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# IMPACT OF POTASH DELIVERY METHODS ON SOIL PLANT WATER RELATIONS AND YIELD TRAITS OF MUNGBEAN UNDER MOISTURE STRESS

*Original Article*

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## ABSTRACT

**Background:** Water scarcity is a critical barrier to sustainable mungbean (*Vigna radiata* L.) production in arid and semi-arid regions. Limited soil moisture significantly reduces plant growth, pod set, seed filling, and yield. Potassium (K) is a vital nutrient that enhances drought tolerance by improving osmotic adjustment, photosynthesis, and assimilate translocation. However, comparative evaluation of different application methods of potassium in mungbean under water-deficit conditions has received limited attention.

**Objective:** This study aimed to investigate the influence of different potassium application methods on growth, physiological traits, and yield of mungbean grown under water-limited conditions in southern Punjab, Pakistan.

**Methods:** A field experiment was conducted during the spring season of 2017 at the Research Farm of Bahauddin Zakariya University, Multan. The trial was laid out in a Randomized Complete Block Design with three replications. Four treatments were applied: $T_0$ (control, no K), $T_1$ (seed coating with potassium), $T_2$ (foliar spray at 30 days after sowing), and $T_3$ (broadcasting before land preparation). The mungbean cultivar NM-92 was sown manually at 20 kg ha$^{-1}$ with a 30 cm row spacing. Urea and triple super phosphate were applied uniformly, and potassium was supplied as sulfate of potash according to the treatment protocols. Standard agronomic practices were followed, and data on plant height, fresh and dry weights, leaves per plant, pod and seed traits, 1000-seed weight, biological yield, and grain yield were recorded and statistically analyzed.

**Results:** Significant variations were observed among treatments. Seed coating ($T_1$) achieved maximum plant height (58.67 cm), fresh weight (53.33 g), dry weight (21.67 g), and leaf number (102). It also produced the highest pod number (142), seeds per pod (10.33), seed weight per pod (188.21 g), 1000-seed weight (288.11 g), biological yield (38.11 t ha$^{-1}$), and grain yield (8.11 t ha$^{-1}$). Foliar application ($T_2$) followed, with plant height of 56.33 cm, pod number of 133.67, 1000-seed weight of 262.62 g, biological yield of 26.62 t ha$^{-1}$, and grain yield of 6.62 t ha$^{-1}$. Broadcasting ($T_3$) showed moderate improvements, while the control ($T_0$) consistently produced the lowest values.

**Conclusion:** Seed coating with potassium was identified as the most effective method for enhancing growth and yield of mungbean under drought stress, offering a practical nutrient management strategy to improve productivity in water-deficit environments.

**Keywords:** Biological Yield, Drought Stress, Grain Yield, Mungbean, Nutrient Management, Potassium, Seed Coating.

## INTRODUCTION

Mungbean (*Vigna radiata* L. Wilczek), commonly known as green gram, is a short-duration pulse crop of high nutritional and agronomic importance. It has been cultivated for centuries across tropical and subtropical regions, particularly in South and Southeast Asia, and is now also grown in parts of Africa and South America. As a member of the Fabaceae family, it contributes significantly to food security through its rich protein, dietary fiber, and micronutrient content, including potassium, magnesium, folate, and zinc. Its nitrogen-fixing ability further enhances soil fertility, making it a valuable component of sustainable cropping systems in resource-limited environments (1-3). Globally, mungbean occupies nearly 7.3 million hectares with a production exceeding 5.3 million metric tonnes annually, highlighting its growing role in dryland agriculture (4). In Pakistan, mungbean cultivation spans approximately 218,000 hectares with a production of about 137,000 metric tonnes. However, despite its potential, the national average yield remains at only 711.2 kg $ha^{-1}$, considerably below achievable levels (5). This gap stems largely from poor agronomic practices, lack of high-yielding cultivars, and most critically, water scarcity. Drought stress is especially detrimental during sensitive growth stages such as flowering and pod filling, leading to reductions in pod set, seed size, and overall productivity. Moreover, drought impairs physiological processes including photosynthesis, nutrient uptake, and assimilate translocation, further diminishing yield (6,7).

Among mineral nutrients, potassium (K) has been consistently recognized for its role in mitigating drought-induced stress. It facilitates osmotic adjustment, stomatal regulation, enzymatic activation, and protein synthesis, while also improving chlorophyll stability and assimilate partitioning under stress conditions (8,9). Studies in legumes and other crops have shown that potassium application enhances leaf water retention, root development, and ultimately yield performance under water-limited conditions (10-12). Despite this evidence, limited attention has been given to optimizing the method of potash application in mungbean, particularly under drought stress. Whether applied as basal soil doses, in splits, or as foliar sprays, the efficiency of potassium uptake and its contribution to water-use efficiency may vary considerably, yet this aspect remains underexplored in the context of Pakistani agro-ecological conditions. Therefore, the present study was designed to evaluate the comparative effectiveness of different potassium application methods on growth, yield, and water-use efficiency of mungbean under water-deficit conditions in the Multan region of Pakistan. The objective was to identify a practical nutrient management strategy that could enhance mungbean productivity and resilience in water-limited environments, thereby contributing to sustainable agriculture and food security in the region.

## METHODS

A field experiment was undertaken during the spring season of 2017 at the Research Farm of the Department of Agronomy, Bahauddin Zakariya University (BZU), Multan, Pakistan. The site was located in the arid climatic zone of southern Punjab, which is characterized by high temperatures, scarce rainfall, and sandy loam soils. Prior to sowing, a comprehensive soil analysis was performed to assess physicochemical properties, including soil texture, pH, electrical conductivity, organic matter content, and available nitrogen, phosphorus, and potassium levels. These baseline measurements ensured a clear understanding of soil fertility and guided the experimental nutrient management practices. The experimental design followed a Randomized Complete Block Design (RCBD) with three replications, which is a statistically robust approach to minimize environmental variability and enhance reliability of the findings. The mungbean cultivar NM-92, recognized for its relatively high yield potential and drought tolerance, was used as the test variety. Certified seeds were procured from Syngenta (Pvt.) Ltd. Potassium fertilizer was provided in the form of Sulfate of Potash (SOP), while nitrogen and phosphorus sources included Urea and Triple Super Phosphate (TSP), respectively. These fertilizers were uniformly applied according to recommended agronomic standards. The field was prepared through a pre-sowing irrigation followed by two passes of a cultivator and planking to ensure uniform soil tilth. Sowing was carried out manually on March 15, 2017, using a single-row hand drill at a seed rate of 20 kg $ha^{-1}$ with row spacing of 30 cm.

Four treatments were established: $T_0$ = control (no potash application), $T_1$ = seed coating with potash, $T_2$ = foliar spray of potash, and $T_3$ = broadcasting of potash in soil. In $T_1$, seeds were uniformly coated with potassium solution before sowing; in $T_2$, foliar sprays were applied at 30 days after sowing using a calibrated backpack sprayer; and in $T_3$, SOP was broadcasted evenly over the soil prior to final land preparation. Urea and TSP were applied basally at sowing to ensure uniform availability of nitrogen and phosphorus across treatments. Irrigation was applied according to crop water requirements and prevailing weather to simulate water-deficit conditions. Weeding was performed manually twice during the season, and standard plant protection measures were employed. The crop was harvested at physiological maturity, indicated by yellowing and drying of pods, and harvested manually. Data collection involved several morphological, physiological, and yield-related parameters. Randomly selected plants from each plot were used to minimize sampling bias. Measurements were taken using standard agronomic tools such as meter rods for height, electronic balances for weights, and oven-drying methods for biomass assessment.

**Observations and Traits Studied**

**Plant Height (cm):** Plant height was measured from the soil surface to the tip of the main stem at the flowering stage. An average of three representative plants per plot was recorded.

**Number of Leaves per Plant:** Fully developed leaves were counted on three randomly selected plants per plot, and the mean was calculated.

**Fresh Plant Weight (g):** At the pod development stage, three plants from each plot were uprooted, and their fresh weight was measured using an electronic balance.

**Dry Plant Weight (g):** Subsamples from the fresh plants were oven-dried at 70 °C until constant weight was attained to determine dry biomass.

**Number of Pods per Plant:** At maturity, the number of pods was counted on three randomly selected plants per plot and averaged.

**Number of Seeds per Pod:** Seeds were extracted from pods of representative plants, and the mean number of seeds per pod was calculated.

**Seed Weight per Pod (g):** Seeds from each pod were weighed with a precision balance to determine average seed weight.

**1000-Seed Weight (g):** A random sample of 1000 seeds from each treatment was weighed to assess seed size and quality.

**Biological Yield (t ha$^{-1}$):** The above-ground biomass (grain and straw) was harvested from a unit area, dried, and weighed to calculate biological yield.

**Grain Yield (t ha$^{-1}$):** Grain yield was obtained by manually threshing, cleaning, and weighing harvested seed, which was then extrapolated to tons per hectare.

All collected data were statistically analyzed using analysis of variance (ANOVA) to determine treatment significance, with mean comparisons performed under an appropriate post hoc test at a defined probability level. This ensured rigorous evaluation of treatment effects and minimized the risk of Type I error. Ethical considerations were observed, and the study was approved by the Departmental Research and Ethics Committee of Bahauddin Zakariya University, Multan. Although the study did not involve human or animal participants, adherence to institutional ethical standards ensured transparency and credibility.

## RESULTS

The results revealed significant differences among the four potassium application methods under water-deficit conditions. Plant height varied considerably, with the tallest plants recorded in the seed coating treatment at 58.67 cm, followed by foliar application at 56.33 cm, broadcasting at 56.10 cm, and the control at 55.41 cm. Fresh plant weight followed a similar trend, with the highest value in seed coating at 53.33 g, while foliar application and broadcasting recorded 51.00 g and 49.33 g, respectively, and the control treatment produced the lowest biomass at 46.00 g. Dry plant weight also showed marked variation, with seed coating achieving 21.67 g, foliar application 21.33 g, broadcasting 19.33 g, and the control only 18.67 g. Leaf number per plant ranged from 97.67 in the control to 102.00 under seed coating, while foliar application and broadcasting resulted in 100.33 and 99.33 leaves per plant, respectively. Pod formation was strongly influenced by potassium treatments, with seed coating producing 142 pods per plant, foliar application 133.67, broadcasting 120.33, and the control only 99.67. The number of seeds per pod also varied, with seed coating achieving the maximum at 10.33, followed by foliar application with 9.33, broadcasting with 8.00, and the control with 7.67. Seed weight per pod was highest in the seed coating treatment at 188.21 g, followed by foliar application at 172.52 g and broadcasting at 163.33 g, while the control remained lowest at 139.67 g. In terms of 1000-seed weight, seed coating again outperformed with 288.11 g, compared to 262.62 g in foliar application, 253.43 g in broadcasting, and 239.56 g in the control. Biological yield showed marked improvement under seed coating, reaching 38.11 t ha$^{-1}$, while foliar application and broadcasting produced 26.62 and 25.43 t ha$^{-1}$, respectively, and the control yielded only 23.60 t ha$^{-1}$. Grain yield followed the same trend, with seed coating achieving the maximum at 8.11 t ha$^{-1}$, foliar application at 6.62 t ha$^{-1}$, broadcasting at 3.43 t ha$^{-1}$, and the control at 2.39 t ha$^{-1}$. Overall, seed coating with potassium consistently outperformed other treatments across all morphological, physiological, and yield traits, demonstrating its superior role in sustaining mungbean growth and productivity under drought stress.

**Table 1: Physio-Chemical Properties of The Experimental Soil**

| Determination | Unit | Value | Status |
|---|---|---|---|
| Physical Properties | | | |
| Sand | % | 25.6 | |
| Silt | % | 53.8 | |
| Clay | % | 20.3 | |
| Textural class | Silty clay loam | | |
| Chemical Properties | | | |
| PH | | 9.2 | |
| EC | dS/m | 3.39 | |
| Organic matter | % | 0.72 | Very low |
| Total nitrogen | % | 0.027 | Very low |
| Available phosphorus | Ppm | 4.71 | Low |
| Available potassium | Ppm | 254 | Medium |

**Table 2: Meteorological Data Recorded at The Observatory Multan 2017**

| Date | Air Temp (oC) | | Differ 1&2 | Rel. Humidity % | | Pan Evaporation (mm) | | Rain fall (mm) | Wind velocity (km hour-1& days) | | Dew | Cloudy | | Soil Temp. (100 cm depth) | Sun Shine Hours | | Fog |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Max | Min | | 8am | 5 pm | 8am | 5 pm | | 8 am | 5 pm | | Days | Nights | | H | M | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| March | 27.7 | 13.0 | 14.7 | 78.1 | 46.2 | 1.2 | 2.0 | 17.8 | 1.7/19 | 3.6/29 | 20 | 2 | 10 | 20.4 | 7 | 13 | 11 |
| April | 33.9 | 19.0 | 14.9 | 62.1 | 40.6 | 1.7 | 3.4 | 14.7 | 1.9/14 | 3.1/25 | 23 | 1 | 4 | 25.6 | 08 | 31 | - |
| May | 41.9 | 24.9 | 17.0 | 49.4 | 28.7 | 2.7 | 4.8 | 7.6 | 2.2/12 | 4.9/29 | 25 | - | 4 | 30.7 | 10 | 25 | - |
| June | 41.8 | 28.2 | 13.6 | 53.3 | 32.6 | 3.4 | 5.6 | 11.4 | 4.4/24 | 6.8/30 | 26 | - | 2 | 35.2 | 10 | 26 | 41.8 |
| **July** | **37.6** | **28.6** | **9.1** | **77.4** | **60.8** | **2.2** | **3.7** | **180.8** | **5.9/27** | **4.9/25** | **24** | **2** | **4** | **33.9** | **7** | **58** | |

**Table 3: Effect of Different Application Methods of Potash on Yield and Yield Related Trades of Mungbean Plants Under Water Deficit Conditions**

| Sr.No | Traits observed | T1 (Seed coating) | T2 (Foliar application) | T3 (Broadcasting) | T0 (Control) |
|---|---|---|---|---|---|
| 1 | Plant height (cm) | 58.667 | 56.333 | 56.100 | 55.413 |
| 2 | Fresh weight of plant (g) | 53.333 | 51.000 | 49.333 | 46.000 |
| 3 | Dry weight of plant (g) | 21.667 | 21.333 | 19.333 | 18.667 |
| 4 | Number of leaves per plant | 102.00 | 100.33 | 99.33 | 97.67 |
| 5 | Number of pods per plant | 142.00 | 133.67 | 120.33 | 99.67 |
| 6 | Number of seeds per pod | 10.333 | 9.333 | 8.000 | 7.667 |

| Sr.No | Traits observed | T1 (Seed coating) | T2 (Foliar application) | T3 (Broadcasting) | T0 (Control) |
|---|---|---|---|---|---|
| 7 | Weight of seeds per pod (g) | 188.21 | 172.52 | 163.33 | 139.67 |
| 8 | 1000-seed weight (g) | 188.21 | 172.52 | 163.33 | 139.67 |
| 9 | Biological yield (t ha-1) | 10.333 | 9.333 | 8.000 | 7.667 |
| 10 | Grain yield (t ha-1) | 102.00 | 100.33 | 99.33 | 97.67 |

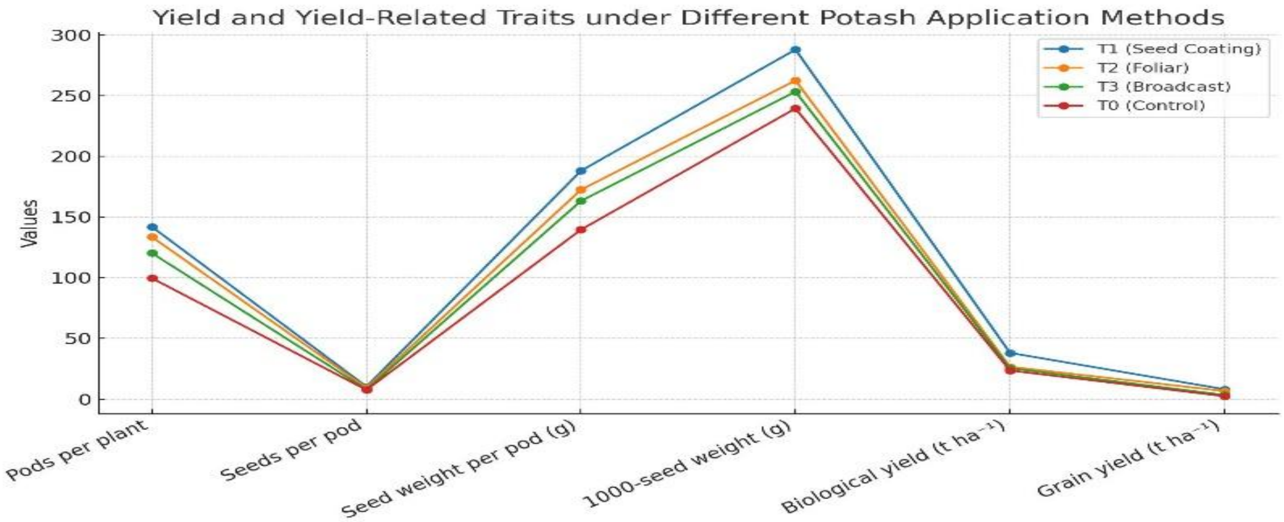


*Figure 2 Yield and Yield-Related Traits Under Different Potash Application Methods*

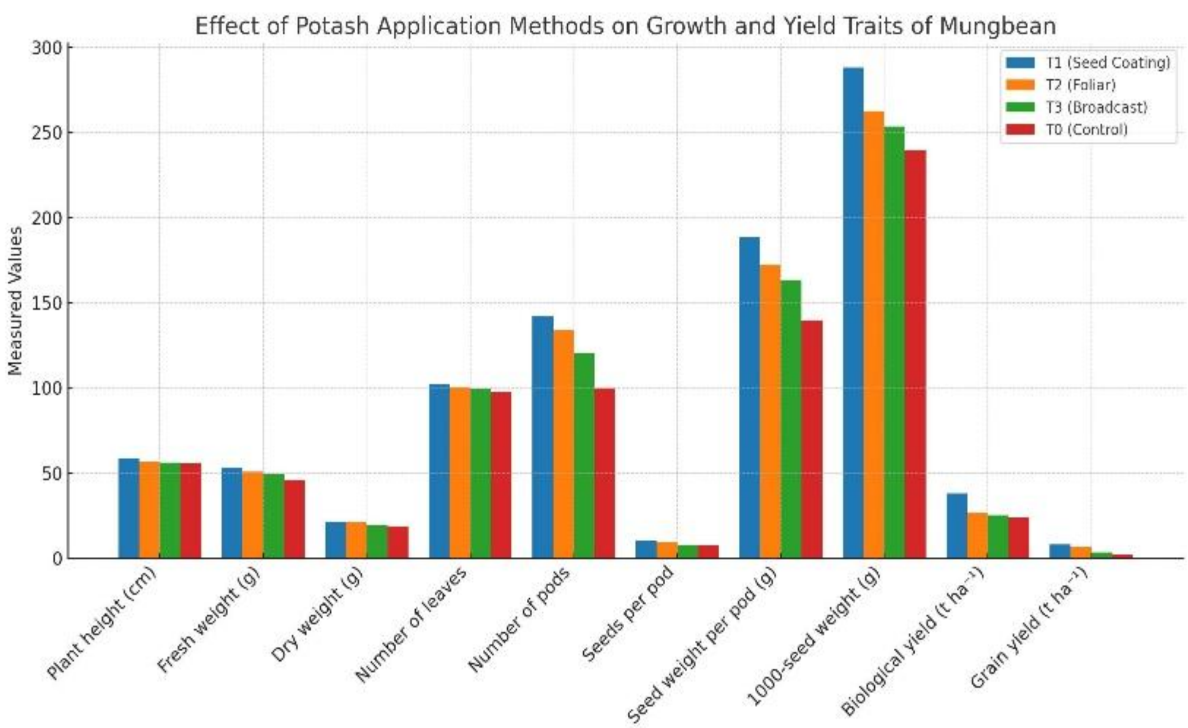


*Figure 2 Effect of Potash Application Methods on Growth and Yield Traits of Mungbean*

 

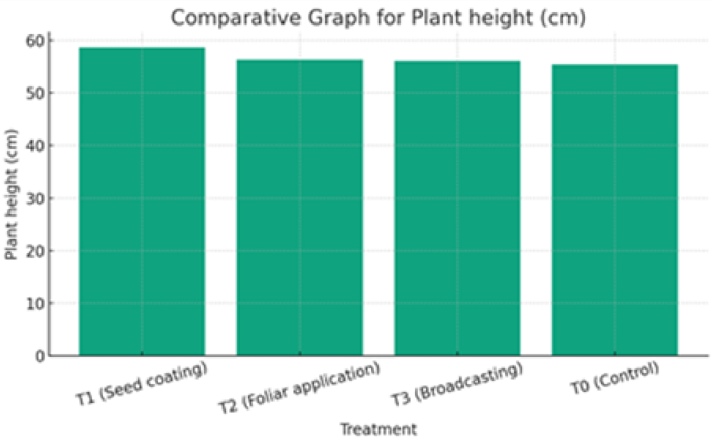


*Figure 4 Comparative Graph for Plant Height (cm)*

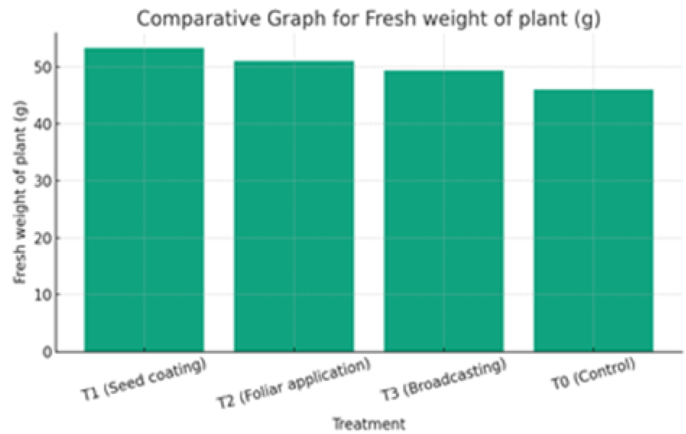


*Figure 3 Comparative Graphs for Fresh Weight of Plant (g)*

## DISCUSSION

The findings of this study demonstrated that potassium application methods had a significant influence on the growth, biomass, and yield attributes of mungbean grown under water-deficit conditions. Seed coating with potassium consistently produced the most favorable results across all morphological and yield-related parameters, while foliar application also showed beneficial effects but to a lesser degree. Broadcasting of potassium, though superior to the control, remained less efficient compared with other methods. The superior performance of seed coating was evident in plant height, biomass accumulation, and pod formation. This outcome aligned with earlier reports which suggested that early and localized availability of potassium at the seed level enhanced root vigor, nutrient absorption, and cell elongation under stress conditions (13-15). Potassium's role in osmotic adjustment and turgor maintenance likely contributed to better shoot elongation, as water-deficit stress generally restricts vegetative growth by impairing water balance and nutrient uptake (16,17). In comparison, broadcasting potassium across the soil surface exposed nutrients to potential fixation and losses, while foliar sprays provided only transient availability, particularly effective during critical reproductive stages but not throughout the entire growth cycle. Fresh and dry biomass accumulation further highlighted the importance of sustained potassium availability. Plants receiving seed-applied potassium exhibited greater hydration and assimilate storage, supporting higher fresh and dry weights compared with the control. These observations were consistent with previous evidence that potassium promotes stomatal regulation, photosynthetic efficiency, and translocation of assimilates under drought conditions (18,19). Although foliar sprays provided supplemental potassium at key stages, they could not fully replicate the early establishment advantage of seed coating. Broadcasting, on the other hand, produced lower biomass gains due to inefficient nutrient uptake under dry soil conditions.

Reproductive traits such as number of pods, seeds per pod, and seed weight per pod were strongly enhanced by seed-applied potassium. These results emphasized potassium's essential role in reproductive physiology, particularly in flower initiation, pollen viability, and ovule fertilization under moisture stress (20). While foliar applications contributed positively during flowering, they did not sustain the same level of reproductive performance as seed coating. Broadcasting again underperformed, most likely due to nutrient heterogeneity in the soil profile. The poor reproductive performance of the control treatment underscored the compounded impact of nutrient and water deficiency, leading to reduced fertilization success and pod development. Grain and biological yields demonstrated the cumulative benefits of potassium application, with seed coating achieving nearly three times higher grain yield than broadcasting. Such results corroborated earlier findings where potassium supplementation improved source-sink dynamics, carbohydrate partitioning, and ATP synthesis under drought stress (21,22). By providing consistent potassium availability throughout the crop cycle, seed coating not only improved water-use efficiency but also enhanced crop resilience to environmental stress. Foliar application provided a viable alternative, particularly under conditions where early soil application is impractical, but its effect was less pronounced than seed coating. Broadcasting, although traditional, was revealed as the least efficient method under water-limited conditions, mainly due to reduced uptake efficiency.

 

The strength of this study lay in its field-based evaluation of multiple potassium application methods under naturally occurring water stress. Such a design enhanced the practical relevance of the results, particularly for regions with similar agro-climatic conditions. Furthermore, the study assessed a broad set of traits, covering morphological, physiological, and yield components, which provided a comprehensive understanding of treatment responses. Nonetheless, limitations were evident. The absence of direct measurements of water-use efficiency restricted the ability to fully validate the physiological mechanisms by which potassium improved drought tolerance. Parameters such as transpiration efficiency, harvest index, or leaf water potential would have provided more precise evidence regarding the water-conservation role of potassium. Another limitation was the single-season and single-location design, which constrained the generalizability of results across environments and seasonal variability. Moreover, only one mungbean cultivar was evaluated, restricting conclusions regarding the broader genetic variability of crop response. Future studies should address these limitations by including multi-location and multi-year trials, incorporating diverse mungbean cultivars, and quantifying water-use efficiency indicators (23). Additional physiological parameters such as chlorophyll fluorescence, stomatal conductance, and root hydraulic traits should also be explored. Evaluation of combined nutrient management strategies, including integrated nitrogen and phosphorus application with potassium, could provide a more holistic understanding of optimal resource management under stress. Overall, the study confirmed the critical role of potassium in sustaining mungbean growth and yield under drought stress, with seed coating emerging as the most effective application method. These findings provide a practical nutrient management strategy for farmers in drought-prone regions, while also highlighting the need for further mechanistic and multi-environment research to refine recommendations for sustainable pulse production.

## CONCLUSION

This study demonstrated that the method of potassium application played a decisive role in improving the growth and productivity of mungbean under water-deficit conditions. Among the evaluated approaches, seed coating with potassium proved most effective, followed by foliar application, while broadcasting was comparatively less efficient. The consistent availability of potassium through seed treatment enhanced vegetative vigor, reproductive success, and overall yield stability, thereby offering a practical solution for sustaining mungbean production in drought-prone regions. These findings underscore the importance of adopting efficient nutrient management practices as a means to strengthen crop resilience, optimize resource use, and support food security in water-limited environments.

**AUTHOR CONTRIBUTION**

| Authors | Contribution |
|---|---|
| Nureen Rafeeq | Substantial Contribution to study design, analysis, acquisition of Data<br>Manuscript Writing<br>Has given Final Approval of the version to be published |
| Shabir Hussain | Substantial Contribution to study design, acquisition and interpretation of Data<br>Critical Review and Manuscript Writing<br>Has given Final Approval of the version to be published |
| Asia Bibi | Substantial Contribution to acquisition and interpretation of Data<br>Has given Final Approval of the version to be published |
| Ubaid ur Rehman | Contributed to Data Collection and Analysis<br>Has given Final Approval of the version to be published |
| Muhammad Noman Manzoor | Contributed to Data Collection and Analysis<br>Has given Final Approval of the version to be published |
| Muhammad Irfan | Substantial Contribution to study design and Data Analysis<br>Has given Final Approval of the version to be published |
| Shaista Suleman | Contributed to study concept and Data collection<br>Has given Final Approval of the version to be published |
| Hania Maryam | Writing - Review & Editing, Assistance with Data Curation |
| Roop Zahra | Writing - Review & Editing, Assistance with Data Curation |
| Natasha Kanwal | Writing - Review & Editing, Assistance with Data Curation |
| Javeria Azam | Writing - Review & Editing, Assistance with Data Curation |

 

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