Hastings, W. H., G. D. Miller, and Muhammad Akram, 1962. Biochemical and biological measures of the effect of laboratory pelleting of cereals. Cereal Science Today, 7:80-85.

Law, Duncan K., Russell O. Sinnhuber, T. C. Yu, Wallace F. Hublou, and Thomas B. McKee, 1961. Seventh progress report on salmon diet experiments. Technical Paper No. 1477, Oregon Agricultural Experiment Station, Corvallis.

March, B. E., 1961. Fish meal and condensed fish solubles in poultry and livestock feeding. Fish as Food, Vol. II, 377-434. Academic Press, N. Y.

Tarr, H. L. A., 1962. Changes in nutritive value through handling and processing procedures. Fish as Food, Vol. II, 235-266, Academic Press, N. Y.

Phillips, Arthur M., A. V. Tunison, and Donald R. Brockway, 1948. The utilization of carbohydrates by trout. Bull. No. 11, New York State Conservation Department, Albany.

U. S. Food and Drug Administration, 1963. Food Additives, Subpart G., p. 2, Published in the Federal Register, August 21, 1963; 28 F. R. 9208. p. 3, Published in the Federal Register, August 30, 1963; 28 F. R. 9526.

## THE NEED, USE, AND VALUE OF FERTILIZERS

Everything and everybody have to eat if they are to live and serve their purpose. What is eaten by an organism tremendously influences its growth, development, and performance. All too often we see men, plants, and animals which due to the lack of the proper kind and amount of food, fail to develop normally. Consequently, those that do reach maturity at all have to overcome great odds to perform normally.

This is manifested in the corn production in this area. It is not difficult to average 80 to 100 bushels per acre, but the actual production is much nearer one-half that amount. If we want to grow 100 bushels of corn, there are certain essential management factors which must be recognized and provided. We must select the corn land, feed the crop properly, plant plenty of seed of an adapted hybrid, and control the pests.

Though we know that each of these factors must be provided for, at this time we will only think of feeding the crop. This is one of the most serious limiting factors in production. One approach to feeding the crop would be to consider the amounts of the various plant foods actually eaten by it. This approach without some knowledge of plant physiology and soil chemistry can be very misleading; but along with a basic understanding of plant physiology and soil chemistry, the kind and amount of plant foods eaten by a good crop can be a helpful guide.

In the case of corn, as in most crops, the plant is made up largely of carbon, hydrogen, and oxygen. But these plant foods come from water and air and under well-managed conditions may not be the most seriously limiting factors. The other plant foods contained in a 100-bushel crop of corn are grouped into three divisions and are shown below:

I. Primary Plant Foods
   A. Nitrogen—157#
   B. Phosphorus—60#
   C. Potash—122#

II. Secondary Plant Foods
   A. Calcium—38# ) Lime
   B. Magnesium—26#)
   C. Sulfur—16#

III. Micro-Plant Foods
   A. Boron—.08#
   B. Copper—.07#
   C. Iron

D. Manganese—1.06#
E. Zinc—.30#
F. Some authorities also include molybdenum and chlorine

### *Micro-Plant Food Nutrients*

Some of these plant food nutrients assist others but each one has a function to perform. In this paper we will attempt to briefly explore the function of each of these, but will look more in detail at the primary plant food nutrients.

The micro-nutrients are also sometimes called trace or minor plant food nutrients. These names should not be interpreted to mean that these plant foods are of little importance to the crops. Actually, they are very important, but they are used in very small amounts. Because they are used in such small amounts, and because they are all contained in the soil, there has not been a need for general applications of them to the soil. Some of the most important functions of the micro-plant foods are shown below:

1. *Boron* is associated with calcium utilization and transfer of sugars within the plant; it helps in seed production of small seeded legumes; and it improves the quality of alfalfa, fruit, and vegetables.
2. *Copper's* function within the plant is not very well understood, but it serves an important function in reclaiming and utilizing peat and muck soils.
3. *Iron* is essential in the production of chlorophyll in the plant. Deficiencies of iron are most often found on alkaline or highly calcareous soils.
4. *Manganese* increases the availability of calcium, magnesium, and phosphorus and tends to accelerate germination of seeds. Deficiencies are most often observed on calcareous or alkaline soils.
5. *Zinc* plays a part in chlorophyll production in plants. Deficiencies are most often observed when crops are grown on calcareous or alkaline subsoils where the topsoil has been removed.
6. *Molybdenum* is essential in nitrogen fixation and utilization by legume crops. It is usually more apt to be deficient under acid conditions.
7. *Chlorine's* function in the plant is not very well understood. It is very seldom deficient under field conditions.

### *Secondary Plant Food Nutrients*

Some of the more important functions of the secondary plant nutrients are shown below:

1 *Calcium* seems to improve germination of seeds; promotes early root hair formation and growth; improves general plant vigor; encourages seed production; increases the calcium content of food and feed crops; neutralizes some toxic materials in the plant; improves the structure of some soils; and, as lime, corrects acid conditions.
2. *Magnesium* is an essential part of chlorophyll; is necessary in the formation of sugars; acts as a carrier of phosphorus in the plant; promotes formation of oils and fats; and helps regulate uptake of other plant foods.
3. *Sulfur* is an essential part of protein; promotes nodule formation on legumes; stimulates seed production; helps maintain a dark green color in plants; and encourages more vigorous plant growth.

### *Primary Plant Food Nutrients*

The functions of the primary plant food nutrients are shown below:

1. *Nitrogen*
   A. Gives dark green color.
   B. Promotes rapid growth.
   C. Increases yields of leaves.
   D. Improves quality of leaf crops.

E. Improves protein content of food and feed crops.
F. Feeds soil micro-organisms during the time they are decomposing low nitrogen type of organic matter.
G. Excessive amounts when out of balance with other plant foods may delay maturity.

2. *Phosphorus*
   A. Stimulates early root formation and growth.
   B. Gives rapid and vigorous start to plants.
   C. Hastens maturity.
   D. Stimulates blooming and aids seed formation.
   E. Increases winter hardiness in fall seeded grains and hay crops.
3. *Potassium*
   A. Increases vigor and disease resistance.
   B. Helps in protein formation in plants.
   C. Stiffens the straw and stalks, thus reducing lodging.
   D. Increases plumpness of grain and seed.
   E. It is essential to the formation and translocation of starches, sugars, and oils.
   F. Improves quality of fruits and vegetables.
   G. Helps in the development of tubers and root crops.

In addition to these plant food nutrients which have been named and briefly treated upon, undoubtedly there will be others recognized as essential plant foods as high yields are reached and maintained.

Since the major plant food elements are the ones which most often limit the growth and production of crops, their behavior will be explored a little further.

In an effort to show some of these actions and behavior of the primary plant foods, they are going to be compared to human beings insofar as their marital status is concerned. It will be remembered that an automobile battery has two electric poles—a positive and a negative pole. From these electric poles come positive and negative charges. These two different kinds of charges carry an attraction for each other. They want to get together. When the two charges come together, they unite or marry and create a force which can do work.

The plant food elements in the soil also carry charges. Some carry positive charges while others carry negative charges. Here again these opposite electric charges are attracted to each other. They want to get together and marry.

Nitrogen is very unusual in this analogy in that it has a double personality. Some plants can eat or take up nitrogen in the ammonia form. The rice crop is an example, but there are a number of plants which can use ammonia when those plants are young and small. But most crops use most of their nitrogen in the nitrate form.

When the nitrogen is in the ammonia form it carries a positive charge. It is a gentleman of the soil. So it is attracted to some active lady of the soil. Who would this be? Soil particles are the predominating ladies of the soil. Consequently, Mr. Ammonia unites or marries Miss Soil Particle. These two honeymoon and live forever, as long as ammonia is not changed, at the site where they were married. This nitrogen cannot be washed or leached out of the soil as long as it remains in the ammonia form.

But remember, nitrogen has a double personality. When favorable growing conditions for most crops come about, this Mr. Ammonia changes to nitrate nitrogen who is a lady. This is accomplished by the soil microorganisms. This conversion starts at 55 to 60° F. and with favorable conditions otherwise, is going full force at 80 to 90° F. Now nitrate nitrogen being a lady has no particular interest or attraction to Miss Soil Particle. Consequently, Miss Nitrate Nitrogen is very unstable. She moves with the water. If she happens to be in a sandy type of soil where the soil water can move easily and quickly, so does Miss Nitrate Nitrogen. If the water moves down out of reach of plant roots, as often happens during a big rain or a very heavy application of irrigation water, so does Miss Nitrate Nitrogen. Under such conditions, much or all of the nitrate nitrogen may be lost from the crop in this way. This is not the only way which nitrogen is lost from the soil, but it is a very important factor on sandy soils or a soil which permits free and easy movement of water through it.

Much nitrogen is lost from the soil. It is very doubtful, for example that under average field conditions more than 50 per cent of the applied nitrogen is actually recovered and used by the crop.

Potash is one of the very important gentlemen of the soil. Mr. Potash in his active form quite naturally marries some active lady who is present in the soil. This could be Miss Chlorine, Miss Nitrate, or Miss Sulfate. But there may not be a sufficient number of these ladies around; consequently, some of the potash gentlemen often marry the soil particle ladies.

These potash gentlemen which marry these very active ladies don't make a very stable family. The couple can move about to some extent with the soil water. In sandy soils where the soil water moves freely and easily, this couple may be washed or leached out of reach of the plants and thus lost from the crop. Potash may be lost in other ways too. He may marry the soil particle in such a manner (become fixed) that the plant root can't get it.

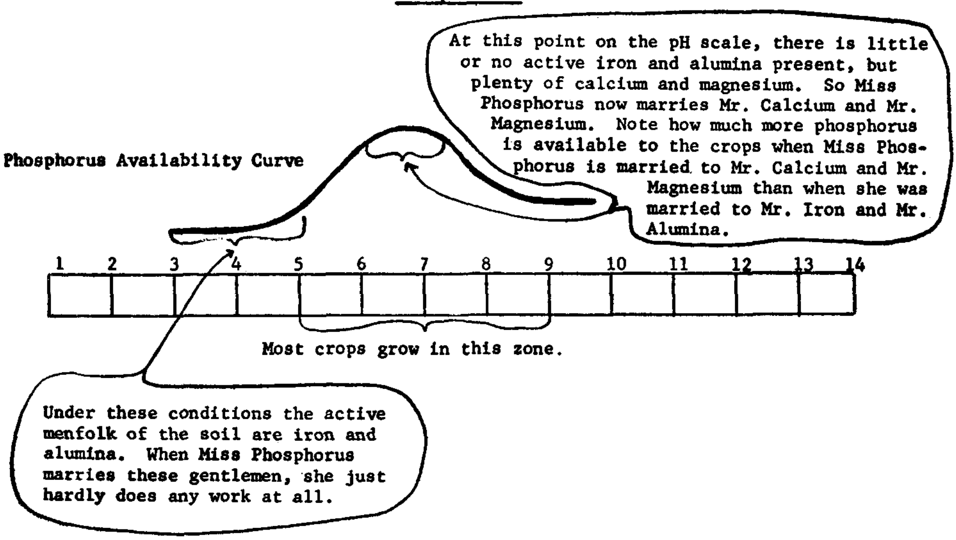
When all of these forms of losses are combined, Mr. Potash's efficiency fits into about the same category as nitrogen. Again, perhaps one-half of the applied potash under average field conditions is recovered by the current crop.

This Lady Phosphorus is an extremely interesting character. She is a very important lady in that she is the principal fruiting element of the soil. The fruit of the crop includes the blossom on the nursery crops; grain on the corn, grain sorghum, wheat, oats, barley, rye, and soybeans; the lint and seed in the case of the cotton crop, and on and on this could go.

Obviously, her work is very important, but she is an extremely lazy, faithless, and unpredictable woman. She is extremely active and in pure form will not live a single life except under water. She is a polygamist, but doesn't hesitate to let one or all of her husbands go and take others if it best accommodates her purpose.

Perhaps this can best be shown in the drawing showing some of her actions as affected by the pH of the soil. Remember that below 7.0 is acid and above 7.0 is alkaline.

THE pH SCALE




Though much more of the phosphorus is available to crops when she is married to calcium and magnesium than when she is married to iron and alumina, her efficiency is still very low. Under average field conditions it is doubtful that more than 20 per cent of the applied phosphorus is available to the current crop. Some of the applied phosphorus may become available during the second and third year on sandy and loam type soils, but not much on clays and particularly red clays.

### *Fertilizing Ponds or Lakes*

To be sure, there is a great deal of difference in growing field crops to feed and clothe man and to feed animals, and in growing water crops to feed fish. Yet, the starting point in growing natural food for fish is phytoplankton (a water plant). In its broadest sense, why shouldn't it behave somewhat like other plants? Why shouldn't it use the various plant foods for the same purposes? Why shouldn't nitrogen be the growth element, phosphorus the fruiting or reproduction element, and potash the health and vigor element? Why shouldn't the availability of phosphorus be greatly affected by the pH of the water?

It is very doubtful that satisfactory answers to all these questions are now at hand. But it has been shown by Alabama researchers that fish production can be tripled under their condition by proper use of inorganic fertilizers. The kind and amount of plant food needed to grow phytoplankton depends on many things including the plant food status of the native or untreated water.

If the water comes from a fertile watershed it is more apt to contain appreciable quantities of nitrogen and very likely more potash too than when the watershed is a non-productive type soil. Phosphorus, being fixed in the soil, doesn't move about much nor does it leach from the soil appreciably. Therefore, when the watershed is fertile land, the ratio of nitrogen to phosphorus needed may be somewhat less than where the water comes from poor land.

Blue-green algae can and does fix nitrogen from the air if sufficient phosphorus is present. So if any appreciable amount of blue-green algae is present, it can reduce the amount of nitrogen needed. Furthermore, the organic matter content in the water of an old pond may be high enough to supply very considerable amounts of nitrogen.

This can make a problem, especially when decomposition is speeded up by the application of some quickly available nitrogen. This stepped up decomposition activity by the microorganisms uses large amounts of the available oxygen, not leaving enough to support the fish, particularly the large fish. The resulting effect is that the fish die for lack of oxygen.

Because of this danger which exists when large amounts of organic matter in the water are decomposed rapidly, relatively smaller amounts of nitrogen should be applied at the first application. After this first period of accelerated decomposition, subsequent normal applications should not make any problem.

Ponds and lakes which receive sewage run-off from septic tanks, stock feed lots, effluent from primary or secondary sewage works, or animal manure lagoons, would contain a great deal of available plant food. Sawer in Wisconsin estimated that the sewage from one person for one year would supply about six pounds of nitrogen and one to two ounces of phosphorus. He further estimated that the sewage from 750 persons would supply as much nitrogen as the water from a one-square mile watershed in Southern Wisconsin. Europe uses sewage effluent to grow fish a great deal.

Phosphorus plays an important part in the fertilization of ponds and lakes. The availability of phosphorus is undoubtedly affected by the pH of the water. It would seem logical to expect that the availability of phosphorus in the pond or lake water would be affected by the pH of the water somewhat similar to the way it is affected in the soil. If true, the lime status of the water and the soil in the bottom of the lake would exert a great influence upon the availability of the phosphorus in the water.

Besides the effect of the lime status upon the availability of phosphorus, the pH of the water also exerts an important influence upon the fish themselves. Fish apparently thrive in water where the pH ranges from 6.0 to 9.0. But according to Neess, at a pH of 5.5 fish develop hypersensitivity to bacterial parasites and usually die at a pH of 4.5 or lower. In Europe where the soils of the watershed are acid, the lime is added to the soil in the watershed rather than to the water in the lake or pond.

*Suggestions for the Effective Use of Commercial Fertilizers in Growing Fish in the South*

1. Check the soil in the watershed area. If this soil is very fertile, the water in the pond or lake is apt to contain some nitrogen and potash. Since phosphorus doesn't leach out appreciably, the water may not contain comparable amounts of phosphorus. On the other hand, when the soil in the watershed is sandy or non-productive for other reasons, commercial fertilizers are apt to be needed badly.
2. Don't fertilize overflow bodies of water. There is too much likelihood that the fertilizer will be lost in the overflow water.
3. Don't fertilize in the spring until the water warms up to about 65° F. Fertilization of cold water may stimulate the growth of filamentous algae much more than the phytoplankton.
4. If it is an old lake or pond where considerable amounts of organic matter have accumulated, reduce the first application to one-half rate. Perhaps 50 pounds of 16-16-4 fertilizer per acre could be considered a normal application in this area.
5. Repeat normal application of fertilizer every 10 days until the desired bloom is attained and only as needed to maintain the desired "bloom" thereafter.
6. If the desired "bloom" is not attained in three to five treatments, better stop and find the trouble. Very likely something has gone wrong. It may be that filamentous algae or other plants are present and are eating the plant food. If true, these plants will have to be killed before the phytoplankton can do its job.
7. Apply fertilizer in bags, traps, or baskets submerged in the water, to prevent the phosphorus from coming in contact with the soil and becoming fixed into an unavailable form.

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# PHOSPHATE FERTILIZATION OF PONDS

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*ABSTRACT*

Pond fertilization with N-P-K has been used in the Southeast for the past 20 years to increase fish production and to control aquatic weeds and mosquitoes.

In ponds which had been fertilized previously for a 15-year period with N-P-K, no significant decrease in production resulted from omitting both nitrogen and potassium from the fertilizer mixture during a four-year experimental period. It appeared that adequate nitrogen for plankton production became available from nitrogen fixation by bacteria or algae and from the organic matter and ammonium stored in the bottom muds. Omission of phosphate, however, caused a decrease in

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