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POTASSIUM: THE OVERLOOKED NUTRIENT IN PLANT HEALTH AND SOIL FERTILITY

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Abstract: *Potassium (K) is a vital macronutrient essential for soil fertility and plant growth. It exists in various forms within the soil: readily available, exchangeable, and fixed within mineral structures. The mobility and bioavailability of potassium are influenced by factors such as soil composition, cationic exchange capacity, microbial activity and fertilization practices. Recent research highlights the importance of sustainable potassium management strategies to optimize nutrient cycling and minimize environmental impacts. Potassium plays a key role in maintaining soil structure and fertility by enhancing root growth and the secretion of organic acids, which improve soil nutrient availability and promote beneficial microbial activity. This results in healthier soils that are better at retaining nutrients and supporting plant growth. This paper reviews the behavior of potassium in soil, its interactions with soil fractions, and the impact of mineral and organic fertilizers on its bioavailability.*
Keywords: potassium, , nutrient dynamics, mineral fertilizers, plant nutrition, soil fertility

• Introduction

Potassium (K), a vital macronutrient for plant growth, plays a key role not only in enhancing crop but also in strengthening agroecosystem resilience against climate change. While the productivity environmental impacts of nitrogen and phosphorus have been widely studied, potassium's influence on soil health, plant stress tolerance, and carbon dynamics often receives less attention (MOHAMAD, 2015; OLANIYAN et al., 2022). Recent research underscores potassium's significant contribution to mitigating climate variability by supporting essential physiological processes and soil functions (ZHANG et al., 2013; SMITH et al., 2021).In the context of climate change, potassium aids in carbon sequestration by promoting biomass accumulation and root development. Its role in boosting photosynthetic efficiency supports higher carbon assimilation, directly impacting atmospheric CO_2 levels (WANG et al., 2013). Additionally, potassium strengthens plant tissue stability, which is essential during extreme climate events such as droughts, floods, and heatwaves (SMITH et al., 2021; HAN et al., 2021).Recent studies also associate adequate potassium availability with lower greenhouse gas emissions from agricultural soils. By optimizing nitrogen use efficiency, potassium helps reduce nitrous oxide (N_2O) emissions, while its positive effects on soil structure and moisture retention further support sustainable land management practices (LIU et al., 2024; OLANIYAN et al., 2022). These collective benefits position potassium as a vital component in developing climate-resilient cropping systems.As agriculture adapts to evolving climate challenges, a deeper understanding of potassium's diverse functions will be essential for researchers, agronomists, and policymakers. Advancing potassium-related research, refining fertilization strategies, and educating farmers on nutrient balance are pivotal steps toward fostering resilient and productive agricultural systems for the future (ALVAREZ et al., 2019; GARCIA et al., 2014). This review aims to highlight the often-overlooked significance of potassium in plant fertilization by presenting current scientific insights into its role in promoting plant health and enhancing resilience to climate change.

• Material and method

A comprehensive literature search was carried out using Web of Science, Scopus, and other international scientific databases, employing the keywords 'potassium as a plant nutrient' and 'potassium plant resilience'. The selection criteria focused on books and articles published between 2010 and 2025, with language restricted to English. Only studies presenting empirical data on the role of potassium in plant health and resilience were included, while papers lacking experimental evidence or case studies were excluded. To ensure reliability, findings were cross-validated through comparative analysis across multiple studies

• Results and discussions

Potassium in Soil

Potassium in soil occurs in four primary forms: solution K^+, exchangeable K^+, non-exchangeable K^+, and structural K^+ (fig.1). Solution K^+ is readily absorbed by plants, while exchangeable K^+, loosely bound to cation exchange sites, can be replenished easily. Non-exchangeable and structural forms are locked within clay minerals like illite and feldspar, contributing slowly to the available potassium pool through weathering and microbial activity (JOHNSTON and ADDISCOTT, 1971; HAN et al., 2021). Native soil minerals such as feldspars and micas contain potassium in a very slowly available form, which is released over time but often insufficient to meet the demands of high-yielding crops (SPARKS, 1985).

The soil texture and mineral composition influence potassium availability. Clay-rich soils, especially those with vermiculite and illite, tend to retain potassium due to their high cation exchange capacity (CEC), whereas sandy soils with lower CEC have limited retention, making potassium susceptible to leaching (Mouhamad et al., 2015). Most potassium reserves are held on clay minerals and organic matter, with some readily available for plant uptake and others more strongly bound, released gradually (LUNGU et al., 2017).

Soil pH and water content affect potassium mobility. In acidic soils, potassium leaches more easily due to low CEC, whereas alkaline conditions may hinder uptake due to competition with calcium and magnesium. In saline soils, sodium displacement can further reduce potassium availability. Meanwhile, adequate moisture facilitates potassium movement in soil solution, promoting uptake by roots, while dry conditions restrict diffusion (SMITH et al., 2021).

Potassium dynamics in soil involve physical, chemical, and biological processes that regulate its availability. Understanding these interactions is key to optimizing potassium management and sustaining agricultural productivity in varying environmental conditions.

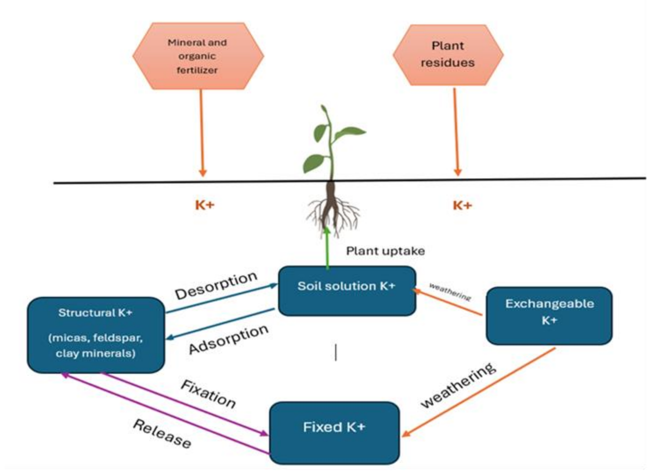

Figure 1. Potassium forms in soil

Potassium in Plants

Potassium (K^+) is the most abundant cation in the cytoplasm of plant cells and plays a vital role in numerous physiological processes. Unlike nitrogen and phosphorus, which integrate into organic structures, potassium remains in its ionic form, allowing for high mobility within plant tissues (WANG et al., 2013; ZHANG et al., 2013).

Potassium (K^+) is a crucial macronutrient that regulates numerous physiological functions in plants, including water balance, enzyme activation, nutrient transport, and metabolic processes (fig.2).

One of its primary roles is osmoregulation, ensuring proper water movement within cells, particularly in guard cells, which control stomatal opening and closing. This regulation is essential for balancing CO_2 uptake for photosynthesis with water conservation through transpiration. Potassium-deficient plants often exhibit impaired stomatal function, resulting in reduced photosynthetic efficiency and increased drought susceptibility (JIANG et al., 2021). During water-deficit conditions, potassium is actively pumped out of guard cells to induce stomatal closure, minimizing water loss through evapotranspiration.

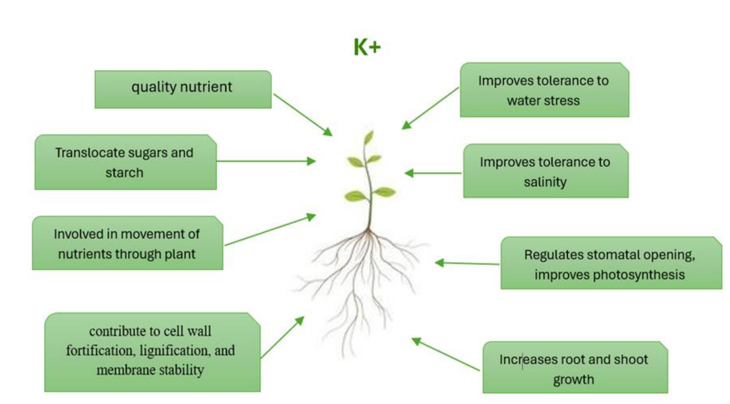

Figure 2. Potassium role in plants

Among essential nutrients, potassium is particularly significant for temperature stress tolerance. It regulates photosynthesis, respiration, and nutrient homeostasis, while improving tissue water potential, thereby strengthening plant adaptation to extreme temperature fluctuations (KANAI et al., 2011). Potassium also plays a critical role in drought resistance, helping to maintain cell turgor, osmotic balance, and aquaporin function. Studies show that adequate potassium enhances root growth, increasing root surface area and water uptake efficiency under drought conditions.

Under salinity stress, potassium helps maintain osmotic balance, membrane potential, cytoplasmic stability, protein synthesis, and enzyme activation. In saline environments, excess sodium and chloride ions inhibit root growth and nutrient absorption, especially potassium uptake, thereby further compromising plant development (WENG et al., 2013).

• Conclusions

Potassium plays a dual role in sustainable agriculture: it serves not only as a macronutrient but also as a regulator of critical physiological functions and stress responses. In soils, potassium availability is influenced by physical, chemical, and biological factors, which can be managed to optimize crop performance. In plants, potassium regulates key processes, including protein synthesis, photosynthesis, osmotic balance, and defense signaling, all of which directly impact productivity and adaptability.

As agriculture faces increasing climate challenges, potassium's role in water regulation, nutrient balance, and stress resilience becomes even more significant. Recognizing potassium as a central element in climate-smart agriculture is essential for ensuring long-term sustainability. Implementing precision fertilization, organic amendments, and microbial enhancers will not only boost crop productivity but also promote environmental health. Future research should continue exploring potassium dynamics and their potential to contribute to global efforts in climate change mitigation and adaptation.

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