A fertilizer is any material of natural or synthetic origin (other than liming materials) that is applied to soils or to plant tissues to supply one or more plant nutrients essential to the growth of plants. Many sources of fertilizer exist, both natural and industrially produced.

**Three main macronutrients:**

1. Nitrogen (N): leaf growth
2. Phosphorus (P): Development of roots, flowers, seeds, fruit;
3. Potassium (K): Strong stem growth, movement of water in plants, promotion of flowering and fruiting;

**Three secondary macronutrients:**

1. Calcium (Ca)
2. Magnesium (Mg)
3. Sulfur (S)

**Micronutrients:**

- Copper (Cu), Iron (Fe), Manganese (Mn), Molybdenum (Mo), Zinc (Zn), Boron (B). Of occasional significance are Silicon (Si), Cobalt (Co), and Vanadium (V).

**Plants are made up of four main elements:**

- Hydrogen, oxygen, carbon, and nitrogen. Carbon, hydrogen and oxygen are widely available as water and carbon dioxide.
- Although nitrogen makes up most of the atmosphere, it is in a form that is unavailable to plants.

**Nitrogen**

- Nitrogen is the most important fertilizer since nitrogen is present in proteins, DNA and other components (e.g., chlorophyll).
- To be nutritious to plants, nitrogen must be made available in a "fixed" form.
- Only some bacteria and their host plants (notably legumes) can fix atmospheric nitrogen (N$_2$) by converting it to ammonia.

**Phosphate:**

- Phosphate is required for the production of DNA and ATP, the main energy carrier in cells, as well as certain lipids.
- Micronutrients are consumed in smaller quantities and are present in plant tissue on the order of parts-per-million (ppm), ranging from **0.15 to 400 ppm DM**, or less than **0.04% DM**.
### Classification:

- Fertilizers are classified in several ways.
- They are classified according to whether they provide a **Single Nutrient** (e.g., K, P, or N), in which case they are classified as "Straight Fertilizers", "Multinutrient Fertilizers" (or "complex fertilizers") provide two or more nutrients, for example N and P.

#### Single nutrient fertilizers:

- The main nitrogen-based straight fertilizer is **ammonia** or its solutions.
- **Ammonium nitrate** (NH₄NO₃) is also widely used.
- **Urea** is another popular source of nitrogen, having the advantage that it is solid and non-explosive, unlike ammonia and ammonium nitrate, respectively.
- A few percent of the nitrogen fertilizer market (4% in 2007) has been met by **calcium ammonium nitrate** (Ca(NO₃)₂ · NH₄NO₃ · 10H₂O).
- The main straight **phosphate fertilizers** are the **superphosphates**.
- "**Single superphosphate**" (SSP) consists of 14–18% P₂O₅, again in the form of Ca(H₂PO₄)₂, but also **phosphogypsum** (CaSO₄ · 2H₂O).
- **Triple superphosphate** (TSP) typically consists of 44–48% of P₂O₅ and no gypsum.

#### Multinutrient fertilizers:

- These fertilizers are the most common. They consist of two or more nutrient components.

#### Binary (NP, NK, PK) fertilizers:

- Major two-component fertilizers provide both nitrogen and phosphorus to the plants. These are called **NP fertilizers**.
- The main NP fertilizers are **monoammonium phosphate** (MAP) and **diammonium phosphate** (DAP).
- The active ingredient in MAP is NH₄H₂PO₄.
- The active ingredient in DAP is (NH₄)₂HPO₄.
- About 85% of MAP and DAP fertilizers are soluble in water.

#### NPK fertilizers:

<table>
<thead>
<tr>
<th>Fertiliser</th>
<th>Formula</th>
<th>Essential elements</th>
<th>Acid</th>
<th>Alkali</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium nitrate</td>
<td>NH₄NO₃</td>
<td>nitrogen</td>
<td>nitric acid</td>
<td>ammonia</td>
</tr>
<tr>
<td>Ammonium phosphate</td>
<td>(NH₄)₃PO₄</td>
<td>nitrogen and phosphorus</td>
<td>phosphoric acid</td>
<td>ammonia</td>
</tr>
<tr>
<td>Ammonium sulfate</td>
<td>(NH₄)₂SO₄</td>
<td>nitrogen</td>
<td>sulfuric acid</td>
<td>ammonia</td>
</tr>
<tr>
<td>Urea</td>
<td>(NH₂)₂CO</td>
<td>nitrogen</td>
<td></td>
<td>ammonia</td>
</tr>
<tr>
<td>Potassium nitrate</td>
<td>KNO₃</td>
<td>potassium and nitrogen</td>
<td>nitric acid</td>
<td>potassium hydroxide</td>
</tr>
</tbody>
</table>
NPK fertilizers are three-component fertilizers providing nitrogen, phosphorus, and potassium.
NPK rating is a rating system describing the amount of nitrogen, phosphorus, and potassium in a fertilizer.
NPK ratings consist of three numbers (e.g., 10-10-10 or 16-4-8) describing the chemical content of fertilizers.

1. The first number represents the percentage of nitrogen in the product
2. The second number, $P_2O_5$.
3. The third, $K_2O$.

Fertilizers do not actually contain $P_2O_5$ or $K_2O$, but the system is a conventional shorthand for the amount of the phosphorus (P) or potassium (K) in a fertilizer.
Most fertilizers are labeled according to this N-P-K convention, although Australian convention, following an N-P-K-S system, adds a fourth number for sulfur, and uses elemental values for all values including P and K.

Micronutrients:
- The main micronutrients are molybdenum, zinc, and copper.
- These elements are provided as water-soluble salts.
- Iron presents special problems because it converts to insoluble (bio-unavailable) compounds at moderate soil pH and phosphate concentrations.
- The micronutrient needs depend on the plant.
- For example, sugar beets appear to require boron, and legumes require cobalt.

<table>
<thead>
<tr>
<th>Country</th>
<th>Total Nitrogen use</th>
<th>Amt. used for feed/pasture</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>18.7</td>
<td>3</td>
</tr>
<tr>
<td>India</td>
<td>11.9</td>
<td>N/A</td>
</tr>
<tr>
<td>U.S.</td>
<td>9.1</td>
<td>4.7</td>
</tr>
<tr>
<td>France</td>
<td>2.5</td>
<td>1.3</td>
</tr>
<tr>
<td>Germany</td>
<td>2</td>
<td>1.2</td>
</tr>
<tr>
<td>Brazil</td>
<td>1.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Canada</td>
<td>1.6</td>
<td>0.9</td>
</tr>
<tr>
<td>Turkey</td>
<td>1.5</td>
<td>0.3</td>
</tr>
<tr>
<td>UK</td>
<td>1.3</td>
<td>0.9</td>
</tr>
<tr>
<td>Mexico</td>
<td>1.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Spain</td>
<td>1.2</td>
<td>0.5</td>
</tr>
<tr>
<td>Argentina</td>
<td>0.4</td>
<td>0.1</td>
</tr>
</tbody>
</table>
• Nitrogen fertilizers are made from ammonia (NH$_3$), which is sometimes injected into the ground directly. The ammonia is produced by the Haber-Bosch process.
• In this energy-intensive process, natural gas (CH$_4$) usually supplies the hydrogen, and the nitrogen (N$_2$) is derived from the air.
• This ammonia is used as a feedstock for all other nitrogen fertilizers, such as anhydrous ammonium nitrate (NH$_4$NO$_3$) and urea (CO(NH$_2$)$_2$).

Phosphate fertilizers:

• The most popular phosphate-containing minerals are referred to collectively as phosphate rock.
• The main minerals are fluorapatite Ca$_5$(PO$_4$)$_3$F (CFA) and hydroxyapatite Ca$_5$(PO$_4$)$_3$OH.
• These minerals are converted to water-soluble phosphate salts by treatment with sulfuric (H$_2$SO$_4$) or phosphoric acids (H$_3$PO$_4$).

Potassium fertilizers:

• Potash is a mixture of potassium minerals used to make potassium (chemical symbol: K) fertilizers.
• Potash is soluble in water, so the main effort in producing this nutrient from the ore involves some purification steps; e.g., to remove sodium chloride (NaCl) (common salt).
• Sometimes potash is referred to as K$_2$O, as a matter of convenience to those describing the potassium content.
• In fact potash fertilizers are usually potassium chloride, potassium sulfate, potassium carbonate, or potassium nitrate.

Compound fertilizers:

• Compound fertilizers, which contain N, P, and K, can often be produced by mixing straight fertilizers.
• In some cases, chemical reactions occur between the two or more components. For example, monoammonium and diammonium phosphates, which provide plants with both N and P, are produced by neutralizing phosphoric acid (from phosphate rock) and ammonia:

\[
\text{NH}_3 + \text{H}_3\text{PO}_4 \rightarrow (\text{NH}_4)\text{H}_2\text{PO}_4 \\
2\ \text{NH}_3 + \text{H}_3\text{PO}_4 \rightarrow (\text{NH}_4)\text{HPO}_4
\]

Organic fertilizers:
“Organic fertilizers” can describe those fertilizers with an organic — biologic — origin—that is, fertilizers derived from living or formerly living materials.

The “organic fertilizer” products typically contain both some organic materials as well as acceptable additives such as nutritive rock powders, ground sea shells (crab, oyster, etc.), other prepared products such as seed meal or kelp, and cultivated microorganisms and derivatives.