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# Climate-Smart Pulse Production: Growing More Pulses under a Changing Climate

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Pulses are central to food, nutritional and soil security, supplying affordable plant protein while fixing atmospheric nitrogen and improving soil health. Yet these same crops are highly sensitive to climatic variability: rising temperatures, terminal heat and moisture stress around flowering, erratic monsoons, and occasional waterlogging routinely erode germination, pod-set and seed-filling, capping yields well below genetic potential. This article examines the major climate-related constraints facing chickpea, pigeonpea, lentil, mungbean, urdbean and field pea, and reviews agronomic strategies to build resilience and climate-resilient varieties, water-smart practices, balanced nutrition with rhizobial inoculation, integrated weed and pest management, conservation agriculture, diversified cropping systems, and emerging digital advisories. Rather than presenting a single solution, the article argues for locally adapted combinations of practices: right variety, right sowing window, healthy soil, efficient water use, and timely, information-based decisions. For South Asian farming systems in particular, where pulses occupy marginal, rainfed niches, such climate-smart agronomy offers a practical, evidence-based pathway to more stable pulse yields, strengthening both farm livelihoods and national food and nutritional security under an increasingly uncertain climate.

**Keywords:** climate-smart agriculture, pulse crops, drought and heat stress, conservation agriculture, biological nitrogen fixation, water management, sustainable intensification

## Introduction: Why Climate-Smart Pulses Matter

If we Walk through any Indian kitchen and pulses are present in some form of dal, sprouts, or split gram flour. Pulses supply affordable, high-quality plant protein along with iron, zinc, folate and dietary fibre, and carry one of the lowest environmental footprints of any protein source, with a markedly smaller water and carbon cost per unit of protein than most animal foods (Mondor et al., 2024). Through their symbiosis with rhizobia, they also fix atmospheric nitrogen, cutting fertiliser needs in the crops that follow and building long-term soil fertility (Ferguson et al., 2021). Global demand for pulses is rising even as the climate farmers depend on becomes less predictable. India must expand pulse output substantially to reduce import reliance and meet nutritional demand (Chintagunta et al., 2025). Most South Asian pulses are grown as rainfed or residual-moisture crops on marginal land, squeezed into short windows between cereal harvests â€" acutely exposed to the very stresses climate change intensifies. Meeting rising demand while using less water and fewer inputs is therefore a necessity, and this is the challenge climate-smart agronomy addresses.

## How Climate Change Threatens Pulse Production

Pulse crops have a comparatively narrow physiological safety margin during their reproductive phase. Elevated temperature during flowering disrupts pollen viability and flower retention, while combined heat and drought increasingly the norm rather than the exception depress yields far more severely than either stress alone (Cohen et al., 2021). In chickpea, terminal drought alone is responsible for roughly 40-50% of yield reduction in many production environments (Kaloki et al., 2022). The physiological chain of damage is well characterised: heat and moisture deficit impair germination and seedling vigour, restrict root and shoot growth, reduce photosynthetic efficiency, and cause oxidative cellular damage (Sato et al., 2024). During the reproductive window, these translate into flower and pod abortion, poor seed-filling, and shrivelled grain. Erratic rainfall compounds the problem: dry spells at flowering alternate with unseasonal downpours that cause waterlogging, to which most pulses intolerant of saturated soils respond with poor nodulation and root asphyxiation. Warmer, more humid conditions are also shifting pressure from pod borers, aphids and fungal diseases such as wilt and blight, adding a biotic dimension (Bailey-Serres et al., 2019). These stresses rarely act alone; their increasing overlap, more than any single event, is what defines the climatic challenge for pulse agronomy today.

## Choosing Climate-Resilient Varieties

The first and most cost-effective line of defence is genetics. Early-maturing and short-duration varieties let the crop complete its reproductive phase before terminal drought or heat sets in, effectively "escaping" late-season stress rather than tolerating it (Kaloki et al., 2022). This trait is especially valuable as sowing windows shift with delayed monsoon withdrawal. Breeding programmes across chickpea, lentil and other pulses have also targeted deeper, more efficient root systems, better water-use efficiency, and stable performance across environments, drawing on large germplasm collections and marker-assisted selection (Arriagada et al., 2022). Where waterlogging is a recurring risk as in rice-fallow belts of eastern India tolerance to short-duration soil saturation is an increasingly important criterion. No single variety performs best everywhere; agro-climatic zone, sowing date and typical stress pattern must guide choice, underscoring that varietal selection is inherently a location-specific decision.

## Water-Smart Pulse Production

Because most pulses are grown with limited or no assured irrigation, managing the water available becomes central to resilience. Where irrigation is possible, scheduling it to coincide with the most sensitive stages flowering and early pod development gives the greatest yield return per unit of water applied (Kumar et al., 2026). Even a single "life-saving" irrigation at a critical stage can substantially offset a dry spell. Complementary practices reduce dependence on irrigation altogether. Mulching and residue retention lower soil surface temperature and evaporative loss, conserving moisture longer into the crop cycle. Rainwater harvesting at farm or watershed scale captures monsoon runoff for later use, and conservation tillage improves infiltration and reduces runoff (Kumar et al., 2026). None of these alone substitutes for adequate rainfall, but together they narrow the yield gap between good and poor rainfall years.

## Soil and Nutrient Management

Healthy soil is a pulse crop's first buffer against climatic stress, and nowhere is this more evident than in the rhizobium “legume symbiosis. Soil-testing based, balanced fertilisation with particular attention to phosphorus and sulfur, which support nodulation and protein synthesis sets the stage, but the single most consistently documented intervention for pulses is rhizobial inoculation. Field trials have repeatedly shown substantial yield gains from seed inoculation with compatible rhizobial strains, alongside improved nitrogen and phosphorus uptake in grain (Ahmad et al., 2021; Shah et al., 2024). Because biologically fixed nitrogen is released gradually and is less prone to leaching than mineral fertiliser nitrogen, it also supports more resilient nutrient cycling under variable rainfall (Ferguson et al., 2021). Integrated nutrient management combining inoculants, need-based mineral fertiliser and organic amendments such as farmyard manure or crop residues helps build soil organic matter over time, improving water-holding capacity, microbial activity and, ultimately, the soil's own resilience to both drought and waterlogging. This is a cumulative, multi-season investment rather than a single-season fix, but it is one of the more durable ways of preparing pulse fields for a less predictable climate.

## Climate-Smart Weed and Pest Management

Warmer, more variable conditions are shifting the timing, intensity and range of weed flushes, insect pests and fungal diseases in ways only partly predictable from historical patterns. Erratic early-season rainfall can trigger staggered weed emergence, while warmer winters allow pod-borer and aphid populations to build up earlier. Relying solely on calendar-based spraying is poorly matched to this variability and risks both economic loss and resistance build-up. Integrated Weed Management, timely sowing, optimal plant density, stale seedbeds and need-based herbicide use field scouting, economic thresholds, biological control and judicious pesticide use offer more adaptive alternatives. Both depend on close, season-specific field observation rather than fixed schedules, which suits a climate that no longer follows a fixed calendar.

## Conservation Agriculture and Pulses

Minimum or zero tillage, permanent residue retention, and crop rotation or diversification form the core of conservation agriculture (CA), and pulses fit naturally within this framework. Long-term experiments in pulse-based rotations show that zero-tillage systems with residue retention conserve soil moisture, reduce erosion, and build soil organic carbon over successive seasons, improving productivity and resource-use efficiency relative to conventional tillage (Kumar et al., 2026; Bhattacharyya et al., 2022). In semi-arid pulse-wheat rotations, these benefits accumulate over time rather than appearing immediately, so CA is best viewed as a medium-term investment in soil resilience (Alhameid et al., 2020). CA is not without trade-offs. Residue retention can, in some environments, favour particular weed species or provide overwintering sites for pests and pathogens, and the literature is careful to note that CA's benefits are environment-dependent rather than universal (Bhattacharyya et al., 2022). Where well matched to local conditions, though, it remains one of the more evidence-backed pillars of climate-smart pulse production.

## Pulses in Climate-Smart Cropping Systems

Beyond the individual field, pulses play an outsized role at the cropping-system level. Cereal pulse rotations and legume intercropping with maize, wheat or sorghum consistently improve nitrogen economy: legume-fixed nitrogen allows meaningful reductions in fertiliser nitrogen applied to the following cereal without yield penalty (Layek et al., 2018; Peng et al., 2024). Reviews across sub-Saharan Africa similarly report sizeable yield gains in cereals grown after a legume versus continuous cereal cropping, reflecting both nitrogen and non-nitrogen benefits such as improved soil organic matter and reduced pest carryover (Franke et al., 2018). In India's cropping landscape, pulses also serve as short-duration catch crops in rice-fallow systems, diversifying income and improving soil health without competing heavily for water. This systems-level role â€” nitrogen provider, risk-diversifier, soil-health builder â€” is arguably as important to climate resilience as any single in-field practice, because it spreads climatic risk across crops and seasons.

## Digital and Precision Technologies

A newer, still-evolving layer of climate-smart agronomy involves digital tools: weather-based sowing and spray advisories via mobile phone, soil-moisture sensors that guide irrigation timing, and satellite or drone-based remote sensing for early detection of stress or pest outbreaks. In India, government and private platforms increasingly combine such data streams into farmer-facing advisories for more timely, site-specific decisions. These technologies show promise, but adoption among smallholder pulse growers remains limited by cost, digital literacy and patchy rural connectivity, and the regional soil and climate datasets needed for accurate advice are still being built in many pulse-growing tracts. Precision tools should be understood as an emerging complement to, not a replacement for, the fundamentals of variety choice, water and nutrient management.

## Climate-Smart Pulse Production: A Practical Roadmap

No single practice discussed above is sufficient on its own. Climate-smart pulse production works best as a locally adapted combination:

***Right variety + right sowing time + healthy soil + efficient water management + balanced nutrition + integrated weed/pest management + weather-based decisions.***

## Conclusion

Pulses are not merely a food crop grown on the margins of the farming calendar; they are a keystone of climate-resilient, sustainable agriculture feeding people, feeding soils, and diversifying farmer income and risk. Building their resilience to a changing climate will not come from any single breakthrough, but from the patient, locally adapted combination of better varieties, smarter water and nutrient use, integrated pest and weed management, conservation agriculture, diversified cropping systems, and, increasingly, digital decision support. Investing in climate-smart pulse agronomy today is an investment in the stability of both farm livelihoods and national food security tomorrow.

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