Table V. Soil Test Results for Tomatoes, 1958

Phosphorus	Potassium Low	Medium	High	Total
	Per Cent of Samples			
Low	7	1	3	11
Medium	5	19	4	28
High	13	14	34	61
Total	25	34	41	

from a large number of samples from different soils and crops will show areas of nutrient deficiencies, fertilizer use patterns, and probable percentage of samples, in a given area and for a given crop, requiring various grades of fertilizer. The use of summaries of soil-test results to show probable fertilizer needs for a particular crop is demonstrated in Table V. Soils used for tomatoes in New Jersey tend to be low in potassium and high in phosphorus. These data indicate that a 1–2–2 or 1–1–1 fertilizer would be recommended for about 61% of the soils used for tomatoes; 1–1–2 for some 32% of the samples; and 1–2–1 for only 7% of the soils. Fitts, Welch, and Nelson (*4*) have used this same type of data to predict fertilizer ratios needed for a particular crop in various areas of North Carolina. Only a limited number of such crop summaries have been made in New Jersey, because soil test data will be completely transferred to punch cards only as funds permit. Rather complete summaries have been made (*5*, *14*) for three counties—Warren, Monmouth, and Gloucester—where recent soil surveys have been completed.

One type of summary of soil-test data that has been made is illustrated in Table VI. Phosphorus and potassium tests for Warren County have been sorted according to age of soil and type of parent material. In this county there is a rather sharp boundary between areas covered during the glacial periods.

Table VI. Soil Test Results in Warren County

(Per cent each soil)

Land Type Areas	Phosphorus Low	Phosphorus Medium	Phosphorus High	Potassium Low	Potassium Medium	Potassium High
Early drift						
Shale uplands	75.8	24.0	0.2	65.6	34.4	0
Limestone valleys	68.5	23.1	8.4	46.4	46.1	7.3
Gneiss highlands	86.4	10.4	3.2	59.2	32.0	8.8
Later drift						
Shale uplands	73.0	21.9	5.1	70.9	24.1	5.0
Limestone valleys	49.4	37.1	13.5	71.2	24.3	4.5
Gneiss highlands	72.7	22.1	5.2	59.7	39.6	1.3
The Moraine	61.1	25.0	13.9	48.1	43.6	8.3
Muck	6.1	21.7	72.2	3.5	23.5	73.0

The shale soils show little difference in phosphorus or potassium levels between the two time periods. Soils of the limestone valleys have become more acid with time and as a result soils on the earlier drift are more acid, as indicated by pH tests, and have lower available phosphorus. On the other hand, these limestone soils have higher potassium in the area of the earlier drift, where a longer time of weathering and soil formation has resulted in more acid soils. These data point to the difference in the amount of weathering with time between the shale and gneiss parent materials. Highly fertilized vegetables are grown on the muck.

All soil-test calibration studies are being expanded as funds permit. Fertilizer recommendations are modified according to results of laboratory, greenhouse, and field experiments as needed to give New Jersey growers the best possible information on the fertilizer requirements of their crops and soils.

Literature Cited

(1) Baird, B. L., Fitts, J. W., "Economic and Technical Analysis of Fertilizer Innovations and Resource Use," Chap. 13, Iowa State College Press, Ames, Iowa, 1957.
(2) Bradfield, R., *J. Am. Soc. Agron.* **19,** 1015–20 (1927).
(3) Dean, L. A., *Soil Sci.* **37,** 253–66 (1934).
(4) Fitts, J. W., Welch, C. D., Nelson, L. L., *Soil Sci. Soc. Am. Proc.* **20,** 36–40 (1956).
(5) Flannery, R. L., "Influence of Land Type Areas and Past Management Practices on the Fertility Levels of Certain Coastal Plain Soils," Ph.D. thesis, Rutgers University, 1957.
(6) Hader, R. J., *et al.*, *Soil Sci. Soc. Am. Proc.* **21,** 59–64 (1957).
(7) Hanna, W. J., "Availability of Phosphorus in Various Compounds as Determined by Electrodialysis and Plant Growth," Ph.D. thesis, Rutgers University, 1951.
(8) Hanna, W. J., Purvis, E. R., N. J. Agr. Expt. Sta., Bull. **780** (1955).
(9) Harper, H. J., *Soil Sci.* **35,** 1–16 (1933).
(10) Hester, J. B., *et al.*, Va. Truck Expt. Sta., Bull. **95** (1937).
(11) Humfield, R., Alben, A. O., *J. Am. Soc. Agron.* **19,** 984–93 (1927).
(12) Mattson, S., *J. Agr. Research* **33,** 553–67 (1926).
(13) Morgan, M. F., Conn. Agr. Expt. Sta., Bull. **333** (1932).
(14) Musen, H. L., "Factors Affecting Fertility Levels of Certain New Jersey Soils," Ph.D. thesis, Rutgers University, 1955.
(15) Purvis, E. R., Hanna, W. J., *Soil Sci.* **67,** 47–52 (1949).
(16) Purvis, E. R., *et al.*, N. J. Agr. Expt. Sta., Circ. **578** (1957).

Interpretation of Soil Tests and Application as Charted by Current Research

E. J. KAMPRATH and J. W. FITTS

Department of Soils, North Carolina Agricultural Experiment Station, Raleigh, N. C.

Soil tests should provide information about the soil which will serve as a guide to liming and fertilization. Since the time of Liebig, the goal of agronomists has been evaluation of soil fertility and prediction of crop yield from soil tests. However, the yield of a crop (both quantity and quality) is a function of several factors, which can be expressed by the equation:

$$\text{Yield} = f\,(\text{crop} + \text{soil} + \text{climate} + \text{management})$$

If an index or value can be obtained for each variable, the yield can be calculated. Soil testing furnishes information about the soil variable in the equation in respect to fertility or special soil conditions. Other sources of information are needed for the other variables.

Soil tests furnish information to guide in liming and fertilization of soils. In the future soil tests will be very important as tools to assess the condition of the soil and provide information about building and maintaining soil fertility. Basic research is necessary to provide information about the chemical properties of the soils.

Fitts and Nelson (*3*) point out that there are four major phases of soil testing: calibration of the test with crop response, securing of representative samples, chemical testing procedures, and interpretation and recommendation. This paper deals largely with interpretation of results.

Early Attempts at Soil Testing

Soil testing has been viewed in many ways—from a psychological tool to a single-value soil management cure-all. One of the first problems encountered was interpretation of the results obtained from various procedures. Crop rotations, with and without application of manure, were the principal field studies under way in the early days. Unsuccessful efforts were made to calibrate soil tests by taking soil samples from the rotation plots and explaining crop yields on the basis of the soil-test results.

Soil Testing Today

Information gained from soil testing is used in many ways. Some of the more important objectives (*3*) include:

To group soils into classes for suggesting fertilizer and lime practices.
To predict the probability of getting a profitable response to the application of plant nutrients.
To help evaluate soil productivity.
To determine specific soil conditions which may be improved by addition of soil amendments or cultural practices.

Soil tests are calibrated in several ways. One procedure is the correlation of soil test values with per cent yield of plant material or with total uptake of the nutrient element being studied from treated and untreated soils. In this technique, yield responses to fertilization at a given soil level may vary considerably because of differences in properties of the soil other than fertility or other variables in the yield equation.

Another method of predicting lime and fertilizer responses from soil tests values is the "probability" approach suggested by Fitts (*2*). The probability of obtaining a profitable increase in yield for a given fertilizer treatment is plotted against the soil-test results. The index of probability used is the percentage of fields within a given range of soil-test values that do or do not respond to application of the soil amendment. The chances of getting a profitable response to fertilization are much greater on a soil that tests low in a given nutrient than on one that tests high. This concept does not rule out the possibility of a profitable response from fertilizer application at a high level of fertility, if yield factors other than fertility are optimum. Likewise, a profitable response on soils of low fertility is not assured when other factors such as climate and management are poor.

Trends in Soil Testing

A big problem in soil-test interpretation and recommendations is how much fertilizer should be applied. Although crops vary in their nutrient requirements, the addition to the soil of amounts equivalent to those absorbed by the plants is not valid, because only a portion of the applied fertilizer will be utilized. The remainder may be lost by leaching or made immobile by fixation. The release of nutrients from the soil must also be taken into consideration.

The addition of fertilizers and lime to the soil changes the immediate environment of the plant roots. Although a large increase may be obtained from application of a fertilizer to a soil low in a given element, the yield obtained is not likely to approach that obtained on a "fertile" soil.

The importance of the fertility level in the yield of crops is shown by experiments on a Norfolk soil (*5*).

P_2O_5 Added, Lb./Acre	Soil Phosphorus Level: Low	Soil Phosphorus Level: High
	Yield of Seed Cotton, Lb./Acre	
None	834	2112
50	1403	2287

The highest yields of seed cotton were obtained on the soil with a high phosphorus level. Addition of phosphorus to the soil deficient in this element increased yield but did not bring it up to that obtained at the high soil level. When all the other factors affecting yield are satisfactory, a profitable response can be obtained to fertilization even at a high soil level, as shown by the increase in the yield of seed cotton when 50 pounds of P_2O_5 were applied to the soil high in phosphorus.

Interpretation of soil-test results and recommendations become a question of how to improve the fertility status of the soil. How much fertilizer will be needed to change the soil from low to medium or high in that element? What soil factors will influence the amounts of fertilizer required? What will be the most economical level at which to maintain the nutrient status of the soil? Many factors will influence the possibility of building and maintaining high nutrient levels. An important one is the capacity of the soil to fix phosphorus in insoluble forms.

In Table I are shown the amounts of phosphorus that had to be applied to bring three soils to the same phosphorus level. On the Norfolk considerably less phosphorus is required to raise the soil phosphorus level than on the Cecil or Rabun soils. The relative phosphorus-fixing capacities of soils can be determined by laboratory methods.

Soil	P-Fixing Capacity, Meq./100 G.
Norfolk (*4*)	2.0
Cecil (*7*)	6.8
Rabun (*7*)	14.4

Table I. Phosphorus Additions Required to Increase Soil Phosphorus Level (*6*)

Soil	Initial P Soil Level, P.P.M.	P_2O_5 Added, Lb./Acre	Final P Soil Level, P.P.M.
Norfolk	13	200	28
Cecil	6	400	28
Rabun	7	800	29

Table II. Relation of Corn Yields to Rate of Potassium Fertilization on a Portsmouth Soil (*7*)

K_2O Added, Lb./Acre	Initial Soil K Level, Meq./100 G.: 0.08	Initial Soil K Level, Meq./100 G.: 0.29
	Average Corn Yield, Bushels/Acre	
0	82	103
20	97	105
80	96	103

Table III. Influence of Rate of Potassium Fertilization on Soil K Level of Portsmouth Soil (*7*)

K_2O Added, Lb./Acre	Initial Soil K Level, Meq./100 G.: 0.08	Initial Soil K Level, Meq./100 G.: 0.29
	Soil K Level, Meq./100 G.	
0	0.08	0.22
20	0.11	0.26
80	0.15	0.28

Once this information is available, the soils of an area can be grouped according to their relative phosphorus-fixing capacities, and recommendations for phosphorus fertilization can be made.

The available potassium content is another important factor in evaluating the fertility level of a soil. The availability of potassium in a given soil for annual crops is related in large part to the amount of exchangeable potassium, which is the form generally measured by a soil test. The ability of a soil to supply potassium over a long time, however, depends upon the amount of nonexchangeable potassium present. Therefore, in evaluating the potassium status of a soil the level of both exchangeable and nonexchangeable potassium must be considered.

The importance of a high level of soil potassium is shown by Table II. The highest average yields of corn for a 3-year period were obtained at the high soil potassium level. The yield response data indicate that at the low soil level 20 pounds of K_2O per acre was sufficient, while at the high soil level none was needed. However, a fertilization program should take into account not only the effect on the yield but also the effect on the soil. The soil-test data show that to increase the potassium level of the soil appreciably at least 80 pounds of K_2O per acre must be applied; to maintain the high level at least 20 pounds of K_2O must be applied (Table III). In making recommendations based on soil tests it is important to consider what is happening to the fertility level of the soil as well as the nutrient requirements of the crop.

The level to which potassium can be built in a soil depends upon the cation exchange capacity and the cations present on the exchange complex. Generally, the higher the cation exchange capacity, the larger is the reservoir in which potassium can be stored. Therefore, it is usually possible to build the available potassium content of soils with a high cation exchange capacity to a higher level than those of a low capacity.

Soil	% of Applied K Retained	
	Acid	Limed
Norfolk (low cation exchange capacity)	22	49
Cecil (medium cation exchange capacity)	60	89

The amount of potassium held was greatly increased when the soils were limed, which resulted in the replacement of exchangeable hydrogen and aluminum by calcium and magnesium (*8*). If the potassium level of acid soils is to be increased by fertilization, it is important that the soils first be limed.

Information about the lime status of a soil also is obtained from a soil test. Generally, the pH of the soil is used as the criterion for determining whether or not a response will be obtained to the addition of lime. Soil pH alone, however, is not a good index for determining the lime needs of a soil. Coleman, Kamprath, and Weed (*1*) pointed out that the nature of the ion exchange material is important in determining at what pH level a response to lime will be obtained. The amount and kind of clay and the amount and characteristics of the organic matter determine the ion exchange properties of the soil. Plants differ as to the optimum pH and lime level necessary for good growth. Therefore, it is necessary to consider the kind of plant to be grown as well as the chemical properties of the soil when making lime recommendations for acid soils.

Literature Cited

(1) Coleman, N. T., Kamprath, E. J., Weed, S. B., *Advances in Agron.* **10,** 475–522 (1958).
(2) Fitts, J. W., *Better Crops with Plant Food* **39,** No. 3, 17–21 (1955).
(3) Fitts, J. W., Nelson, W. L., *Advances in Agron.* **8,** 241–82 (1955).
(4) Mehlich, A., *J. Assoc. Offic. Agr. Chemists* **36,** 445–57 (1953).
(5) Nelson, W. L., Krantz, B. A., Welch, C. D., Hall, N. S., *Soil Sci.* **68,** 137–44 (1949).
(6) NeSmith, J., "Phosphorus Studies on Certain North Carolina Soils," Ph.D. thesis, North Carolina State College, 1956.
(7) North Carolina Agricultural Experiment Station, unpublished data.
(8) Thomas, G. W., "Distribution of Fertilizer Potassium in Soils," M.S. thesis, North Carolina State College, 1956.

Submitted with the approval of the director as Paper 1084 of the Journal Series.

Commercial Laboratory and Advisory Procedures in Subtropical Agriculture

BENJAMIN WOLF
Dr. Wolf's Agricultural Laboratories, Hollywood, Fla.

Advisory systems based on soil and plant analysis are of great value in subtropical agriculture. Considerable attention must be paid to trace elements because of light soils and extreme leaching. The combination of soil and climate necessitates sampling on a 2-week schedule soils producing vegetables, gladioli, chrysanthemums, and other plants having limited food storage capacity. A much less frequent schedule (three to four times per year) is needed for citrus, cane, pasture, sod, and other perennials.

The importance of advisory procedures based on adequate analysis of soil and plant has increased considerably in the last decade. Today it has come of age, although much remains to be done to increase its accuracy and usefulness.

Procedures and calibrations were established in the Middle Atlantic states, primarily in New Jersey. The methods used are based on Morgan's extracting solution, carefully calibrated with crop response at Seabrook Farms and later at laboratories at Bridgeton, N. J., and Hollywood, Fla. The requirements in terms of soil nutrient levels have been established for a number of crops, but correlations are still going on to define nutrient levels and amounts of fertilizer necessary to change one level to another.

About 10% of our work deals with determination of soluble nutrients and total nutrients in plants. Plant tests check on soil tests and also point out possible deficiencies. Soil tests point out deficiencies or excess of nutrients in time to make corrections without seriously lowering crop production. Often by the time such deficiencies or excesses are noted in plant analysis,