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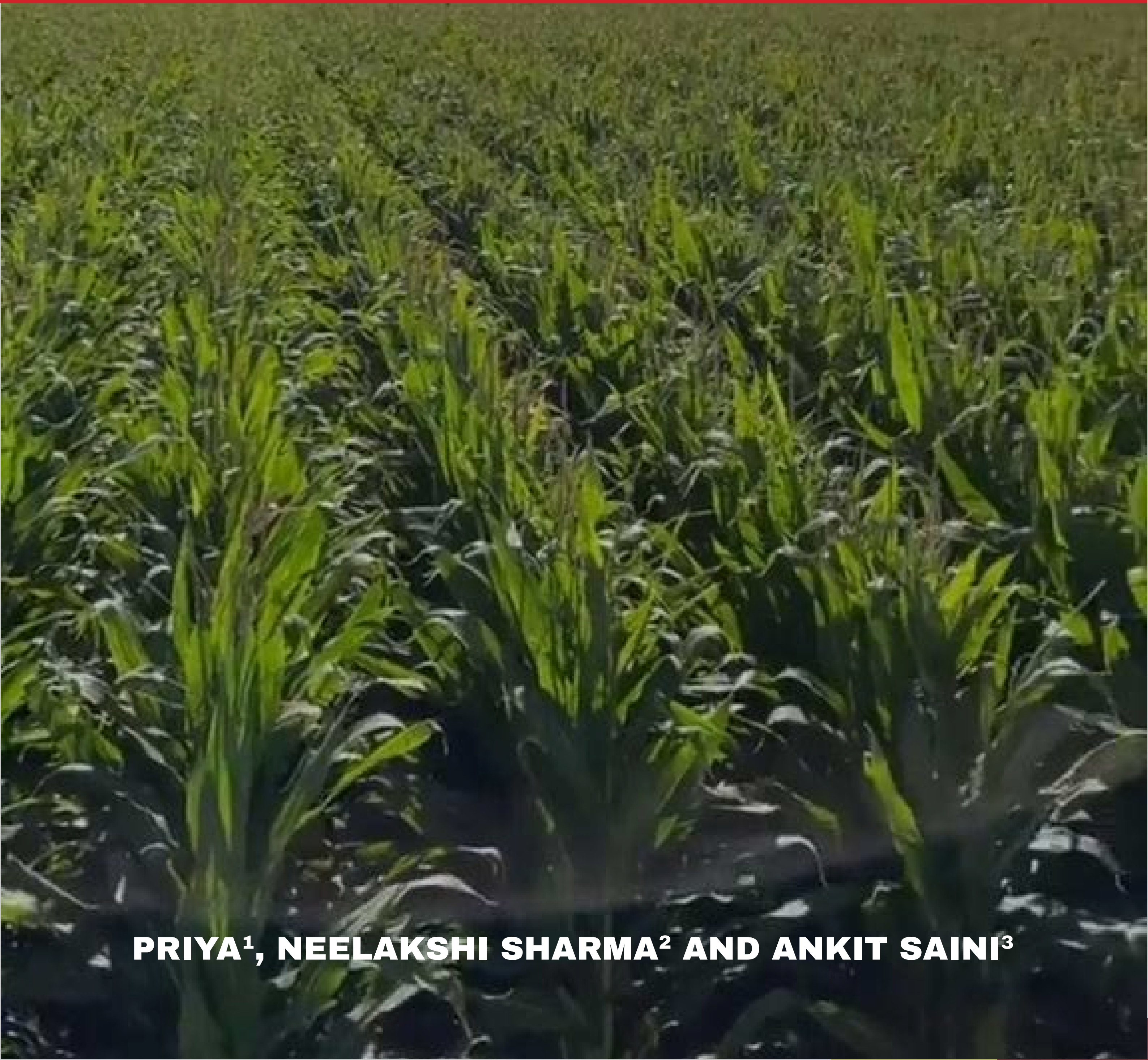

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Agronomic Practices for Cereal Crops: Enhancing Productivity and Sustainability

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Abstract

Cereal crops such as wheat (*Triticum aestivum*), rice (*Oryza sativa*), and maize (*Zea mays*) are vital for global food security but face increasing challenges from climate change, soil degradation, water scarcity, and biotic stresses. Recent agronomic research (2020–2025) has focused on sustainable and climate-resilient production strategies, including integrated nutrient management, biological nitrogen fixation, conservation agriculture, precision farming, remote sensing, and AI-based decision support systems. This review highlights key innovations in cereal agronomy that improve productivity, resource-use efficiency, nutritional quality, and environmental sustainability. The study emphasizes that adopting locally adapted, technology-driven, and farmer-centric practices can strengthen resilience and support global sustainability goals related to food security, climate action, and sustainable land management.

Introduction

Wheat, rice, and maize together contribute more than 70% of global cereal output. While the Green Revolution significantly boosted production in the past century, these gains are plateauing. In many developing countries, current yields are still far below potential due to improper agronomic practices, input misuse, and climate-induced stress. A recent multi-country review noted that in South Asia alone, the average yield gaps in wheat and rice remain above 30%, largely due to mismanagement of water, nutrients, and crop timing (Subedi et al., 2025). To close these gaps, a paradigm shift is underway—from input-intensive to knowledge-intensive agronomy. Researchers are now focusing on systems that are not only productive but also resource-efficient, environmentally sound, and climate-resilient.

Integrated and Site-Specific Nutrient Management

Traditional fertilizer practices—often based on blanket recommendations—have led to both overuse and underuse of key nutrients like nitrogen and phosphorus. In response, integrated nutrient management (INM) strategies are now promoted that combine chemical fertilizers with organic amendments and biofertilizers. For instance, field trials in wheat fields in India demonstrated that combining urea with farmyard manure significantly improved soil microbial biomass and increased grain protein content, compared to urea alone (Chakraborty et al., 2025).

In rice, the application of *Azospirillum and Phosphobacteria* along with half-dose of NPK fertilizers resulted in higher tiller density and improved grain yield under both irrigated and rainfed conditions. Similarly, maize grown with poultry litter and zinc-enriched fertilizers produced 20% more biomass and exhibited higher chlorophyll content.

Site-specific nutrient management (SSNM) tools, such as Nutrient Expert®, have also shown promising results. In maize trials conducted in Punjab and Nepal, SSNM practices reduced nitrogen input by 25–30% while maintaining or improving yields, demonstrating both environmental and economic benefits (Deb et al., 2025). Moreover, integrating real-time crop diagnostics—like leaf colour charts and Green Seeker sensors—enables farmers to adjust nutrient doses mid-season, preventing over-fertilization and leaching losses.

Climate-Resilient Agronomic Interventions

Mitigating Heat and Drought Stress

With rising global temperatures, cereal crops—especially wheat and maize—face increasing risks of yield loss due to heat stress during flowering and grain filling stages. Agronomic responses have included shifting sowing dates,

adopting heat-tolerant varieties, and using foliar protectants.

In wheat, early sowing by 2–3 weeks helped avoid terminal heat stress and increased yields by up to 15% in the Indo-Gangetic Plains. Foliar applications of silicon and seaweed extract were found to reduce heat-induced oxidative damage by enhancing antioxidant enzyme activity (Ponmani et al., 2025). In maize, conservation furrow planting and mulching helped retain soil moisture and buffer canopy temperatures during dry spells.

Salinity and Abiotic Stress Management

Saline soils, particularly in coastal and arid regions, present another growing challenge. In response, agronomic practices such as raised-bed planting, gypsum application, and organic mulching are increasingly used. A notable innovation is the application of olive mill wastewater as a bio stimulant under saline conditions. Recent greenhouse studies on wheat reported that olive waste extract improved root elongation, chlorophyll content, and relative water content under moderate salinity stress (Asencio-Vicedo & García-Cano, 2025).

In rice systems, the use of salt-tolerant cultivars like CSR-36 combined with alternate wetting and drying (AWD) irrigation not only improved salt tolerance but also saved water.

Crop Diversification and Sustainable Rotations

The dominance of rice–wheat monocultures has led to multiple sustainability issues: declining soil fertility, groundwater depletion, and pest pressure. Crop diversification offers a way forward.In northwestern India, replacing rice with short-duration maize or millet varieties in kharif season and introducing pulses like chickpea or lentil in rabi significantly improved soil health and enhanced farm income. Intercropping systems, such as maize + cowpea or wheat + mustard, have also shown yield advantages due to complementary resource use and natural pest suppression.

One study in Haryana demonstrated that a maize–mustard–mungbean rotation improved total productivity by 28% over traditional rice–wheat, while reducing irrigation needs by 40% (Singh, 2025). Additionally, diversified systems are more resilient to market and climate shocks.

Conservation Agriculture for Soil Health and Carbon Sequestration

Conservation agriculture (CA)—which includes minimal tillage, residue retention, and crop rotation—is increasingly adopted in cereal systems to improve long-term sustainability. In wheat–maize systems, zero tillage has been shown to reduce production costs by 20%, increase water infiltration, and improve soil organic carbon content.

Residue mulching, particularly in rice fields, suppresses weeds, reduces evaporative losses, and adds organic matter to the soil. Long-term CA trials in eastern Uttar Pradesh showed that after five years of residue retention and no-till sowing, wheat yields improved by 12%, while soil compaction decreased significantly.

Precision Agriculture and Digital Tools

Remote sensing, GIS, and drone-based monitoring are revolutionizing cereal agronomy. Vegetation indices such as NDVI (Normalized Difference Vegetation Index) and thermal imaging now help in identifying crop stress, nutrient deficiencies, and disease hotspots well before visual symptoms appear.

Recent work by Haq et al. (2025) introduced a multi-spectral remote sensing model capable of detecting early-stage drought stress in maize and rice with 92% accuracy. These technologies enable site-specific interventions, optimizing input use and minimizing losses.

Artificial intelligence (AI) is also being used in crop protection. For example, the AgriSense platform developed in Algeria uses smartphone-captured images to detect leaf rust in wheat and rice blast with 85–90% accuracy, providing farmers with real-time management suggestions.

Biofortification and Nutritional Enhancement through Agronomy

Agronomic biofortification addresses hidden hunger by increasing the micronutrient content of cereals through field-based interventions. For instance, foliar application of zinc sulfate at the booting stage in wheat increased grain zinc concentration by over 40% without affecting yield. Similarly, selenium sprays in rice improved its antioxidant properties and nutritional value. Combined strategies—applying micronutrient-rich fertilizers and using biofortified seed varieties—offer a synergistic approach. Tessema et al. (2025) report that such combinations are essential for meeting international nutrition targets, especially in regions with

cereal-based diets.

Biological Nitrogen Fixation and Eco-Friendly Inputs

Reducing reliance on synthetic nitrogen is a major sustainability goal. In maize and rice, biological nitrogen fixation (BNF) using microbial inoculants is gaining momentum. Inoculation with *Azospirillum* and *Herbaspirillum* has resulted in N savings of up to 50 kg/ha under field conditions.

Forghieri et al. (2025) showed that integrating BNF organisms with reduced nitrogen fertilizers in maize systems maintained yields while lowering nitrous oxide emissions by 35%. Similarly, intercropping legumes like soybean or cowpea with cereals creates a synergistic system where nitrogen fixed by legumes benefits the cereal crop.

Circular Agriculture and Policy Integration

To scale these agronomic innovations, enabling policies and institutional support are essential. Circular agriculture—using organic waste like compost, biogas slurry, and treated wastewater—is gaining traction. Chojnacka (2025) notes that large-scale adoption of organo-mineral fertilizers in rice and maize systems across sub-Saharan Africa improved yields while reducing fertilizer costs by 25%.

Subsidy reform, training programs, and digital extension services are critical in driving adoption. Integration of these practices into national food security and climate adaptation strategies will be crucial in the coming decade.

Conclusion

Agronomic practices for wheat, rice, and maize are evolving rapidly to meet the dual challenges of food security and environmental sustainability. From integrating organic and site-specific nutrient management, to deploying climate-resilient cropping strategies and digital tools, the shift is clear: precision, sustainability, and resilience are the new pillars of modern cereal agronomy. These innovations, when adapted to local conditions and backed by supportive policies, hold immense promise to transform cereal production into a more productive, nutritious, and ecologically sound enterprise.

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