

# Potassium and Sodium: fraternal twins!

## 1. Two alkaline cations

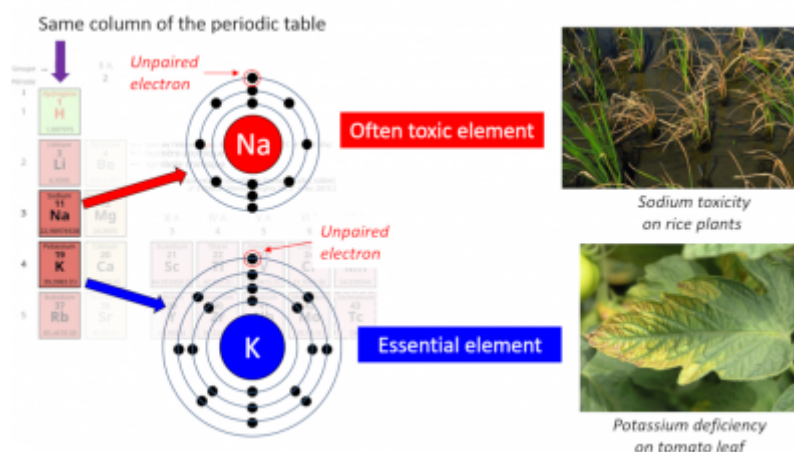


Figure 1. Sodium and potassium are very close from a physicochemical point of view. [Source: © EEnv diagram / Photos: rice plants © International Rice Research Institute / CC BY-NC-SA 3.0; tomato leaf © Goldlocki / CC BY-SA 3.0]

The two alkaline cations  $\text{Na}^+$  and  $\text{K}^+$  have **similar relative abundances** in the earth's crust but show **very different distributions** in the biosphere. [1] In the earth's crust and in seawater, they are (by far!) the most available monovalent inorganic cations.

Physically and chemically, these two ions are **very similar**. [2] Root uptake by plants occurs exclusively from the  $\text{K}^+$  and  $\text{Na}^+$  cations dissolved in the soil solution.  $\text{K}^+$  is a macroelement that represents **2-5% of the plant's dry mass**. It is the most abundant cation in the cytosol with a concentration of ~100 mM; that of  $\text{Na}^+$  is kept below 30 mM. In the soil,  $\text{K}^+$  must be at a concentration of the order of a millimolar to allow optimal plant growth.

On the other hand,  $\text{Na}^+$  is frequently **toxic to plants** while  $\text{K}^+$  is essential to plant life (Figure 1). Indeed, salinity is one of the major and growing threats to agricultural production.  $\text{Na}^+$  is an element only for some **halophytes**.

## 2. Potassium is essential for plants

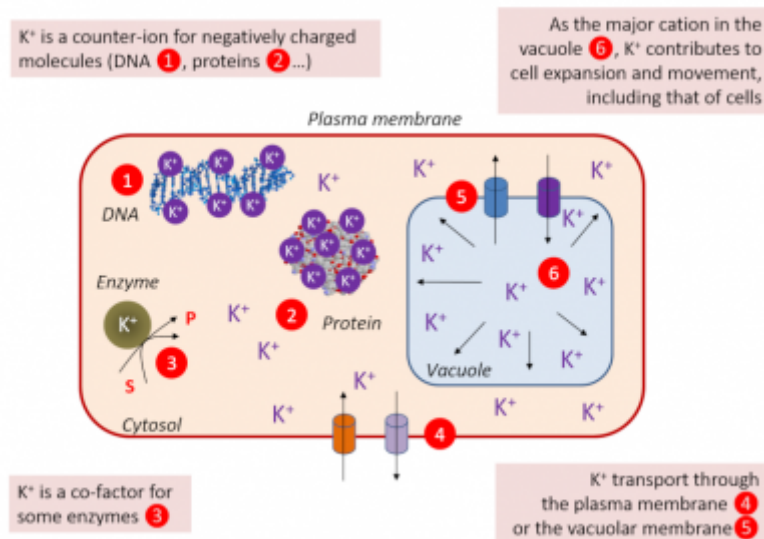


Figure 2. Potassium is essential for plant life. [Source: © EEnv diagram]

Plant growth requires **large amounts of K<sup>+</sup> ions** that are absorbed by the roots in the soil solution and then distributed throughout the plant. K<sup>+</sup> ions are slowly released by soil particles and clays into the soil solution, and their availability is often **limiting** for optimal growth in most natural ecosystems. K<sup>+</sup> plays a role in plant physiology:

- Essential for **enzymes** as a co-factor in glycolysis (pyruvate kinase), starch synthesis (starch synthase), protein synthesis, photosynthesis (phosphoenol-pyruvate-carboxylases) [3], ...
- Ensuring the cell's **turgidity**, which is essential for cell expansion and therefore for tissue and plant growth.
- Responsible, as a major solute, with its counter-ions (malic acid and chloride ion), for an **osmotic gradient** necessary for the entry of water into guard cells when opening stomata. The depolarization of the plasma membrane of the guard cells causes the K<sup>+</sup> to exit, the deflation and the closure of the **stomata**. This stomatal movement is a key element responsible for gas and water exchanges.
- The **membrane potential of the cells** varies according to the K<sup>+</sup> concentration on each side of the plasma membrane. Membrane potential affects the transport of different solutes across the membrane (Figure 3).

### 3. Membrane potential and transport of Potassium and Sodium

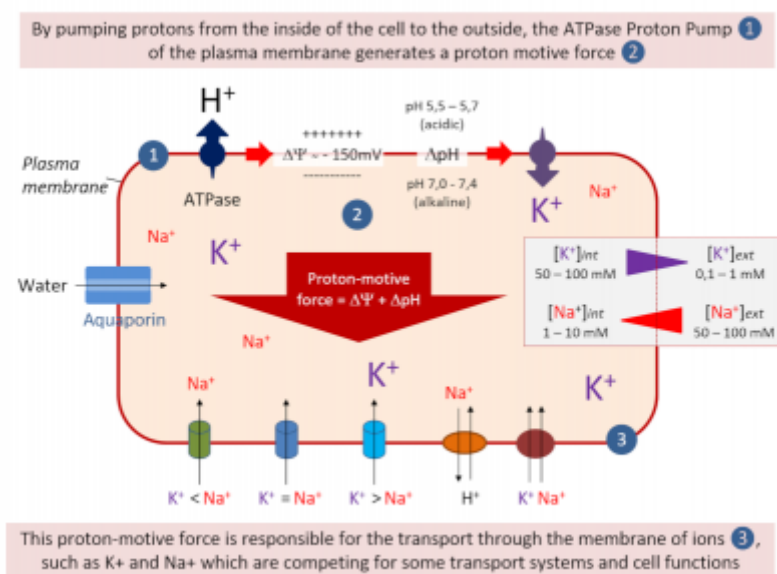


Figure 3. The protomotive force generated by the ATPase proton pump of the plasma membrane allows membrane transport of K<sup>+</sup> and Na<sup>+</sup>. [Source: © EEnv diagram]

Establishing the **electrical polarization of** the plasma membrane is an essential membrane process, especially in plants. Thus:

- On either side of the plasma membrane, there is an electrical potential difference called the **membrane potential**. In other words, the cytosolic side of the plasma membrane is negatively charged and its outer side positively charged (Figure 3).
- It is the **ATPases**, proton pumps inserted into the plasma membrane, that hydrolyze the ATP, providing the energy needed to transport protons ( $H^+$ ) from the cytosol to the external environment. This creates a negative potential on the cytosolic side of the membrane (Figure 3).
- This **electric potential**, stabilized between -100 and -200 mV by the proton pumps, "**energizes**" the plasma membrane, thus contributing to the ions transport through the membrane (Figure 3).

$K^+$  plays a crucial role in establishing the electrical polarization of the plasma membrane in plants. Thus, external  $K^+$  concentrations can vary the value of the membrane potential, and **Shaker-type  $K^+$  transport systems** inserted into the plasma membrane are responsible for these variations.

On the other hand,  **$Na^+$**  has deleterious effects in the cell, but also on the cell surface, as it also **seriously disrupts the electrical polarization** of the plasma membrane (See [How do plants tolerate a salty diet?](#)).

**$Na^+$  competes with  $K^+$**  (Figure 3) for the absorption of the latter in the root cell, as both ions are transported across the plasma membrane by several identical transport systems (non-selective cation channels of the NSCC type and high affinity transporters HKT). This phenomenon is **exacerbated** in situations of **salinity stress** (See [How do plants tolerate a salty diet?](#)).

## Notes and References

**Cover image.** Sodium toxicity on rice plants. [Source: *International Rice Research Institute* / CC BY-NC-SA 3.0]

[1] Nieves-Cordones M., Al Shiblawi F.R. & Sentenac H. (2016) Roles and Transport of Sodium and Potassium in Plants. In: Sigel A., Sigel H., Sigel R. (eds) *The Alkali Metal Ions: Their Role for Life. Metal Ions in Life Sciences*, vol 16. Springer, Cham. [https://doi.org/10.1007/978-3-319-21756-7\\_9](https://doi.org/10.1007/978-3-319-21756-7_9)

[2] Benito B., Haro R., Amtmann A., Cuin T.A. & Dreyer I. (2014) The twins  $K^+$  and  $Na^+$  in plants. *J Plant Physiol.* 171(9):723-731. doi:10.1016/j.jplph.2013.10.014

[3] Morot-Gaudry J.-F. & Joyard J. (2020), [The path of carbon in photosynthesis](#), Encyclopedia of Environement, [online ISSN 2555-0950]

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