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Key Importance of Foliar Application of Potassium Nitrate on Growth and Development of Plant

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Potassium nitrate (KNO_3) is a soluble fertilizer that provides two essential nutrients for plants. It is frequently used for high-value crops that need nitrate (NO_3^-) and potassium (K^+) but not chloride (Cl^-). KNO_3 (13-00-45) is suitable for any fertigation system and all crops, offering a N ratio of 13:45, which is ideal for plants with high potassium demands. Both nutrients are absorbed efficiently by crops due to the synergistic effect of NO_3^- and K_2O. Additionally, potassium nitrate is non-toxic to plant roots and, unlike ammonia, the nitric nitrogen in it does not harm plant roots even at high soil temperatures.

Role of Potassium nitrate in plants

Activation of more than 60$^+$ enzymes: Potassium (K+) serves as a key activator for over 60 plant enzymes, including those responsible for glycolysis, nitrogen assimilation, chlorophyll breakdown, and the Krebs cycle.

Maintain plant-cell homeostasis: Potassium (K^+) plays a vital role in regulating the transport of water, metabolites, and nutrients throughout plant tissues and organs, defending the plant against oxidative stress, and maintaining osmotic balance.

Act as potassium battery to plant: Potassium directly regulates phloem transport. Increased photosynthetic activity in leaves boosts the transcription of genes responsible for creating and assembling membrane channels for K^+ transport and photosynthate-induced phloem K(+) channels (AKT2 K^+), which manage transmembrane potentials and transport. Higher photosynthetic activity leads to increased saccharide concentrations, which potassium helps transfer from parenchymal cells to the phloem. The "potassium battery" concept describes how a transmembrane K^+ gradient serves as an energy source for plants, transported through the phloem stream to store and provide energy for other transport processes. Thus, potassium is essential for controlling the movement of water and nutrients from roots to various plant tissues and molecules among different plant organs, managing cell osmosis, turgor, and pH, and ensuring proper cell organelle function and movement.

Promote photosynthesis: Potassium nitrate enhances CO_2 assimilation efficiency by optimizing stomatal function, which leads to increased sugar production. It also promotes a larger leaf surface, higher chlorophyll density, and a longer leaf lifespan, all contributing to improved fruit quality. Additionally, potassium nitrate boosts the transport and storage of assimilates. A sufficient K^+ concentration in chloroplasts is crucial for maintaining a well-structured stroma lamella, thereby supporting chloroplast integrity and light absorption efficiency. Conversely, K^+ deficiency significantly impairs rubisco biosynthesis and activity, which reduces the plant's photosynthetic efficiency.

Improves fertilizer use efficiency: Potassium nitrate is essential for any sustainable fertilization strategy. Effective nutrient management reduces the amount of fertilizer needed per unit area and per unit of yield, thereby increasing farmers' revenue. The nitrate in potassium nitrate boosts the production of organic acids (carboxylates) and their release into the growing medium. This process helps to release phosphate and micronutrients from soil particles into the soil solution.

Improves water use efficiency: Potassium regulates the opening and closing of stomata. An adequate supply of potassium optimizes plant transpiration and lowers its water needs. Sufficient potassium enhances the plant's ability to efficiently extract water from the soil. The potassium in potassium nitrate helps prevent water loss and improves water uptake from the soil. Additionally, potassium nitrate prevents salt buildup, eliminating the need for extra water to flush salts from the soil.

Maintain stomatal conductance and transpiration: Potassium (K^+) in potassium nitrate is essential for regulating the cell's osmotic potential. The Potassium Ion Concentration Theory explains that the opening and closing of stomata depend on the generation of a potassium ion gradient. ATP, produced in the guard cells during photosynthesis, is later used to move potassium ions from adjacent cells into the guard cells. This increase in potassium ions makes the guard cells hypertonic, causing water to flow in and open the stomatal pore. Conversely, when potassium ions are removed and water exits, the guard cells become flaccid, closing the stomatal pore. Stomata are critical for transpiration and expelling excess water as vapor. Osmotic potential influences water absorption, stomatal movement, and cell turgidity. During drought conditions at the pre-flowering stage, there is a rise in reactive oxygen species (ROS) and a decrease in the efficiency of plant photosystems, resulting in lower photosynthetic energy. Water shortages can also delay flowering, cause leaf curling, lead to flower abortion, and reduce the size and weight of panicles and plants due to diminished stomatal conductance. Potassium nitrate enhances osmotic adjustment and the enzymatic antioxidant system, improving photosynthesis, stomatal function, transpiration, and overall plant nutrition under water stress. This also supports the 'stay green' function, which helps preserve photosynthetic pigments and processes.

Involve in defense system of plant: Potassium deficiency is likely a major factor leading to increased NADPH oxidase activity and ROS formation, largely due to elevated abscisic acid (ABA) levels. Potassium helps counteract ROS formation by its role in sensing and signaling during osmotic stress from water shortages. This stress is detected by K^+ transporters in vacuole membranes (TPK channels) or in guard cell membranes (HAT and LAT transporters, and GORK channels). These processes are essential for managing plant water status, causing rapid changes in gene expression that increase ABA production and suppress auxin synthesis. Potassium uptake also involves the movement of counter-ions like chloride, nitrate, malate, and sulfate, along with malate synthesis, depending on environmental conditions and the time of day. These osmolytes, together with sucrose accumulation, enhance turgor in guard cells and promote stomatal opening. ABA boosts the activity of high-affinity potassium transporters in root cell membranes and inward GORK transporters in leaf stomata, while decreasing auxin levels. Lower auxin levels lead to stomatal closure, which reduces water loss and enhances resistance to stresses such as drought and salinity. Low auxin levels activate inward K+ channels, leading to stomatal opening, whereas high auxin levels stimulate outward K^+ channels and inhibit inward K^+ KAT channels, causing stomatal closure. Plants under stress have increased potassium needs and show more oxidative damage due to ROS, particularly during photosynthesis. Excess ROS production under drought conditions can lead to increased cellular lipid peroxidation, raising membrane permeability as seen by higher electrolyte leakage and malondialdehyde (MDA) levels. Hence, sufficient K^+ supply is crucial for improving plant stress tolerance through the regulation of gene expression, increased antioxidant levels, osmolyte production (such as GABA, mannitol, and sorbitol), maintenance of osmotic potential, and optimal dry matter and moisture content, all of which enhance produce storage quality and extend shelf life. Higher potassium concentrations are associated with better recovery from oxidative stress and improved performance of antioxidant enzymes, including ascorbate peroxidase, dehydroascorbate reductase, glutathione reductase, superoxide dismutase, catalase, peroxidase, and NADPH oxidase. Thus, maintaining adequate potassium levels in plant tissues helps manage ROS formation by regulating stomatal movement, osmoregulation, and water use, while also reducing ROS generation by inhibiting NADPH oxidase and limiting lipid peroxidation.

Frost resistance: Potassium nitrate enhances frost tolerance by aiding in the development of thicker cell walls and boosting electrolyte levels within cells. The potassium in potassium nitrate strengthens these cell walls and improves electrolyte concentration, thereby increasing the plant's resistance to frost.

Helps in first line defense against biotic stress: Potassium nitrate boosts the plant's resistance to diseases by preventing the buildup of short-chain carbohydrates and non-protein nitrogen, which helps defend against bacteria, fungi, nematodes, and viruses.

Salinity stress resistance: The nitrates in potassium nitrate help plants reduce the absorption of chloride, even when it is present in the soil or water. Additionally, the potassium in potassium nitrate mitigates the adverse effects of sodium. As a result, potassium nitrate is highly recommended for salt-sensitive crops and when using irrigation water of poor quality.

Aids rapid root and seed developments: K^+ affects root growth and architecture through various mechanisms, including promoting root cell expansion and stimulating root hair development.

Improve nutrient quality of grains: Potassium nitrate enhances the protein content, oil levels, and vitamin C in plants. The nitrogen in potassium nitrate supports seed protein synthesis, while potassium (K^+) influences ribosomal transport and movement, thereby affecting protein synthesis rates.

Improves seed germination: Potassium nitrate (KNO_3) serves as a nitrogen source that can be applied as a pre-sowing treatment to enhance seed germination, break seed dormancy, and promote uniform growth across various plant species. It can modify the balance of hormones such as abscisic acid and gibberellic acid in seeds, aiding in germination. Additionally, KNO_3 improves the mineral composition of seeds and supports protein synthesis, which can enhance seed quality. It also boosts seedling establishment and vigor. Exogenous KNO_3 increases the expression of genes involved in nitrogen and carbon metabolism, as well as energy production. The induction of nitrate reductase plays a role in nitrogen assimilation and antioxidative processes. Furthermore, KNO3 application has been shown to elevate the activity of antioxidant enzymes, including superoxide dismutase (SOD), catalase (CAT), peroxidase (POX), and ascorbate peroxidase (APX), in seedlings. During seed imbibition, the increased oxygen uptake leads to higher reactive oxygen species (ROS) levels and a shift in the redox state, thereby improving seed germination with KNO_3 application.

Improve quality of seeds and fruits: Potassium nitrate is used to enhance diameter, size uniformity, coloring of seeds and fruits. Improve 100 seed weight of seeds. KNO_3 on the regulation of plant hormones are unclear, but may be improves ABA levels. KNO_3 is increase the germination of seeds due to its ionic salt of nitrate ions (NO_3^-) and potassium ions (K^+). Nitrogen helps seeds to synthesize proteins, which affects the quality of seeds. KNO_3 has positive effects on modulation of ABA metabolism or signaling of ABA in the development of seeds. So, by potassium nitrate aid to improve uniform ripening of seeds.

Conclusion

Potassium nitrate (KNO_3) is a highly effective and versatile fertilizer, crucial for optimizing plant health and productivity. By providing essential nutrients, potassium (K^+) and nitrate (NO_3^-) it supports a wide range of vital plant functions. Potassium nitrate enhances enzyme activation, supports cell osmotic balance, and improves water and nutrient transport within plants. Its role in boosting photosynthesis, optimizing fertilizer use, and increasing water use efficiency highlights its importance in sustainable agriculture.

In addition, potassium nitrate promotes seed germination, enhances the quality of seeds and fruits, and ensures consistent growth. Its capacity to increase frost resistance, plant defenses against diseases, and alleviate salinity stress makes it especially beneficial for high-value and salt-sensitive crops. By fostering rapid root development and improving nutrient content, potassium nitrate supports overall plant health and productivity.

In summary, potassium nitrate is essential for maintaining plant health and enhancing agricultural efficiency. Its diverse benefits, from improving nutrient uptake and stress tolerance to supporting robust growth and high-quality yield, underscore its role as a key component in modern fertilization strategies.

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