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Climate-Resilient Seed Production - Coping with Heat, Drought, Flood and Salinity Stresses

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ABSTRACT

Climate change poses a serious threat to sustainable agriculture, particularly the production of high-quality seeds. Rising temperatures, erratic rainfall, drought, flooding, and salinity disrupt seed production systems by affecting critical stages such as flowering, pollination, and seed development. These stresses reduce seed set, viability, vigor, and genetic purity, ultimately impacting crop productivity and food security. Heat stress accelerates crop growth and shortens the seed filling period, while drought leads to shriveled seeds with poor germination. Flooding damages seed production fields and reduces seed longevity, whereas salinity interferes with physiological processes, resulting in poor seed formation. In hybrid seed production, climate variability further affects synchronization between parental lines, leading to reduced pollination efficiency and seed yield. Developing climate-resilient varieties capable of withstanding multiple stresses is essential for maintaining seed quality under changing environments. Modern breeding approaches, including genomic selection, speed breeding, and the use of diverse genetic resources, are accelerating the development of stress-tolerant crops. Strengthening climate-resilient seed production systems is crucial to ensure a continuous supply of quality seeds and sustain agricultural productivity under future climate scenarios.

INTRODUCTION

Climate change is emerging as a major threat to quality seed production worldwide. Rising temperature, erratic rainfall, prolonged droughts, and unexpected floods are disrupting seed production systems, thereby affecting the availability of high-quality seeds and ultimately food security. Most existing crop varieties were developed under relatively stable environments and often lack the genetic capacity to withstand multiple stresses simultaneously. Hence, there is a growing need to develop varieties that can consistently produce high-quality seeds even under adverse conditions such as heat, drought, and flooding.

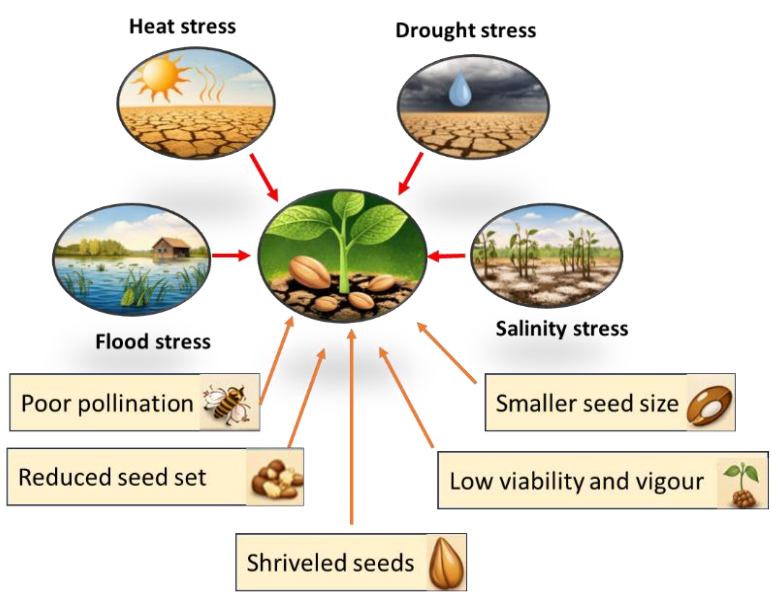

Figure 1. Impact of Abiotic Stresses on Seed Yield and Quality

Seed production is particularly sensitive to climatic variability, as the development of quality seeds depends on optimal temperature, sufficient moisture, synchronized flowering, and effective pollination. Multiple stresses like elevated temperature, irregular rainfall and drought stress affect seed production at various levels of crop growth like hastening crop growth, shortening seed filling period, reducing seed size, impairing pollination, viability, vigor and lowering overall seed quality (Figure 1.)

In hybrid seed production, climatic fluctuations further complicate the process by disturbing synchronization between male and female parental lines. This can result in poor pollination, reduced seed yield, and compromised genetic purity, all of which directly affect seed quality. Additionally, concerns over unsustainable agricultural practices and inefficient resource use have shifted breeding priorities toward developing climate-resilient varieties capable of maintaining stable reproductive development and producing high-quality seeds under variable environmental conditions.

Climate change is already having measurable impacts on the productivity of major crops, which directly influences seed yield and quality. Projected yield reductions under future climate scenarios highlight the severity of these challenges in India (Table 1).

Table 1. Impacts of climate change on the yields of major crops in India

Crop	Yield reduction	Reference
Rice	-40% by 2080	Aryal et al., 2019
Wheat	-5.2% by 2030	Gupta et al., 2017
Maize	-20% by 2030	Bandra and Cai et al., 2014
Sugarcane	-30% by 2030	Kumar et al., 2014
Cotton	-7% by 2030	Aryal et al., 2019
Sorghum	-11% by 2050	Srivastav et al., 2010
Potato	-13.72% by 2050	Naresh et al., 2015

Therefore, next-generation crop varieties must be designed not only for high grain yield but also for reliable and efficient quality seed production. Key traits include improved water and nutrient use efficiency, tolerance to abiotic stresses, stable flowering behavior, and the ability to consistently produce seeds with high viability and vigor across diverse environments. Strengthening climate-resilient seed production systems is essential to ensure a continuous supply of quality seeds, which forms the foundation for sustainable agricultural productivity and long-term food security.

HEAT STRESS

Extreme temperatures, both high and low, negatively influence key stages of crop growth such as germination, flowering, pollination, and seed development. Rising temperatures have been consistently linked with declines in crop productivity; even a small increase of 1–2°C can significantly reduce yields in major food crops. Heat stress is particularly damaging during the reproductive phase, as plant reproductive organs are highly sensitive to temperature fluctuations. Elevated temperatures can reduce pollen viability, disrupt fertilization, and weaken the source–sink balance, ultimately leading to poor seed set and lower yields.

In seed production, high temperatures during flowering and seed filling stages reduce seed size, weight, viability, and germination potential. In hybrid seed production, heat stress can also disturb synchronization between male and female parents, resulting in ineffective pollination and reduced hybrid seed yield. Major crops such as wheat, rice, maize, and soybean have already shown yield declines under heat stress, and future projections indicate substantial losses if temperatures continue to rise. Understanding these effects is essential for developing heat-tolerant varieties and ensuring stable seed production under changing climatic conditions.

DROUGHT STRESS

Drought stress severely affects plant physiological processes and poses a major threat to both crop and seed production. Limited soil moisture reduces nutrient uptake, increases soil salinity, and weakens plant defense systems, making crops more vulnerable to pests and diseases. The reproductive stage especially flowering and seed formation is highly sensitive to water stress.

In seed production systems, drought can lead to shriveled seeds, reduced seed weight, poor germination, and low seedling vigor. In hybrid seed production, water stress may also disrupt flowering synchronization between parental lines, reducing pollination efficiency and seed yield. Despite these challenges, the development of drought-tolerant varieties, particularly in crops like maize and sorghum, has significantly improved productivity and livelihoods in water-limited regions.

FLOOD STRESS

Flooding is a major environmental hazard that causes extensive damage to agriculture by eroding fertile topsoil, leaching nutrients and reducing land productivity for several years. In addition to physical damage, floods can increase soil salinity, especially in coastal areas, and intensify pest and disease outbreaks.

For seed production, flooding can be highly destructive. Waterlogging during critical growth stages affects pollination, reduces seed set, and lowers seed quality. Floods may also destroy seed production fields, wash away seeds, and degrade soil fertility. Excess moisture during seed maturation and harvesting further reduces seed viability, germination, and storage life, posing serious constraints to sustainable seed production.

SALINITY STRESS

Soil salinity is an increasing problem in many agricultural regions, particularly in arid, semi-arid, and coastal areas. High concentrations of salts, especially sodium and chloride, disrupt nutrient balance and induce oxidative stress in plants. Salinity affects crops throughout their life cycle, from germination to seed development, resulting in reduced growth and productivity.

In seed production, saline conditions delay germination, weakens seedling establishment, and impair reproductive development. Salinity also affects physiological processes such as photosynthesis, enzyme activity, and hormone regulation, leading to poor seed formation. As a result, both seed yield and quality including seed size and vigor are significantly reduced, making salinity a major challenge for sustainable agriculture.

DEVELOPING CLIMATE-RESILIENT SEEDS FOR MULTI-STRESS CONDITIONS

To ensure stable crop production, it is essential to develop seed varieties that can withstand multiple environmental stresses simultaneously. In real farming conditions, crops are often exposed to combined stresses such as heat and drought or flooding and salinity. Therefore, breeding programs must focus on multi-stress tolerance rather than single stress resistance.

Modern approaches such as speed breeding, genomic selection, high-throughput phenotyping, and artificial intelligence are accelerating the development of resilient varieties. In addition, prebreeding with wild relatives and traditional landraces serve as valuable sources of stress-tolerant genes and can help broaden the genetic base of crops. Integrating these strategies will enable the production of seeds that maintain yield and quality under complex and changing climatic conditions.

CONCLUSION: SECURING QUALITY SEED PRODUCTION FOR THE FUTURE

Climate change presents significant challenges to agriculture, particularly in maintaining high-quality seed production. However, advances in plant breeding combining conventional techniques with modern genomic tools, speed breeding, and farmer involvement provide effective solutions. Developing climate-resilient varieties is crucial for ensuring consistent seed quality and performance under stress conditions such as heat, drought, salinity and flooding. Strengthening climate smart seed production systems today is essential to sustain productivity and ensure long-term food security.

REFERENCES

Abusaleha, A. and Shanmugavelu, K.G. 1988. Studies on the effect of organic versus inorganic sources of nitrogen on growth, yield and quality of okra. *Indian Journal of Horticulture* 45: 312–318.

FAO. 2009. *Seed industry for food security in the light of climate change and soaring food prices: Challenges and opportunities*. Food and Agriculture Organization, Rome.

Hampton, J.G. 2002. What is seed quality? *Seed Science and Technology* 30: 1–10.

Hatfield, J.L. and Prueger, J.H. 2015. Temperature extremes: Effect on plant growth and development. *Weather and Climate Extremes* 10(A): 4–10. doi: 10.1016/j.wace.2015.08.001.

Singh, R.P., Prasad, P.V.V. and Reddy, K.R. 2013. Impacts of changing climate and climate variability on seed production and seed industry. *Advances in Agronomy* 118: 49–110.

Sravani, C., Prasanna, T. and Mrudula, D. 2024. Climate change impact on quality seed production. In: *Climate Change and Agriculture – Its Impact and Mitigation Potential*. KD Publications, India. pp. 94–104.