the soil's tilth, water-holding capacity, support of soil bacteria, and ability to store plant nutrients.

Measuring soil pH, to determine percentage or degree of acidity or alkalinity of the soil.

Determining hydrogen—this being a by-product of plant root activity, it denotes the soil's degree of activity and reserve acidity.

Determining magnesium.
Determining calcium.
Determining nitrogen.
Determining phosphorus.
Determining potassium.
Interpreting results with regard to the soil type tested.

Also made available are the Illinois, Missouri, Iowa, Wisconsin, and Indiana series of soil testing, plus tests for manganese and boron. Equipment in the laboratory includes the Spectronic 20 used for interpretation, a custom-built pH meter, a distillation apparatus for determining available nitrogen, a soil-grinding and screening unit, automatic pipet equipment for metering reagents, a soil dryer, an exhaust system, a glass dryer, special shakers, and an air conditioner for maintaining constant temperatures. Plans are also in the making to add a flame photometer to aid in the speed and accuracy of testing.

The laboratory's facilities are geared to handle 2000 soil samples per day. The final results and the interpretation are mailed back to the fertilizer dealer—or salesman—who is trained to explain the results of the test to the farmer and to assist him in procuring the needed fertilizer materials. A copy of the test results and the laboratory's recommendations is retained by the laboratory and filed alphabetically by area or state. Samples are retained only briefly. When a retest is needed, new samples are collected from the farmer's field.

Consolidated Laboratories was established for a number of reasons—primarily to give faster service and more complete tests than were readily available to farmers in the sales territory service by the laboratory. Simplicity in analyzing the report was a must to enable the farmer to understand the fertilizer requirements of his soil. Another reason was to strengthen fertilizer sales programs, for it has been proved that after a dealer or salesman collects the soil samples and helps the farmer to interpret the results, it is easier to break down sales resistance and to promote his buying the right kinds of fertilizer materials.

One of the biggest problems confronting salesmen and dealers is gettting farmers to take accurate samples. The farmers themselves are aware of this failing, and consequently, a high percentage will wait for the dealer or salesman to take the samples for them. In many cases it is even difficult to get the farmer to accompany the dealer or salesman while his fields are being sampled. He is content to allow the dealer or salesman to collect the samples and then wait to review the final report as to what is recommended to bring his farm up to the desired level of fertility.

Value of Soil Testing

For years articles in farm magazines, farm newspapers, and college bulletins and pamphlets have stressed the value of soil testing. Yet, in spite of all this publicity, including specific instructions on obtaining accurate soil samples, many farmers still do not take the time to have their soil tested. Most farmers do not use enough fertilizer. Others may purchase quantities of various costly elements not required by their soil. In some instances they purchase fertilizer materials on the basis of what their neighbor buys, even though they are not farming exactly as he is, and may not have the same type of soil. With a soil test—and perhaps by spending a few more dollars per acre—profits can be materially increased.

A soil test report is vital to the farmer. He should keep it in a safe place, but available for easy reference. Consolidated Laboratories emphasizes the importance of the soil test by forwarding the laboratory report in an attractive, durable folder, suitable for placing in a file or bookcase. Handled in this manner it has less tendency to become mixed with other papers and misplaced.

In the Midwest, and in the center of the Corn Belt, there is an extremely wide variation in soil types and classifications. Soils range from practically pure sand to highly organic to almost pure clay—with all the various combinations in between. Some soils are highly calcareous, others podzolic, others well drained, still others subject to severe erosion. The midwest area has been farmed a shorter length of time than most other areas in the United States, and only in recent years have recommendations called for fairly high rates of supplemental plant food. Climatic factors generally favor high yields of corn, soybean, and hay crops.

Soil testing has definite value—to the dealer and the customer. However, experience has shown also that the report on the soil test must be expressed in simple terms so the farmer can understand its meaning. By having the report sent to the dealer or salesman, a twofold purpose is accomplished. After discussing the farmer's soil requirements, both know what fertilizer materials are needed to raise the desired bushels per acre. And after following recommendations, the farmer knows the soil-testing program really works.

Looking Ahead in Soil Testing

WERNER L. NELSON, J. FIELDING REED, and R. D. MUNSON

American Potash Institute, Inc.

It is essential to think ahead and consider what will be important 10 years from now. The prime objective is to bring about the most efficient and profitable use of plant nutrients by the agricultural producer.

While soil testing is only one of many tools to assist the farmer in doing a precision job, it is an important link that demands top-flight programs. Thus we need to think ahead and consider what the agricultural producer might want in the future—say 10 years hence. We must keep in mind that he will have a high investment business operation and will be interested in maximum profits. He will want to eliminate as many limiting factors as possible. Through adequate soil testing one controllable factor, plant nutrient supply, will be taken care of. The prime objective is the most efficient and profitable use of lime and fertilizer by agricultural producers.

All business operations take a periodic inventory of their resources. Each farmer knows how many cattle, hogs, and machines he owns. Today, however, very few have an inventory of their soil resources. But before long those who obtain all their income from the farm will be forced to have an inventory of their soils to stay in business. Soil testing will thus become a necessary operation in farming.

Some soil scientists have had reservations as to the value of soil testing. These reservations are gradually being dispelled and soil testing is enjoying greater acceptance from this group. The ultimate aim of soils research is to assist in solving crop production problems. Soil testing is a very important link between this research and the farmer. Admittedly much is yet to be learned in the field of soil and plant chemistry, but much progress has been made in the last few years.

Sampling

Who Will Do the Sampling? One might predict that as soil testing and fertilizer usage mature, proper amounts of plant nutrients will be supplied more on a service basis. This would mean that someone other than the farmer would take over much of the sampling. Sampling could be a part of the complete service rendered by a laboratory or the fertilizer industry. A sampling service on a charge basis has been initiated in several Michigan counties as a part of the extension program.

Number of Samples. From 1955 to 1957 the number of samples increased 35% in the United States. In some states numbers of samples might double in the next ten years. Certainly the trend will be upward, as soil testing becomes a cog in the farmer's business operation.

Frequency of Sampling. Sampling every three to five years should be adequate for most purposes. With heavy corrective applications of plant nutrients the soil would probably not reach a stage of adequate mixing for sampling in much less than three years. With the gradual nutrient build-up type of recommendation, the fertility level of the soil or the needs of the crops would not change rapidly enough to warrant resampling in much less than five years. On the basis of the one sample more effort should be made to provide recommendations for the next three or four crops in the rotation.

Method of Sampling. As fertilizer use increases, it becomes more difficult to take a representative sample. One core of soil which contains a high concentration of phosphorus or potassium may distort the reading for the whole sample. There may be a trend to fewer cores per composite sample and more samples. Illinois has been using a system of five cores per composite and 11 composite samples per 40 acres.

Who Is Reached in a Soil-Testing Program?

It is important to know what level of farmer is reached in a soil-testing program. Where soil samples are taken and sent in outside of governmental aid programs, the better farmer is no doubt sending in the samples. Where the samples are taken through ASC programs, or where a county makes soil tests mandatory in order to receive payment for certain practices, the entire range of farmers will be represented.

The following estimates come from a survey conducted in the Midwest by a NPFI Research and Education Committee.

	No. of States	State Average, 1953–57	Yield of Farmers Sending in Soil Samples	Goals in Soil Test Program
Corn, bushels	9	44.6	61.2	82.4
Wheat, bushels	9	20.3	27.2	36.0
Alfalfa, tons	8	1.9	2.8	3.8
Soybeans, bushels	7	18.6	24.0	31.1

The obvious conclusion is that the higher yields are due to more effective use of fertilizer and lime. However, the fact that these farmers are able to employ high rates to advantage indicates that they probably possess above-average management ability. The very fact that the farmer uses the soil-testing service is a favorable reflection on his management ability.

Economists have predicted that in the not too distant future there will be only 1,000,000 farmers in the United States. What will these farmers want in the way of soil-testing service? It seems of increasing importance that we know with whom we are working and their objectives. A summary of certain data on the soil-test information sheet, such as previous yields, yield desired, size of farm, and number of acres sampled in any one year might assist in formulating future soil-testing programs.

Level of Recommendations

One of the best ways to encourage the use or sale of a product is to have one that performs much better than the one the consumer already possesses. If a farmer is averaging 80 bushels of corn per acre, are our recommendations based on soil tests enough better really to sell the soil testing program? Are the top 5 to 10% of the farmers already ahead of our educational programs and information?

If the recommendation is aimed merely at achieving average yields, the value of soil testing is greatly reduced. It may do more harm than good, as it creates doubt in the minds of top farmers. In the next few years, as the farmers' usage of fertilizer increases, recommended rates may be considerably less than the amounts used by the leaders.

Two or More Levels. In some soil-testing programs recommendations are made at two or more levels. Iowa uses three levels. An example from Minnesota is shown below:

Soil Test	N,[a] Lb./Acre	P_2O_5, Lb./Acre	K_2O, Lb./Acre
	75 bushels of corn		
High	60	20	0
Medium	80	40	60
Low	100	40[b]	120
	100 to 140 bushels of corn		
High	60	20	20
Medium	100	60	80
Low	140	80	160

[a] After nonlegumes.
[b] Very low P test, apply additional 20 to 30 pounds.

Such an approach seems to have merit. It provides something for the highest quartile of farmers, who really are making a significant contribution. It provides for the lower level farmers, some of whom need slower education.

In ten years a more positive approach might be to give the top level recommendations and management practices as the first choice in all reports. Then qualification might be made that if the farmer is not planning to do his best in stand, pest control, variety, and management, he can use the lower recommendation. The penalty he is imposing on himself might well be spelled out, however.

Build-Up Approach. In this type of recommendation enough nutrients are supplied for good crop yields and also for nutrient build-up on soils testing low and medium. In Ohio, the suggested average annual application of P_2O_5 and K_2O in the rotation is 80, 60, and 40 pounds per acre at the low, medium, and high soil levels, respectively. Nitrogen is suggested according to crop and rotation.

These recommendations are designed to supply nutrients for 100 to 125 bushels of corn, 40 to 50 bushels of wheat, 80 to 100 bushels of oats, 35 to 40 bushels of soybeans, and 4 to 5 tons of hay per acre.

A well balanced fertility program involves building fertility reserve to a reasonably high level, maintaining fertility once a high level is reached. Much emphasis will be placed on this approach in the next few years, with the idea of keeping the sights high.

Detail of Recommendations

There is a trend to report a fewer number of levels. Only five are being used in some states, with some reporting just three—low, medium, and high.

Perhaps the soil test should be used merely to indicate levels in the soil. Recommendations may then indicate the amounts necessary to raise the nutrient to the optimum level. Below is an example from the Purdue testing program:

Test Value	P_2O_5 to Raise P Test Level to 180 Lb./Acre
0- 25	400
26- 50	300
51- 75	225
76-100	150
101-125	90
126-150	50

Possibly too much emphasis has been placed on the "recommendation" as such. Actually, the soil test does not tell the kind of fertilizer to use. It assists in evaluating the fertility level of the soil. With this information, one can better estimate the fertilizer needs.

If a soil is acid or low in a particular plant nutrient, a farmer can take this into account and plan to correct the condition. How this is done is bound to vary with the farmer. Over the years, records can be kept of changes in fertility levels and corrective treatments.

Uniformity of Reporting

The variation in reporting from one state to another is confusing to the person attempting to use soil testing. Farmers operating near a state line or fertilizer producers operating in several states have difficulty in seeing why a river or a state line should materially affect recommendations.

Sometimes it is said that uniformity would not be desirable, because it would kill initiative. There is ample opportunity for initiative in research and development of soil testing. When it comes to actual use, however, there may not be too much reason for widely divergent methods of reporting results and making recommendations. With the various regional soil-test committees at work, some of these problems are gradually being brought out and approached.

Amount of Service Demanded

As the farmer operates more land, he will want more specialized information. When a program passes from the research to the service stage, the question arises as to who should provide the service.

The following are possibilities:

More from Extension? While Extension at present is not set up to provide much more specialized information, it is using soil testing as an educational tool.

Service from industry agronomists.

Service from a commercial laboratory with advice on a number of management phases.

A specialist employed by a group of farmers.

A full-time specialist employed by one farmer.

It appears that the farmer will demand more and more service, depending on the size of his operation. He will be willing to pay for it. If the extension service cannot meet this demand, commercial agencies will step in and do the job.

Who Will Be Doing the Testing and Recommending?

Official Laboratories (Central or County). They will be doing much of the testing, particularly in the newer testing areas, and where the official leaders insist on it. In the central lab system there is a trend to have more and more of the recommendations made by county agents or by district agronomists. This follows the need for more intelligent recommendations based on individual needs.

This testing service might be used by the specialist the farmer employs. The specialist would make the recommendation based on response curves obtained by the college.

Private Laboratories and Consulting Firms. A package program of testing and management service should gain rapidly in popularity. Service might be an all-inclusive soil, crop, and livestock management program. The colleges might develop standard procedures for use by such laboratories.

Fertilizer Companies. The industry can do much to foster getting the samples taken and many feel this to be its most important role in soil testing. Its expansion in the area of actual testing probably will be limited.

Evaluation of Residual Fertility

A major problem in many fertilizer recommendations is inadequate attention to residual effects. While immediate return on the fertilizer investment is important, the better farmers are interested in top returns over the years.

The need to place a price tag on residual fertility will be a must for the progressive grower 10 years from now. Detailed economic evaluation is needed. The calibration of our soil tests to evaluate residual effects and the establishment of response tables will be an important task.

Research

Many of our field calibration studies are already out of date, because of limiting factors such as stand, insect damage, inadequate variety, or improper placement. It is difficult to predict what management practices farmers will be using 10 years from now, but it would seem essential to conduct field calibration studies with the best practices we now know. This will ensure being ready with the answers when the grower demands them.

Research on soil and plant chemistry for both major and minor elements must continue if diagnostic techniques are to continue to improve. Up to now the land grant colleges and USDA have been doing the research. Who will be doing the research for the private laboratories and consulting firms in the future? If the research is to be continued by official agencies, more help should be given by industry either by direct grants or by aid in obtaining appropriations. Will the agricultural producer be sufficiently convinced of the value of the service to pay not only for the technological performance of the test and its interpretation, but also for the research behind the soil test?

Plant Tests

This diagnostic tool appears to have great potential for use along with soil tests. Actually plant composition should better reflect availability of nutrients to the plant than soil tests can. Perhaps the greatest use is in annual crops for predicting needs in subsequent years.

Personnel

An important problem in soil testing is setting the sights high in quality of the leaders and then keeping this personnel. In some states the soil-testing laboratory is used as the training ground for graduate students. As soon as one completes his graduate work another moves in. Too, it may be difficult to keep well trained personnel. In one state testing laboratory there were six directors in 10 years, all Ph.D's. Fortunately, more emphasis on the key nature and the importance of the soil testing program is now being given by the administration in most states.

Marked changes in certain aspects of soil testing appear to be in store for the near future. It will take top-flight personnel to stay on top of the problems and to adjust with changing times.

This is a condensed version of the meeting paper. The complete article appeared in the October 1959 issue of Commercial Fertilizer and Plant Food Industry.

END OF SYMPOSIUM ON SOIL TESTING

PLANT GROWTH REGULATORS

Synthesis and Preliminary Evaluation of Amino Acid Derivatives of 2-(2,4,5-Trichlorophenoxy)propionic Acid

CHARLES F. KREWSON, JOAN F CARMICHAEL, and THOMAS F. DRAKE[1]

Eastern Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture, Philadelphia 18, Pa.

JOHN W. MITCHELL and BERNARD C. SMALE

Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture, Beltsville, Md.

A series of D-, L-, and DL-amino acids involving 2-(2,4,5-trichlorophenoxy)propionic acid has been prepared and evaluated. A wide variety of notable differences in behavior pattern in this new series is in sharp contrast to generalities reported for the halogen-substituted phenoxyacetic acid series. The derivatives of L- and DL-amino acids reported here proved generally to be active plant-growth regulators with high selectivity during the test period on the assay plants used; an exception was the derivative of L-tryptophan, which was completely inactive. The D-amino acid derivatives were almost completely lacking in growth-regulating properties with the exceptions of the D-alanine and D-tryptophan derivatives which showed some degree of activity. Most of these derivatives are easily prepared and purified and those with sharp melting points may be useful in characterization of amino acids.

Aryloxyalkyl carboxylic acids form an important group of synthetic growth-regulating substances now available; of these DL-2-(2,4,5-trichlorophenoxy)propionic acid, designated 2,4,5-TP, has achieved merit. Recently the optical forms of the amino acids derivatized with 2-(2,4-DP) (*4*) have shown a specificity in their mode of action on plant growth, indicating a varying relationship between the optical configuration of the amino acid and the biological activity. The need for further studies using an extended series of these amino acids was evident. Hence the reason for preparing this series of D-, L-, and DL-amino acid derivatives of 2,4,5-TP. This work with 33 new compounds represents an elaboration of previous studies (*4–6*) in which only 18 compounds were prepared for each series.

Many of the compounds in this and in series previously reported (*3–8*) have now been submitted to various agencies for evaluation as anticancer agents, estrogenic substances, fungicides, herbicides, insecticides, and nematocides.

[1] Present address, Courtaulds, Inc., Mobile, Ala.

Experimental

The general procedure used in the preparation of the amino acid derivatives of 2,4,5-TP was that previously described (*5*) utilizing Schotten-Baumann techniques. The 2,4,5-TP used was of technical grade and the amino acids were the best obtainable from commercial sources.

2-(2,4,5-Trichlorophenoxy)propionyl Chloride. A 73% yield of this compound was obtained by the reaction of 2,4,5-TP (1 mole) with thionyl chloride (1.7 moles) essentially as described (*7*). The acid chloride boiled at 111–17° C. and 0.3 mm. of mercury, with a constant index of refraction (n_D^{26} = 1.5601).

An abbreviated description illustrates the general procedure employed (*5*) in the preparation of the amino acid derivatives of 2,4,5-TP.

***N*-[DL-2-(2,4,5-Trichlorophenoxy)-propionyl]-L-methionine.** In the cases involving the preparation of L-methionine, L-leucine, and L-phenylalanine derivatives of 2,4,5-TP, 0.03 to 0.04 molar ratios of amino acid to acid chloride were used. For cystine derivatives ratios were 2 to 1; all other derivatives were synthesized with 1 to 1 proportions. For synthesis of the L-methionine derivative 4.48 grams of the amino acid were used with 11.5 grams of 2-(2,4,5-trichlorophenoxy)-propionyl chloride; this produced a crude yield of 9.80 grams (81.5%) with a melting range of 120° to 128° C. The crude product was dissolved in boiling ethyl acetate and precipitated with petroleum ether (boiling point 63° to 70° C.). The final yield was 7.93 grams (66.0%) melting at 127° to 130.5° C. (Table I).

The most difficult amino acid derivatives to prepare were those of DL-aspartic acid, DL-cystine, and D-, L-, and DL-leucine. These separated as oils and