Growth and physiological responses on drought stress in black gram (*Vigna mungo* L.)

Gayathri Gunasekaran[1], Ashok Subiramaniyan[2], Ashokkumar Natarajan[1], Selvakumar Gurunathan[1], Chandrasekaran Perumal[1*]

[1]SRM College of Agricultural Sciences, SRM Institute of Science and Technology, Chengalpattu- 603 201, Tamil Nadu, India.
[2]Department of Crop Physiology, School of Agricultural Sciences, Dhanalakshmi Srinivasan University, Samayapuram, Tiruchirapalli – 621 112, Tamil Nadu, India.

[*]**Correspondence**
Chandrasekaran Perumal
chandrumano11@gmail.com

Volume: 2, Issue: 3, Pages: 11-16
DOI: https://doi.org/10.37446/corbio/ra/2.3.2024.11-16
Received: 13 April 2024 / Accepted: 12 August 2024 / Published: 30 September 2024

Food security is increasingly threatened by rapid growth in population and drastic climatic changes. Among the abiotic stresses intensified by climate change, drought has started to emerge as a major constraint to crop productivity. Reduced precipitation and altered rainfall patterns have led to frequent and severe drought events across the world. Black gram, experiences yield losses of 21-40% under severe drought conditions. Drought stress restricts water availability to the roots or increases water loss through transpiration, disrupting plant growth and developmental processes. The extent of damage depends on multiple factors such as rainfall distribution, soil moisture retention capacity, and evapotranspiration rates. In black gram, drought stress adversely affects vegetative growth, nutrient uptake, water relations, and assimilate partitioning, ultimately reducing productivity. Variations in tolerance mechanisms across growth stages and genotypes reflect the complexity of physiological responses to drought, necessitating detailed understanding for breeding and management interventions.

Keywords: *global food security, climate change, water relations, drought tolerance, yield reduction*

Introduction

Pulses are the chief source of protein in human diet and they have a major role in ensuring nutritional security of the developing countries. In human diet, pulses have a vital role as besides protein, it is also rich in vitamins, complex carbohydrates and minerals. Pulses cultivation improves the soil fertility by biological nitrogen fixation. India ranks first in world's pulses production (Gurusamy et al., 2022). In recent years, there is a constraint in pulse production due to climate change, combined with frequent occurrence of abiotic and biotic stresses. Black gram is one of the important pulse/leguminous crops in India with high nutritional and economic value. It is cultivated on an area of more than 6 million hectare all over the world in warmer regions (Singh et al., 2018). It requires relatively less water and low input, and has a wide adaptability as compared to the other pulses. India is the largest producer and consumer of black gram with about 65% and 54% of world acreage and production (Pandiyan et al., 2023). Being a leguminous crop, it improves the soil fertility by fixing atmospheric nitrogen at a rate of 58-109 kg/ha by its symbiotic association with *Rhizobium*. It is a good source of protein (~25 %) and it also suitable for baby food because of its high digestibility. Besides protein, it also contains carbohydrate, vitamins and minerals and it contains very low levels of oligosaccharides (Chandrasekaran et al., 2022; Dutta et al., 2022).

Globally, agricultural productivity is highly affected by abiotic and biotic stresses; In particular the abiotic stresses are becoming one of the major and potential threats to agricultural production. Due to climate change, drought occurs simultaneously which severely affect the plant growth and development. Plants are unable to escape these adverse environmental conditions due to their sessile nature. Drought stress is one of the serious threats for black gram cultivation; it causes multiple damaging effects in crop. The dehydration in leaves was increased during drought stress. It primarily disrupts the osmotic balance, affects the metabolic pathway and leads to physiological disorders. Under field condition, plants are mostly exposed to multiple stress condition which inturn adversely affects the physiological and biochemical processes of plants and productivity is being subjected to increasing abiotic stresses, particularly to drought (Seleiman et al., 2021; Ashok et al., 2018; Ashok et al., 2021).

Nutritional value black gram

Black gram is an excellent source of protein, dietary fiber, and various vitamins and minerals. It is particularly rich in iron, which is important for maintaining healthy blood hemoglobin levels and preventing anemia. The high fiber content supports digestive health and helps regulate blood sugar levels. The legume also provides a good amount of potassium, which is essential for heart and muscle function, as well as magnesium for bone health. Including black gram in diet can contribute to your overall nutrient intake, especially for plant-based sources of protein and essential nutrients (Ajaykumar et al., 2023)

Drought stress – constraints in black gram production

The global agriculture productivity of blackgram has been constrained by various abiotic stresses such as drought, high temperature, cold and salinity; drought and high temperature being one of the major factors due to climate change and is highly detrimental for plant growth and development. Under field conditions plants are exposed to multiple stresses which negatively affect the plant physiological processes. Meteorologically, drought is referred to a period devoid of sufficient or evenly distributed rainfall which is a characteristic situation in the arid and semi- arid regions around the globe, with additional constrains like limited availability of water supply from other sources and deterioration of available water reservoirs. Globally, drought is prevalent in an area of about 1.2 billion hectare of land where rainfed agriculture is practiced and causes a loss in crop yield up to 45%. In India 68% of the net sown area of about 140 million ha is vulnerable to drought. Drought causes disruption in the osmotic balance which leads to a devastating multiple damaging effect leading to morpho-physiological and biochemical disorders such as changes in morphological traits, change in pigment composition, and changes in biochemical activities (Fahad et al., 2017; Sivakumar et al., 2017; Chandrasekaran et al., 2022; Senthil et al., 2018; Sezhiyan et al., 2023; Sathyabharathi et al., 2022) (Table 1).

Table 1. Effect of drought stress on black gram growth and yield

S.No	Physiological changes during drought stress	Effect on growth and yield
1.	Reduced Cell Water Potential	Decreased cell enlargement Decrease in leaf area Reduction of shoot growth
2.	Inhibited Chlorophyll formation	Low photosynthetic rate Low assimilate production Poor yield
3.	Reduction of Enzymes Activity	Nitrate Reductase- Decreased nitrogen assimilation & fixation- Inhibition of protein synthesis RuBisCO enzyme activity- Decline of carbon fixation- Photosynthetic rate decreased Nitrogenase enzyme activity- Nodulation inhibited
4.	Accumulation of Hormones – ABA & Ethylene	Stomata closure- Reduced transpiration
5.	Accumulation of compatible solutes	Help to maintain the water potential of plant during drought

Effect of drought stress on growth, water and nutrient relation

Negative impacts of drought stress on germination and seedling growth have been reported in various studies. The seedling growth characters (germination potential, early seedling growth, root and shoot dry weight and hypocotyl length) have been reported as reduced significantly in important field crops under drought stress. Growth is mainly determined by cell division, elongation, and differentiation. The mitosis and elongation of cells impaired by drought stress which results in poor growth of plants due to the loss of turgor. Because of the poor water flow from xylem to the nearby cells cell elongation have been reduced significantly. Reduced turgor pressure and slow rate of photosynthesis under drought conditions mainly limit the leaf expansion. Fresh and dry weights are also severely reduced under the water limiting conditions. Plant height, leaf size, and the stem girth were significantly reduced under the water limiting conditions in black gram (Wahab et al., 2022; Subiramaniyam et al., 2022; Sala et al., 2022). Exposure to drought stress disturbs all certain factors including the leaf water potential, leaf and canopy temperature, transpiration rate, and stomatal conductance in plants however, stomatal conductance is affected the most. Under drought conditions, there was a decrease in leaf water potential and transpiration rate, which eventually raised the temperature of the canopy. Water use efficiency, or the ratio of dry matter accumulated to water used, is another crucial component for plant physiological regulation. Under drought stress, blackgram cultivars that are more efficient use water more efficiently. The formation of dry matter by using less water as a result of stomata shutting and lower transpiration rates is the primary cause of this gain in water use efficiency. Plants' nutritional relationships are significantly impacted by drought stress. Along with water, roots absorb a number of essential elements, such as calcium, silicon, nitrogen, and magnesium. Drought circumstances restrict the diffusion and mass entry of these nutrients, which slows down plant growth (Hussain et al., 2022; Divya et al., 2018). In order to absorb the less mobile nutrients, plants alter the architecture of their roots and expand their length and surface area. A lack of moisture in the soil can hinder root development and the absorption of less mobile nutrients like phosphorus. Each plant's nutrient relations are also significantly influenced by root-microbe interactions. Certain legumes' capacity to fix nitrogen (N) was hampered by the reduced carbon and oxygen flow to the nodules combined with nitrogen (N) accumulation during drought stress. The soil water deficiency has a detrimental effect on the microbial colonies' composition and activity, which ultimately disrupts the plant-nutrient relationships. Different crop species react differently to the uptake of minerals under moisture stress. Under drought conditions, N uptake generally increases, P uptake decreases, and potassium is unaffected. However, nutrient relations become more complicated due to interactive effects of different nutrients on each other and overall plant physiology (Balliu et al., 2021).

Effect of drought stress on seed germination and seedling growth

Blackgram when cultivated in summer season faces drought stress at various stages of crop growth. Drought impairs the mitosis and cell elongation which results in poor growth (Basu et al., 2022). Stress has a detrimental impact on a number of physiological processes in plants, which tends to lower yield. Because yield is a complex integration of many physiological processes, yield reduction varies according to the degree of stress and the stage of the plant at which stress occurs. The osmotic potential has a major impact on germination. An increase in drought stress markedly decreased the germination percentage of *E. songoricum* (Hasanuzzaman et al., 2013).

Effect of drought stress on the morphological parameters

Because there is less water flowing onto the xylem, plants under water stress show reduced germination, leaf size, leaf area, leaf number, biomass, and cell elongation. Leaf rolling, stomata shutting, leaf tip drying, and root shortening are other noticeable morphological changes (Bhandari et al., 2023). Drought stress during vegetative stage reduces the individual leaf size and number due to reduced turgor pressure and photosynthesis, because expansion of leaf depends on turgor pressure and the supply of assimilates. Plant height is another morphological trait severely affected by drought stress in Black gram than the yield parameters such as harvest-index, 100 - seed weight and length of the pod, reduction in plant height is due to reduction in cell enlargement. Fresh and dry weight of plants are also reported to be severely reduced under the water deficit conditions. However, drought stress during later vegetative periods (e.g., trifoliate formation) causes less damage though cell elongation, cell division and cell differentiation were retarded. The adverse effect of drought in leaf area, plant height and root growth interfere with the realization of yield components such as pod number per plant and harvest index (Khatun et al., 2021).

Effect of drought on the physiological parameters

Water shortage has a detrimental effect on a number of black gram physiological characteristics, such as net photosynthetic rate, transpiration rate, stomatal conductance, WUE, PSII activity, relative water content, and membrane stability index. The physiological reactions include membrane stability and an increase in osmo-protectants (Balliu et al., 2021). Water is the essential resource for all metabolic processes in a cell; therefore, measurement of the status of water content in crop plants would reflect its response to stress. Relative water content (RWC) is a measure of the water status in plants which expresses the absolute amount of water required to attain artificial saturation by a plant. RWC is related to water uptake by plants and the water loss through transpiration (Ievinsh, 2023). Chlorophyll stability index (CSI) indicates the performance of chlorophyll under stress conditions. High drought stress disrupts the functional integrity of the photosynthetic apparatus leading to inhibition of the whole leaf photosynthesis. High CSI and RWC indicates the plants ability to tolerate stress and maintain a stable chloroplast membrane photosynthetic pigments for normal functioning of photosynthesis and thus dry matter production (Sameena & Puthur, 2021).

ABA content

Abscisic acid (ABA) is a sesquiterpenoid phytohormone that is mainly accumulated in plants under stress conditions. Along with its widely recognized role as a stomatal closure agent, ABA have other roles to drought stress. High temperature and drought stresses, result in increased levels of ABA in roots rather than shoots, which enables the plant to overcome abiotic stresses, such as drought, cold, salt and wounding. The osmotic stress induced by drought, salt and cold stress the ABA acts as a signal molecule for regulation and induction of the physiological responses (Vishwakarma et al., 2017).

Conclusion

Drought stress remains one of the most critical challenges to sustaining global food production, particularly under the escalating pressures of climate change. In black gram, the physiological and biochemical disruptions caused by limited water availability severely compromise growth, yield, and overall productivity. The extent of drought-induced damage varies among genotypes and developmental stages, emphasizing the complexity of plant responses and the need for an integrated understanding of underlying tolerance mechanisms. Advancing drought resilience in black gram will require a multidisciplinary approach-combining physiological screening, molecular characterization, and improved agronomic practices-to identify and develop tolerant cultivars. Such efforts are essential to ensure good stable yields and contribute to food and nutritional security in drought-prone regions.

Acknowledgement

None.

Author contributions

Conceptualization – Gayathri Gunasekaran, Chandrasekaran Perumal, Ashokkumar Natarajan, Selvakumar Gurunathan. Writing (original draft) - Gayathri Gunasekaran, Chandrasekaran Perumal, Ashok Subiramaniyan. Writing (review & editing) - Gayathri Gunasekaran, Ashok Subiramaniyan, Chandrasekaran Perumal, Ashokkumar Natarajan, Selvakumar Gurunathan.

Conflict of interest

The authors declare no conflict of interest.

Funding

No funding.

Ethics approval

Not applicable.

AI tool usage declaration

The authors have used ChatGPT and QuillBot for the improvement of language and readibility. Authors have not used AI tools for creating the scientific content of the article. Authors aussured that the article has been thouroughly checked for its scientific integrity.

References

Ajaykumar, R., Harishankar, K., Chandrasekaran, P., Kumaresan, P., Sivasabari, K., Rajeshkumar, P., & Kumaresan, S. (2023). Physiological and biochemical characters of blackgram as influenced by liquid rhizobium with organic biostimulants. *Legume Research: An International Journal*, *46*(2), 160-165.

Ashok, S., Chandrasekhar, C. N., Senthil, A., Jeyaprakash, P., Srinivasan, K., & Prabhakaran, N. K. (2021). Changes in the physiological and biochemical activities of traditional rice landraces affected by water stress during reproductive stage under field condition. *JPP*, *10*(1), 2328-2330.

Ashok, S., Senthil, A., Sritharan, N., Punitha, S., Divya, K., & Ravikesavan, R. (2018). Yield potential of small millets under drought condition. *Madras Agricultural Journal*, *105*(7-9), 370-372.

Balliu, A., Zheng, Y., Sallaku, G., Fernández, J. A., Gruda, N. S., & Tuzel, Y. (2021). Environmental and cultivation factors affect the morphology, architecture and performance of root systems in soilless grown plants. *Horticulturae*, *7*(8), 243.

Basu, P. S., Chaturvedi, S. K., Gaur, P. M., Mondal, B., Meena, S. K., Das, K., ... & Sharma, K. (2022). Physiological mechanisms of tolerance to drought and heat in major pulses for improving yield under stress environments. In *Advances in plant defense mechanisms*. IntechOpen.

Bhandari, U., Gajurel, A., Khadka, B., Thapa, I., Chand, I., Bhatta, D., ... & Shrestha, J. (2023). Morpho-physiological and biochemical response of rice (*Oryza sativa* L.) to drought stress: A review. *Heliyon*, *9*(3).

Chandrasekaran, P., Ashok, S., & Sampath, S. (2022). Cotton defoliant chemicals-a powerful tool for mechanical harvest in cotton. *Vigyan Varta*, *3*(6), 147-149.

Divya, K., Senthil, A., Sritharan, N., Ravikesavan, R., Ashok, S., & Prabha, V. V. (2018). Morpho-physiological traits influencing the grain yield potential in small millets. *Madras Agric J*, *105*(7-9), 476-479.

Dutta, A., Trivedi, A., Nath, C. P., Gupta, D. S., & Hazra, K. K. (2022). A comprehensive review on grain legumes as climate-smart crops: challenges and prospects. *Environmental Challenges*, *7*, 100479.

Fahad, S., Bajwa, A. A., Nazir, U., Anjum, S. A., Farooq, A., Zohaib, A., ... & Huang, J. (2017). Crop production under drought and heat stress: plant responses and management options. *Frontiers in plant science*, *8*, 1147.

Gurusamy, S., Vidhya, C. S., Khasherao, B. Y., & Shanmugam, A. (2022). Pulses for health and their varied ways of processing and consumption in India-a review. *Applied Food Research*, *2*(2), 100171.

Hasanuzzaman, M., Nahar, K., Alam, M. M., Roychowdhury, R., & Fujita, M. (2013). Physiological, biochemical, and molecular mechanisms of heat stress tolerance in plants. *International journal of molecular sciences*, *14*(5), 9643-9684.

Hussain, T., Hussain, N., Tahir, M., Raina, A., Ikram, S., Maqbool, S., ... & Duangpan, S. (2022). Impacts of drought stress on water use efficiency and grain productivity of rice and utilization of genotypic variability to combat climate change. *Agronomy*, *12*(10), 2518.

Ievinsh, G. (2023). Water content of plant tissues: So simple that almost forgotten?. *Plants*, *12*(6), 1238.

Khatun, M., Sarkar, S., Era, F. M., Islam, A. M., Anwar, M. P., Fahad, S., ... & Islam, A. A. (2021). Drought stress in grain legumes: Effects, tolerance mechanisms and management. *Agronomy*, *11*(12), 2374.

Pandiyan, M., Sivaji, M., Yuvaraj, M., Krishnaveni, A., Sivakumar, C., & Jamuna, E. (2023). Molecular and physiological approaches for effective management of drought in Black Gram. In *Legumes: Physiology and Molecular Biology of Abiotic Stress Tolerance* (pp. 259-278). Singapore: Springer Nature Singapore.

Sala, M., Vadivel, T. S., Sarankumar, C., Ashok, S., & Yuvarani, R. (2022). Unlocking the characters association and path analysis to frame out the idiotype for a breeding program in black gram (*Vigna mungo* L. Hepper). *Biological Forum–An International Journal* (Vol. 14, No. 4, pp. 134-137).

Sameena, P. P., & Puthur, J. T. (2021). Differential modulation of photosynthesis and defense strategies towards copper toxicity in primary and cotyledonary leaves of *Ricinus communis* L.. *Journal of Photochemistry and Photobiology*, *8*, 100059.

Sathyabharathi, B., Nisha, C., Jaisneha, J., Nivetha, V., Aathira, B., Ashok, S., ... & Sampath, S. (2022). Screening of genotypes for drought tolerance using PEG 6000 in different landraces of rice (*Oryza sativa* L.). *International Journal of Plant & Soil Science, 34*(22), 1424-1434.

Seleiman, M. F., Al-Suhaibani, N., Ali, N., Akmal, M., Alotaibi, M., Refay, Y., ... & Battaglia, M. L. (2021). Drought stress impacts on plants and different approaches to alleviate its adverse effects. *Plants*, *10*(2), 259.

Senthil, A., Ashok, S., Sritharan, N., Punitha, S., Divya, K., & Ravikesavan, R. (2018). Physiological efficiency of small millets under drought condition. *Madras Agricultural Journal*, *105*.

Sezhiyan, A., Subiramaniyan, A., Perumal, C., Natarajan, A., Arumugam, R., Ramalingam, K., & Chinnaraju, N. K. (2023). Salt stress and its impact on rice physiology with special reference to India-A review. *Journal of Applied & Natural Science*, *15*(3).

Singh, S., Singh, Y. P., & Tomar, S. S. (2018). Review on climatic abnormalities impact on area, productivity of central India and strategies of mitigating technology on yield and benefits of black gram. *J. Pharm. Phytochem*, *7*, 1048-1056.

Sivakumar, R., Nandhitha, G. K., Chandrasekaran, P., Boominathan, P., & Senthilkumar, M. (2017). Impact of pink pigmented facultative methylotroph and PGRs on water status, photosynthesis, proline and NR activity in tomato under drought. *Int J Curr Microbiol App Sci*, *6*(6), 1640-1651.

Subiramaniyam, A., Chandran, S., Ramalingam, K., & Alagarswami, S. (2022). An approach to climate resilient agriculture farming system using Rice landraces collected from Tamil Nadu. *Journal of Cereal Research 14 (Spl-2): 49-54. http://doi. org/10.25174/2582-2675/2022*, *124374*.

Vishwakarma, K., Upadhyay, N., Kumar, N., Yadav, G., Singh, J., Mishra, R. K., ... & Sharma, S. (2017). Abscisic acid signaling and abiotic stress tolerance in plants: a review on current knowledge and future prospects. *Frontiers in plant science*, *8*, 161.

Wahab, A., Abdi, G., Saleem, M. H., Ali, B., Ullah, S., Shah, W., ... & Marc, R. A. (2022). Plants' physio-biochemical and phyto-hormonal responses to alleviate the adverse effects of drought stress: a comprehensive review. *Plants*, *11*(13), 1620.