Methods and Materials Used in Soil Testing.

By H. A. Huston.

The consumption of commercial plant foods in the United States has reached approximately 5,000,000 tons and the cost to the consumer is nearly equal to the sum which we formerly paid for imported sugar, and which became the slogan in the campaign to establish the beet sugar industry in America—$100,000,000.

The industry is established, but by no means stationary. It has increased at least 50 per cent. during the past five years, a very high rate considering the magnitude of the business.

In the manufacture and control of these products there is employed a large number of chemists, and the Association of Official Agricultural Chemists, now over a quarter of a century old, was originally formed for devising suitable methods of analysis for these products. Thirty-three States have special laws for fertilizer inspection. The American Chemical Society recently organized a Division of Fertilizer Chemists, and most of our agricultural colleges and experiment stations devote a considerable amount of attention to the subject.

The farmer wants to know the facts about commercial plant foods and all officialdom, from the bureau chiefs of the National Department of Agriculture to the local speaker at the township farmers' institute, undertakes to enlighten him.

In those sections of the country where fertilizers have been longest used—along the Atlantic, the eastern gulf coast and the upper Ohio Valley—the experiment stations and control officials appreciate the magnitude and importance of the industry and understand its vital relation to crop production. In marked contrast to this is the state of affairs in the greater part of the great area drained by the Mississippi, where the most of our maize, wheat and oats are produced. Here we find also the curious combination of land rapidly increasing in money value and at the same time declining in productiveness, while the cost of farm labor is increasing. These circumstances cause the farmer to inquire how his crops may be increased and whether commercial plant foods may be profitable in this connection.

Some thirty-five years ago the winter wheat growers of the Ohio Valley began to use fertilizers, most of the material being the side products of the packing houses, mainly bone meal. Very profitable results were secured and the trade rapidly increased. In time acidulated goods were introduced, often being mixtures of equal parts of acid phosphate and bone. Later came the "complete" fertilizer, being ammonia 2, available phosphoric acid 8, and potash 2 per cent. This is still the so-called basal formula, that is, the one used as a starting point in calculating the trade value of goods with different formulas. About two-thirds of the fertilizer used in that section consist of complete fertilizer; the use of bone and ammoniated phosphate is declining and the use of mixtures of acid phosphate and potash is rapidly increasing. Common applications for wheat are from one to two hundred pounds per acre, and it is almost invariably applied with a fertilizer attachment at the same time the seed is sown. The efficiency of the fertilizer in securing a stand of clover, the seed of which is sown before the wheat starts its spring growth, is a point to which the farmers attach considerable importance and the increase in clover production may in part account for the reduction in the amount of nitrogen in the fertilizers now used as compared with that used at an earlier period.

The use of fertilizers gradually extend to other crops, but fully two thirds of the fertilizer sold in the Ohio Valley are used on winter wheat. The general tendency in composition has been to reduce the nitrogen and increase the potash, while the phosphoric acid has remained practically unchanged. Ready mixed brands are the rule, home mixing the rare exception.

It is, however, unnecessary to state that much of this plant food has been used in a most haphazard way and that both buyer and local seller knew little about the composition of the goods sold or their fitness for the crop or soil on which they were to be used.

The one thing which stood out very clearly was that they paid; that by their use good crops of wheat could be secured where unprofitable crops grew before; and that a stand of clover or grass could be secured, a suitable rotation of crops established and maintained, and that the cost of the fertilizer was returned many fold in the increase of wheat grain alone. Ten pounds of fertilizer costing from ten to fifteen cents produced on the average an increase of a bushel of wheat. This condition exists over much of the winter wheat belt extending from Kansas east and comprising an area of probably 200,000 square miles. These facts have existed too long and cover too much territory to be ascribed to local peculiarities of soil or season. The wheat grower knows that fertilizers pay. But as brands multiplied the question arose which is the more profitable. and many made simple tests of different brands in which the popularity of the local agent received more consideration than the amount and kind of plant food in the goods; they obtained the confusing results that might have been expected under these conditions. Better informed farmers applied to their experiment stations and agricultural colleges for aid, and in most cases were surprised to be told either that commercial plant foods did not pay or that they were unnecessary.

An examination of the records of field tests conducted by experiment stations in the winter wheat section shows that many experiments have been made, especially on wheat, and that most of them have been reported unprofitable. This apparent conflict between the results of practical and scientific agriculture has to some extent prevented the extension of the sale of plant food to territory where it was very much needed. One may fairly inquire why the results of the experimental field tests differ so widely from the results obtained in ordinary farm practice in the same sections.

First, we may consider certain things that are general in their nature. Many experiments are reported where relatively heavy applications of farm yard manure have been compared with applications of various brands and quantities of fertilizers without any clear statement or apparent knowledge of the composition of the latter. Such experiments are almost invariably reported as showing that manure is more profitable than the fertilizer, which is not strange in view of the fact that in the valuations the full cost of the fertilizer is charged up, while to the manure is charged only the cost of hauling. In such reports there is often a very clear intimation that the result is quite in line with the preconceived notions of the experimenter and that in discouraging the use of "expensive fertilizers" he is at least telling farmers what they like to hear even though it conflicts with what they need to know.

The method of application of the plant food is in many cases responsible for a considerable part of the difference observed between field practice and plot experiments. Application with the drill at the time of sowing small grains, which is the common method, frequently gives profitable results when the same amount and kind of fertilizer applied broadcast is unprofitable. and the same remark applies to light applications on maize.

One of the principal reasons for unprofitable results from plot tests is found in failure to make a distinction between the fertilization of crops producing high money values per acre, like truck and fruit, where the whole plant food supply may be profitably secured from chemical manures, and such crops as wheat, oats and maize, where the chemical fertilizers must be used to supplement and balance the supplies from the soil, farm yard and legume field. The cost of full rations of commercial nitrogen can only occasionally be recovered in the wheat crop and rarely if ever in the case of oats and maize. Double rations of phosphoric acid are often profitable and from one-half to full rations of potash. In most of the early plot experiments full rations were used, and sometimes the cost of the fertilizer for maize was greater than the total sum received for the crop even when the yields were good.

Perhaps the contrast between the plot tests and the farm practice can be shown better in the form of the amounts per acre and the formula. In some of the wheat plot tests extending over twenty years the fertilizer is the equivalent of 500 pounds per acre of goods having formula of nitrogen 10 per cent., phosphoric acid 5 per cent. and potash 6 per cent.; at the same time this series was started the common wheat fertilizer was 100 to 200 pounds per acre of 2-8-2, which has gradually changed to 2-8-6; nitrogen is sometimes increased to 3 per cent. The maize series of plots received the equivalent of 1,000 pounds per acre of a goods having a formula of nitrogen 12 per cent., phosphoric acid 4 per cent. and potash 6 per cent., while farm practice on maize uses 100 to 300 pounds per acre of goods having little or no nitrogen and containing from 5 to 10 per cent. phosphoric acid and 4 to 10 per cent. of potash. For clay soils a common maize fertilizer is 0-10-4, for loams 0-8-8 and for black sandy soils 0-6-10, while on the peat or muck soils 100 pounds per acre of muriate of potash or its equivalent in kainit are commonly used. A small amount of nitrogen is sometimes added, usually about 1 per cent.—rarely over 2.

The cost per acre of the maize fertilization would be about $30 for the plot work and from $1 to $4 per acre for the fertilizers commonly used. The cost per acre of the wheat fertilization would be about $15 for the plot work and from $1 to $3 per acre for the fertilizers commonly used.

In general it may be said that the fertilizers used on wheat and maize furnish about as much phosphoric acid as the crop removes, rarely as much as one half ration of potash and never over one-fifth ration of nitrogen, while the plot experiments have undertaken to supply full rations for a full crop, which is fully double an average crop.

The quantities of fertilizer used in the plot tests mentioned above seem quite absurd to the American grain grower, yet they are very conservative compared with another set inaugurated at about the same time in which 2,000 pounds of acid phosphate, 600 pounds of sulphate of potash and 600 pounds of sulphate of ammonia per acre were used, or with an extensive set of orchard experiments in which the plans called for the application of 40 pounds of muriate of potash with corresponding amounts of nitrogen and phosphates to each two year old tree.

In the case of the plot experiments conducted for the purpose of determining the value of the different plant foods, the excessive quantities have often caused a profit to be shown for only the particular plant food which was most deficient, while if more reasonable quantities had been used each would have shown a profit. It is not unusual to find reports of these experiments that recommend the use of a single plant food as all that is necessary merely because it was the one that chanced to give the largest profit.

As compared with this line of plot experiments with full rations we may, perhaps, devote a moment to results of plot experiments where amounts and formulas generally used in farm practice were taken as a basis.

On a typical worn clay wheat land an experiment was undertaken on the basis of 300 pounds per acre of goods containing nitrogen 3 per cent, available phosphoric acid 10 per cent and potash 6 per cent, each element being omitted in turn in the usual way.

The following results were obtained:

Fertilizers applied per acre. Equal to—	Yield, bushels per acre.	Reduction from Omitting			
		Nitrogen.	Phos. Acid.	Potash.	All.
300 lbs. 3–10–6	33.8	......	......	....	....
300 lbs. 0–10–6	29.1	4.7	......	....	....
300 lbs. 3– 0–6	7.6	......	26.2	....	....
300 lbs. 3–10–0	25.0	......	......	8.8	....
None	6.5	......	......	....	27.3

The nitrogen in the fertilizer cost per acre	$1 80
The phosphoric acid cost per acre	1 50
The potash cost per acre	1 10
The complete fertilizer cost per acre	$4 40

The nitrogen increased the crop 4.7 bushels at a cost of $1.80, the phosphoric acid increased it 26.2 bushels at a cost of $1.50, while the potash increased it 8.8 bushels at a cost of $1.10. As wheat sold at 90 cents per bushel it will be seen at a glance that all the plant foods were used at a profit, although, of course, we are not in a position to show that the combination is the one most profitable. Nor do we know that this was the most profitable amount. We do know that it was very profitable even neglecting the value of the increase in the straw and the very striking effect on the clover which followed the wheat.

The experiment is a typical one for soils in the winter wheat belt, and numerous others could be given showing results of just the same character and even more striking in profits.

The figures show how the lack of phosphoric acid limited the crop, and they serve to explain why bone gave such increases on these soils that for nearly a generation it was considered the only profitable thing to use.

In another series at a different place the amounts of the plant foods were varied, but the season was so unfavorable that the crop was limited by other considerations than plant food, the maximum crop being only about 13 bushels per acre and that of the unfertilized plots being only 2 bushels.

In these experiments the nitrogen is supplied from blood, the phosphoric acid from precipitated calcium phosphate free from gypsum, and the potash from muriate of potash, the purpose being to use materials exerting as little indirect effect as possible.

This matter is too often overlooked in planning such experiments, and for a considerable time the indirect effects may be so great as to mislead one who does not take them into consideration. Thus the gypsum in ordinary acid phosphate, amounting to about one-third of its weight and the sodium in the nitrate, may each release so much potash from zeolites in the soil that the plot with nitrate acid phosphate and potash may show little if any increase over that with nitrate and acid phosphate. Comparatively few experiments exist which have been conducted long enough and in such a way as to shed much light on the extent to which the indirect effects mask the direct effects.

In such cases one always turns to the admirable work at Rothamsted for help and the constantly increasing difference between the yields of plots 11 and 13 Broadbalk Field seem to show that the indirect effects are decreasing. The gypsum alone on plot 11 would theoretically release 90 pounds per acre of potash annually while the total annual application of potash on plot 13 is 100 pounds. The theoretical amount of potash that could be released by the bases in the minerals used on the fully fertilized plots at Rothamsted amounts to about 400 pounds of potash per acre annually while the potash applied in sulphate amounts to 100 pounds. While Director Hall has clearly pointed out the difference between the early years and the later, too many who use Rothamsted results to fortify their arguments simply take the average for the whole period and neglect to consider the results by decades.

Especially when we wish to secure indication of soil needs as promptly as possible should we take pains to use materials that will exert as little indirect effect as possible. By using blood as a source of nitrogen and gypsum free precipitated phosphates as the source of phosphoric acid we can remove most of these indirect effects and at the same time use materials easily secured and of high availability.

Another point that is never considered in planning the plot tests in the section under consideration is the marked difference in the fixing power of soils for plant foods and the firmness with which they hold them. This is roughly recognized in providing for an excess of phosphoric acid in commercial formulas but is seldom considered in plot tests.

The plot tests in most cases have simply been copied from plans made before the nitrogen gathering power of bacteria associated with legumes was understood and sometimes altered because of the injurious effect of the excessive nitrogen applications or too often abandoned altogether because the growth of the institution demanded the land for other purposes. The frequent changes in the staff of workers has also interfered seriously with both the conduct of the work and the interpretation of the results.

The conditions in the winter wheat section of the United States are such that large crops must be produced in order to realize a suitable return on the selling value of the land and the money spent for farm labor. The small grain crops are so related culturally with the clover crop that they are almost necessary in a rotation if we expect to utilize our most widely distributed legume as a source of nitrogen.

The chemical industries supplying plant foods and the purchaser of these products would both be greatly benefited by the inauguration at our experiment stations in the grain growing section of experiments properly planned to solve the question of the most profitable method of supplementing the plant food resources of the farms.

Up to the present time it must be confessed that the purely empirical methods of the fertilizer manufacturers have produced results that yield the farmer better returns than anything derived from the experiments started under the old system by the educational institutions in the grain growing section, but these are far from being the best obtainable. Both farmer and fertilizer manufacturer need the help of the educational institutions in the direction of securing facts relative to the most profitable methods of utilizing plant foods in the production of our great cereal crops—facts that will help and not discourage.

But such experiments must take into consideration

The kind of materials to use,

The avoidance of indirect effects,

The right methods of application,

The question of the most profitable amount, and finally

The rational interpretation of the results obtained.

German Kali Works, Chicago, Ill.