soil test is calibrated, this value can be interpreted. In the case of corn, for example, we know that this level of Modified-Truog extractable P has been found to be adequate for good growth.

Methods of collecting calibration data

Two basic ways of collecting data can be used to calibrate soil and plant analyses for crops. One is with field experiments. The other is to collect soil, plant, and yield data from plants that are believed to be growing well and compare it with data from plants that are growing poorly in the same field. If these data can be obtained from a farmer's fields under the farmer's management conditions, they likely will be more applicable to the farmer's conditions than experiments conducted on experiment stations.

Field experiments

Field experiments can provide the data needed for calibrating soil and plant analyses. To gather data that will have the greatest value, calibration experiments in general must

- be managed in a manner consistent with calibration objectives
- be conducted on a range of soils
- grow important, representative crops
- have several levels of the nutrient.

Because of the need to collect information on a range of soils, these experiments must be conducted in different areas so that the necessary range of data can be obtained.

Requirements for calibration experiments

Calibration experiments are quite exacting and must be done carefully so that reliable data will be obtained. The following requirements are discussed below:

- have several levels of the nutrient (at least three)
- be adequately replicated
- assign treatments at random among plots in blocks
- collect soil samples before the experiment is installed
- collect soil samples from each plot after the crop is harvested
- collect plant samples of the appropriate tissue at the proper time
- collect quantitative yield data on the marketable portion of the crop
- collect data on the quality of the marketable portion of the crop, if appropriate.

Several levels of the nutrient. It is desireable to have a range of levels from zero to the amount required for maximum yield. A zero treatment is needed because the crop may not respond to additions of the nutrient. At least three levels of the nutrient are needed, because the yield response to only two levels, when graphed, results in a straight line, which could be interpreted to mean that the more fertilizer applied, the higher the yield. This is not a very useful recommendation. To identify the upper limit of crop response to an application, it is necessary to apply enough of the nutrient to approach or reach the "yield plateau" (the maximum yield, where the graph of the response "levels off"). Three levels of the nutrient are the minimum needed to achieve this result, and the more levels one can afford, the better will be the estimate of the yield response curve.

Another point to consider is the size of increments of the nutrient. To go from zero to the maximum yield with a minimum number of treatments, a geometric progression of levels is usually best; for example, 0, 100, 200, and 400 lb/acre, which is a doubling of the increment. One could also triple the increment, i.e., 0, 50, 150, 450. The most important portion of the yield response curve is the point at which it changes from linear to curvilinear, or just before the maximum yield.

Adequate replication. A minimum of two replicates of the treatments is needed so that a measure of variation can be obtained to allow statistical analysis of the yield data. Unreplicated trials are wasteful of effort because—by chance—the site of the planting may be high in the nutrient and no response will be shown, while the field as a whole may be low in the nutrient. The reverse situation can also occur. Statistical analysis cannot be done with data from unreplicated trials, so observed yield differences cannot be tested for statistical significance.

What does it mean when results from the two replicates of a trial are different? Generally, it shows that there is soil variation in the field. Divergent results from two plots in the same field illustrate the danger of using information from unreplicated trials. When more replicates are installed, the precision of the experiment is increased, which means that smaller differences between treatment means can be shown to be significant.

Random assignment of treatments to plots. Treatment plots are arranged within replicates of the experiment in groups called blocks. To minimize the possibility of biases affecting the results of the experiments, the treatments must be assigned at random to the plots within the blocks. This is done with a table of random numbers, or by writing treatments on pieces of paper, placing them in a container, and picking them at random to assign treatments to the plots. It is sometimes a useful demonstration to have treatments arranged in order in one block, rather than randomized, so that the treatment effects can be more easily seen. This is statistically acceptable provided that the treatments are randomized in the other replicates.

Collect soil samples before installing the experiment. The nutrient status of the experiment site must be assessed by collecting soil samples before the experiment is installed. This allows identification of nutrients that are possibly deficient and suggests their use

as variables in the experiment. Soil tests will also identify nutrients that are in excess. There is no good soil test for the N status of soils in the tropics, and it is generally assumed that there is little N remaining in the soil after a crop. However, this is not always true, and there may or may not be a response to added N. The zero-N treatment is therefore especially critical in N experiments.

Collect soil samples from each plot after the experiment is harvested. A measure of the soil nutrient status of each plot after the experiment allows establishment of the relationship between soil nutrient level and crop yield. This is the basis for calibrating the soil analysis values. A soil sample taken from each plot either during or at the end of the crop provides a measure of the nutrient status at the time the crop was produced. Several subsamples should be taken from the harvest area of each plot and composited for analysis. The depth of sampling should be the rooting depth of the crop.

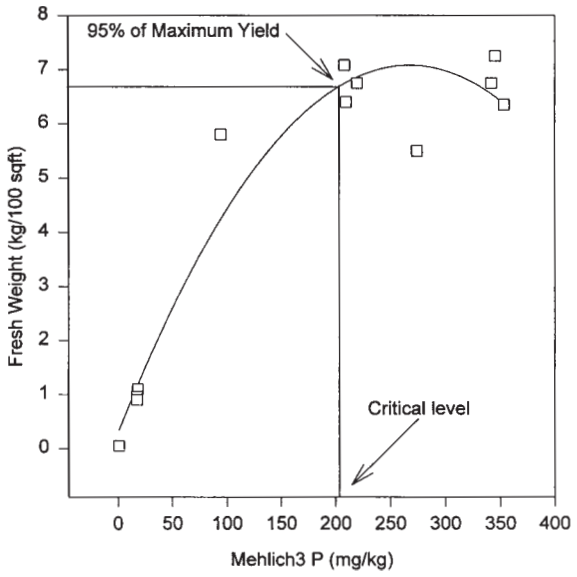
Collect plant tissue samples from each plot. A measure of the nutrient status of the appropriate plant tissue from each plot allows establishment of the relationship between plant nutrient level and crop yield. This will calibrate the nutrient level in the tissue so that deficient and sufficient levels will be identified. It is important to collect the appropriate tissue at the correct time.

Collect quantitative yield data on the marketable portion of the crop. Quantitative yield data are absolutely necessary for calibration analysis. Data on yield, soil nutrient levels, and plant nutrient contents can be subjected to regression analysis to identify the sufficiency and deficiency ranges of the nutrients tested. An adequate number of plants from an area of sufficient size should be harvested to obtain a reliable yield estimate. The area from which the plants are harvested and the number of plants harvested should be recorded.

Collect data on the quality of the marketable portion of the crop. In some cases, excess or inadequate nutrition can affect the quality of the crop. For crops where quality may vary (e.g., sweet corn, taro, tomato), a measure of quality should be obtained. This may be the percent or number of marketable ears or corms, the weight of marketable fruit, its shelf life, etc.

The yield, soil, and plant data are subjected to regression analysis. A regression equation is developed to describe the relationship between soil analyses data and yield data, for example, and the predicted response

Figure 8-1. Determining the critical level of soil P (as measured by "Mehlich 3" extraction) for optimal yield of Chinese cabbage.



curve is plotted (Figure 8-1). The critical level is generally the point at which the rate of yield increase begins to decrease, just before the maximum yield is attained. Some researchers select the point that is 95 percent of the maximum yield. The critical level thus identified is used to interpret soil and plant test values for the nutrient in similar soils.

Treatment and experimental designs

A treatment design that has often been used in calibration experiments is one with four levels of a nutrient applied in a geometric progression, e.g., 0, 100, 200, and 400 lb/acre. More levels are even better, if field space is available for the plots. In experiments in farmers' fields, it is best to vary only one nutrient, such as N or P, and apply other nutrients each at the same levels to all plots. Where possible, the farmer's fertilizer and management practice should be followed.

For example, a farmer may apply a mixed fertilizer containing N, P, and K. If soil K is found to be deficient, then the practice is modified so that only N and P will be applied at the same levels and, if possible, in the same forms, whereas K is applied in variable amounts. The test levels of K may be zero (none), and half, the same as, and twice the amount the farmer usually applies.

If micronutrients are to be studied, the farmer's usual application of N, P, and K is used on all plots, and the micronutrient treatments are applied at a range of levels, including zero. To study P or K, an area low in the nutrient must be found. This may be difficult, because the soil in many agricultural fields is high in P and sometimes in K.

The simplest experimental design for field experiments is a randomized complete block design with two or more replicates. The replicates ("blocks," or "reps") are located so that conditions within each of them are as uniform as possible, and any known source of variation at the site is isolated by properly arranging the blocks. If, for example, the field has a gradient in soil fertility and there are to be three replicates, they would be arranged consecutively so that the first block was in soil with high fertility, the second in soil with medium fertility, and the third in soil with low fertility. In this way, fertility would be relatively uniform within each block but could be quite different between blocks. In the analysis of variance, the effect of fertility will be removed in the block variation and the treatment effects will be relatively free of any effect of soil fertility.

Experiments on commercial farms should be kept simple so as not to take up too much land. The plot size can be small for crops such as lettuce, choy sum, green onion, etc., because only a small number of plants is needed to provide a reliable estimate of yield. The plot area should be large enough to adequately represent conditions in the field. Replicates may be located in different sections of a field to provide a better estimate of the fertility status of the field. Generally, it is believed that if at least 10 plants are harvested and weighed, a reasonably good yield estimate is obtained. This is a "rule of thumb" for the minimum number of plants, and if growth seems variable, a larger sample should be taken for the yield estimate. The number of plants harvested is recorded and the area from which the plants were taken is measured, which allows yields to be expressed in units that are meaningful to the farmer and can be applied to other situations.

Calibration experiments require careful work, and sample and data collection are usually done by researchers. Adequate resources must be available for this activity. Often, extension agents do not have the time to conduct calibration experiments on a large scale because of their other responsibilities. However, if calibration experiments could be incorporated into ongoing extension programs, the data needed could be gathered more rapidly. It would help if efforts on particular crops were coordinated so that more efficient progress can be made. For example, an effort might be made to obtain calibration data for choy sum on farms in several locations so that a reasonable estimate of the sufficiency and deficiency ranges for choy sum on several soils will be obtained. When such experiments are done in Hawaii, the data on soil and plant analyses, yield, number of plants, and area harvested should be sent to the CTAHR researcher working on nutrient calibration for processing and incorporation into the FACS database.

Samples from "good" and "poor" crops

Another way to obtain crop data to help identify nutrient sufficiency ranges is to collect data from field areas where the crop appears to be growing very well. Identify at least two harvest areas and collect yield data from each of them. Record the size of the area harvested and the number of plants harvested. Take soil samples and plant tissue samples from each harvest area. When these samples are analyzed and the yield data are obtained, they will represent soil and plant tissue levels associated with good plant growth. This will help to identify the sufficiency range, but not the deficiency range for a crop.

To identify the nutrient deficiency range, it is necessary to have yield, soil, and plant data from an area that did not receive the particular nutrient or from an area where crop growth is poor. Use the same harvesting and sampling procedures just described. Data should always be collected from at least two harvest areas so that a measure of variation is obtained and the data can be analyzed statistically. In commercial fields, it is necessary to leave a small part of the field unfertilized so that data can be collected to identify the deficiency range. Coordination of these activities across multiple farms or fields would also help increase the efficiency of data collection and analysis. These data should be sent to a centralized location for processing and incorporation into a database such as Hawaii's FACS database.

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