# Soil Fertility and Fertilizers



Elements are the basic building blocks of chemistry and biology. Of the over 100 which have been identified, about 80 occur in nature, and only 16 are required for plants to complete their life cycle.

Three of the 16 (carbon, hydrogen, and oxygen) are provided to plants through photosynthesis. The others must be provided by, or through, the soil. These 13 are usually present as part of larger chemical compounds, but are generally able to divide into charged particles called ions which are used by growing plants. These ions are present in the soil solution (water between solid soil particles) and the roots of the plant from the water and move up through the plant in xylem tissue.

Table 1. The essential elements and their chemical symbol

| Element | Symbol | |
|---|---|---|
| Carbon | C | |
| Hydrogen | H | photosynthetic elements |
| Oxygen | O | |

| | | |
|---|---|---|
| Nitrogen | N | |
| Phosphorus | P | Primary plant food elements, macro-nutrients |
| Potassium | K | |

| | | |
|---|---|---|
| Calcium | Ca | |
| Magnesium | Mg | Secondary plant food elements |
| Sulfur | S | |

| | | |
|---|---|---|
| Boron | B | |
| Manganese | Mn | |
| Copper | Cu | |
| Zinc | Zn | Micro-nutrients |
| Iron | Fe | |
| Molybdenum | Mo | |
| Chlorine | Cl | |

The terms primary, secondary, and micronutrient do not reflect the relative importance of these groups, but rather the amount needed for plant growth. If any element is missing, abnormal patterns of growth may be expected.

**Natural Nutrient Sources: Air, Water, Soil**

Usually it is not necessary to be concerned about the elements of oxygen, hydrogen, and carbon. Although air is an unending source of carbon and oxygen, carbon can become a limiting factor in enclosed areas with slow air exchange. The plant uses carbon as carbon dioxide in the photosynthetic process. In winter, carbon dioxide is needed in enclosed areas like greenhouses and solariums.

Water is also a source of hydrogen and oxygen, and may supply some secondary and micronutrients. Growers should become familiar with the chemical analysis of the water supply in their area. The various water districts usually furnish this information on request.

The plant-availability of many micro-nutrients and phosphorus (and many other soil processes) depends on the pH or soil acidity. For instance, molybdenum becomes very unavailable at low pH, but maganese becomes very available (to the point of toxicity) in the same conditions. Knowledge of particular plant materials is necessary to set optimum pH levels.

Also important are the pH (acidity or alkalinity) factor and total salts in water. Irrigation practices can be critical if the water contains high total salts. Frequent light irrigations may cause salt accumulations in the roots and lead to serious plant injury. To avoid salt damage, water applications should be less frequent, but longer in duration to wash excess salts below normal root depth.

Plants obtain the primary and secondary nutrients and some micronutrients solely from the soil. While we can generalize and say soils often contain most elements required by higher plant life, there are many possible variations.

Some soils, particularly sands, can be deficient in several elements, either because they have been depleted by plants or because they have been leached out by rain and irrigation.

**Macro-nutrient Functions**

Nitrogen is part of every living cell and usually increases plant growth more than any other element. Inside the plant, nitrogen is part of amino acids, which in turn make up proteins. Thus nitrogen is an important component of DNA. It is also part of the chlorophyll molecule, thus it is important in photosynthesis.

Phosphorus serves as the currency of energy exchange within the plant itself. Thus it plays roles in photosynthesis, respiration, cell division, cell enlargement, and many other processes within the plant. It promotes early root formation, and improves the quality of many fruits and vegetables.

Potassium is somewhat of an enigma. It is essential for plant growth, however the exact functions within plants are not well understood. The primary function may be related to plant metabolism. It is known to be vital to photosynthesis, because it declines when potassium is deficient. Respiration increases when potassium is deficient. Combined, increased respiration and decreased photosynthesis reduces the plant carbohydrate supply. Potassium is known to be essential for protein synthesis and enzyme activation.

**Deficiency Symptoms**

The following are guidelines, and thus are not infallible. If doubt exists, plant tissue samples should be analyzed by a reputable laboratory.

Nitrogen: Plants with adequate nitrogen have a dark green color because of high concentrations of chlorophyll. Conversely, nitrogen deficiency leads to reduced chlorophyll concentrations and thus chlorosis (yellowing) of leaves. This is shown first on the oldest leaves and then younger leaves as the deficiency worsens. Some plants ( strawberries ) show a reddening of the older leaves.

Phosphorus: The first indication of phosphorus deficiency is an over-all stunted plant. Leaves may be unusually dark green at some stages, may have distorted shapes, and may become purple. Lower leaves may turn yellow between the veins. If stunting is suspected, confirm the visual symptom with plant tissue analysis.

Potassium: Scorching, or firing occurs along margins of older leaves. However, some plants under certain conditions will exhibit deficiency on younger leaves first. Growth rate is slow, root systems are poorly developed, weak stalks, and lodging often occurs. Disease resistance is very low.

Calcium: Deficiency symptoms commonly occur on the youngest tissues because calcium does not move within the plant. Root growth is poor, the growing point may die and the roots turn black and rot. Leaf tips will turn jelly-like and die. Blossom-end rot of tomatoes is calcium deficiency. (Maintenance of soil pH normally precludes calcium nutrition problems.)

Magnesium: Margins of older leaves curl. Leaves may show yellowish, bronze, or reddish colors while the veins remain green.

Sulfur: Leaves have a pale green color usually seen first on younger ones, however the whole plant may take on the pale green appearance. Sulfur deficiencies most commonly occur on sandy soils or other low organic matter soils.

Iron: Younger leaves yellow between veins, but yellowing spreads to whole leaf and the leaves die from the edges.

Manganese: Upper leaves become yellow between the veins. In severe cases dead spots form. The veins remain greenand get checkered effect on young leaves.

Boron: Plants become brittle and growing tips may die.

Deficiency symptoms should not be solely relied on for fertilizer recommendations due to two complicating factors. First, a great number of problems cause symptoms (many nutrients, virus and other diseases, physiological problems, genetic factor, insect damage, etc.) that confuse even experts. Second, is the law of the minimum, whatever nutrient is the shortest in supply will be the first to limit growth, however other nutrients also may be deficient. Therefore, soil testing using a reputable soils laboratory, and/or plant tissue testing is recommended before making remedial fertilizer applications.

**Fertilizer Grades/Analysis**

Macro-nutrient (primary nutrients) fertilizers are identified by a series of three numbers, for example 5-10-15. In the United States, these numbers have a very exact meaning, and furthermore, most states by statute, including Mississippi, require fertilizer manufacturers to verify these numbers for their products.

The first number (5 in the example) represents what percentage of the fertilizer material is available nitrogen. It may be in nitrate ($NO_3^-$), ammoniacal ($NH_4^+$), or organic form. The law stipulates that the percentage of the nitrogen in each form appear on the label. The source of any organic nitrogen (blood meal, tankage, seed meal, urea, etc.) also must be shown. The form of nitrogen is important in fertilizer timing as most plants use nitrates preferably and the conversion of other forms to nitrates requires time for microbial activity to proceed.

Table 2. Nitrogen forms and plant utility

- Organic Nitrogen - organic residue from decomposed plants and animals, N must be converted

- Ammonia ($NH_3$) - not normally useful to plants
- Ammonium ($NH_4^+$) - plants use $NH_4^+$, but quickly converted to other forms in soils.
- Nitrites ($NO_2^-$)- not useful to plants, usually exists for brief times in soils before transformation.
- Nitrates ($NO_3^-$) - useful to plants

The second and third numbers of fertilizer grades are not as straight forward. The numbers represent the nutrients as being in the 'oxide' form, but this is rarely the true case. This convenient fiction has been in place for many years. The majority of fertilizer recommendations from soil testing laboratories acknowledge this situation.

The second number (10 in the example) is the percentage phosphorus content expressed as phosphate. If the actual phosphorus content of the material is desired, simply multiply the phosphate ($P_2O_5$) by 0.44. To convert back, multiply phosphorus by 2.29 to calculate phosphate.

The third number is the percentage potash content (15 in the example) which is an expression of the potassium in the material. To convert to elemental potassium, multiply the potash number by 0.83. To do the opposite, multiply the potassium number by 1.20 to determine potash.

Fertilizer materials containing other nutrients are available. For example, ammonium sulfate is sold both for its nitrogen content and its sulfur content. The label must be read closely to determine what nutrients are guaranteed by the manufacturer/seller.

In summary, for our 5-10-15 fertilizer: there is 5 % nitrogen (the forms of nitrogen provided on the label), 10% phosphate, and 15 percent potash. One hundred pounds of the product has 5 pounds of nitrogen, 10 pounds of phosphate equivalent, and 15 pounds of potash equivalent. Fifty pounds of 5-10-15 has 2.5 pounds N, 5 pounds phosphate, and 7.5 pounds of potash.

Some fertilizers do not contain all the macro-nutrients. In those cases, a zero is included in the analysis for whatever nutrient is not present in the material.

Mixing fertilizers allows the formulation of any desired analysis. A list of commonly available materials is provided in the Appendix below.

**Nutrient Management**

The days of simply grabbing a bag, or jug, of something with a few numbers on the front of it and putting it on or in the growth media are gone. Nutrient management is the combining of soil fertility recommendations with an eye to larger environmental issues such as surface and ground water quality.

Even though individual flower beds or lawns may seem benign within a landscape, there can be tremendous cumulative effects as well as the occasional ëworst case'. Research, tracking the actual sources of surface water nutrients in a ënon-point source' pollution study of one watershed, found one small lawn (significantly less than 1 acre) received over 1300 pounds of nitrogen ñ in one summer!

The chemical behavior of the macro-nutrients in soils is key to understanding their fertility management. Potassium is always a positively charged ion (cation) in soils. Most soil clay particles (see Introductory Soils) are negatively charged. Because of the particular chemistry of the potassium cation and the fact that opposites attract, potassium is relatively immobile in soils. It stays ëstuck' to the soil clay particles, and becomes slowly available to plants. Potassium movement and enrichment in waters has rarely been an environmental issue.

Nitrogen in the ammonium form ($NH_4^+$) also adheres closely to the negatively charged soil particles, plus it is also subject to loss to the atmosphere. Some soil micro-organisms utilize ammonium in their own life cycle, and release it as nitrite ($NO_2^-$). Other microbes then utilize the nitrite and convert it to nitrate ($NO_3^-$).

Plants can use either ammonium or nitrate, but much more is in the nitrate form in the soil solution (water in the soil). Because it is negatively charged, it does not adhere closely to soil particles. Also, nitrate is a very soluble compound and thus subject to leaching (movement downward through the soil) to ground waters or within water moving laterally above or below the surface to surface or ground waters. The Environmental Protection Agency has set 10 parts per million as the maximum nitrogen content of drinking water.

Phosphorus normally exists in soils with pH values between 5 and 7 as the ortho-phosphate ion (H2PO4-). While it is negatively charged like nitrate, the chemistry of ortho-phosphate is much different. It forms very tight bonds to soil particles through different mechanisms than potassium. Phosphorus movement through landscapes is closely associated with transport of soil particles. When phosphorus is translocated to surface waters, algae growth is often stimulated to the point other more desirable species are crowded out through a process called eutrophication.

**Liming to Reduce Soil Acidity**

When soils are too acid, limestone or other liming materials can be added to neutralize the excess acidity. The chemical process is rather complex, but how lime works can be described simply:

As shown in the Basic Soils section, pH expresses the hydrogen ion activity. Lime reduces acidity (increases pH) by using some of those hydrogen ions to make water and other chemical products. Calcium from the lime replaces two hydrogen ions in the soil. The hydrogen ions combine with hydroxyl ions (-OH) to form water (H2O). The pH increases because the hydrogen ion concentration decreases.

The opposite of the above also happens, making acid soils more acid. Calcium, magnesium, and potassium can be lost from the soil by crop uptake or leaching and replaced by hydrogen, thus making soils more acid as well. Regular liming programs, based on soil tests, are therefore required to prevent continuing increased acidity (lowered pH).

Two factors affect lime quality: neutralizing value and fineness of the particles. Lime usefulness is improved on contact with the soil. Most liming materials are only sparingly soluble in water and should be mixed well into the soil. Smaller particles will neutralize acidity soon after application. Optimal results are obtained by liming two to three months prior to planting. Moisture is critical in getting lime to work, however large particles may never dissolve.

**Liming Materials**

Common liming materials available in Mississippi include calcitic based materials which are called limestone. Dolomite or dolomitic limestone contains magnesium as well as calcium and should be used if the soil test indicates a need for magnesium.

Mississippi marl and basic slag are widely available in the state. Both are effective for neutralizing acidity, but must be managed carefully to avoid application problems.

Gypsum has no neutralizing value and is not a liming material. It can be used as a source of calcium or sulfur, if needed, and has positive effects on soil structure.

**Fertilizer Application**

There are a few basic, fundamental questions that must be addressed when planning fertilization.

- Is the fertilizer necessary?
- How much should be applied?
- What source of plant food should be used?
- When should it be applied?

- Where/how should it be applied?

The need for preplant phosphorus and potassium should be assessed by soil testing. If growing plants show apparent deficiency symptoms, plant tissue tests should be performed to confirm suspected problems.

Because nitrogen exists in several forms in the soil, and interchanges rapidly between those forms, soil testing for nitrogen has not proven advantageous in the warm, humid south. Nitrogen management depends on knowledge of nitrogen requirements of the various species. Nitrogen recommendations are often provided for many garden, lawn, and vegetable situations when soil tests for phosphorus and potassium are performed. Split or multiple applications will provide the nitrogen when the plant can most efficiently use it, and reduce possible movement through the landscape.

Phosphorus and potassium soil test results will have an index value assigned to each pounds per acre value. These indices are commonly very low, low, medium, and high. The interpretation is that soils with a high index will rarely respond to fertilizer application of the nutrient, therefore it would be unwise to add it. Medium index soils often will have a ëmaintenance' recommendation of fertilizer which depends solely on the manager whether to apply. Fertilizer recommended when indices are low or very low will likely have a visual response in the growing crop.

If erosion is controlled, movement of potassium and phosphorus in soils is limited, so annual gardens should have these nutrients applied prior to planting and worked into the ground.

Appendix: Common Fertilizer Grades

| Fertilizer | Nitrogen % | Phosphate % | Potash % |
|---|---|---|---|
| 10 - 10 - 10 | 10 | 10 | 10 |
| 13 - 13 - 13 | 13 | 13 | 13 |
| Ammonium nitrate | 33.5 - 34 | 0 | 0 |
| Ammonium sulfate | 21 | 0 | 0 |
| Calcium nitrate | 16 | 0 | 0 |
| Sodium nitrate | 16 | 0 | 0 |
| Potassium nitrate | 13 | 0 | 0 |
| Urea | 45 | 0 | 0 |
| Animal tankage | 9 | 10 | 1-2 |
| Blood, dried | 13 | ? | 1-2 |
| Fish meal | 10 | 5 | 1-2 |
| Manures | highly variable | | |
| Ordinary superphosphate | 0 | 20 | 0 |
| Triple superphosphate | 0 | 46 | 0 |
| Bonemeal, steamed | ? | 22 | 1-2 |
| Muriate of potash | 0 | 0 | 60-62 |

| | | | |
|---|---|---|---|
| Potassium nitrate | 0 | 0 | 44 |
| Potassium sulfate | 0 | 0 | 50 |

**Publications**

Extension Soils/Fertilization publications
Soils for Vegetable Production
Nitrogen in Mississippi Soils
Phosphorus in Mississippi Soils
Soil Testing for the Farmer