IV  General Concepts and Definitions

Fertilizers: General Definition

Broadly speaking, a fertilizer is any material, organic or inorganic, natural or synthetic, that furnishes to plants one or more of the chemical elements necessary for normal growth. The list of elements recognized as being necessary for plant growth has increased over the years and now totals 16, as shown in table 1. The first nine elements are required in relatively large amounts and are called macronutrients. Of these, carbon, hydrogen, and oxygen are supplied by air and water and are, therefore, not dealt with as nutrients by the fertilizer industry. The other macronutrients are subdivided into primary elements (nitrogen, phosphorus, and potassium) and secondary elements (calcium, magnesium, and sulfur). The remaining seven elements are required in much smaller amounts and are known as micronutrients or trace elements (see chapter XX).

In addition to the 16 essential elements listed above, some other elements have been shown, in certain circumstances, to be helpful in increasing crop yields or in improving the value of crops for animal or human nutrition. Examples are sodium, silicon, and cobalt.

Fertilizer Availability

A commercial fertilizer is a material containing at least one of the primary nutrients in a form assimilable or "available" to plants in known amounts. Generally, a plant nutrient is taken up by plant roots or foliage in the form of a solution in water. The primary nutrient elements form many different chemical compounds having varying degrees of solubility in water. Thus, it would seem that water solubility should provide a simple conclusive measure of the availability to plants. Unfortunately, the situation is far too complex for water solubility alone to serve as a measure of availability. All materials are soluble in water to some extent, even the most "insoluble."

Many sparingly soluble materials have been found to be available to plants and, in some cases, even more effective than readily water-soluble materials. (See Controlled-Release Fertilizers, chapter XXI.) However, some materials are so insoluble as to be virtually worthless as fertilizers. Therefore, most countries specify some degree of solubility of the nutrient content in water or other reagents or alternatively require identification and approval of the source of the material.

For example, natural organic materials may be acceptable on the basis of total N, P2O5, and K2O content, provided the source of the material is identified and approved. Synthetic organic materials, if sparingly soluble, may require special methods of analysis, particularly if intended for controlled-release fertilizers. Likewise, special tests may be required for coated controlled-release fertilizers.

Since most common nitrogen and potassium fertilizers are readily water soluble, water solubility usually is accepted as evidence of plant availability, and special methods are applied to less soluble materials only when there is some evidence to indicate that the low (or controlled) solubility may be advantageous.

In the case of phosphate fertilizers, there is a wide variety of both readily and sparing water-soluble materials, and several methods are in use for evaluating their agronomic availability. The most common methods other than water solubility are based on solubility of P2O5 in neutral or alkaline ammonium citrate solutions or in solutions of citric or formic acid. In addition, the total P2O5 may be acceptable for some materials. Some examples of the basis for quality control of phosphate fertilizers are:

Federal Republic of Germany--Phosphate is expressed as the sum of P2O5 soluble in water and (alkaline) ammonium citrate. For superphosphate, at least 90% of the sum must be soluble in water. For compound fertilizers, at least 30% of the sum must be soluble in water.

Belgium--For TSP, only the water-soluble P2O5 may be guaranteed. The product must contain at least 38% water-soluble P2O5.

Soft rock phosphate must contain not less than 25% P2O5 soluble in mineral acids, of which not less than 50% must be soluble in formic acid. It must be ground to a fineness such that at least 90% passes through a 0.15-mm mesh sieve.

For compound fertilizers the P2O5 content may be expressed as that soluble in water, in alkaline

TABLE 1. ELEMENTS ESSENTIAL FOR PLANT GROWTH

<table>
<thead>
<tr>
<th>Macronutrients</th>
<th>Carbon</th>
<th>Hydrogen</th>
<th>Oxygen</th>
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</thead>
<tbody>
<tr>
<td>Primary nutrients</td>
<td>Nitrogen</td>
<td>Phosphorus</td>
<td>Potassium</td>
</tr>
<tr>
<td></td>
<td>Calcium</td>
<td>Magnesium</td>
<td>Sulfur</td>
</tr>
<tr>
<td>Secondary nutrients</td>
<td>Boron</td>
<td>Chlorine</td>
<td>Copper</td>
</tr>
<tr>
<td></td>
<td>Manganese</td>
<td>Molybdenum</td>
<td>Zinc</td>
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</tbody>
</table>

For compound fertilizers the

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For compound fertilizers the P2O5 content may be expressed as that soluble in water, in alkaline
ammonium citrate, or the sum of the two. If the compound fertilizer contains Thomas (basic) slag as the only source of phosphate, the P₂O₅ claimed is that soluble in citric acid.

United States--The guaranteed P₂O₅ content of all fertilizers is based on the "available phosphoric acid" (APA) content which is the P₂O₅ content soluble in neutral ammonium citrate including that soluble in water. There is no provision for determining or stating the water-soluble P₂O₅ content separately. The total P₂O₅ may be stated but is not included in the guaranteed APA content.

European Economic Community (EEC)--Regulations adopted December 19, 1977, specified the following permissible solvents as a basis for evaluation of phosphate fertilizers:

1. Water for those materials "where applicable"
2. Formic acid (2%) for soft natural phosphates
3. Citric acid (2%) for basic slag
4. Petermann's solution at 65°C for precipitated dicalcium phosphate dihydrate
5. Petermann's solution at ambient temperature for "disintegrated phosphates"
6. Joulie's solution for all straight and compound fertilizers in which phosphate occurs in alumino-calci form
7. Neutral ammonium citrate solution for all fertilizer

Joulie's and Petermann's solutions are alkaline ammonium citrates containing free ammonia. Solvent compositions, extraction methods, ratios of sample to solvent, and methods for analysis are specified for each solvent.

It is beyond the scope of this manual to describe the details of analytical methods that are used for fertilizers. The development of suitable methods for analyzing fertilizers for availability has claimed the attention of agricultural chemists since the beginning of the industry. The methods are constantly being revised and improved as new knowledge and new tools become available to the chemist.

Fertilizer Regulations

Since a wide variety of natural and synthetic materials are beneficial to the growth of plants, a virtually unlimited number of products could truthfully be labeled "fertilizer" and marketed as such. The main drawback to uncontrolled marketing of fertilizer materials is the problem of the relative effectiveness of the product, and this depends on its composition. Unless the farmer can be sure that each lot of fertilizer he buys will have the same effectiveness as the preceding lot, he cannot be sure that he is fertilizing his crops in a rational manner, regardless of his stock of personal experience or advice from agricultural experiment stations.

Another drawback to uncontrolled marketing of fertilizer is the lack of a rational basis for pricing. A ton of low-analysis fertilizer is less valuable to the farmer than a ton of higher analysis fertilizer; therefore, the farmer should have a simple method for determining the best buy from the existing market.

Because of the foregoing factors, regulations (some of them in the form of laws) have been established in many parts of the world to govern the labeling and marketing of commercial fertilizers at the retail level. Since these regulations are intended for local conditions, they may vary from place to place, but the primary purposes are to ensure uniformity and to provide a simple method whereby the farmer can select the most economical product available to him.

Regulations add to the cost of fertilizer. In order to guarantee a given nutrient percentage, the manufacturer must provide some surplus, and the amount of the surplus depends on the degree of technical control during manufacture. Enforcement of regulations adds further to the cost of fertilizers. These costs, inherent in controlling fertilizer composition at the retail level, are compensated by the inherent benefits. Without basic regulations, the fertilizer trade would become chaotic. Like other regulations, care should be taken to limit them to the essentials.

Expression of Plant Nutrients--Oxide vs. Elemental Form

At present, most countries express quantities or percentages of plant nutrients in terms of elemental nitrogen (N), phosphorus pentoxide (P₂O₅), and potassium oxide (K₂O). Secondary and micronutrient elements usually are expressed on the elemental basis although calcium and magnesium sometimes are given as oxides. However, several countries have adopted the elemental basis for all plant nutrients. Recently FAO has moved toward the elemental form and during a transitional period will use both forms for phosphorus and potassium (P and P₂O₅, K and K₂O).

Conversion factors are shown in table 2.

<table>
<thead>
<tr>
<th>Table 2. Conversion Factors of Plant Nutrients (From Oxide to Elemental and from Elemental to Oxide Form)</th>
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<tbody>
<tr>
<td>P₂O₅</td>
</tr>
<tr>
<td>P</td>
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<tr>
<td>K₂O</td>
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<tr>
<td>K</td>
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<td>CaO</td>
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<td>Ca</td>
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<tr>
<td>Mg</td>
</tr>
<tr>
<td>SO₃</td>
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<td>S</td>
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³ The figures in parentheses could be used as conversion factors for some calculations when very high accuracy is necessary (in research papers, plant nutrient balance, etc.).


Definition of Some Fertilizer Terms

The following definitions of terms in common use in the fertilizer industry are limited to those whose meaning might not be obvious from usual dictionary definitions.

Grade--The grade of a fertilizer is the nutrient content expressed in weight percentages of N, P₂O₅, and K₂O in that order. In most countries the grade, when used for commercial purposes, includes only that amount of nutrient found by prescribed analytical procedures, thereby excluding any nutrient present in a form that is deemed to be unavailable for plant nutrition. For example, a grade of "10-15-18" indicates a fertilizer containing 10% N, 15% P₂O₅, and 18% K₂O as found by prescribed analytical procedures.

Some countries express fertilizer grades on an elemental basis as noted above. In this case, the grade 10-15-18 would become 10-6.5-14.9. Some countries express the grade on both an oxide and elemental basis. In this manual, the oxide basis will be used unless otherwise specified.

In some cases the "grade" may be called the"an-