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EFFECTS OF POTASSIUM ON MUNG BEAN YIELD COMPONENTS, YIELD, AND YIELD QUALITY UNDER DROUGHT STRESS

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ABSTRACT

Mung bean (*Vigna radiata* L.) is an important crop contributing to global food security. However, its productivity is severely affected by drought stress, particularly during the growth and grain filling stages. Drought stress reduces yield components such as pod number, seeds per pod, and grain weight due to disruptions in physiological and metabolic processes. It also negatively impacts crop quality by limiting nutrient accumulation and grain development. Potassium plays an important role in increasing plant tolerance to drought stress through various mechanisms. At the physiological level, potassium increases the efficiency of photosynthesis, regulates stomatal function, and maintains cellular osmotic balance, allowing plants to maintain turgor and metabolic activity under conditions of water deficit. At the biochemical level, potassium activates antioxidant enzymes that mitigate oxidative damage caused by reactive oxygen species. Furthermore, potassium supports the translocation of assimilates from source to recipient organs, thus promoting pod formation and grain filling. Adequate potassium supply also improves crop quality, including better nutrient content and grain uniformity. The interaction between potassium and water availability exhibits a synergistic effect, with optimal potassium levels increasing water use efficiency and mitigating the negative impacts of drought stress. Therefore, proper potassium management combined with efficient irrigation strategies is crucial for maintaining mung bean productivity and quality under drought conditions, thus supporting a more adaptive and sustainable agricultural system.

Key words: Drought stress, Mung bean; Potassium.

INTRODUCTION

Mung bean (*Vigna radiata* L.) is a member of the family Fabaceae, with an increasing consumption of sprouts due to their health benefits and high nutritional value (Badessa *et al*., 2026). In terms of food production, legumes rank second, contributing 27% of global primary crop production and 33% of protein requirements (Khatun *et al*., 2021). Mung bean Accounting for 5% of total global legume production (Islam *et al*., 2024). They are rich in plant-based protein, carbohydrates, dietary fiber, vitamins (such as folate, vitamin C, and vitamin K), and minerals, including potassium, magnesium, sodium, and iron. These beans are also known for their low-fat content and prospective antioxidant activities, which contribute to their positive impact on human health (Idris *et al*., 2025). Mung bean are involved in various biological activities, including antimicrobial, antioxidant, lipid metabolism accommodation, and antitumor effects (Jalal *et al*., 2024).

Mung bean is cultivated on about 7 million hectares worldwide. Currently, nearly 90% of the mung bean production is found in Asia, India, China, Pakistan, and Thailand are among the most important producers, however, mung beans are also produced in parts of Africa, Australia, North and South America (Somta *et al*., 2022). This crop has many advantages that make it a good choice for inclusion in crop rotations or intercropping systems. Mung bean has a short growth cycle 60 days, high drought tolerance, adapt ability to semi-arid and arid environments, which makes them suitable for sustainable cultivation in water-limited regions, with low-input requirements, it is capable of fixing a significant portion of its own nitrogen, enabling farmers to increase the profitability and sustainability of their farms (Volpato *et al*., 2025).

However, global mung bean production is threatened by drought stress that leads to a reduced growth and yield, particularly in tropical and subtropical regions where water scarcity due to uneven rainfall is a common phenomenon (Islam *et al*., 2024). These adverse conditions can cause a reduction in yield of approximately 25% during the early stages, 39% during the late vegetative stage, and a significant reduction of 59% during the flowering stage (Islam *et al*., 2023). Furthermore, temperatures exceeding 35°C and direct solar radiation due to global climate change have been shown to be detrimental to summer-grown mung beans, which experiences growth suppression at various developmental stages. This crop requires irrigation throughout all phenological growth stages. However, terminal drought stress during the flowering and seed-filling stages severely inhibits seed productivity (Nawaz *et al*., 2021).

Potassium (K^+) has been reported as an essential element in mitigating the adverse effects of soil water stress (Shivashankar *et al*., 2023). Potassium plays a crucial role, both directly and indirectly, among the nutrients provided, especially under various stress conditions, and is a vital part of essential plant mechanisms (Islam *et al*., 2024). The role of potassium as a mitigation strategy against drought stress in increasing yield components, yield, and quality in mung bean remains underexplored. Therefore, this study aims to provide a comprehensive evaluation of potassium role in supporting improvements in yield components, yield, and yield quality.

RESULTS AND DISCUSSION

Plant responses and adaptation mechanisms under drought stress

Drought is an abiotic stress that occurs due to a water deficit which causes a decrease in soil water content so that water availability for plants becomes limited (Nadeem *et al*., 2019). Plants have developed various adaptive responses to cope with drought stress, which cause morphological, physiological, biochemical, and molecular changes (Ali *et al*., 2025). Drought stress generally begins to occur when the soil water content drops below 60% (Nazran *et al*., 2019). Physiologically, drought stress often causes reduced leaf water content, stomatal closure, and decreased photosynthesis rates (Singh *et al*., 2021). his decrease in photosynthesis causes a reduction in the production of assimilates needed for the growth and development of reproductive organs (Islam *et al*., 2024).

Biochemically, drought increases the accumulation of osmoprotectants such as proline, glycine betaine, and soluble sugars, which maintain cell turgor and protect cell structures (Chaudhary *et al*., 2022). Furthermore, drought stress triggers the production of reactive oxygen species (ROS), which cause oxidative damage (Ahmad *et al*., 2024). To mitigate this, plants increase the activity of antioxidant enzymes such as superoxide dismutase (SOD), catalase (CAT), and peroxidase (POD) to scavenge ROS and protect cell integrity (Ighodaro & Akinloye, 2018). At the morphological level, transpiration weakens first to reduce water evaporation, after which the relative water content in the leaves decreases. As the water deficit increases, wilting occurs, and plant height and color change (Guo *et al*., 2023).

Effect of drought stress on yield components, yield, and yield quality

These physiological and morphological disturbances directly impact the reproductive phase by reducing flower formation and increasing flower abortion due to assimilate limitations and hormonal imbalances (Anwar *et al*., 2023). Extreme temperatures disrupt plant reproduction by causing delayed flowering and damage to reproductive organs, particularly male reproductive organs. High temperatures reduce pollen count, viability, and release, and inhibit germination and pollen tube growth. The pollen formation stage is highly sensitive to heat, disrupting pollination and fertilization. This results in flower and pod abort, leading to reduced fruit set and crop yield (Chaudhary *et al*., 2022). This decrease in flower number leads to a decrease in the number of pods per plant because not all flowers develop into fertile pods (Singh *et al*., 2022). Furthermore, drought stress also disrupts the fertilization process and embryo development, resulting in a decrease in the number of seeds per pod (Reddy *et al*., 2021). Reduced water availability results in fewer leaves, flowers, and branches, and directly impacts the number of pods per plan (Waleed *et al*., 2025). The impaired seed filling process due to assimilate limitations leads to a significant decrease in the weight of 100 seeds (Alghabari *et al*., 2026).

The reduction in yield components due to drought stress directly contributes to a decrease in seed yield per plant because yield is an integration of pod number, seed number, and seed weight (Islam *et al*., 2024). Drought occurring during critical phases such as flowering and seed filling causes a greater yield reduction than during the vegetative phase (Nawaz *et al*., 2021). This is due to the disruption of the source-sink relationship, where assimilate production decreases while the need for seed filling remains high (Waleed *et al*., 2025). Furthermore, drought also reduces water use efficiency and the plants ability to maintain cell turgor, thus disrupting growth and biomass accumulation (Shivashankar *et al*., 2023). The combination of these physiological, morphological, and reproductive disturbances leads to a significant yield reduction in mung bean under water deficit conditions (Volpato *et al*., 2025).

Drought stress not only reduces yield quantity but also seed quality by disrupting plant physiological and metabolic processes (Guo *et al*., 2023). Decreased photosynthesis and protein metabolism lead to reduced nutrient accumulation in seeds (Waleed *et al*., 2025). Furthermore, nutrient transport in plants is highly dependent on water flow, so drought inhibits nutrient absorption and translocation to seed organs. This condition leads to a decrease in the content of essential minerals, such as potassium, in seeds and affects the overall nutritional quality of the yield (Alghabari *et al*, 2026). Furthermore, disruptions in the seed filling process result in suboptimal seed development, resulting in decreased physical and physiological seed quality (Sehgal *et al*., 2018).

Potassium in mitigating drought stress

Potassium is a macronutrient that plays a major role in plant growth and sustainable crop production. Potassium also acts as a buffer against various abiotic stresses such as drought, salinity, metal toxicity, high or cold temperatures, and others. Plants absorb potassium in the form of K^+ cations, which are either present in the soil or supplied through fertilizers. Commonly used potassium sources include potassium chloride (KCl), potassium nitrate (KNO_3), potassium sulfate (K_2SO_4), and potassium carbonate (K_2CO_3). Of these forms, KCl is the most economical and widely used potassium source in agricultural cultivation, although there are some exceptions for certain conditions or plant types (Hussain *et al*., 2016). However, the availability of K^+ ions from soil and fertilizer is influenced by various factors, such as soil texture, water content, soil pH, and other environmental factors.

It is involved in the activation of more than 60 plant enzymes. It provides plant resistance to disease and pest attacks. It also helps maintain cell turgor pressure, which is necessary for cell expansion. It also aids in osmoregulation of plant cells and supports the opening and closing mechanisms of stomata. Under conditions of water shortage, K^+ ions are released from the guard cells, causing the stomata to close tightly. This process allows potassium to play a role in controlling water loss through evapotranspiration, thereby helping plants mitigate the effects of drought stress. Conversely, potassium deficiency can impair stomatal function, characterized by slower or even incomplete closure (Alfred *et al*., 2021).

Overall, potassium aids in starch and protein synthesis, aids in metabolism, plays a key role in stomatal regulation, and also plays a role in chlorophyll formation and seed development. This element provides stem strength and resistance to lodging (Islam *et al*., 2024). Potassium aids in cation-anion balance, osmoregulation, water movement, energy transfer, and many other processes. When plants experience a K deficiency, they exhibit stunted growth and yellowing of the leaf edges. Additionally, poor root systems, lodging, and reduced yields are common phenomena associated with K deficiency. K deficiency increases plant susceptibility to various diseases and pests and makes plants susceptible to damage under various stress conditions (Hasanuzzaman *et al*., 2018).

Potassium fertilizer can be applied, especially during the flowering period, as it helps increase seed and fruit formation in plants (Kiswondo *et al*., 2025). Research by Wang *et al*. (2022) found that potassium can increase the growth and yield of mung bean plants.

Effect of potassium on yield components

Potassium aids in the reproductive processes of mung beans, such as flowering, pod formation, and seed filling, which leads to increased yields (Saha *et al*., 2025). This increase in the number of flowers directly contributes to the increase in the number of filled pods, because potassium helps reduce flower abortion and increases the success of pod formation (Lateef *et al*., 2021). Additionally, potassium plays a role in the translocation of photosynthetic products from leaves to reproductive organs, thereby increasing the number of seeds per pod due to more optimal seed filling (Islam *et al*., 2024). Under conditions of K deficiency, the seed filling process is not complete, resulting in a lower number of seeds per pod (Kumar *et al*., 2022).

Effect of potassium on yield

Potassium application significantly increases mung bean yield by improving plant growth, water relations, and photosynthetic efficiency. Research by Islam *et al*. (2024) showed that increasing potassium doses under drought conditions can increase seed yield by up to 32.52% compared to standard fertilization. This yield increase is due to better water use efficiency, increased biomass, and improvements in yield components such as pod number and seed size. Potassium also plays a role in the translocation of assimilates from source to sink organs, thus supporting optimal seed filling. Potassium deficiency has been shown to reduce yield due to disruption of plant physiological processes (Yin *et al*., 2018).

Effect of potassium on yield quality

Potassium not only plays a role in increasing production yields, but also contributes to improving the quality of the harvest. Potassium plays a crucial role in water movement and the distribution of mineral compounds throughout the plant through the xylem tissue. If potassium is insufficient, the translocation of nutrients such as nitrate (NO_3^-), phosphate (PO_4^{3-}), calcium (Ca^{2+}), magnesium (Mg^{2+}), and amino acid absorption will be reduced. Conversely, optimal potassium provision can help plants cope with water stress by increasing water use efficiency (WUE), which is associated with a decrease in leaf evapotranspiration rates (Hasanuzzaman *et al*., 2018). Potassium plays a crucial role in improving the physical quality of seeds, particularly in producing whole, full seeds through optimal seed filling (Islam *et al*., 2024). Adequate K availability increases cell turgor pressure and starch synthesis, increasing the weight of whole seeds and decreasing the proportion of wrinkled seeds (Islam *et al*., 2024). Conversely, potassium deficiency results in incomplete seed filling, increasing the number of wrinkled and broken seeds due to weak seed tissue structure (Kumar *et al*., 2022). This suggests that potassium plays a role in maintaining seed structural integrity during the ripening phase. In addition to physical quality, potassium also increases seed K content, which contributes to the nutritional quality of the harvest (Islam *et al*., 2024). Seed K content is related to the efficiency of nutrient translocation from leaves to seeds during the generative phase.

Interaction

The application of potassium (K^+) fertilization in mung bean (*Vigna radiata* L.) cultivation cannot be separated from water availability, as the two exhibit a strong and mutually influencing interaction in determining physiological responses and plant yield. Potassium plays a crucial role in stomatal regulation and cell osmotic balance, which directly impacts the plant's ability to regulate water loss through transpiration. Under drought stress, sufficient potassium allows plants to maintain cell turgor and photosynthetic activity, but the effectiveness of this function is highly dependent on the level of water availability in the soil. Therefore, plant responses to potassium fertilization are not monolithic but are influenced by environmental conditions, particularly water status, reflecting a significant interaction between the two factors (Wang *et al*., 2013).

Furthermore, the interaction between potassium and water is clearly evident in increased water use efficiency, where plants with an optimal potassium supply are able to utilize water more efficiently than plants lacking potassium, especially under water deficit conditions. Research shows that under drought stress conditions, potassium application can mitigate the negative impacts on growth and yield, but these improvements are more significant when supported by proper irrigation management (Kataria & Singh, 2022). This suggests that the effect of potassium on crop yield is not independent, but rather is enhanced or weakened by water availability.

This interaction is also crucial during critical growth phases, such as flowering and seed set, where water and nutrient requirements increase simultaneously. Deficiencies in either factor, potassium or water, can limit yield potential even if the other is adequately supplied. Therefore, the combination of potassium fertilization and synchronized irrigation management can increase pod number, seed number, and seed weight more optimally than applying each factor separately (Ahanger & Agarwal, 2017). In other words, there is a synergistic effect that enhances final crop yield.

Overall, the relationship between potassium fertilization and water availability in mung bean cultivation shows a synergistic interaction pattern, where both factors mutually support each other in increasing drought resistance, physiological efficiency, and crop productivity. Therefore, a management approach that integrates these two aspects is crucial in modern agricultural systems, particularly in water-limited areas. This strategy not only increases crop yields but also supports efficient resource use and agricultural resilience to climate change.

CONCLUSION

Drought stress causes a decrease in yield components, yield, and seed quality of mung beans because it disrupts physiological processes, photosynthesis, and pod and seed formation. Potassium supplementation plays a crucial role in increasing plant drought resistance through osmotic regulation, water use efficiency, and increased photosynthesis. Furthermore, potassium can increase flower formation, seed filling, yield, and seed quality of mung beans. Appropriate potassium fertilization and good irrigation management can be effective strategies for increasing crop productivity under water-stressed conditions. The combination of these two approaches supports more sustainable agriculture and adaptation to climate change.

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