

Chemistry in a coffee cup: does coffee waste contain key elements for plant growth?

Infosheet 2: What do plants need to grow?

What do plants need to grow?

Plants have the amazing ability to synthesize sugars from carbon dioxide and water using sunlight through photosynthesis. However, to build all the compounds they need to grow, they also need several essential elements, including nitrogen, phosphorus, potassium, and magnesium.^[1,2]

Nitrogen (N): vital for the production of amino acids; proteins; and chlorophyll, which is essential for photosynthesis.

Phosphorus (P): essential for energy transfer through adenosine triphosphate (ATP), nucleic acid synthesis, and root development.

Potassium (K): important for enzyme activation, water regulation, and overall plant health.

Magnesium (Mg): central component of the chlorophyll molecule and cofactor of many enzymatic reactions.



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These elements are absorbed from the soil and are essential for various physiological and biochemical processes in plants. Nitrogen, phosphorus, and potassium are particularly critical elements that are often present in low amounts in soil, which is why fertilizers often contain these, and you can buy mineral fertilizers that focus on them, called NPK fertilizers.

These nutrients are not taken up as pure elements. Pure nitrogen exists as N_2 gas in the air and plants can't use it in that form. Elemental phosphorous is highly reactive and unstable, and it is not found in nature. Finally, potassium is a reactive alkali metal that [reacts violently with water](#) (you may have seen this in a chemistry lesson), so it's also not found in the soil. Plants thus access these elements via inorganic compounds.

Nitrogen

Nitrogen is one of the most important nutrients for plant growth. It is used by plants to build amino acids, which are the building blocks of proteins, and is essential for forming chlorophyll, the green pigment that allows plants to do photosynthesis.

Nitrogen helps plants grow faster, develop more leaves, and increase their protein content. It also plays a key role in enzyme activity, vitamin formation, and overall plant health. Without enough nitrogen, plants may grow slowly, turn yellow (a symptom called chlorosis), and produce fewer flowers or fruits.



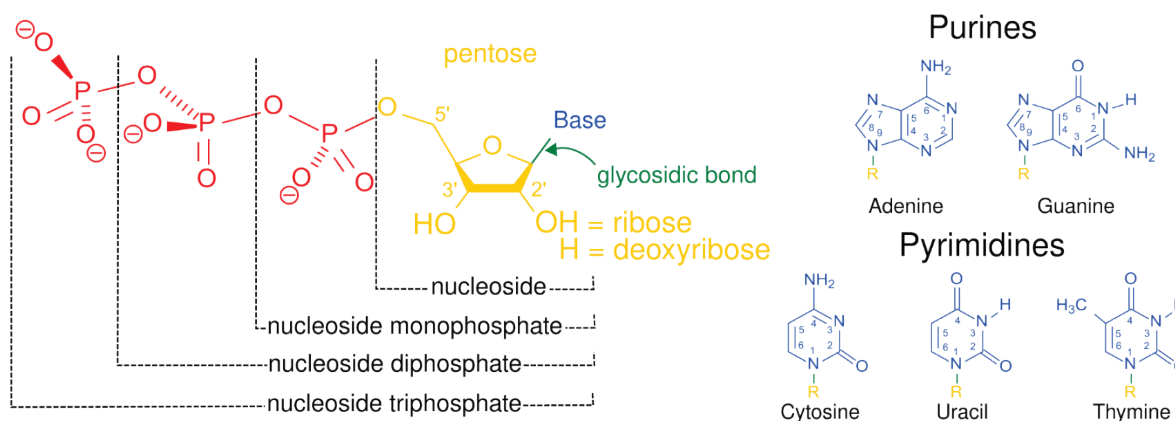
Nitrogen-deficient wheat plants (right) showing growth depression and yellowing due to chlorosis, compared to healthy control plants on the left

Image: International Maize and Wheat Improvement Center/[flickr](#), [CC BY-NC-SA 2.0](#)

Nitrogen (N_2) gas is quite stable and needs to be split and 'fixed' as an inorganic compound for plants to be able to use it. Plants absorb nitrogen mainly in two forms: nitrate (NO_3^-) and ammonium (NH_4^+). These forms are created through natural processes like lightning, [microbial action in the soil](#), and organic matter decomposition.

Phosphorus

Phosphorus is an essential plant nutrient that plays a key role in plant energy transfer; root development; and flower, fruit, and seed formation. It is part of important molecules such as ATP and DNA that help plants grow and function properly. Young plant tissues, such as roots and shoots, need a lot of phosphorus because they are growing rapidly.



Chemical structures of nucleotides, which are the building blocks of DNA and have other important functions in cells, like the energy currency of the cell: ATP. Note all the phosphorus atoms in the phosphate (red) part

Image: Boris/Wikipedia, Public Domain

Phosphorus compounds occur naturally in the soil at an average of about 0.05 wt%, but only a small amount is available to plants. Plants take up phosphorus in the form of dihydrogen phosphate (H_2PO_4^-) and monohydrogen phosphate (HPO_4^{2-}) ions. The former is soluble in water and readily available to plants, while the latter is only soluble in weak acids (such as citric acid) and is therefore absorbed more slowly. In fertilizers, the amount of available phosphorus is usually expressed as a percentage of P_2O_5 (phosphorus pentoxide) by mass.

Potassium

Unlike nitrogen or phosphorus, potassium does not become part of the plant's cells or structures. Instead, potassium ions are directly involved in many important plant processes. Potassium helps plants move water and nutrients around and activates many enzymes in plant cells. It plays an important role in photosynthesis and helps plants resist drought, disease, and cold. It also helps plants grow stronger roots and produce better-quality fruit and seeds.



A leaf from a tomato plant with potassium deficiency. The leaf leaves start to turn yellow and the edges start to curl and turn brown.

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In the soil, potassium comes from potassium-containing minerals. Some soils have a lot of potassium, while others do not.

References

- [1] Uchida R (2000) Essential nutrients for plant growth: nutrient functions and deficiency symptoms. In Silva JA, Uchida R (eds) *Plant Nutrient Management in Hawaii's Soils, Approaches for Tropical and Subtropical Agriculture* pp 31–32. University of Hawaii. ISBN: 1929235088
- [2] Information on nutritional requirements for plants: <https://openstax.org/books/biology-2e/pages/31-1-nutritional-requirements-of-plants>