

Climate-Resilient Wheat Production Technologies for Sustainable Yield Stability

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ABSTRACT

Wheat (*Triticum aestivum* L.) is a cornerstone of food security in many countries, yet its productivity is increasingly threatened by climate variability, particularly rising temperatures, erratic rainfall, terminal heat stress, and declining soil moisture. These stresses adversely affect wheat establishment, phenology, grain filling, and final yield. Climate-resilient wheat production technology focuses on integrating stress-tolerant varieties with precise agronomic practices such as optimized sowing time, conservation tillage, efficient irrigation, and balanced nutrient management. This article highlights key climate-resilient wheat production technologies that enhance yield stability, improve resource-use efficiency, and reduce climate-induced production risks in wheat-growing regions.

INTRODUCTION

Wheat is one of the most widely cultivated cereal crops and serves as a primary source of calories and protein for a large proportion of the global population. In major wheat-producing regions, particularly semi-arid and subtropical areas,

climate change has emerged as a serious constraint to wheat productivity (FAO, 2017; Reynolds, 2010). Increasing frequency of heat waves, delayed or early onset of rainfall, and prolonged dry spells are disrupting traditional wheat production practices and reducing yield

stability. Wheat is especially sensitive to temperature and moisture stress during reproductive stages, where even short periods of stress can cause substantial yield losses (Fischer and Maurer, 1978). As climatic uncertainty intensifies, conventional wheat cultivation practices are no longer sufficient to sustain productivity. Therefore, adoption of climate-resilient wheat production technologies has become essential to maintain stable yields and ensure food security (FAO, 2017).

Rising temperatures accelerate wheat phenological development, leading to shortened crop duration and reduced grain-filling period (Reynolds, 2010). Terminal heat stress during flowering and grain filling reduces grain size and thousand-grain weight, thereby lowering final yield (Fischer and Maurer, 1978). Moisture stress during crown root initiation and tillering limits root development and tiller formation, directly affecting yield potential. Erratic rainfall further complicates sowing decisions and increases dependence on irrigation, particularly in rainfed wheat systems (FAO, 2017).

Climate-resilient wheat production technologies are designed to reduce the adverse effects of heat and moisture stress while improving input-use efficiency. The foundation of such systems lies in the use of stress-tolerant wheat varieties possessing traits such as heat tolerance, drought tolerance, early or medium maturity, and improved root architecture (Reynolds, 2010). These varieties are better adapted to escape terminal heat stress and utilize available soil moisture efficiently, thereby contributing to yield stability under changing climatic conditions (Fischer and Maurer, 1978).

Optimized sowing time and precision planting are critical technological interventions in climate-resilient wheat production. Timely sowing ensures proper crop establishment and allows wheat to complete sensitive growth

stages before the onset of high temperatures (FAO, 2017). The use of seed drills and zero-tillage machines enables early planting after rice harvest, reduces turnaround time, and improves soil moisture conservation, particularly in intensive cereal-based systems (Sharma *et al.*, 2025).

Conservation agriculture practices, including zero tillage, residue retention, and crop rotation, play a significant role in enhancing wheat resilience to climate stress (FAO, 2017). Residue retention reduces soil evaporation, moderates soil temperature, and improves soil organic carbon, which collectively enhance moisture availability during dry periods. Zero-tillage wheat has been shown to perform better under terminal heat stress due to improved soil moisture status and reduced soil disturbance (Reynolds, 2010).

Efficient irrigation management is another key component of climate-resilient wheat production technology. Scheduling irrigation at critical growth stages such as crown root initiation, booting, and grain filling improves water-use efficiency and stabilizes yield under limited water availability (FAO, 2017). Adoption of precision irrigation methods and avoidance of excess irrigation help conserve water and reduce stress-induced yield losses, particularly under increasing climatic variability (Sharma *et al.*, 2025).

Balanced and site-specific nutrient management strengthens wheat tolerance to climatic stress. Adequate nitrogen application improves canopy development and photosynthetic efficiency, while potassium enhances stress tolerance and water-use efficiency (Reynolds, 2010). Integrated nutrient management using organic manures and biofertilizers improves soil structure, nutrient availability, and microbial activity, contributing to sustained wheat productivity under adverse climatic conditions (FAO, 2017; Sharma *et al.*, 2025).

The use of biofertilizers and plant growth-promoting microorganisms further enhances root growth, nutrient uptake, and physiological resilience of wheat under stress conditions. These biological inputs support sustainable wheat production by improving soil health, enhancing nutrient-use efficiency, and reducing dependency on chemical fertilizers, thereby contributing to long-term system resilience (Sharma *et al.*, 2025).

CONCLUSION

Climate change poses a major challenge to wheat production, particularly in heat- and drought-prone regions. Climate-resilient wheat production technologies provide a practical solution by integrating stress-tolerant varieties with precise sowing methods, conservation agriculture, efficient water and nutrient management, and biological inputs. Adoption of these technologies improves yield stability, enhances resource-use efficiency, and reduces production risks under climatic uncertainty. Strengthening research, extension services, and farmer access to climate-resilient technologies will be crucial for sustaining wheat productivity and food security in the future.

SUMMARY

Climate-resilient wheat production technologies focus on maintaining stable

wheat yields under climate stress through improved varieties, timely sowing, conservation tillage, efficient irrigation, and balanced nutrient management. These technologies reduce the negative effects of heat and moisture stress, improve soil health, and enhance resource-use efficiency. Wider adoption of such technologies is essential for ensuring sustainable wheat production and long-term food security under changing climatic conditions.

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