Rerun
January 1961

POT-TESTING METHOD FOR SOIL FERTILITY

Prepared by J. Vlamis, Department of Soils and Plant Nutrition,
University of California, Berkeley

The fertilizer requirement of soils can be measured by growing plants in pots with various combinations of nutrients. The usual elements tested are nitrogen, phosphorus, potassium, and sulfur. In some cases calcium and magnesium are included, but deficiencies of these two elements do not occur as frequently as the others.

The procedure described here has been used extensively to determine the mineral deficiencies of soils, and the method lends itself to adaptation for classroom or home use.

Collecting the Soil. The method of sampling will depend on the size of the field, its uniformity, and the nature of the crop. The surface cover of leaf litter should be swept away, exposing the surface of the soil. About 40 pounds of soil are needed for the test and it may be collected from a limited area where the site looks uniform, or sampled at random throughout the field if it seems to be irregular. The soil should be dug to 8 inches depth and collected in a burlap sack or similar container. If two or more soil types occur within a field, they should not be mixed but treated as separate samples.

For a field supporting a deep-rooted crop such as alfalfa or trees, the sub-soil should be tested as a sample distinct from the top-soil.

Preparing the Soil. If the soil is in a pulverized condition, it only needs to be mixed thoroughly and it is ready for use. But if it contains stones and chunks of soil larger than one-half inch in size, it must be broken into small pieces and sieved. A soil that is too wet will be sticky on handling and difficult to crumble. Exposing it to the air for a few days will make it dry enough to break into small pieces. A soil that is too dry may have chunks too hard to break up. Sprinkling the clods with water will soften them to the point where they can be crumbled by hand.

Pass the pulverized soil through a sieve with a half-inch mesh, or if a sieve is lacking, simply remove the stones and lumps of soil larger than one-half inch. Spread the soil on a smooth surface and mix it thoroughly with a shovel. It is now ready to be weighed and mixed with the fertilizer.

Setting up the Experiment. Obtain ten 6-inch pots and saucers. They may be used directly but it is preferable they be painted to avoid contaminating the soil, or vice versa if the pots are to be used in a future test. Apply a coat of black asphalt paint to both the inside and outside of the pot. A day later, put another coat of black paint on the inside of the pot, and a coat of aluminum paint on the outside. The aluminum finish will absorb less radiation from sunlight and will keep the pots from heating as much as they would with a black exterior. After a couple of days the pots are dry enough to use.

Insert a piece of broken crockery to cover the hole at the bottom of each pot to prevent the soil from running out.

Weigh two samples of 1600 grams of soil (about $3\frac{1}{2}$ pounds) and pour into each of two pots. These will remain unfertilized and serve as checks on the effects of the fertilizers added to the other pots. It will also give an indication of the inherent

FROM YOUR
HUMBOLDT - DEL NORTE COUNTY
AGRICULTURAL EXTENSION SERVICE
SPRUCE POINT
P. O. BOX 1009, EUREKA, CALIF.

fertility of the soil at the time it was sampled. The reason for having two pots is to measure the variability in the system and to improve the validity of the test. If a scale is not available, fill the pots to within an inch of the top with soil.

The Fertilizer Treatments. The fertilizers may be purchased from a nursery or drug store. In more refined work, chemically pure salts are required, and they may be obtained from a scientific supply house or a chemical laboratory.

The treatments to be compared to the check and each other are as follows: nitrogen alone (N), phosphate alone (P), the two together (NP), and the two combined with potassium (K) and sulfur (S), making a combination of NPKS. Such a comparison will account for a major part of the nutrient deficiencies usually found in soil.

Measure another quantity of soil (1600 gms.) and spread it on a piece of wrapping paper about two feet square placed on a table or workbench. Weigh .457 grams of ammonium nitrate, and sprinkle it on the soil. This amount of chemical contains .160 grams of N and is equivalent to a rate of 200 lbs. N per acre. The calculations for deriving this may be found in the Appendix.

Mix the soil and fertilizer thoroughly by running your hands through the mixture several times and pour it into a pot. Set up a duplicate of this and the pair will constitute the nitrogen treatment which should be labeled (N).

The next pair of pots containing 1600 grams of soil each will be fertilized with phosphorus. A good phosphate fertilizer source is treble superphosphate. This runs to more than 40% phosphate which is calculated as P_2O_5. Single superphosphate is also a good source but it includes sulfur. In a controlled experiment this is an undesirable complication because it leaves unanswered the question of whether its effects are due to the phosphorus or the sulfur. Therefore, it is better to use the treble super for present purposes.

It may be obtained as a fertilizer under the trade name of treble superphosphate, or as a chemical called primary calcium phosphate. Weigh two samples of .426 grams each, and mix with the pair of soils to constitute the phosphate treatment (P). This amount of fertilizer includes .240 grams of P_2O_5 per pot or 300 lbs. per acre (see Appendix).

Now, in many soils you have to deal with a multiple deficiency. Thus, a soil may be deficient in not just N or P, but both at the same time. The addition of either of these nutrients alone will not produce a good crop. The combination of the two will. To test this possibility, prepare two pots of soil, and add the combination (NP) of ammonium nitrate and primary calcium phosphate in the amounts and in the manner described above.

Thus far we have a test for nitrogen and phosphorus, separately and jointly. After these deficiencies have been met, there is some possibility that a deficiency of potassium (K) or sulfur (S) will appear. But this does not ordinarily show up until the N and P have been added.

For the last treatment, add to two pots of soil the nitrogen and phosphate plus .296 grams of potassium sulfate to each of the pots. This is equivalent to a rate of 200 lbs. of potash per acre, expressed as K_2O. This may be regarded as the complete fertilization and should be labeled NPKS.

If this treatment produces larger and healthier-looking plants than the NP combination, then it is likely that a potassium or sulfur deficiency has been found. The next

problem is to decide if the effect is due to the K or the S. A clue will be obtained by studying the symptoms. If the plants grown with NP are pale in color compared to the NPKS, then the odds are that it is a sulfur deficiency. If the color is good but the tips of the leaves show a scorched appearance, then it is more likely a deficiency of potassium.

To clear up this point conclusively requires a more elaborate test in which NP is combined with potassium chloride, another NP with sodium sulfate, and a third with potassium sulfate. This will tell you if it is a deficiency of potassium, sulfur, or both. The details of such a setup are supplied in the Appendix.

Planting the Crop. In selecting the species of plant to be used, several requirements must be considered. A good test-plant is one which is capable of rapid growth, resistance to insects and disease, and some degree of sensitivity to nutrient deficiencies. Barley is such a plant and is obtainable at most feed stores.

Plant 9 seeds in each pot about a half-inch below the surface. Moisten the soil with about a half-cup of water. If distilled water can be obtained without too much trouble, it should be used in preference to piped or well water. If not, a good quality drinking water will be satisfactory.

Water the plants as needed. This may be once a day in the beginning and on cloudy days, or two to three times a day on hot days when the plants are fully grown. After a few days, judgment is acquired as to how often and how much to water. The things to avoid are letting the plants wilt, or excessive watering that keeps the soil constantly saturated. Put a saucer under each pot. This will prevent the loss of nutrients. Any water which drains into the saucer should not be removed as the plant roots at the bottom of the pots will absorb it.

Growing the Plants. Locate the pots in a place where the plants will be exposed to strong sunlight for a good part of the day. Out of doors will be satisfactory if protection is provided against rain, birds, and rodents. A good range of day temperatures is between 70 and 90 degrees fahrenheit. Night temperatures may run between 50 and 70 degrees. Freezing weather should be guarded against. If necessary, the use of a greenhouse should be explored.

About a week or so after the seeds have been planted, pull out enough plants so that five seedlings remain in each pot.

Allow the plants to grow for 6 weeks after planting. During this time, differences in size and appearance will show up. Make note of these at weekly intervals. Measure the height of each plant and count the number of leaves per plant.

Harvesting. Clip the barley plants at the ground line and weigh the plants from each pot. This is called the fresh weight. Place them in labeled bags and dry them in an oven at 160 degrees fahrenheit. After two days in the oven, weigh them again. This is the oven dry weight.

Analyzing the Data. Each treament has two weights, one for each pot. Take the average of each pair. Compare the averages of all treatments. If the soil was deficient in nitrogen only, then the plants which were fertilized with nitrogen will have larger weights than those not fertilized with N. The same line of reasoning applies of phosphate. If the soil was deficient in both N and P, then the plants receiving NP will be larger than the single fertilizers or the check. If the NPKS combination is greater than the NP, then a deficiency of potassium or sulfur is indicated.

(The difference between the fresh and the dry weights of the plants represents the loss in moisture upon drying. A simple calculation will show that the major part of the fresh weight of plants consists of water. Figure out the per cent moisture content of the plants grown in each treatment and see if it is related to the nutrients added.)

Interpreting the Results. The results obtained with the pot test will serve as a guide as to what to expect in the field. The same differences usually do not appear in the field to the same degree as in the pots. The reason is that in the field the plants have a larger volume of soil to explore and have a longer growing season to develop in, and the effect of this is to smooth the differences due to fertilizer treatments. With this caution in mind, it is possible now to establish field plots to see the extent to which the results from the pot test will be reflected in the field.

APPENDIX

Section 1. Transposing pounds per acre to grams per pot.

On the average, an acre of soil seven inches deep will weigh about 2 million pounds. It will take 1600 grams of such a soil to almost fill a 6-inch pot.

The following calculations will show how to convert 200 lbs. of N per acre to grams of ammonium nitrate per pot.

To get grams of N per pot, set up this ratio: $$\frac{\text{Lbs. N per acre}}{\text{Lbs. soil per acre}} = \frac{\text{Grams N per pot}}{\text{Grams soil per pot}}$$

Substituting figures we get: $$\frac{200}{2{,}000{,}000} = \frac{X}{1600}$$

Solving for X, we get .160 grams N per pot. Next, we must convert grams of N to grams of ammonium nitrate. The atomic weight of N is 14. Since there are 2 N atoms in a molecule of ammonium nitrate, this makes 2 x 14 or 28. Adding up the molecular weight of ammonium nitrate (NH_4NO_3) we get the following:

$$\begin{aligned} 2\ N &= 2 \times 14 = 28 \\ 4\ H &= 4 \times\ 1 = 4 \\ 3\ O &= 3 \times 16 = 48 \\ & \qquad\quad 80 \end{aligned}$$

Setting up the equation: $.160 \times \frac{80}{28} = .457$ grams of ammonium nitrate.

The same procedure is used to calculate the grams of primary calcium phosphate: First, let us convert 300 lbs. of P_2O_5 per acre to grams per pot: $$\frac{300}{2{,}000{,}000} = \frac{X}{1600}$$

Solving for X gives .240 grams P_2O_5 per pot. This must be changed to grams of calcium phosphate. Phosphorus has an atomic weight of 31, and oxygen 16.

$$\begin{aligned} 2\ P &= 2 \times 31 = 62 \\ 5\ O &= 5 \times 16 = 80 \\ & \qquad\quad 142 \end{aligned}$$

Now add up the molecular weight of calcium phosphate ($Ca(H_2PO_4)_2 \cdot H_2O$)

$$\begin{aligned} 1\ Ca &= 1 \times 40 = 40 \\ 6\ H &= 6 \times\ 1 = 6 \\ 9\ O &= 9 \times 16 = 144 \\ 2\ P &= 2 \times 31 = 62 \\ & \qquad\quad 252 \end{aligned}$$

Set up this equation: $.240 \times \frac{252}{142} = .426$ grams of primary calcium phosphate to be added to each pot.

For the potash, we have already established that 200 lbs. per acre is equivalent to .160 grams per pot. Now convert K_2O to potassium sulfate.

Potassium has an atomic weight of 39.

$$\begin{aligned} 2\ K &= 2 \times 39 = 78 \\ 1\ O &= 1 \times 16 = 16 \\ & \qquad\quad 94 \end{aligned}$$

The molecular weight of potassium sulfate (K_2SO_4) is:

$$\begin{aligned} 2\ K &= 2 \times 39 = 78 \\ 1\ S &= 1 \times 32 = 32 \\ 4\ O &= 4 \times 16 = 64 \\ & \qquad\quad 174 \end{aligned}$$

This comes out to .296 grams of potassium sulfate per pot. $.160 \times \frac{174}{94} = .296$

Section 2. Separation of potassium and sulfur effects.

If an improvement in growth is obtained with the complete NPKS treatment over the NP, it is uncertain whether the effect is due to the potassium or the sulfur. The symptoms already described are helpful, but they cannot be regarded as proof.

To clear up this point, two additional treatments are required. One of them should be an NPK and the other NPS. This requires an additional 4 pots of soil. All of them will get NP. Two of them will also receive potassium chloride (KCl). This has a molecular weight of 74.6.

$$\begin{aligned} 1\ K &= 1 \times 39 = 39 \\ 1\ Cl &= 1 \times 35.6 = 35.6 \\ & \qquad\quad 74.6 \end{aligned}$$

We want to add a comparable amount of potassium from chloride as we did before with potassium sulfate. Set up a ratio as follows:

$$\frac{\text{Mol. wt. KCl}}{\text{Mol. wt. } K_2SO_4} = \frac{\text{grams of KCl}}{\text{grams of } K_2SO_4}$$

$$\frac{74.6}{174} = \frac{X}{.296}$$

Solving for X gives .127 grams of potassium chloride per pot.

Another pair of pots will get NP plus sodium sulfate. To calculate how much to add, we need the molecular weight of sodium sulfate ($Na_2SO_4 \cdot 10H_2O$):

$$\begin{aligned} 2\ Na &= 2 \times 23 = 46 \\ 1\ S &= 1 \times 32 = 32 \\ 14\ O &= 14 \times 16 = 224 \\ 20\ H &= 20 \times 1 = 20 \\ & \qquad\quad 322 \end{aligned}$$

Again, set up a ratio:

$$\frac{\text{Mol. wt. } Na_2SO_4\ 10H_2O}{\text{Mol. wt. } K_2SO_4} = \frac{\text{grams of } Na_2SO_4\ 10H_2O}{\text{grams of } K_2SO_4}$$

$$\frac{322}{174} = \frac{X}{.296}$$

and X comes out to equal to .548 grams of sodium sulfate per pot.

These two treatments added to the five previous ones will provide a test for nitrogen, phosphorus, potassium, and sulfur.

Section 3. Special problems found in acid soils, alkali soils, serpentine soils, and soils with micro-nutrient deficiencies:

In addition to the four nutrients considered thus far, in certain areas special problems of soils arise from the nature of the climate, the parent material from which the

soil is derived, or the topography. Therefore, it is necessary to correct these underlying difficulties of acidity, alkalinity, etc., before the standard nutrient test is made.

Such problems will usually require the attention of a specialist, so if a student encounters them he may have to consult the local farm advisor.

In general, it may be said that acid soils are found in areas of high rainfall and require large applications of lime -- 2 to 4 tons per acre (3.2 to 6.4 grams per pot) -- in addition to the standard nutrient treatments described above. This will double the amount of soil needed, since each nutrient treatment will require two pots with lime and two without.

Alkali soils usually occur in valley floors with poor drainage and low rainfall. They first must be reclaimed by adding large amounts of gypsum or sulfuric acid followed by heavy leaching. Then the standard nutrient test may be run on soils which have been so reclaimed. The amount of gypsum or acid to be added will depend on the degree of alkalinity and requires the technical assistance of a specialist.

Serpentine soils are related to the underlying rock from which they were derived, usually blue or green rocks containing serpentine minerals. These soils suffer from a deficiency of calcium and an excess of magnesium. This condition may be corrected by the addition of 4 tons per acre of gypsum, $CaSO_4 \cdot 2H_2O$, (6.4 grams per pot).

Mix the gypsum well into 1600 grams of soil and place it in a pot. Add a cup of water and let it stand for one week. This is to allow the gypsum to react with the soil. Then leach the soil in the pot with water until the leachings come through the pot with a weak indication of sulfate, as tested in a test tube with a few drops of barium chloride. Now the soils are in condition for a regular nutrient test. Discard the leached water.

Micro-nutrient deficiencies are difficult to detect unless extreme care is taken to eliminate contamination acquired in the test. One requirement would be to use distilled water, or even re-distilled water. Another would be to use chemically pure salts or even re-crystallized chemicals. Vigorous growing conditions of light and temperature must also exist. Also, it is preferable to grow tomato plants instead of barley as they are more sensitive to micro-nutrient deficiencies. Obviously, this is a job for an experiment station or laboratory with excellent facilities and trained personnel. Fortunately, the procedures outlined above will take care of the growth-limiting conditions found in most soils. However, if they should not be adequate, and there is reason to suspect a micro-nutrient deficiency, then a farm advisor or other technical expert should be consulted.