THE ROLE OF POTASSIUM IN CEREAL CROPS AND POTASSIUM SOURCES IN NATURE

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ABSTRACT

Cereal crops are widely cultivated throughout the world. Cereal crop production must be increased to meet the world's increasing food requirements. One of the nutrients needed by cereal crops is potassium. Potassium is an essential nutrient for plants. This article aims to review previous research related to the role of potassium nutrients in several cereal crops and reveal the sources of potassium in nature to reduce the use of synthetic potassium fertilizer in supporting low external input sustainable agriculture (LEISA). The results of previous studies revealed that potassium plays a role in influencing plant morphology and physiological functions, including improving plant quality, photosynthetic processes, osmotic regulation, enzyme activity, stimulation of assimilation and transportation, protein synthesis, and stress tolerance. In cereal crops such as rice and wheat, potassium improves adaptation in the face of environmental stress. In addition, potassium also plays a role in stomatal regulation in cereal plants. In the current environmental conditions, soil potassium reserves are running low, so it is essential to maintain the sustainability of K resources. Several sources of potassium can be obtained from organic sources such as banana peels, straw, and seaweed, and some potassium is sourced from mineral materials such as Biotite, Muscovite, Greensand, and Microline.

Keywords: cereals; food security; potassium; potassium sources

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INTRODUCTION

Many cereal crops come from the Poaceae family (Shavanov, 2021). Cereal crops are a food source for humans and feed for animals. They are widely cultivated worldwide because they have high economic value (Awika, 2011; Wrigley, 2017). The main cereal crops are wheat, rice, barley, rye, oats, maize, sorghum, and pearl millet (Saari et al., 1985).

The demand for cereal crops increases as the world's population increases (Prosekov, 2016). Food security is critical with the increase in the world's population (McCarthy et al., 2018). In addition, extreme environmental conditions such as drought stress, heat stress, flooding, salinity, and drought nutrient availability will adversely affect cereal crops and food security (Zörb et al., 2014).

Cereal crop production needs to be increased to supply the world's population. Therefore, a constant supply of nitrogen (N), phosphorus (P), and potassium (K) is necessary to increase cereal crop production and fill the growing world food demand. One of the nutrients needed by cereal crops is potassium (Dhillon, 2019). However, a problem in agricultural practice so far is how to increase the efficiency of fertilizer use, especially K fertilizer. Some research revealed that some K fertilizers are lost from the root environment and are not available to plants (Dhillon, 2019).

Potassium is required for carbohydrate-producing crops, especially for grain and yam crops (Pushpalatha et al., 2017; Vivien & Claude, 2017). Potassium is one of the macronutrients for plants that other nutrients cannot replace (Torabian et al., 2021). Attention to providing K nutrients for cereal crops is still relatively low compared to N and P, caused by a low understanding of the role of K nutrients in crop production by cereal farmers (Subandi, 2013). This paper discusses the role of K nutrients in several cereal crops to increase yield production and maintain food security worldwide. The article also reveals the sources of potassium in nature to reduce the use of artificial potassium fertilizer in supporting low external input sustainable agriculture (LEISA).

THE ROLE OF POTASSIUM FOR CEREAL CROPS

As an essential nutrient, plants need potassium in large quantities (Hasanuzzaman et al., 2018). It is needed as a plant cation but not a constituent of organic compounds in plants, even though it is required in large quantities (Subandi, 2013).

The majority of potassium in soil remains inaccessible to plants and can be classified into four distinct groups: soil solution potassium, exchangeable potassium, non-exchangeable potassium, and structural potassium (Moody & Bell, 2006). Exchangeable and soluble forms are compartments available to plants (Wirayuda et al., 2023). Potassium uptake in rice and maize plants from the soil is mainly taken when entering the booting stage, and the remaining 25% is absorbed before seed formation begins. In rice and maize, most of the K element is found in straw (89%) (De Datta & Mikkelsen, 1985), while in maize, 79% of K is found in the leaves and stalks (Cooke, 1985).

Potassium affects plant morphology and physiological functions: This encompasses enhancing plant quality, processes photosynthesis, regulating osmosis, boosting enzyme function, promoting assimilation and transport, aiding in protein production, and enhancing resilience to stress (Wang et al., 2013). Potassium plays a significant function in the growth and development of plants and is closely related to biophysical and biochemical processes (Beringer, 1980). In biophysical processes, potassium is essential in regulating osmoregulation, membrane potential regulation, sugar cotransportation, and stress adaptation. It will affect cell growth and development and stomatal opening and closing (Sanyal et al., 2020; Sardans & Penuelas, 2021). Potassium is regulated in various biochemical processes associated with synthesizing proteins, metabolizing carbohydrates, and activating enzymes (Hasanuzzaman et al., 2018). The role of K is closely related to 60 kinds of enzymatic reactions, including enzymes for carbohydrate and protein metabolism. Sufficient potassium is crucial for converting organic compounds (Subandi, 2013).

THE ROLE OF POTASSIUM ON STRESS ADAPTATION IN CEREAL CROPS

Potassium significantly influences plant growth and physiological metabolism (Ul-Allah et al., 2020). Additionally, it aids plants in responding to external stresses, empowering them to adjust to the impacts of abiotic push through the control of physiological and biochemical forms (Aslam et al., 2013). Several studies have proved that K will increase in plants when water or drought stress conditions are lacking. The study also proves that potassium has an influence on plants as a defense against drought stress by inducing signals such as reactive oxygen species current signals, peptides, hydraulics, calcium ions, and phytohormones (CuA Liar et al.; Santos et al., 2021). During drought conditions, K^+ ions also play a role in maintaining water balance by regulating guard cells (Cherel & Gaillard, 2019). In addition, potassium can support cell expansion by maintaining photosynthetic activity through electron transport to encourage the formation of cereal crop yields under water shortage conditions (Chen et al., 2018).

In situations where cereal crops such as rice experience water shortage, potassium application can increase the tolerance of rice plants to withstand water shortage by increasing the ability of rice plants to absorb water by their root system and, at the same time, the water potential of leaves decreases significantly, causing stomatal closure which inhibits photosynthetic gas exchange (Zain et al., 2014; Chen et al., 2017; Liu et al., 2020). When faced with water scarcity, substances such as proline, K^+ ions, and soluble sugars will accumulate in seeds to increase adaptation and the ability of cells to retain water (Dien et al., 2019). Based on several studies in rice plants, K is also able to maintain the concentration of K^+, which functions to encourage cell expansion in leaves and stems (Bhattacharyya et al., 2012; Wang & Wu, 2013).

Potassium has a similar role in other cereal crops, such as wheat. Bahrami-Rad (2017) revealed that the application of potassium positively impacted both roots and leaves despite an increase in water loss. This statement suggests that potassium application improved stomatal function, facilitating carbohydrate synthesis and promoting plant growth even under water-deficient conditions. Moreover, potassium was found to play a role in reducing the concentration of abscisic acid (ABA) in wheat plants. ABA is a phytohormone crucial for regulating responses and resistance to drought stress at various levels within plants. Specifically, ABA is central to the regulation of stomatal closure. The findings indicated that potassium application decreased ABA concentration, resulting in more efficient stomatal conductance, which aligns with previous research by Lotfi et al. (2022). Hosseini (2016) concluded that wheat plants with high potassium nutrient levels in their flag leaves enhanced drought tolerance through the promotion of ABA degradation.

THE ROLE OF POTASSIUM IN STOMATAL REGULATION IN CEREAL PLANTS

Earlier research has highlighted the significance of potassium in regulating stomatal function through the preservation of turgor pressure, as demonstrated by studies conducted by Mengel et al. (2001) and Zhao et al. (2001). During stomatal movement, potassium is crucial in turgor regulation pressure within guard cells (Marschner, 2012). Given that stomatal closure involves the rapid release of potassium ions (K^+) from guard cells into the leaf apoplast, it is reasonable to assume that keeping stomata open can be a challenge under conditions of potassium deficiency. Several studies, such as that conducted by Jin et al. (2011), stated that potassium deficiency can cause stomata to close and reduce the rate of photosynthesis in certain plants. On the contrary, several research studies have shown that potassium does not have a notable effect on stomatal conductance and photosynthetic rates when water conditions are optimal. Nevertheless, in specific crops facing drought stress, potassium deficiency might induce stomatal opening and raise transpiration rates compared to situations where potassium levels are sufficient (Benlloch-Gonzalez et al., 2010).

Based on research in rice plants, stomatal regulation is a significant mechanism through which rice manages water loss during water deficits (Caine et al., 2019). In situations of water scarcity, there is a tendency for stomatal density to rise while stomatal area decreases (Ouyang et al., 2017). However, the impact of potassium on rice stomatal characteristics contrasts with the effect of water deficit; potassium addition treatments decrease stomatal density but increase stomatal area (Yang et al., 2022). Stomata are crucial for rice in absorbing carbon dioxide for photosynthesis, and their opening facilitates assimilation synthesis. However, the risk of increased water loss may occur during transpiration due to the opening of the stomata (Caine et al., 2013). According to Wang et al. (2013), in response to water deficit, rice increases stomatal closure to minimize the loss of water and improve plant water status, although at the expense of yield potential.

ORGANIC POTASSIUM SOURCES FOR POTASSIUM FERTILIZER SUBSTITUTION

Appropriate potassium application can tolerate crops from biotic and abiotic stress.

Although there are no known harmful effects of K application on the environment or human health, the consequences of K deficiency can worsen plant growth and reduce the utilization efficiency of other nutrients such as N and P. Maintenance of K sufficiency is essential for both organic and conventional crop production. Potassium was initially derived from hardwood tree ashes that were leached and concentrated, but this method of collecting potassium is rarely practiced because it causes much environmental pollution (Mikkelsen, 2007).

Along with the development of the agricultural world, potassium reserves in the soil are also starting to deplete due to continuous agricultural practices that make the soil vulnerable to K leaching (Rashmi et al., 2017). Maintaining the sustainability of K resources as a long-term source of nutrients for plants is essential while still paying attention to the environment (Shah & Wu, 2019). Several sources of potassium can be obtained from organic sources such as banana peels, straw, seaweed, and others (Dianjun et al., 2022).

Several organic potassium sources, such as banana peel, can be used as potassium source material for organic fertilizer (Table 1). Potassium content in banana peels is 15% higher, while phosphorus content is 12% higher compared to the pulp (Supriyadi, 2007). With this high K nutrient content, banana peels have the potential to be used as an organic fertilizer that is also environmentally friendly (Rachmawati, 2021).

Rice straw is an organic material that is widely processed and used as a fertilizer containing potassium sources. It is known that rice straw contains much potassium, and 89% of K absorbed by rice plants accumulates in straw (De Datta & Mikkelsen, 1985). Based on laboratory analysis research, it was found that rice straw ash extract contains potassium carbonate, potassium bicarbonate, calcium, silica, iron, and aluminum, and dry rice straw ash extract is very hygroscopic (Maulinda et al., 2017).

An organic source of potassium can be obtained from seaweed. Seaweed typically contains about 0.4 g/kg potassium and can accumulate several percent potassium. When harvested, seaweed can be directly used as a potassium source, or soluble potassium can be extracted. These potassium sources are generally soluble and usually have a potassium content of less than 2% (Mikkelsen, 2007).

Potassium is not only sourced from biotic materials; some potassium is sourced from mineral materials such as Biotite, Muscovite, Greensand, and Microline (Eno et al., 1955). Greensand is commonly used for sandy rocks or sediments that contain a high percentage of the green mineral glauconite because its K content can reach up to 5% K (Mikkelsen, 2007).

Table 1 Potassium Sources and Content

Potassium Sources	Content
Greensand	1.392 g/kg K (Fraps, 1931)
Seaweed	0.4 g/kg K (Mikkelsen, 2007).
Rice Straw	22.66 mg/g K (Sarkar et al., 2017)
Banana Peel	78 g/kg K (Hussein et al., 2019)

CONCLUSION

As an essential nutrient, potassium plays a vital role for plants in regulating osmoregulation, membrane potential regulation, sugar transportation, and stress adaptation, which in turn will affect cell growth and development as well as the opening and closing of stomata. Several sources of potassium, both from minerals and organic materials, can replace synthetic potassium fertilizers.

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