

Black Gram: A Climate-Resilient Pulse for the Future: A Promising Pulse Crop for Changing Climates

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Climate change is becoming one of the major challenges to agricultural production. Rising temperatures, irregular rainfall, prolonged dry periods, sudden heavy rains and increasing soil salinity are affecting crop growth and productivity. Under these changing conditions, farmers need crops that can perform well with limited resources and tolerate environmental stresses. Black gram (*Vigna mungo* (L.) Hepper) is one such promising pulse crop. Black gram, popularly known as urd bean or urd dal, is an important pulse cultivated widely in India. It is a short-duration crop and fits well into different cropping systems. Its grain is rich in protein and is widely used in dhal, idli, dosa, vada and several traditional food products. In addition to providing food and nutrition, black gram contributes to soil fertility through biological nitrogen fixation. However, the productivity of black gram is affected by several constraints. Among them, drought, high temperature, salinity, excess moisture, insect pests and diseases are becoming increasingly important under changing climatic conditions. Developing climate-resilient black gram varieties is therefore an important goal for future crop improvement.



Why is black gram important for climate-resilient agriculture?

One of the major advantages of black gram is its short duration. Many varieties can complete their life cycle within a relatively short period. This enables farmers to fit the crop between major crops and also helps the plant escape prolonged periods of drought or high temperature. Black gram can also be grown under rainfed conditions and residual soil moisture. Its adaptability to different seasons and cropping situations makes it useful in climate-smart farming systems. Another important advantage is its role in soil fertility improvement. As a legume, black gram forms a symbiotic association with beneficial bacteria in its roots and contributes biologically fixed nitrogen to the cropping system. Thus, increasing black gram cultivation can support both food security and sustainable soil management.

Drought: A major challenge

Water scarcity is one of the most serious threats to pulse production. Drought can reduce germination, plant growth, flowering, pod formation and ultimately seed yield. Interestingly, plants have several mechanisms to cope with water shortage. In black gram, the root system plays an important role in searching for and absorbing available soil moisture. Genotypes with favourable root characteristics may be able to explore a larger volume of soil and maintain better water status during drought.

Important root characteristics include:

- Deeper and well-developed roots;
- Greater root length;

- Appropriate lateral root development;
- Higher root biomass;
- Efficient soil exploration; and
- Favourable root-to-shoot balance.

Therefore, “breeding from below the ground” is becoming an important concept in climate-resilient crop improvement. Scientists are increasingly interested in identifying black gram genotypes with better root development and improved performance under moisture stress. Such genotypes can serve as valuable parents in breeding programmes.

Heat tolerance: Preparing for a warmer future

Increasing temperature is another major concern. High temperature can be particularly damaging during flowering and pod formation. Heat stress may reduce pollen viability, flower retention and pod setting, resulting in yield reduction. Therefore, future varieties should not only produce high yield under normal conditions but should also maintain reproductive performance under higher temperatures. Screening diverse black gram germplasm has already identified genotypes showing better performance under heat stress. These genetic resources can be utilized in breeding programmes to develop varieties with improved heat resilience.

Beyond drought and heat

Climate resilience is not limited to drought and heat. Heavy rainfall and water logging can also damage black gram by restricting oxygen availability around roots and disturbing normal root function. Similarly, salinity can interfere with water absorption and cause ionic imbalance. This means that future breeding programmes should aim for broad climate resilience rather than resistance to only one stress. A farmer's field may experience drought during one season, excessive rainfall during another season, and high temperature during the reproductive stage. Therefore, varieties capable of maintaining stable yield under several environmental conditions will have greater value.

The role of plant breeding

Developing climate-resilient black gram varieties requires a combination of traditional and modern breeding methods. The first step is to identify useful genetic diversity. Landraces, traditional varieties, improved cultivars, breeding lines and wild relatives can provide valuable traits for climate adaptation. Breeders can then cross selected parents and identify superior progenies. Selection can be based not only on seed yield but also on traits associated with stress tolerance.

For drought tolerance, breeders can consider:

- Root traits;
- Relative water content;
- Early maturity;
- Flowering behaviour;
- Pod setting;
- Seed yield; and
- Yield stability.

For heat tolerance, reproductive traits such as pollen fertility, flower retention and pod setting become particularly important. Modern molecular technologies are further improving the efficiency of breeding. DNA markers, QTL mapping, genome-wide association studies, genomic selection and high-throughput phenotyping can help breeders identify useful genes and genomic regions associated with stress tolerance.

From yield selection to climate-smart selection

Traditionally, crop improvement has focused mainly on selecting plants with higher grain yield. However, yield is strongly influenced by the environment. A genotype may perform very well in one location but poorly in another. Therefore, climate-resilient varieties must be

evaluated across different environments. Modern approaches such as genotype $\times$ environment analysis, stability analysis and multi-trait selection can help identify genotypes that combine high yield with reliable performance.

For example, a desirable black gram genotype could combine:

Good root development + better water status + heat tolerance + disease resistance + high yield + stable performance.

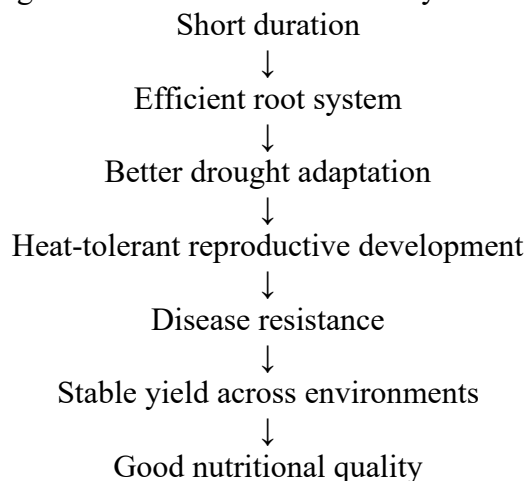
Such an integrated approach can help breeders develop varieties that are better suited to uncertain climatic conditions.

The future: Breeding a climate-resilient black gram

The future of black gram improvement lies in integrating genetics, physiology, root science, genomics and field-based selection. New technologies can make this process faster. Digital imaging can be used to study root architecture, while sensors and remote sensing can monitor plant growth and stress responses. Genomic tools can help identify useful genes, and artificial intelligence may eventually assist breeders in predicting which genotypes will perform best under particular climatic conditions. However, technology alone is not sufficient. The ultimate test of a climate-resilient variety is its performance in farmers' fields.

A new breeding vision

The climate-resilient black gram of the future should ideally be:



Conclusion

Climate change demands a new approach to pulse improvement. Black gram, with its short duration, nutritional importance, adaptability and role in sustainable agriculture, has considerable potential to become an important climate-resilient pulse crop. The future challenge is to develop varieties that can produce stable yields despite drought, heat, salinity, excess rainfall and other environmental stresses. Integrating root traits, physiological characteristics, conventional breeding and modern genomic technologies can accelerate this process. A climate-resilient black gram will not only benefit farmers through more stable production but will also contribute to food security, nutritional security, soil health and sustainable agriculture. The black gram of tomorrow must be bred not merely for higher yield, but for reliable yield under an uncertain climate.