RELATING SOIL, WATER, AND FERTILIZER NUTRIENTS

A. I. Dow
Extension Specialist in Outlying Testing
Wash. State University, Prosser, Wash.

Diagnosing fertilizer needs of a crop and applying correct amounts of needed elements is a complex problem. For P and K, we have the help of the soil test. However, in view of some recent developments, certain considerations for those two elements are very important.

PHOSPHORUS

In recent years marked responses to phosphorus have been obtained and large applications of this element have been necessary for maximum yield in certain areas in the Columbia Basin. This has been associated with heavy leveling operations which were necessary in preparing the land for irrigation. In many cases the leveling exposed calcareous subsoils which were extremely low in available P according to the soil test.

These results have raised the following questions:

1. Why are these large amounts of phosphorus necessary for maximum production?
2. What forms of phosphorus fertilizers are best to use? What about water solubility?
3. Does added P become fixed, or unavailable to the crop?
4. Does the soil test accurately measure the P available the year following the application of phosphorus?

Forms of Phosphorus

The following chart shows the forms of phosphorus found in soil and in fertilizer:

Native P (rock phosphate)	$Ca_3 (PO_4)_2$	insoluble
Dicalcium P	$Ca H PO_4$	citrate soluble
Monocalcium P	$Ca(H_2PO_4)_2$	90% water soluble
Phosphoric acid	H_3PO_4	100% water soluble
Absorbed by plants	$H_2PO_4^-$ or $H PO_4^=$	

Solubility ↓

These are listed in order of solubility. There is a great deal of phosphorus, essentially unavailable and insoluble, in central Washington soils. This is similar to rock phosphate and is chemically "tied up" as tricalcium phosphate complexes. Dicalcium phosphate is present in soils and is used in some fertilizer materials. It is a good source of phosphorus for the plant, but is not water soluble. Monocalcium phosphate is the chief source of phosphorus in treble superphosphate. It is essentially water soluble. Phosphoric acid is completely water soluble and is, of course, a readily available source of P. The form of P most readily absorbed by plants is probably $H_2PO_4^-$.

Occasionally in the irrigated soils of the West, an experiment has shown that, under certain conditions, water soluble P has shown a slight advantage. However, many experiments in central Washington and in other irrigated areas of the western States have shown that, where the phosphorus was applied according to recommendations, water solubility was not a factor. In fact, it has been shown that a portion of applied water soluble P such as monocalcium phosphate will revert immediately to dicalcium phosphate. This does not affect its availability.

Certain results in phosphorus experiments in recent years could lead one to wonder whether or not the fertilizer P applied had become "fixed" or unavailable to the plant. Briefly these results were:

1. Large applications of P (up to 400 lbs./acre) were necessary for maximum yields.

2. Subsequent samples still did not always test high in P.

Figure one illustrates the fact that, in many cases, samples were not taken sufficiently deep to reach the phosphorus which had been applied and plowed down. In the 10-inch samples the soil tests were at the expected levels. This indicates no "fixation" of the fertilizer phosphorus. In addition to this, broadcast applications resulted in as high, or higher, yields than banded applications. This again indicates no fixation. It is believed that the large quantities applied were necessary simply because of an extreme deficiency.

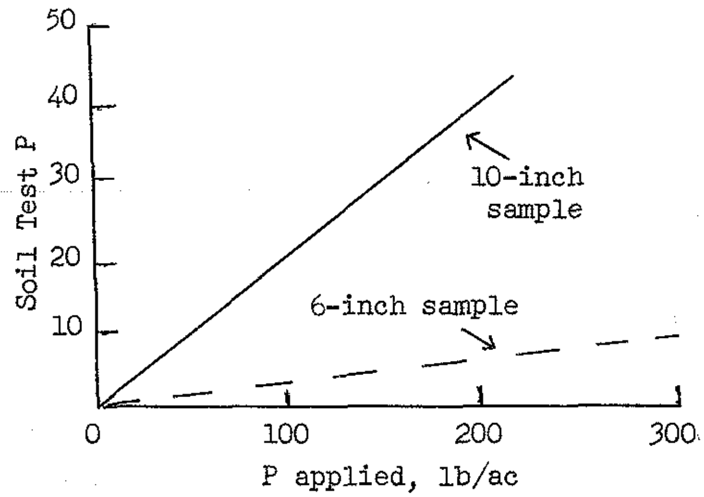

Figure 1. Soil tests for P in samples taken six inches deep and ten inches deep six months after adding various amounts of phosphorus. The fertilizer was plowed down about ten inches deep.

POTASSIUM

During the past three years, potash deficiency has been observed in potatoes. These observations have been confirmed by soil tests, tissue analyses, and yield responses to added potassium.

Potassium exists in the soil in three forms as shown in Figure 2.

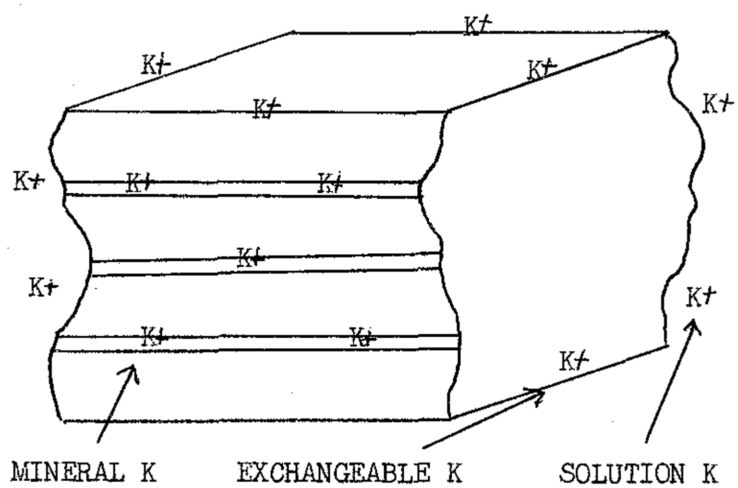

Figure 2. A diagram of a clay particle showing different forms of K.

Mineral K, sometimes referred to as non-exchangeable or "fixed" K is situated within the clay particles in such a way as not to be readily available. Exchangeable K is attached to the surface of the clay particles and solution K is in the soil solution apart from the clay particles. These latter two exchange positions with one another and are readily available to plants. As solution K and exchangeable K are removed, mineral K may be slowly released and become available for plant use. The rate at which mineral K is released is called the soil's "potassium releasing power." This rate of release is for different soils as indicated in Figure 3. It can be seen that, after the exchangeable K has been removed from both soils, Soil No. 2 continues to release K, whereas Soil No. 1 does not, as measured by a laboratory procedure.

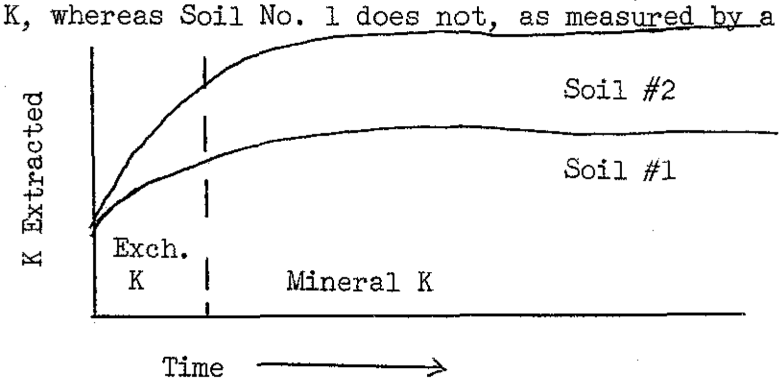

Figure 3. The release of mineral K from two different soils after exchangeable K has been removed. These measurements were taken in the laboratory.

Potassium release has some very important implications and may explain why, on a soil testing low in K, one high requirement crop will become deficient while, apparently, another will not.

This can best be illustrated by using a comparison between potatoes and sugar beets as a case in point. Both of these crops will extract large amounts of K from the soil. However, observations and experimental evidence indicates that, on a soil testing low in K, potatoes may show extreme potash deficiency where sugar beets will not. The explanation is probably in the time-period for the requirement of K as related to the rate of release of mineral K from the clay minerals in the soil. Sugar beets extract K slowly over a long period. Potatoes, on the other hand, have an extremely high requirement for K within a relatively short period. When the small amount of readily available K has been used, the rate of release of mineral K is too slow for potatoes but appears to be adequate for sugar beets.

SAMPLING FOR THE SOIL TEST

Soil testing for P and K has been shown to be approximately 75% accurate. This means that about three-fourths of the time the soil test will reflect a reasonable accurate condition of the field sampled. Probably most of the error in the other 25% is largely a problem of sampling. We have already indicated an error in "vertical" sampling. That is, we should be sampling to plow depth or about 10 inches in order to sample the added fertilizer which has been plowed down.

Another serious source of error is in "horizontal" sampling. Figure 4 illustrates a typical example of variation in soil test due to heavy leveling. This type of variation occurs both for phosphorus and potassium. A composite sample of the field in Figure 4 will result in one of the following:

1. A test of "medium." The entire field may receive 60 lbs. P_2O_5 per acre although a third of the field should have had 200 lbs.

2. A test of "low." In this case, two-thirds of the field will receive too much phosphorus and the other one-third will still not have enough.

3. A test of "very low." Here, two-thirds of the field will receive far more phosphorus than necessary.

There are some other alternatives:

4. Do not take a soil sample or disregard the soil test. In this case a guess is made for the amount of phosphorus needed in a "blanket" application. An average guess might be 100 lbs. per acre, in which case a third of the field still is far short of the needed amount.

   It is important to remember that: <u>frequently, the biggest factor in "poor" spots in a leveled field is inadequate phosphorus</u>. These spots frequently require large amounts of phosphorus for normal crop growth. The spots, therefore, will not disappear until this need has been met. As long as only maintenance applications of P are applied, the spots will remain.

5. Take individual soil samples on a "grid" system as indicated in Figure 4. From the soil test report of each sample, the areas can be delineated, probably with an error that is not great. In the example in Figure 4, the cost for soil tests would be only one dollar per acre.

If "cut and fill" sheets can be obtained or if the grower has determined where the "cut" areas are, this information along with suggestion No. 5 is probably the best approach to the problem.

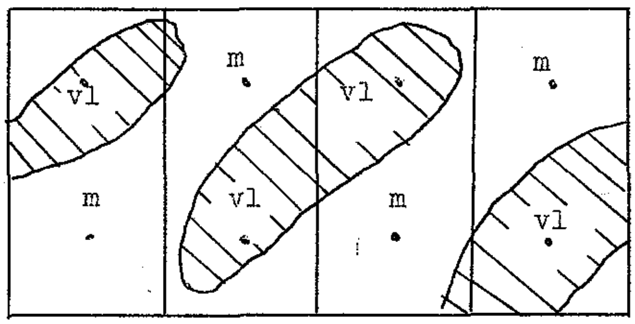

Figure 4. A 20-acre field showing the variation in soil test for P from heavy leveling for irrigation.