SOIL AND TISSUE TESTING CONFERENCE

Department of Soils
Ontario Agricultural College
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ADVISORY FERTILIZER BOARD MEETING  
and  
SOIL AND TISSUE TESTING CONFERENCE  
March 10, 1960.  

N. R. Richards  

I am pleased to welcome you to this meeting of the Advisory Fertilizer Board and to the Soil Testing Conference. For a number of years it has been the custom of the Advisory Board to hold an open meeting the day prior to our annual meeting. The program for the open meeting has been arranged by the Research Review Committee with a view to presenting the results of recent investigational work in the field of fertilizer use. A year ago we discussed such topics as the economics of fertilizer use, fertilizer placement, and inclusion of insecticides with fertilizer for soil application.

In planning this meeting, the committee of the Advisory Board felt that those who would attend our meeting from industry and from the different branches of the Department of Agriculture would have a common interest in developments that have taken place in the field of soil testing. The program that has been arranged will provide an opportunity to not only bring you up to date concerning developments but to review the place of soil testing in advisory programs in the Department of Agriculture and its importance to industry as well.

I am very pleased to welcome former members of the Board who are meeting with us.

This is not the first soil testing conference we have held in the department. It is now about twenty-five years since the first meeting was held. According to Mr. Hampson a group assembled at Vineland at which time Mr. Scarseth and Mr. Hoffer, names well know in the field of soil testing were present. It was following 1935 that greater emphasis was placed on soil testing here in Ontario and the late Professor Ruhnke gave active and brilliant leadership in this particular field.

The first soil testing conference with which we in the Department were most closely associated was held in 1952. In reading over the report that was published following that conference the following recommendations were made.

1. That this meeting go on record as approving present soil testing services as are now available in Ontario, at the same time realizing their limitations and the need for correlating them with tissue tests, plant symptoms, and physical characteristics of the soil.

2. That this meeting recommends that the soils laboratory of the O.A.C. become the reference laboratory for soil testing in Ontario, excepting greenhouse soils.

3. That this meeting strongly recommends accelerating research aimed at providing further correlations of soil tests with plant performance in the field.

4. That this meeting go on record as recommending a speed-up program on the publication of soil maps and reports.

I do not intend to take the time to discuss what action has been taken concerning these recommendations. As the papers are presented during this morning, the answer should be evident.
At the close of our 1956 Soil and Tissue Testing Conference we agreed that we would not hold another meeting until such time as we felt it necessary to report to you concerning changes, improvements and progress in general. This appears to be an appropriate time to call those interested in soil testing together.

Since our last meeting the development associated with our soil testing program that has afforded me great personal satisfaction has been the witness of the completion and occupancy of the new building. We recognize that physical facilities are of little value unless staff is available to make use of them. The facilities provided in this building make it possible for the staff members to use their training and talents to good advantage. We have come through a tremendously interesting and challenging period in the agricultural history and development of Canada. Those of us associated with soils work, be it in the field of research, or advisory services, with government or industrial agencies must be conscious of the need for providing accurate and precise agronomic information to our farmers to help them cope with the many complexities with which they are faced.

In our research endeavours in the department we have placed more effort and time in projects related to soil testing than any other single endeavour. But research results are of small value unless they are interpreted and find application at the farm level. In my opinion, we have in soil testing programs one of the best examples available to illustrate the integration of research endeavours with effective advisory services.

As soil testing methods have been improved and refined they have not been simplified. The "quick test" as we once knew it no longer exists. With refinement and improvement have come methods and procedures that remove testing of soils from the realm of any quick test procedure. The objective of soil testing is to provide as precise information as possible for making fertilizer recommendations. To-day with the type of soil testing service available to farmers in Ontario it is a part, and a very real part of the overall farm management program in that it is designed to help in "decision-making" on the farm and form the basis for using the fertilizer dollar to the greatest possible profitable advantage.
DEVELOPMENTS AND REFINEMENTS IN SOIL TESTING METHODS

T.J. Heeg, Associate Professor

We have been soil testing at O.A.C. since about 1930. The first system of testing used in the old Chemistry Department was that of Spurway. This was essentially a water soluble extract of the soil on which we determined nitrate nitrogen, phosphate, potash, calcium and magnesium. pH was determined with brom thymol blue, using wax paper strips.

When soils work moved to the old Horticulture Building, later called the old Soils Building, the methods for phosphate and potash were changed to the Thornton system. Phosphate was extracted by a solution of HCl which was about 0.75 normal and in which was dissolved ammonium molybdate. The latter was considered not to have any phosphate dissolving power, but was placed in the extracting solution for convenience. This saved the separate operation of having to add it later to develop the well known phospho-molybdenum blue colour.

The Thornton potash method consisted of extracting the soil with sodium cobaltii nitrate solution. The sodium acted as the exchange ion for potassium in the soil. After filtering, a standard aliquot of 5 ml. was taken for analysis. Isopropyl alcohol was added to this extract and potash was precipitated as sodium potassium cobaltii nitrate. The yellow orange turbidity was measured against standard colour charts.

While this was a relatively rapid method, it was an inaccurate one. Our readings were usually reliable on soils which were low or high in potash, but were anything but reproducible on medium amounts. The method was extremely sensitive to temperature so that hot summer days gave us lower readings than cool summer days. We tried to correct this with a standard temperature bath and while this helped, it was still not satisfactory.

A new potash method was considered of first importance and this was the target in our research program. We were greatly aided at this point by the development of flame photometers of simpler construction and ease of operation. Our chief concern then was not how to make the reading, but what should be the extracting solution. Prof. J.A. Smith of our soil testing research staff, after trying several extracting solutions, decided upon 0.1 N NH₄Ac with 0.05 N H₂SO₄. The potash extracted by this solution gave the best correlations with field trials of those methods tested. We are often asked why we have the weak sulphuric acid solution with ammonium acetate. This can be explained by the fact that Prof. Smith was searching for a solution which would extract both phosphorus and potassium in one operation. The solution was not found suitable for phosphorus extraction, but did give good results for potassium. There was no point in repeating all the work over with ammonium acetate in different concentrations because of the correlations which were obtained with the solution as it was.

The new potash method came into use in October 1955 and the method is appended to this article.

Coming back to the method for determining phosphate, it was mentioned that Spurway was our first effort. About 1936 we changed to the Thornton techniques. In the short time in which this method was used it was found to give very high phosphate readings on soils which we knew responded to phosphate fertilizer. Prof. W.T. Ewen, working with the late C.P. Rivaz under the direction of the late Prof. G.N. Ruhnke, worked on various phosphate extracting solutions and used as a guide the Neubauer technique. Of the solutions used, 0.05 N HCl gave results which agreed most closely to the Neubauer method and this solution was used in the test lab from 1937 until July 1957.
Prof. J. A. Smith worked on new methods of determining phosphate and correlated his results to field plot data obtained by Mr. R. W. Sheard. He concluded that a modified Bray phosphate test gave better correlations than our old 0.05 N HCl method and others which were tried. The new method uses as an extracting solution 0.1 N HCl in which is dissolved 0.05 N NH₄F. The 0.1 N HCl dissolves the acid soluble phosphate and the 0.05 N NH₄F removes adsorbed phosphate from the soil. As might be expected this method gives much higher phosphate readings for most soils than did our old method. There are two reasons for this. The HCl is twice as strong and therefore would automatically dissolve more phosphate. In addition we are replacing adsorbed phosphate which we previously did not measure. More work is being done at present in the hope of further improvement in phosphate testing.

Our latest addition to the soil test program came on March 1, 1960. At this time we officially started a new incubation nitrogen test. We were actually ready to proceed with this test about a year ago, but our constant temperature equipment was not operating to our satisfaction.

Details of the nitrogen incubation test are reported in the Can. Journal of Soil Science, Aug. 1958. The incubation test is a modification of similar procedures developed by Fitts, Bartholomew, and Heidel along with Hanway and Dumanil, all of whom were working in Iowa. The Ontario modification of the test was established by Mr. D. J. Eagle and was a thesis project in the Department of Soils under the direction of Dr. B. C. Matthews.

Our method requires that the soil be incubated for a one week period at a temperature of 95°F. and under high humidity (95% preferred). At the end of one week the nitrate nitrogen generated is leached from the soil and determined by the phenoldisulphonic acid procedure.

We use glass tubes about 3" long and of 1" diameter. A plastic cap with a small perforation is placed over the bottom. Then is added 2 teaspoons of vermiculite, 2 teaspoons of soil and another 2 teaspoons of vermiculite. 5 ml. of water is added which is sufficient to moisten the top layer of vermiculite and the soil, but not all of the bottom layer of vermiculite. This assures the soil being moist, but not saturated. A perforated cap is placed on the top and incubation is proceeded with.

Original incubation techniques actually call for 2 extractions of the soil with water - one before incubation to wash out nitrate presently there and the second at the end of incubation. The NO₃ in the first portion could be determined separately if so desired. The thought occurred to us that one extraction after incubation might do. It was gratifying to learn on analyzing our data that our correlations with crop response were better with the one extraction than with two. This makes the method simpler and certainly less expensive from the labour standpoint.

There are specific requirements in sampling which must be adhered to for good results in the nitrogen incubation test. Best correlations are obtained when samples are taken moist or wet as in the spring or fall. Samples which are allowed to air dry for long periods before analysis result in dormant or dead micro-organisms. Such samples cannot be treated to overcome dormancy.

When samples are taken from fields in mid-summer when the soil appears dry, a good nitrogen test is still possible, but a two week chill period at 40°F. is required before incubation. Field dry is not quite as dry as air dry. However, field dry samples will dry further, in even a half hour on a warm sunny day. We recommend that such samples be moistened immediately after placing them in the soil box, with a few tablespoons of clean water.

One of the great problems confronting any laboratory is the treatment even of wet samples for nitrogen test. If the laboratory is busy we cannot store these samples on simple racks. We propose
to dry the samples overnight at 95°F. and prepare them immediately. A portion will be put into incubation tubes and remoistened. Thence they can be incubated immediately or stored cool at 40°F. until space or time permits incubation. There may still be some production bugs to exterminate as we gain experience with the method and these will likely show themselves from the time of arrival of samples through the drying, preparation and storage period. I do not foresee too much trouble from the time incubation starts through the analysis.

The other determinations regularly made in our soil test laboratory are pH, calcium and magnesium. Our present method of determining pH dates back to 1939. Previous to this time we were using the indicator dyes of brom thymol blue and brom cresol green. Little work was reported up to this time determining soil pH by the new glass electrode meters. The author of this paper tried many soil samples with varying amounts of water. It was found that a mud made by adding just enough water to wet the soil, without free water floating on the surface, gave the most stable readings. When surplus water was present, pH fluctuated considerably, but with time and no additional stirring, the eventual pH came to rest at the same point as that registered by the paste or mud method. Many American laboratories are using a soil water ratio of 1:1 or 1:2 or 1:5 and use a stirring device while pH is being read. The stirring device eliminates pH drifting with the soil settling out of suspension. However, we have retained our paste method on the premise that a soil with no free water comes closer to actual values in the field when such soil is at field capacity.

We are still determining calcium and magnesium in the water soluble forms. About 1945 the author modified the methods to give more accuracy than was permitted by the original Spurway method. These methods are given in detail below. Our future researches will be directed at even greater accuracy in the reading of these elements.

We make additional determinations than those discussed above in our laboratory. Our tobacco men like to have an estimate of the chloride and sulphate content of samples for tobacco fields. On soils over pH 7.0 we sometimes like to know how much carbonate appears in the soil as judged by effervescence on addition of dilute HCl.

On samples with very high readings of nitrogen, potash, chlorides or sulphates, where we suspect soluble salt accumulations we make a solu-bridge test. This is a most useful test on samples from home gardens, fields near highway sand piles and other areas when growth is impaired but cannot be related to low fertility.
ESTABLISHMENT OF A GROWER LEAF ANALYSIS SERVICE

J. A. Archibald,
Research Scientist, H. E. Station
Vineland Station, Ontario.

At the time of the last Soil and Tissue Testing Conference four years ago, I outlined to you the need for the establishment of a Leaf Analysis Service for tree fruit crops and also the steps which we were planning to take to provide such a service. Now, four years later, the preliminary work we outlined at that time has been completed and the service has been in operation for two years. Also, in 1956, I pointed out that our laboratory facilities were totally inadequate. I am pleased to report that this situation has now been corrected. We now occupy a new, well equipped administration and laboratory building with adequate facilities for carrying on the leaf analysis work.

For a more detailed report both on the preliminary research work and on the actual establishment of a grower service, you are referred to the following two articles in the 1957-1958 Report of the Horticultural Experiment Station and Products Laboratory, (1) Nutrient Status of Ontario Peach and Apple Orchards as Determined by Leaf Analysis, pages 8 to 14, and (2) Establishment of a Grower Leaf Analysis Service, pages 59 to 65.

As we mentioned to you four years ago, a survey was made of a large number of apple and peach orchards to determine the present status of nutrition in these orchards and also to determine seasonal and varietal differences in leaf composition. This survey was carried out during the 1955, 56 and 57 seasons. Several interesting results came out of this study. Perhaps the most striking was the marked effect of season in altering the nutrient levels in the leaf, particularly for nitrogen and potassium. The 1955 season was hot and dry with a total rainfall for the April to July period of 8.7 inches. This compared to 13.9 in 1956 and 12.6 in 1957. For the same 4-month period, degree-day heat units above 50° totalled 1,786 in 1955, 1,234 in 1956 and 1,498 in 1957. As an example of the marked effect season had on nitrogen and potassium levels, the nitrogen level of the Elberta peach variety was 3.06 in 1955, 3.52 in 1956, 3.48 in 1957. The potassium level was 1.41% in 1955, 2.02% in 1956 and 2.29% in 1957. These results point up the need for considering season variation in interpreting the results of leaf analyses. Failure to observe such seasonal differences could result in serious misinterpretation of results.

Variatel differences in composition also became apparent for both peaches and apples. The Golden Jubilee and Elberta varieties were significantly lower in nitrogen and higher in potassium than were the Redhaven and Veteran varieties. The Delicious variety of apple was highest in nitrogen of the 3 varieties, Delicious, Northern Spy and McIntosh. The potassium level of the McIntosh variety was lower than for the other two.

Cost of production survey results were available for all peach orchards included in this study. An attempt was made to correlate yield with nutrient status. The most striking relationship here was between nitrogen and yield, higher nitrogen levels being consistently associated with higher yield of peaches. Observational results in 1956 in particular, indicated a close association between potassium level of peach foliage and degree of fruit set. Conditions for setting fruit were particularly adverse in that year and the general peach crop was light.
With the results of this survey and a similar one on grapes, and more adequate facilities, we felt we were in a position to offer a service beginning in 1958. I should make clear here that we do not claim to have all the answers as to what the levels should be, and expect that as the work progresses, we will be making modifications in the recommendations as to optimum levels for the various crops involved. We did feel that we had enough information to provide a service of considerable value to the grower and certainly of more value than the soil testing service had been. Early in 1958 the Honourable Mr. Goodfellow, the Minister of Agriculture, approved the establishment of the Leaf Analysis Service, and also approved a charge of $5 per sample being levied.

One of the most important sources of error in providing leaf analysis service is in the collection of samples. It seemed to us rather foolish to do a lot of work on setting up standards and improving our laboratory techniques if we were not to have control over the collection of samples. As most of you are aware, there is a considerable variation between the nutrient status of leaves from different parts of the tree and also from very early to late season. In order to overcome this serious sampling problem we obtained the support of Mr. W. B. Fox, Director of Fruit and Vegetable Extension Services, who agreed to having his men collect the samples in their own areas. During the two years the service has been in operation this plan has worked very well. Not only are we assured that the sample is properly taken at the proper time, but the observations of the extension specialist for the particular orchards where the sample is taken, are valuable in making recommendations.

A rather detailed questionnaire form was prepared, a copy of which is contained in the publication No. 2 listed above. There is considerably more information requested on this form than on the soil testing questionnaire form. We have been particularly pleased with the response of the growers to this questionnaire form. Nine out of ten of them have been completely filled out. This seems particularly strange when we have had difficulty in the past in getting growers to complete the much less detailed soil testing questionnaire form. Apparently, if they are paying for the service there is more interest in supplying as much and as accurate information as they can. This is perhaps understandable since they realize this will enable us to give a more accurate recommendation.

Growers wishing to make use of the Leaf Analysis Service are asked to contact their Extension Specialist before mid-June. Reminders of the service are contained in the spray letters that are sent out in the spring from the various extension offices. The grower is asked to return the completed form along with the fee of $5 per sample, to the extension man. By having these forms returned to him by mid-June he can plan his work so that the collection of samples in July will not interfere too seriously with his normal activities and can be fitted in with them. Samples for peaches and apples are collected in mid-July, and samples for grapes in early September. The samples are then forwarded to us at Vineland where the analyses are made. Results of these analyses along with recommendations are returned to the grower not later than the end of December. In this way he is able to plan his orchard operation for the following spring and to take advantage of the discounts available early in the year on fertilizer materials.

Just a word about methods. All samples are air dried on receipt if they have not been previously dried. They are then ground in a Wiley mill and dried to constant weight at 70°C. One-gram samples are weighed out in duplicate for mineral determinations and duplicate samples of the same size for nitrogen. Nitrogen is determined by the standard Kjeldahl-Gunning procedure. While this is time consuming we have found no alternative. Samples for mineral analyses are ashed for 4 to 6 hours at 500°C. The sample is then taken up in dilute hydrochloric acid solution. Potassium is determined using a hydrogen flame with a Beckman DU flame attachment. Originally
we attempted to determine calcium and magnesium with the flame but have experienced some difficulty particularly in samples with high phosphorus contents. We have found that when enough phosphorus is added to eliminate the variation due to phosphorus content, the sensitivity of the machine for determining calcium levels becomes too low. The slit must be opened too wide. For this reason we have reverted to the turbidimetric soap method for calcium and the Thiazole yellow method for magnesium as outlined in Contribution #238, Chemistry Division, Science Service, Chemical Methods of Plant Analysis by Ward and Johnston. Phosphorus is determined colorimetrically by the standard phospho-molybdenum blue method outlined in the same publication.

What has been the grower acceptance of the service to date? Prior to the establishment of the service in 1958 I was asked to make an estimate of the number of samples we expected to receive for the tree crops at present included in the service. I predicted 200 samples. Actually in 1958 we received 280 apple, 63 peach and 33 grape samples - a total of 376. In 1959 we received 195 apple, 62 peach and 57 grape samples - a total of 314. A number of the apple growers requested results of their nitrogen analyses before the apples were put in storage after picking. Nitrogen determinations were made first on the apple samples and the results of these determinations were made available by the first of September, because of the interest in the relation between storage life and nitrogen level.

Surveys are at present underway to determine the nutrient status of Kieffer and Bartlett pear and Montmorency cherry orchards in the province. The third year of this survey will be completed in 1960 and it is hoped to add these crops to the Service in 1961.
FIELD RESEARCH AND DEVELOPMENT OF FERTILIZER REQUIREMENT TABLES

B.C. Matthews
Department of Soils, O.A.C.

During the next few minutes I hope (1) to give you a broad outline of our research activities in the area of soil testing during the past four years, (2) to indicate the present status of our soil test methods in regard to the interpretation of the results, and (3) to suggest the direction in which our research is likely to go in the immediate future. Professor Heeg has outlined the methods which we are now using in our soil testing laboratory. I am sure that neither he nor I wish to suggest that our present methods are entirely satisfactory. On the contrary, there is still much to be done in improving the accuracy and reliability of these tests. However, we have made some significant progress during the four years since the last soil testing conference.

The Approach:

At this stage I think it might be wise to review briefly the general objectives and the approach that we have used in developing and refining our soil test methods. In order to have a useful soil testing service, three things are necessary: (1) the methods must be reproducible, that is, we must be able to obtain the same result on the same sample every time it is analyzed. This is a relatively simple problem because it involves only laboratory study. Indeed there are many different methods of soil analysis which are reproducible. (2) a soil testing method must be correlated with actual crop yields in the field and so it is necessary from the many methods which have been or could be devised to show that one method gives a greater correlation or allows us to predict more accurately the actual crop yields in the field. (3) the soil test be calibrated in terms of fertilizer required to give any required yield increase.

The last two requirements necessitate field fertilizer experiments. The crop itself is the final judge of the value and calibration of a soil test. In order to correlate the results of a soil test with the crop yield in the field it is necessary to have some measure of the crop yield which is not affected by variations in climate or rainfall or other factors which are not measured by the soil test. For this purpose, we use the so-called percentage yield concept. In other words, rather than correlate the soil test results with the absolute yield of the crop we correlate it with the yield of crop obtained without the fertilizer as a percentage of the maximum yield possible on that location if adequate fertilizer is supplied. The relationship between percentage yield and the soil test is given by the equation \( \log (100 - Y) = \log 100 - c_1b_1 \). In this equation \( Y \) equals the yield of plot receiving no fertilizer expressed as the percentage of the yield of the plot receiving adequate amounts of fertilizer, \( b_1 \) is the soil test value and \( c_1 \) is the constant which indicates the efficiency with which the soil nutrients may be utilized by the particular crop.

In order to evaluate any number of soil tests it is only necessary therefore to determine the correlation between the soil test \( b_1 \) and the value \( \log (100 - Y) \). By actual experiment in the field therefore we determine \( Y \) by yield measurement and we determine \( b_1 \) by analysis of the soil sample from the particular plot and then we can determine the degree of correlation between the two values.
### TABLE 1

Correlation of Phosphorus Tests With Log (100-% yield) of Several Crops

<table>
<thead>
<tr>
<th>Method No.</th>
<th>Extractant</th>
<th>Correlation Coefficient (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Wheat</td>
</tr>
<tr>
<td>1</td>
<td>(PA₂) 0.1 N HCl + 0.05 N NH₄F, (1:10)</td>
<td>-0.51**</td>
</tr>
<tr>
<td>2</td>
<td>(PA₁) 0.025 N HCl + 0.05 N NH₄F, (1:10)</td>
<td>-0.48**</td>
</tr>
<tr>
<td>3</td>
<td>(PS₀) 0.1 N NH₄Ac + 0.05 N H₂SO₄, (1:10)</td>
<td>-0.42**</td>
</tr>
<tr>
<td>4</td>
<td>0.05 N HCl (1:4)</td>
<td>-0.35*</td>
</tr>
</tbody>
</table>

* significant at 5% level  
** significant at 1% level.

**Phosphorus Soil Test:**

Although we have studied the correlation between the yield of several crops and the soil analysis by a total of fourteen different soil tests we are showing the results for four of the best phosphorus tests in Table 1. The higher the correlation coefficient the more satisfactory is the soil test. You will note the degree of correlation with various methods for these several crops. The method number 4 is the method which was originally used in this laboratory but it has now been replaced by method number 1 which is in fact the modified PA₂ method as originally described by Bray. For the several crops studied the average correlation coefficient for the PA₂ test was 0.46 which is the highest of all the methods studied.

**Potassium Tests:**

We have similar information for several potassium methods of soil analysis. The modified Thornton method which was used in this laboratory originally did not give reproducible results. With the introduction of the flame photometer it was possible to discard this method entirely. At the present time the method which we are using is method number 1 which gives us an average correlation of -0.49. We have, however, some evidence that the exchangeable potassium as measured by method number 1 is not adequate for prediction of crop yields. It is becoming evident that a method such as number 3 which measures exchangeable potassium as well as the so-called non-exchangeable potassium will give a better correlation. The data shown in Table 2 indicate this fact.
TABLE 2

Correlation of Potassium Test Methods With Yields of Several Crops

<table>
<thead>
<tr>
<th>Method No.</th>
<th>Extractant</th>
<th>Correlation Coefficient (r) (1)</th>
<th>Wheat</th>
<th>Oats</th>
<th>Corn</th>
<th>Potatoes</th>
<th>Ave.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.1 N NH₄ Ac + 0.05N H₂SO₄. (1:10) (soil air-dry) (2)</td>
<td>-0.34** -0.24** -0.37** -0.72**</td>
<td>-0.49*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Modified Thornton</td>
<td>results not reproducible.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.1N NH₄Ac (Exch. K) + resin extraction (Non-exch. K) (3)</td>
<td>-0.55** -0.58** -0.54** -0.76**</td>
<td>-0.61**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Exch. K expressed as % K. sat’n (3)</td>
<td>-0.34 +0.43 -0.07 -0.29</td>
<td>-0.07</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*significant at 5% level (1) correlation of soil test values with Log (100-Y0)
**significant at 1% level (2) average of five seasons (3) average of three seasons

At the present time, however, Method 1 is being used in our laboratory. As more information becomes available we may be able to change to Method No. 3.

Nitrogen Tests:

As you are aware, the methods for analyzing soil for available nitrogen have not been satisfactory. In fact, in our laboratory we have not measured the nitrogen status for quite a number of years. However, on March 1 of this year we did begin the routine analysis of soil samples for nitrogen and the basis for the choice of nitrogen tests is shown in Table 3. The nitrate content of soil at any given time is known to vary depending on the weather conditions and crop growth during the time immediately preceding the taking of the sample. Because the nitrogen availability over a growing season is related to the release of nitrogen from the organic matter in the soil, an incubation method has been developed, first in Iowa and then modified in this laboratory here. We have found no correlation between the nitrate content of the soil initially and the crop yield. We do, however, find a correlation between the nitrogen release during a seven day incubation period and crop yield. The highest correlation, however, comes from the soil test which includes the initial nitrogen and the nitrogen released by a seven day incubation period. This gives us a correlation coefficient of -0.41. Therefore the method no. 3 is the method which we are currently using for nitrogen analysis of our soils.
TABLE 3
Correlation of Nitrogen Test Methods With Yields of Several Crops

<table>
<thead>
<tr>
<th>Method No.</th>
<th>Extractant</th>
<th>Correlation Coefficient (r) (I)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Wheat</td>
</tr>
<tr>
<td>1</td>
<td>Initial Nitrate</td>
<td>-0.30**</td>
</tr>
<tr>
<td>2</td>
<td>Incubation N (7 days)</td>
<td>-0.26**</td>
</tr>
<tr>
<td>3</td>
<td>Sum of initial N + Incubation N</td>
<td>-0.39**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) average of three seasons Log (100-Y) as soil test
* significant at 5% level
** significant at 1% level

Calculation of \( c_1 \) Value

After we have chosen on the basis of degree of correlation the best soil test method for each of these nutrients, it is then necessary to go back to the equation which we presented originally and calculate the \( c_1 \) value which is supposed to be a constant indicating the efficiency with which that soil nutrient may be utilized by different crops. This \( c_1 \) value is in fact not a constant because it varies with different crops and therefore it is necessary to set up a different equation for each crop. The variation in \( c_1 \) value for several crops is shown in Table 4.

TABLE 4
Average \( c_1 \) value for Several Crops
1955-56-57-58-59

<table>
<thead>
<tr>
<th>Crop</th>
<th>( c_1 ) value for Nitrogen</th>
<th>( c_1 ) value for Phosphorus</th>
<th>( c_1 ) value for Potassium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>.00541 (3)*</td>
<td>.00483 (4)</td>
<td>.00607 (4)</td>
</tr>
<tr>
<td>Oats</td>
<td>.00573 (4)</td>
<td>.00592 (5)</td>
<td>.00528 (5)</td>
</tr>
<tr>
<td>Corn</td>
<td>.00752 (4)</td>
<td>.00691 (3)</td>
<td>.00561 (5)</td>
</tr>
<tr>
<td>Potatoes</td>
<td>.00790 (4)</td>
<td>.00162 (6)</td>
<td>.00384 (6)</td>
</tr>
<tr>
<td>Hay</td>
<td>.00534 (2)</td>
<td>.00534 (2)</td>
<td>.00460 (2)</td>
</tr>
</tbody>
</table>

* brackets indicate number of season included in average

This variation in \( c_1 \) value from one crop to the other requires therefore that we make a different interpretation of the soil test depending on the crop which is to be grown.

I might also add that the \( c_1 \) value varies from one soil to another and in fact from one season to another. However, we do not as yet have sufficient information to set up a different efficiency constant for different groups of soils for each crop, therefore, we have averaged the efficiency constants for all soils for any particular crop. This indeed brings in some error in the fertilizer requirements tables which are eventually developed but it is unavoidable at this stage in our research.
Calibration of Soil Tests:

After having evaluated the soil test method and having determined the crop yield that can be expected on a soil of a given soil test without any fertilizer added, the next step is to calibrate the soil of a given test without any fertilizer added, the next step is to calibrate the soil test so that we can predict the amount of fertilizer required to give a certain percentage of the maximum possible yield. This is done in the field by adding some additional plots which receive amounts of fertilizer intermediate between the zero rate and the maximum rate. Then it is possible by knowing the soil test and measuring the percentage yield Y and knowing how much fertilizer has been added X, we can calculate the value for c which is in fact, a measure of the efficiency with which the applied fertilizer is utilized by the crop. The efficiency constant for fertilizer use is in fact, not a constant but it varies again with the kind of crop. So it is necessary to establish a different c value for each crop. The efficiency constant also varies with the placement of the fertilizer and therefore the calculation of c value is related to a specific fertilizer placement. Furthermore, as was indicated for the $c_1$ value, the soil type and the weather conditions of the season also affect the c value, however, at the present stage of our research it is not possible to establish a different $c_1$ value for different groups of soil. Therefore, the average $c_1$ values shown in Table 5 are averages over all soils in all seasons but are specific for the different crops listed.

TABLE 5

Average c Values for Different Crops
1955-56-57-58-59

<table>
<thead>
<tr>
<th>Crop</th>
<th>c value for Nitrogen</th>
<th>Phosphorus</th>
<th>Potassium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>.0176 (3)*</td>
<td>.0128 (4)</td>
<td>.0170 (4)</td>
</tr>
<tr>
<td>Oats</td>
<td>.0256 (4)</td>
<td>.0119 (5)</td>
<td>.0149 (5)</td>
</tr>
<tr>
<td>Corn</td>
<td>.00645 (4)</td>
<td>.00770 (3)</td>
<td>.00674 (5)</td>
</tr>
<tr>
<td>Potatoes</td>
<td>.00910 (4)</td>
<td>.00861 (6)</td>
<td>.00695 (6)</td>
</tr>
<tr>
<td>Hay</td>
<td>.00983 (2)</td>
<td>.0102 (2)</td>
<td></td>
</tr>
</tbody>
</table>

* brackets indicate number of seasons included in average.

As a result of the field and laboratory research over the past five years, it is therefore possible to set up equations for each of several crops showing the relationship between percentage yield of crops, soil tests, and fertilizers required.

Fertilizer Requirement Tables:

In the setting up of fertilizer requirement tables, therefore, it is simply necessary to insert in the equation the percentage yield Y which is desired, and then showing the value of fertilizer required for any particular value of the soil test varying from the lowest to the highest range. Because of the fact that the $c_1$ and c values vary from crop to crop and from nutrient to nutrient, it is necessary to have a different requirement table for each nutrient for each crop and this in fact has been done and we have an example of such a requirement table available in printed form.
The Significance of the Fertilizer Requirement Tables:

These fertilizer requirement tables indicate a remarkable step forward in the science of soil testing. It has never been possible before in Ontario at least to present such a good guide for the interpretation of soil analyses. To be sure, the fertilizer requirement tables are not 100% perfect. They do include some approximations particularly in the averaging of these efficiency constants over all soils and seasons. They do, however, give a much more precise guide to those making recommendations. One of the important results of the establishment of these requirement tables is that it is now possible to transfer the task of making the recommendations out to the agricultural representatives in the County offices. This procedure has the advantage in the fact that the agricultural representative usually knows the farm and the farmers in his area much better than an extension person located at the College or elsewhere. The agricultural representatives in several Counties are now making the fertilizer recommendations and others are expected to assume that task in the coming year.
SOIL TESTS - A GOOD SALES TOOL

Werner L. Nelson, American Potash Institute

Soil tests are a good tool for increasing fertilizer sales. You are always looking for ways to increase. If you have sold soil tests, the chances are you have sold the fertilizer. Selling must be based on something, so why not base it on need? In addition to making money for yourself you are enabling your customer to have the kind of fertilizer program which is best for his farm.

What's Best for the Farmer is Best for the Fertilizer Industry

His income will increase.
Your income will increase.

Heavier Users Have More Soil Tests

The farmer by his own admission says that soil tests are a great influence on purchase of fertilizer. A recent survey (NPF) showed the high fertilizer users to be employing soil tests to a greater extent than the low users.

<table>
<thead>
<tr>
<th>Level of Fertilizer Use</th>
<th>% Having Soil Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>63</td>
</tr>
<tr>
<td>Medium</td>
<td>49</td>
</tr>
<tr>
<td>Low</td>
<td>40</td>
</tr>
<tr>
<td>None</td>
<td>24</td>
</tr>
</tbody>
</table>

Soil Testing - A Connecting Link

The official agronomists are saying, "Soil testing is the connecting link between soils research and the farmer." This means that you have the blessing of the agronomists in pushing soil tests.

The fertilizer industry is one of the few industries which has official agricultural groups making tests on an individual field basis to determine what is needed, and then recommending the amount of the industry product needed. The information is being extended to the fertilizer industry. All we need to do is reach out and take it.

Why Soil Tests Help the Industry

1. Grower feels dealer is sincere,
2. Grower uses fertilizer dollar more efficiently,
3. Grower uses more fertilizer,
4. Grower understands fertilization program better,
5. A concrete thing to discuss with grower,
6. Brings in new grower customers,
7. Grower is a satisfied customer, will be back next year,
8. Grower has more money to spend, can buy more of what dealer sells.
More Fertilizer Used

Almost invariably, recommendations based on soil tests will suggest more fertilizer than the farmer is using. Occasionally the fertilizer industry complains that the average recommendations based on soil tests are not high enough. This may be true for a few individual farmers, but on request, special recommendations will be made for these men.

The vast majority are using much less than is recommended. For example, in Ohio in 1957 the average use per cropland acre, excluding pastures, as compared with estimated need was:

<table>
<thead>
<tr>
<th></th>
<th>Use</th>
<th>Need</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>12.0 lbs.</td>
<td>Double</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>26.8 lbs.</td>
<td>Over double</td>
</tr>
<tr>
<td>K₂O</td>
<td>24.8 lbs.</td>
<td>Double</td>
</tr>
</tbody>
</table>

Parts of A Soil Testing Program

1. Sampling.
2. Testing the soil.
3. Calibrating tests.
4. Interpretation and recommendations.
5. Servicing and determining how well the recommendation worked.

*The salesman and dealer can best assist in 1 and 5.

Sampling

The biggest problem in soil testing today is taking the samples. The farmer believes in soil testing but does not get around to sampling. Why?

1. He keeps putting it off until just before he needs fertilizer.
2. He thinks it is too complicated.
3. He believes he does not have proper tools.
4. It is difficult to send in samples.
5. He is not sufficiently motivated.

Dealer opportunity. Here is a real opportunity for the dealer. He might try to motivate the grower by having boxes, information sheets, and sampling tools handy. He might promote a special soil sampling week. These are all good but the sampling still depends on the farmer.
A surefire way to get the samples is for the salesman or dealer to take them himself or hire it done. He must receive training on taking samples, however, and his county agent or extension specialist will be glad to provide training. The salesman then sends the sample to an official laboratory for testing.

Cost. Cost of sampling will vary considerably but it should average around $1.00 per sample. There are many ways to take care of this. One possibility is to charge the farmer for sampling and the testing. This charge can be deducted from the bill if the farmer buys his fertilizer from the dealer. The farmer will probably appreciate testing more if he is charged initially.

Making the Sale

In Ohio when the recommendations are mailed to the farmer, a copy goes to the salesman or dealer who sent in the samples. This is a signal for an approach to the farmer to help explain the recommendations and to sell him the fertilizer. What better entree is there?

Service

Advisory. Farmers are demanding more service. This is an incentive for the dealer to get the knowledge to be able to help. Knowledge, not only on proper fertilizer use, but also on management practices and limiting factors is essential. This knowledge can be obtained from official sources through schools, field days, etc. A well-informed dealer can be of much help to the farmer as he is the last man to see the farmer before the fertilizer is purchased.

Follow-up. Observation of the customer’s crops during the growing season does three things: (1) Helps to determine if fertilization program is adequate, (2) Convinces grower that the dealer is sincere, (3) Encourages the customer to come back.

Soil analysis and recommendations are usually good for four years or more. Hence the initial effort and cost of sampling and testing soil is an investment. It pays dividends for three or four years in terms of improved yields for the grower and more sales for the dealer.

Lime is No. 1

Lime is the first fertility factor to consider in order that full returns be obtained from the fertilizer. Since soil test recommendations show lime requirement as well as fertilizer needs, the dealer is in an excellent position to stress liming. Balanced fertility is essential.

Opportunity for the Manufacturer

Dealers may not adopt soil sampling very rapidly by themselves. The opportunity for the manufacturer is to develop a blueprint for soil sampling and service which dealers might follow. This will take (1) considerable planning, (2) education of dealers, and (3) continued contact with dealers by agronomists and salesmen.

Opportunity for the Dealers

As a trial, how about selecting 25 prospective customers and following through with a soil sampling and service program. Compare your sales in this group for the next two or three years with a group of 25 for whom you do little or nothing.
LOOKING AHEAD IN SOIL TESTING

Werner L. Nelson, J. Fielding Reed and R. D. Munson*

The purpose of this paper is to raise a few questions and encourage more thinking as to the changes which might take place in soil testing in ten years or so.

The aim of business is to strive for the greatest efficiency possible and to use the best technical and management assistance available. Every indication is that the farmer likewise must consider his farming operation as a business in competition with his neighbor.

Soil testing is a readily available and easily usable management skill. While soil testing is only one of the many tools to assist the farmer in doing a precision job, it is an important link that demands top flight soil testing programs. Thus we need to think ahead and consider what the agricultural producer might want in a few years. 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. A controllable factor, such as plant nutrient supply, will be taken care of.

There are five general phases of a soil testing program:

1. Sampling.
2. Analysis.
3. Calibration.
4. Interpretation and recommendations.
5. Evaluating the success.

While several of these points will be mentioned much of the discussion will center around interpretation and recommendations. Within ten years some of the changes mentioned will not be entirely completed. However, certain trends may be evident from which we can extrapolate. We at all times must keep in mind that the prime objective of soil testing is to bring about the most efficient and profitable use of lime and fertilizer by the agricultural producers.

Place of soil testing ten years hence

All business operations take a periodic inventory of their resources. All farmers likewise consider certain aspects of their operation in figuring their income tax. Each knows how many cattle, hogs, etc., he owns. Today, however, very few have an inventory of their soil resources.

*Midwest Director, Southern Director, and Agronomist, respectively, American Potash Institute. NOT FOR PUBLICATION. Publication rights reserved by the American Chemical society.

It is not necessary to repeat what we already know in regard to economic pressures forcing full-time farmers of the future into an efficient operation. 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.

Numerous surveys have shown the importance of soil testing in encouraging the farmer to use fertilizer. For several years some in the fertilizer industry have been stressing soil testing, to the advantage of the farmer as well as themselves through greater sales. At present, much of the industry is awakening to the importance of soil testing. In the next ten years the fertilizer industry could be an extremely important factor in increasing the use of soil tests.
Soil testing a connecting link between soils research and the farmer

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.

Dr. A.G. Norman, past president of the American Society of Agronomy, has expressed an important viewpoint. “It might be pertinent to ask whether there is any way of determining the absolute nutrient requirements of a plant or whether such information would be meaningful if it were obtained. An ideal nutritional environment indeed may be one in which all nutrient elements are available to the point of slight luxury consumption at all times”. (Agron. Jour. 49:618-620, 1957)

Sampling

Who will do the sampling? One might predict that as soil testing and fertilizer usage matures, the supplying of proper amounts of plant nutrients will be developed more and 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. In the period 1955 to 1957 the number of samples increased 35 per cent in United States. In some states numbers of samples might double in 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. 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 buildup 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. Based on the one sample, more effort will 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?

The amount of fertilizer that a farmer can use profitably depends greatly upon his management ability. Hence, 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. Of course, where the samples are taken through ASC program service sampling, or where a county makes soil tests mandatory in order to receive payment for certain practices, the entire range of farmers will be represented.
Keeping in mind the above and the limitations of survey data, the following estimates from a survey conducted in the Midwest by a NPFI Research and Education Committee may be of interest.

<table>
<thead>
<tr>
<th></th>
<th>No. of States</th>
<th>State Average 1953-57</th>
<th>Yield of farmers sending in soil samples</th>
<th>Goals in soil test program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn (bu.)</td>
<td>9</td>
<td>44.6</td>
<td>61.2</td>
<td>82.4</td>
</tr>
<tr>
<td>Wheat (bu.)</td>
<td>9</td>
<td>20.3</td>
<td>27.2</td>
<td>36.0</td>
</tr>
<tr>
<td>Alfalfa (T.)</td>
<td>8</td>
<td>1.9</td>
<td>2.8</td>
<td>3.8</td>
</tr>
<tr>
<td>Soybeans (bu.)</td>
<td>7</td>
<td>18.6</td>
<td>24.0</td>
<td>31.1</td>
</tr>
</tbody>
</table>

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. Also, the fact that the farmer uses the soil testing service is a favorable reflection on his management ability.

Who is doing the producing? It is of interest to study just who is doing the producing (1954 census data).

<table>
<thead>
<tr>
<th>Number of farmers</th>
<th>Per cent of Total number</th>
<th>Per cent of Total production</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,290,000</td>
<td>27%</td>
<td>79%</td>
</tr>
<tr>
<td>812,000</td>
<td>17%</td>
<td>12%</td>
</tr>
<tr>
<td>1,226,000</td>
<td>26%</td>
<td>7%</td>
</tr>
<tr>
<td>1,455,000 (part-time)</td>
<td>30%</td>
<td>2%</td>
</tr>
</tbody>
</table>

Much emphasis in education is placed on the 73% of the farmers who produce a relatively small part of the total. Will there be and should there be greater concentration on the 27% or the upper quartile who are doing the bulk of the producing?

Economists have predicted that in the not too distant future there will be only 1,000,000 farmers in United States. What will these farmers want in the way of soil testing service?

It thus seems of great 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, number of acres sampled in any one year, etc., 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 to really sell the soil testing program? Are the top 5 to 10 per cent of the farmers already ahead of our educational programs and information?
If the recommendation is just average, the value of soil testing is greatly reduced. It may do more harm than good as it creates doubt in the minds of good farmers. Too, soil testing is being promoted among the fertilizer industry on the basis that more fertilizer will be sold. In the next few years, as the farmers' usage of fertilizer increases, this may not always be true. Recommended rates may be considerably less than the amounts used by the leaders.

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

<table>
<thead>
<tr>
<th>Soil test</th>
<th>*N lbs/Ac.</th>
<th>P2O5 lbs/Ac.</th>
<th>K2O lbs/Ac.</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>60</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>Medium</td>
<td>80</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>Low</td>
<td>100</td>
<td>40**</td>
<td>120</td>
</tr>
</tbody>
</table>

75 bushels of corn

<table>
<thead>
<tr>
<th></th>
<th>100 to 140 bushels of corn</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>60</td>
</tr>
<tr>
<td>Medium</td>
<td>100</td>
</tr>
<tr>
<td>Low</td>
<td>140</td>
</tr>
</tbody>
</table>

* after non-legumes
** very low P test, apply additional 20 to 30 lbs.

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

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

Build-up approach. In this type of recommendation enough nutrients are supplied for good crop yields and also for nutrient buildup on soils testing low and medium. In Ohio, the suggested average annual application of P2O5 and K2O in the rotation is 80 lbs., 60 lbs., and 40 lbs. per acre at the low, medium and high levels respectively. N 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 two definite stages (1) building fertility reserve to a reasonably high level, and (2) maintaining the fertility level 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 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:

<table>
<thead>
<tr>
<th>Test Value</th>
<th>P&lt;sub&gt;2&lt;/sub&gt;O&lt;sub&gt;5&lt;/sub&gt; to raise P test level to 180 lbs/Ac.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 25</td>
<td>400</td>
</tr>
<tr>
<td>26 - 50</td>
<td>300</td>
</tr>
<tr>
<td>51 - 75</td>
<td>225</td>
</tr>
<tr>
<td>76 - 100</td>
<td>150</td>
</tr>
<tr>
<td>101 - 125</td>
<td>90</td>
</tr>
<tr>
<td>126 - 150</td>
<td>50</td>
</tr>
</tbody>
</table>

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.

Agricultural producers and agricultural leaders could learn to use the soil test results for what they are—facts about the soil. If a soil is acid or low in a particular plant nutrient, a farmer could 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 could be kept of changes in fertility levels and corrective treatments.

When the farmer learns this simple approach, with some guidance from the agricultural leader, he can do his own interpreting as far as lime and fertilizer needs are concerned. Then the soil test serves its real function—to give further information about the soil—rather than as an infallible figure which must be translated from some table into so many pounds of a certain grade of fertilizer.

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 the fertilizer industry 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 be providing the service. The following are possibilities:

(1) 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.

(2) Service from industry agronomists.

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

(4) A specialist employed by a group of farmers.

(5) 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?

(1) 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 laboratory 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.

(2) Private laboratories and consulting firms. A package program of testing and management service should gain rapidly in popularity. Service might be "built in" and be an all inclusive soil, crop, and livestock management program. One would wonder if it would be possible for the college to develop standard procedures for use by the laboratories.

(3) Fertilizer companies. The industry can do much to foster getting the samples taken and many feel this to be their most important role in soil testing. It would appear that expansion in the area of testing will be limited.

Evaluation of residual fertility

Evaluation of carryover fertility. The following statements are significant: "Optimum application of fertilizer to corn on a one-year basis contributes substantially to succeeding crops. If residual effect also is considered in estimating the most profitable level of application of fertilizer to corn, the optimum level is higher than it would be on a one-year basis". (Subcommittee on Economics of Fertilizer Use of the North Central Farm Management Research Committee, North Central Regional Publication No. 54, Madison, Wisconsin).
It has not been the usual practice to consider fully, residual benefits in making fertilizer recommendations. One might wonder if a major problem in many recommendations is not the 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 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, improper placement, etc. It is difficult to predict what management practices farmers will be using 10 years from now. It would seem essential to conduct field calibration studies with management practices ten years ahead of our time. This will ensure that we will be ready with the answers when the grower demands them.

A central Indiana farmer has an eight-year average of 190 bushels in the Indiana Five-Acre Corn Contest. He applied very high rates of N, P2O5 and K2O. According to present day standards his soil tests extremely high in P and K. However, what does it take for such a long-time average yield?

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. The question might be raised as to 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 for not only 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 can soil tests. Perhaps the greatest use in annual crops is for predicting needs in subsequent years.

Personnel

An important problem in soil testing is setting the sights high in quality of the leader 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 one moves in. Also, 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.

The changes in certain aspects of soil testing appear to be quite marked in the near future. It will take top-flight personnel to stay on top of the problems and to adjust with changing times.
SOIL TESTING AND ITS PLACE IN CROP PRODUCTION PROGRAMS

T. R. Hilliard, Assistant Deputy Minister (Production).
Ontario Department of Agriculture.

As greater emphasis has been placed on soil research and the refinement of soil testing techniques, the Ontario Department of Agriculture has been concerned that fertilizer recommendations based on these tests be as adequate as possible for the farmer.

A program has been adopted to use the knowledge of the various Departmental services to the best advantage. This is a co-ordinated program between the Soils Department, the Ontario Agricultural College and the Agricultural Representative Service. The program allows the Agricultural Representative in each county to make the fertilizer recommendations on each soil test in his county. The soil test report from the Soil Test Laboratory is mailed directly to the Agricultural Representative's office; he in turn makes the fertilizer recommendation and mails the report directly to the farmer.

The advantage of such a co-ordinated program is that it couples the knowledge of the soil scientist with that which the Agricultural Representative has of his county farmers and the soil types on which they farm. It places the Agricultural Representative in a very knowledgeable position insofar as the soil program in his county and its relationship to a farm management program is concerned. This system gives the farmer the feeling that the fertilizer recommendations are not made in some distant laboratory and allows him easy access to the person making the recommendation.

Disadvantages from this system might occur when the Agricultural Representative is moved to a new county. In areas in which specialized crops are grown, the Agricultural Representative must become familiar with a wide range of crop conditions.

This co-ordinated program was initiated in 1959 on a trial basis in five counties, and is being gradually extended to cover more and more counties in Ontario. Agricultural Representatives are given a period of training before the procedure is commenced.

Another policy has been adopted on a co-ordinated basis to provide more specialized soils extension help throughout Ontario. This is the placement of a Soils Specialist from the Soils Department, O. A. C., on a regional, residential basis, located in an Agricultural Representative office to serve a group of counties. Not only does he serve as a Specialist in soils, aiding the work of the Agricultural Representative, but as well, furthers the applied research program in soils directed by the Soils Department.

Co-ordination for these two programs is effected by the Heads of the Soils Department and the Extension Branch, who meet once a year, along with the Agricultural Representatives in the Counties in the area served by the Specialist, to review the work and to lay out a program for the following years. This program provides better use of specialized help with less time spent travelling.

Of prime importance is the fact that Extension has kept close to the research program and Extension Workers are able to help guide the program to be developed in soils research.
Determination of Reaction by Use of a Beckman pH Meter (Model G) or Zeromatic

Fill a 50 ml. beaker or small Dixie cup with the soil to be tested. Add water until all of the soil is just wet, and with a stirring rod, stir the soil and water until a moderately thin sticky consistency is reached. Excess water should be avoided. If water is added to a point where it settles out on the top of the mixture, it may be difficult to obtain a stable pH, and considerable drifting will occur. Increasing ratios of water to soil tends to give higher pH readings. Allow the soil to stand for 10 to 15 minutes, or longer, after which the temperature is taken, the mixture stirred again, and by use of the large external spear type electrodes, pH is determined. Readings on the soil may be taken on immersion of the electrodes and again within two or three minutes' time, noting if there is any drifting of pH. If drifting continues, pH readings should be made until there is no further change in the value. The pH meter should be previously standardized against a buffer solution at pH 7.

Extraction and Determination of Water Soluble Calcium, Magnesium, Sulphates and Chlorides

Extracting Solution:

.6 ml. of glacial acetic acid diluted to 1000 ml. with water.

Extraction: 1 level teaspoon soil is placed in the 50 ml. Erlenmeyer flask and 25 ml. of extracting solution is added. Shake for one minute. The mixture is filtered through a Whatman No. 2, 9 cm. filter paper into a funnel tube. Extracts should be filtered a second time, if they are not clear. If filtered extracts are cloudy because of dissolved organic matter, the addition of 1/2 teaspoon of activated carbon and 1 minute shaking before refiltering usually clears the solution.

Calcium Determination

Reagent:

Ammonium Oxalate Solution: A saturated solution of ammonium oxalate is made by adding about 5 gm. of ammonium oxalate to 100 ml. of water.

Determination of Calcium

1 ml. of extract is placed in a vial (14 x 74 mm.) and to this is added 2 drops of ammonium oxalate solution. Compare against Spurway calcium colour chart or, if preferred, against solutions containing 40 ppm., 70 ppm., 100 ppm., 125 ppm., 150 ppm., 200 ppm. of calcium as Ca in solution.
MAGNESIUM DETERMINATION

(O.A.C. METHOD)

Reagents:

Titan Yellow Solution: 0.2 gm. of Titan Yellow in 50 ml. ethyl alcohol + 50 ml. water.

Titan Yellow varies greatly in composition from one company to another. It is recommended that Thiazol Yellow (Code S-90270) obtainable from General Aniline Works Inc., Albany, N.Y., be used.

Basic Sucrose: 7 gm. of NaOH + 20 gm. of sucrose per 100 ml. water.

The presence of sucrose in the determination appears to lessen, but does not entirely eliminate, calcium interference at high calcium levels.

Starch Solution: 5 gm. of starch per 100 ml. of water. First make a thick paste of the starch in the bottom of a beaker. Then add 100 ml. of vigorously boiling water, stirring continuously. Place back on the heat and bring the starch to the first bubble of boil, stirring vigorously all the while. This solution must be renewed every few days or every day if readings are made in photometer. The starch solution acts as a protective colloid preventing the "flaking out" of dyed magnesium hydroxide when large amounts of magnesium or calcium are present.

Determination of Magnesium

1 ml. of extract is placed in a vial (14 x 75 mm.) and to this is added 1 drop of starch, mix by shaking; 1 drop of Titan Yellow, mix by shaking; and 1 drop of Basic Sucrose, mix by shaking. Read against prepared standards. Present colour charts are very inaccurate.

Colour standards may be prepared from standard solutions made by dissolving 1 gm. of bright, shining magnesium ribbon in 100 ml. of water plus about 10 ml. of glacial acetic acid. After complete solution, dilute to 1000 ml. This gives a 1000 ppm. Mg. standard, from which may be prepared magnesium standards, containing from 1 ppm. Mg. up to 50 ppm. Mg. If a photometer is to be used for readings, use 5 or 10 ml. of soil extract and increase the volume of reagents added in proportion to the volume of extract used.

SULPHATE DETERMINATION

Reagent:

Barium Chloride Solution: Dissolve 7 gm. of barium chloride in 100 ml. water.

Determination of Sulphate

1 ml. of extract in a vial (14 x 75 mm.) to which is added 1 drop of sulphate reagent. If a precipitate forms, add 1 or 2 drops of 1 + 3 acetic acid solution. Read in 1 minute against Spurway colour chart for sulphates, or against prepared standards.
CHLORIDE DETERMINATIONS

Reagent:

Silver Nitrate Solution: Dissolve 5 gm. of silver nitrate in 100 ml. of water.

Determination of Chloride

To 1ml. of extract in a vial (14 x 75 mm.) add 1 drop of silver nitrate solution. If a precipitate forms, add 1 to 2 drops of acetic acid (1 + 3). Read in 1 minute against chloride colour chart, or against prepared standards.

CARBONATE DETERMINATION

Reagent:

HCl Solution: 1 part HCl + 3 parts H₂O.

Determination of Carbonate

To a small amount of soil on a watch glass or on a spoon add several drops of 1 + 3 HCl and note the degree of effervescence.
THE EXTRACTION OF EXCHANGEABLE POTASSIUM
WITH 0.1 N AMMONIUM ACETATE + 0.05 N SULFURIC ACID

Reagents:

1. Ammon. Acetate Stock Sol'n (2 N)

   Dilute 1140 ml. of glacial acetic acid to about 5 litres with distilled water. Add 1400 ml. of conc. ammonium hydroxide with stirring. Dilute to 10 litres.

2. Sulfuric Acid Stock Sol'n (1 N)

   Place about 5 litres of distilled water in a 10-litre bottle, add 280 ml. of conc. sulfuric acid, and dilute to 10 litres.

3. Lithium Stock Sol'n (2000 ppm.)

   Dissolve 122.2 gm. of reagent grade lithium chloride (previously dried at 105°C) in distilled water and dilute to exactly 10 litres.

4. Calcium Stock Sol'n (4000 ppm.)

   Dissolve 10 gm. of reagent grade calcium carbonate in dilute HCl until solution clears, then dilute to 1 litre with distilled water.

5. Potassium Stock Sol'n (500 ppm.)

   Dissolve 1.9069 gm. of reagent grade KCl (previously dried at 105°C) in distilled water and dilute to 2 litres with distilled water.

6. Extracting Solution (0.1N NH Ac + 0.05 N H2SO4)

   Dilute 500 ml. of 2N Ammonium Acetate stock sol'n., and 500 ml. of 1N Sulfuric Acid stock sol'n, and 500 ml. of 2000 ppm. Lithium stock sol'n. to exactly 10 litres with distilled water.

7. Potassium Standard Solutions:

   To make standard solutions containing 0, 5, 10, and 20 ppm. of K+, pipette 0, 5, 10, and 20 ml. of the 500 ppm. Potassium stock sol'n into 500 ml. volumetric flasks, add 25 ml. of the 2 N Ammonium Acetate stock sol'n to each, as well as 25 ml. of the 1 N Sulfuric Acid stock sol'n, 25 ml. of the 2000 ppm. Lithium stock sol'n., and 25 ml. of the 4000 ppm. Calcium stock sol'n. Dilute to 500 ml. with distilled water. Each standard solution is now 0.1N to ammonium acetate, 0.05N to sulfuric acid, and contains 100 ppm. of lithium and 200 ppm. of calcium.

Note: All bottles of solution should be tightly stoppered to prevent evaporation.
Method

Place a ½ level teaspoon of soil (from a sample that has been carefully screened through a 2mm. sieve and thoroughly mixed) in a 125-ml. Erlenmeyer flask. Add 25 ml. of the Extracting Solution and shake on a shaker for 15 min. Filter through a Whatman No. 2 filter paper into a 50 ml. Erlenmeyer flask or other suitable container and save for analysis in the Flame Photometer. The flask containing the filtered extract should be stoppered if it is to be held for more than an hour or two before being analyzed.

OPERATION OF BAIRD FLAME PHOTOMETER FOR DETERMINING K IN SOIL EXTRACTS

(When a 1:10 Soil to extracting Sol'n. ratio is used)

1. Be sure the filter wheel on the top of the instrument is set in the K notch.

2. Turn on the switch in the extension cord to the galvonometer to light up the galvonometer hairline.

3. Turn on the air and adjust to 10 psi.

4. Turn on the gas and light the burner at the top of the chimney.

5. Let the instrument warm up for 15 min. or more.

6. Pour some Haemosol solution in the atomizer and clear the atomizer capillary with a fine wire. Rinse with 2 or 3 portions of distilled water.

7. Set the Balance Indicator to read 480.

8. Set the selector switch to Direct. Adjust the galvonometer hairline to centre zero with the hairline adjustment knob on the galvonometer. This is the electrical zero.

9. Set the selector switch to Internal Standard. Pour some of the 20 ppm K-standard into the atomizer funnel. Adjust the Sensitivity to bring the galvonometer hairline to centre zero.

10. When the funnel has run dry of solution, reset the selector switch to Direct. Rezero the galvonometer using the galvonometer knob.

11. Return selector switch to Internal Standard. Pour in more of the 20 ppm K-standard and readjust the Sensitivity to return the galvonometer to zero. This procedure should be repeated until it is not necessary to make any adjustments to correct for the zero on the galvonometer under the following conditions.

   (a) with the 20 ppm K-standard in the funnel and the selector switch on Internal Standard.

   (b) with the funnel empty and selector switch on Direct.

12. Pour a small amount of soil extract sample to be analysed into the funnel and adjust the galvonometer hairline to centre zero by means of the Balance Indicator. Record the reading on the Balance Indicator. This will be lb./ac. of K₂O.

13. Recheck the calibration of the instrument periodically by repeating steps 8 and 9 and, if necessary, steps 10 and 11 above.
14. When finished, rinse out the atomizer with Haemosol solution followed by distilled water, turn off the galvonometer switch, the gas, and the air.
Appendix

Department of Soils
Ontario Agricultural College

PROCEDURE FOR NITROGEN INCUBATION TEST

Treatment of Samples:

On receipt all samples must be placed in the cool storage incubator at 40°F, and high humidity to prevent drying out. Samples should be kept in cool storage until immediately before drying (drying temperature not above 95°F). If taken between June 1st and September 31st this cool storage should be for a period of two weeks. Samples should be incubated on the same day as they come out of the drier.

Incubation: Place in incubation tube 2 teaspoonfuls of vermiculite followed by 2 teaspoonfuls of soil followed by 2 teaspoonfuls of vermiculite. Add 5 ml. of distilled water to each tube and place in incubator for 7 days at 95°F, and high humidity.

Determination of Nitrate

Reagents

1. Phenoldisulphonic Acid -- Dissolve 75 grams of phenol in 450 ml. of conc. sulfuric acid. Add 225 ml. of fuming sulfuric acid. Mix the solution and heat on a hot plate at 100°C, for 2 hours. Store the solution in a brown bottle.

2. Ammonium Hydroxide Solution -- Mix 1 part of reagent grade ammonium hydroxide with 1 ½ parts of distilled water.

Procedure: Wash soil and vermiculite into 125 ml. beaker-flask with a 50 ml. aliquot of distilled water from automatic pipette. Add a pinch of solid calcium hydroxide, shake for 30 seconds and filter.

Transfer 2 ml. of filtrate into 30 ml. beaker and evaporate to dryness on hotplate at low heat. Cool, add 1 ml. phenol-disulphonic acid, rotate beaker, and allow to stand 10-20 minutes. Add 10 ml. distilled water followed by 10 mls. ammonium hydroxide and read in colorimeter, using 425μ filter.

MODIFIED PA₂ TEST FOR SOIL PHOSPHORUS

Department of Soils, O.A.C.

June, 1957.

Extracting Solution - 0.05N NH₄F + 0.1N HCl. This solution must be stored in a polyethylene container. Do not leave standing in contact with glass.

Procedure - Measure a level ½-teaspoonful of soil into a 50 ml. Erlenmeyer flask. Add 25 ml. of modified PA₂ extracting solution. Shake for one minute. Filter through No. 2. filter paper into a funnel tube marked at 2.5 and 5.0 ml.
Remove all but 2.5 ml. of the soil extract by suction. Add 2.5 ml. of distilled water. Add \( \frac{1}{4} \) ml. of P-B reagent. Mix thoroughly. Add \( \frac{1}{4} \) ml. of P-C reagent and mix immediately.

Pour the coloured solution into an absorption tube and read the color in a colorimeter in 25 to 35 minutes using a 650 or 660 (red) filter.

REAGENTS FOR MODIFIED PA₂ TEST.

Department of Soils, O.A.C.

June, 1957.

1. **Ammonium fluoride stock soln. (2N)**
   
   Dissolve 74 gm. of ammonium fluoride (\( \text{NH}_4\text{F} \)) in distilled water and dilute to 1 litre. Keep in polyethylene bottle.

2. **Mod. PA₂ extracting solution (0.05N NH₄F + 0.1N HCl)**
   
   Dilute 25 ml. of 2N \( \text{NH}_4\text{F} \) (Reagent 1) and 8.33 ml. of conc. HCl to 1 litre with distilled water or 450 ml. of 2N \( \text{NH}_4\text{F} \) (Reagent 1) and 150 ml. of conc. HCl to 18 litres. Keep in polyethylene container. (A 5-gal. polyethylene bottle will hold 18 litres.)

3. **P-B reagent (3.5% ammon. molybdate, 7.3N HCl. boric acid saturated).**
   
   Dissolve 100 gm. of reagent grade ammonium molybdate in 850 ml. of distilled water heated to 60° C. Cool. Make a second solution of 1700 ml. of conc. HCl in 160 ml. of distilled water. Cool. Add the first solution to the second slowly and with constant stirring. Add approx. 110 gm. of reagent grade boric acid and dissolve. This reagent will keep 3 or 4 years in a dark glass bottle.

4. **P-C reagent (amino-néphthol - sulfonic acid solution)**
   
   2.5 gm. of 1, amino - 2 - naphthol - 4 - sulfonic acid
   5.0 gm. of sodium sulfite (\( \text{Na}_2\text{SO}_3 \))
   146.25 gm. of sodium bisulfite (meta, \( \text{Na}_2\text{S}_2\text{O}_5 \))
   
   Mix the above ingredients and grind to a fine powder in a mortar. For use dissolve 16.0 gm. of the powder in 100 ml. of warm distilled water. Add 2 gm. of reagent grade boric acid. Filter. Allow to stand overnight. Store in a dark glass bottle. Renew every 3 weeks.
THE EXTRACTION OF EXCHANGEABLE POTASSIUM

WITH 0.1 N AMMONIUM ACETATE = 0.05 N SULFURIC ACID

Reagents:

1. Ammon. Acetate Stock Sol'n (2 N) -

   Dilute 1140 ml. of glacial acetic acid to about 5 litres with distilled water. Add 1400 ml. of conc. ammonium hydroxide with stirring. Dilute to 10 litres.

2. Sulfuric Acid Stock Sol'n (1 N) -

   Place about 5 litres of distilled water in a 10-litre bottle, add 280 ml. of conc. sulfuric acid, and dilute to 10 litres.

3. Lithium Stock Sol'n (2000 ppm.)

   Dissolve 122.2 gm. of reagent grade lithium chloride (previously dried at 105°C) in distilled water and dilute to exactly 10 litres.

4. Calcium Stock Sol'n (4000 ppm.)

   Dissolve 10 gm. of reagent grade calcium carbonate in dilute HCl until solution clears, then dilute to 1 litre with distilled water.

5. Potassium Stock Sol'n (500 ppm.)

   Dissolve 1.907 gm. of reagent grade KCl (previously dried at 105°C) in distilled water and dilute to 2 litres with distilled water.

6. Extracting Solution (0.1 N NH4Ac + 0.05 N H2SO4)

   Dilute 500 ml. of 2N Ammonium Acetate stock sol'n., and 500 ml. of 1N Sulfuric Acid stock sol'n., and 500 ml. of 2000 ppm. Lithium stock sol'n. to exactly 10 litres with distilled water.

7. Potassium Standard Solutions:

   To make standard solutions containing 0, 5, 10, and 20 ppm. of K+, pipette 0, 5, 10, and 20 ml. of the 500 ppm. Potassium stock sol'n into 500 ml. volumetric flasks, add 25 ml. of the 2 N Ammonium Acetate stock sol'n to each, as well as 25 ml. of the 1 N Sulfuric Acid stock sol'n, 25 ml. of the 2000 ppm. Lithium stock sol'n, and 25 ml. of the 4000 ppm. Calcium stock sol'n. Dilute to 500 ml. with distilled water. Each standard solution is now 0.1N to ammonium acetate, 0.05N to sulfuric acid, and contains 100 ppm. of lithium and 200 ppm. of calcium.

Note: All bottles of solution should be tightly stoppered to prevent evaporation.