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NUTRI CEREALS: SCOPE AND NUTRITIONAL SECURITY IN DEVELOPING COUNTRIES

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ABSTRACT

The confluence of a rapidly burgeoning global population and the escalating impacts of anthropogenic climate change presents a formidable and existential threat to conventional agricultural systems and, by extension, to global nutritional security. This challenge is particularly acute in developing nations, where agricultural productivity is most vulnerable. For more than half a century, the global food security strategy has been overwhelmingly predicated on maximizing the yields of a limited number of staple crops namely rice, wheat, and maize within the intensive-input paradigm of the Green Revolution. While this approach was instrumental in augmenting caloric supply and averting widespread famine, its long-term consequences have been profoundly detrimental. This monoculture-centric model has inadvertently precipitated extensive micronutrient malnutrition, severely eroded vital agrobiodiversity, and engineered food systems characterized by a precarious vulnerability to climatic and environmental shocks. This comprehensive review critically examines the immense potential of nutricereals, a diverse group of ancient grains including millets and sorghum, to address these deeply interconnected and systemic challenges. We meticulously detail how the intrinsic agronomic and superior nutritional attributes of these crops offer a direct, efficacious, and sustainable solution to the manifold limitations of the current agricultural paradigm. Nutricereals are inherently climate-resilient, exhibiting remarkable physiological tolerance to drought, extreme heat, and marginal, low-fertility soils, rendering them optimally suited for the increasingly challenging production environments of the developing world. Nutritionally, they represent a dense repository of essential minerals such as iron and zinc, high-quality protein, complex carbohydrates, and dietary fiber, positioning them as a potent instrument to combat "hidden hunger," manage the rising tide of non-communicable diseases, and enhance overall public health outcomes. However, the realization of this immense potential is contingent upon overcoming decades of systemic policy neglect, navigating underdeveloped and fragmented value chains, and transforming pervasive negative consumer perceptions that have relegated these grains to the status of "orphan crops." Substantial post-harvest losses, constrained access to modern processing technologies, and deficient market linkages persist as significant impediments. This review consolidates and integrates empirical evidence from agronomic, nutritional, and socio-economic research to construct a holistic and compelling case for their strategic mainstreaming. We conclude that a business-as-usual, staple-crop-focused strategy is fundamentally untenable and represents a direct threat to future food and nutritional security. A paradigm shift towards diversified, ecologically robust, and climate-resilient agricultural systems, with nutricereals as a foundational cornerstone, is not merely beneficial but is now an urgent global imperative.

Keywords **:** Nutricereals, Millets, Food Security, Nutritional Security, Climate Resilience, Developing Countries, Sustainable Agriculture, Hidden Hunger, Agrobiodiversity, Value Chain.

Introduction

Achieving sustainable food and nutritional security for a global population projected to exceed 9.7 billion by 2050 represents the most critical and complex challenge of the twenty-first century (Ghosh *et al.*, 2024). This monumental task is disproportionately concentrated in the developing world, where national economies, rural livelihoods, and societal stability are inextricably linked to the performance and resilience of the agricultural sector (Kumar *et al.*, 2023). For over five decades, the dominant global response to food scarcity was defined by the Green Revolution, an agricultural modernization effort that, through the deployment of high-yielding crop varieties and intensive chemical inputs, dramatically increased the yields of staple grains like rice and wheat (Singh *et al.*, 2022). This model was undeniably successful in boosting aggregate calorie production and mitigating the immediate threat of famine in many parts of Asia and Latin America. However, the long-term viability and inherent wisdom of this paradigm are predicated on two critical assumptions that have been systematically invalidated over time: the assumption of stable and predictable climatic conditions, and a reductionist definition of food security based primarily on caloric sufficiency rather than holistic nutritional adequacy (Patel *et al.*, 2024).

This foundational paradigm is now rapidly and visibly eroding under the immense pressure of anthropogenic climate change (Sharma *et al.*, 2025). The entire global food production system faces unprecedented and synergistic challenges from rising mean temperatures, increasingly erratic and volatile rainfall patterns, and a greater frequency and intensity of extreme weather events, including prolonged droughts and catastrophic floods (Hassan *et al.*, 2024). These climatic shifts directly and severely undermine the productivity of the major water-intensive C3 cereals that form the very backbone of the global food supply. Furthermore, the very success of the Green Revolution has engendered severe, unintended consequences. It has catalyzed a drastic and deleterious reduction in both farm-level and dietary diversity, fostering an over-reliance on a small number of highly refined and processed grains that are often deficient in essential micronutrients (Das *et al.*, 2022). This dietary narrowing has, in turn, fueled a silent and pervasive pandemic of micronutrient deficiencies, colloquially known as "hidden hunger," which contributes to a complex "double burden" of malnutrition. This paradox involves the coexistence of undernutrition (stunting and wasting) with a rapid increase in the prevalence of obesity and diet-related non-communicable diseases (NCDs) such as type-2 diabetes, cardiovascular conditions, and certain cancers (Mishra *et al.*, 2025).

It is within this profoundly challenging and dynamic context that nutricereals a diverse group of hardy and nutritionally-rich grains including pearl millet (*Pennisetum glaucum*), finger millet (*Eleusine coracana*), foxtail millet (*Setaria italica*), and sorghum (*Sorghum bicolor*) are gaining long-overdue recognition as a critical, strategic component of a future-proof food system (Jena *et al.*, 2023). Long categorized as "orphan crops" or "food of the poor," they were systematically marginalized by agricultural policies, research funding, and market forces that overwhelmingly favored the "big three" staple grains (Mohanty *et al.*, 2023). Today, their inherent resilience and demonstrably superior nutritional profiles are being re-evaluated as indispensable assets for 21st-century agriculture. With their innate physiological capacity to thrive in arid and semi-arid conditions with minimal external inputs, they are perfectly suited to the climate-stressed, resource-scarce, and marginal environments that characterize large parts of the developing world, particularly in sub-Saharan Africa and South Asia (Ali *et al.*, 2023). This review aims to synthesize the current state of scientific knowledge regarding the pivotal role of nutricereals in ensuring holistic food and nutritional security. We will first conduct a forensic examination of the deep-seated vulnerabilities of the dominant cereal-based system. Subsequently, we will dissect the specific nutritional and agronomic advantages of nutricereals in greater detail, and finally, we will explore the multifaceted strategic, policy, and market-based shifts required to mainstream these "miracle grains" and unlock their vast, untapped potential for a more resilient, sustainable, and nutritious future for all.

The Double Burden: Limitations of Dominant Cereals in a Changing World

The prevailing agricultural model, while historically lauded for its productivity in terms of sheer caloric volume, has created profound systemic vulnerabilities that are becoming increasingly manifest. Its limitations extend far beyond agronomic considerations, permeating public health, environmental integrity, and the economic viability of the smallholder farmers who remain the stewards of global food production.

Nutritional Deficiencies and Hidden Hunger

The strategic and policy-driven focus on calorie-dense but micronutrient-poor staples has had

devastating and well-documented public health consequences. This dietary simplification is a primary etiological factor in the global crisis of hidden hunger, a chronic deficiency of essential vitamins and minerals such as iron, zinc, calcium, and vitamin A (Das *et al.*, 2022). This condition, which affects over two billion people worldwide, can lead to permanently impaired cognitive development in children, weakened immune systems, and increased maternal and infant mortality (Satyavathi *et al.*, 2021). Moreover, the overconsumption of refined cereals, with their characteristically high glycemic index, is a major contributor to the global epidemic of lifestyle diseases. Nutricereals, with their low glycemic index, high concentrations of dietary fiber, and complex carbohydrate profiles, offer a potent and evidence-based dietary tool for the prevention and management of these conditions, thereby reducing the immense strain on national public health systems (Mishra *et al.*, 2025).

Climate Vulnerability and Production Instability

The world's primary food crops are increasingly and alarmingly at risk from climate change. Rice, wheat, and maize, as C_3 plants, are physiologically less efficient under conditions of high temperature and water scarcity and are highly dependent on reliable water sources (Hassan *et al.*, 2024). Their production often relies on extensive and fundamentally unsustainable irrigation practices, which are becoming untenable in regions facing precipitous declines in groundwater levels and increasingly erratic monsoon patterns. Global climate models consistently project that rising temperatures will cause significant yield declines for these crops in the coming decades, creating severe food security risks, particularly in the tropical and subtropical regions of the developing world (Bezbaruah, 2024). This extreme vulnerability of the dominant staple crops exposes a critical and dangerous flaw in a global food system that has placed most of its proverbial eggs in one, increasingly fragile, basket.

High Input Requirements and Environmental Degradation

The Green Revolution model is inextricably linked with high external inputs. Its success is contingent upon substantial and continuous applications of synthetic nitrogen and phosphorus fertilizers, chemical pesticides, and, most critically, vast quantities of fresh water. For a significant proportion of the world's 500 million smallholder farmers, the escalating cost of these inputs is prohibitive, either locking them out of productivity gains or trapping them in pernicious cycles of debt and dependency (Gupta *et al.*, 2023). From an environmental perspective, this chemical-intensive approach has led to widespread soil degradation, loss of soil organic matter, nutrient runoff that pollutes surface and groundwater, and a substantial greenhouse gas footprint. This high-input dependency is fundamentally unsustainable in the resource-constrained and ecologically sensitive contexts that define most developing nations (Rao *et al.*, 2024).

The negative feedback loop created by this paradigm is complex and self-reinforcing, as illustrated in Figure 1.

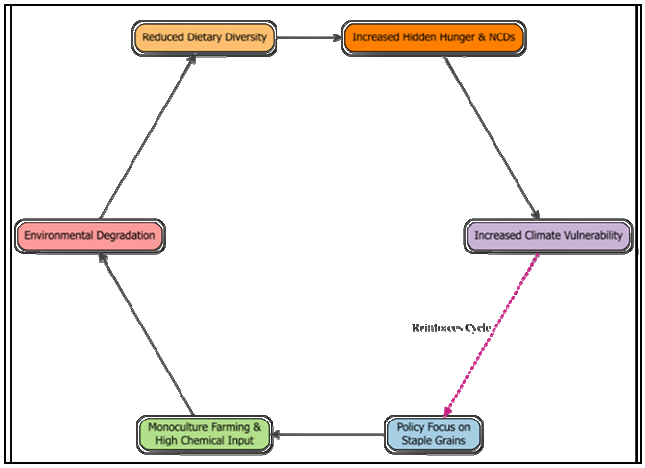

Fig. 1: Conceptual model of the negative feedback loop in conventional agriculture.

Figure 1: This flowchart provides a conceptual model of the negative feedback loop inherent in the conventional, staple-crop-focused agricultural paradigm. It visually depicts how a policy focus on a few staple grains drives monoculture farming and high chemical input, leading to environmental degradation, reduced dietary diversity, increased hidden hunger, and heightened vulnerability to climate shocks. This cycle perpetuates the perceived need for staple grains, thereby reinforcing the policy bias. Breaking this cycle is crucial for mainstreaming nutricereals and achieving sustainable food and nutritional security (Source Patel *et al.*, 2024; Mohanty *et al.*, 2023).

The Nutricereal Advantage: Intrinsic Properties for Resilience and Nutrition

Nutricereals possess a compelling suite of innate biological, physiological, and chemical traits that make them a powerful and multifaceted solution to the manifest shortcomings of the dominant agricultural model. They should not be viewed merely as substitutes for major cereals but are, in many critical respects, demonstrably superior, particularly for the

challenging agro-ecological and socio-economic contexts of developing countries.

Superior and Diverse Nutritional Profile

Frequently lauded as "superfoods" or "future foods," millets are veritable nutritional powerhouses capable of comprehensively addressing the spectrum of malnutrition. As detailed in Table 1, their grain is significantly richer in a wide array of essential minerals when compared to the polished rice and refined wheat that dominate modern diets (Khan *et al.*, 2023). They are an outstanding source of dietary fiber (10-12% by weight), which is crucial for maintaining digestive health, regulating blood glucose levels, and has been scientifically shown to help prevent cardiovascular diseases and certain types of cancer (Verma *et al.*, 2025). A key attribute is that all millets are naturally gluten-free, making them an essential and safe food source for the growing global population with celiac disease or non-celiac gluten sensitivity. Recognizing this immense potential, researchers are actively pursuing the genetic biofortification of millets to further enhance their micronutrient content, a strategy widely regarded as a highly cost-effective and sustainable agricultural approach to addressing hidden hunger at a population scale (Chandra *et al.*, 2024; Satyavathi *et al.*, 2021).

Table 1: Comparative Nutritional Composition of Major Nutricereals and Staple Cereals (per 100g, edible portion)

Nutrient	Finger Millet	Foxtail Millet	Pearl Millet	Barnyard Millet	Kodo Millet	Little Millet	Proso Millet	Rice (Polished)	Wheat (Whole)
Protein (g)	7.30	12.30	11.60	6.20	8.30	7.70	12.50	6.40	11.80
Fiber (g)	3.60	5.50	1.30	10.10	9.30	7.42	2.50	0.30	12.20
Calcium (mg)	344.00	31.00	42.00	20.00	27.00	17.00	14.00	9.00	34.00
Iron (mg)	3.90	2.80	8.00	15.00	0.60	9.30	3.80	0.70	3.50
Zinc (mg)	2.30	2.40	3.10	0.40	1.20	1.20	1.70	1.10	2.70
Phosphorus (mg)	283.00	290.00	296.00	280.00	188.00	220.00	285.00	140.00	350.00
Thiamine (mg)	0.42	0.59	0.38	0.33	0.15	0.30	0.41	0.06	0.41
Riboflavin (mg)	0.19	0.11	0.21	0.10	0.09	0.09	0.28	0.05	0.12
Niacin (mg)	1.10	3.20	2.80	4.20	2.00	3.20	4.50	1.60	5.10

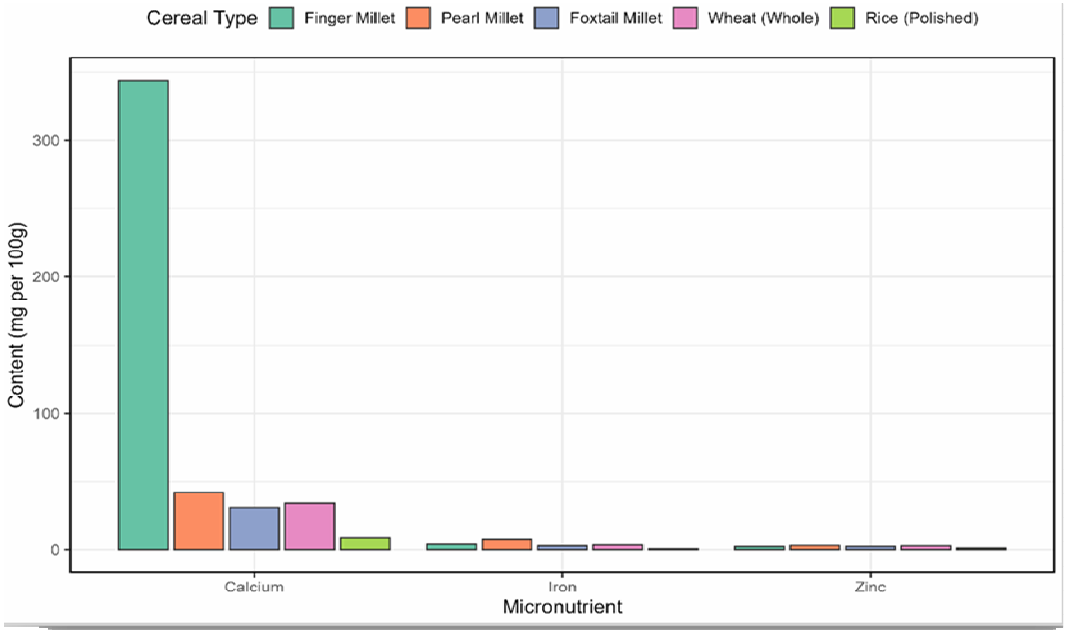

Fig. 2: Comparative Micronutrient Density (Bar Chart)

Adapted from Jacob *et al.* (2024) and the National Institute of Nutrition, India (2017) (Listed above the chart). Additional citations in legend: Reddy *et al.* 2024; Jacob *et al.* 2024.

Figure 2: This grouped bar chart provides a stark visual comparison of the mineral density of key nutricereals versus traditional staple grains. The data clearly illustrates those millets, as a category, offer a

significantly richer source of essential micronutrients than polished rice and whole wheat. Most notably, finger millet contains an exceptionally high level of calcium (344 mg/100g), an order of magnitude greater than that of wheat (34 mg/100g) and rice (9 mg/100g). Similarly, pearl millet stands out for its high iron content (8.0 mg/100g), more than double that of wheat. This visual evidence strongly supports the argument that incorporating millets into diets is a powerful, food-based strategy to combat hidden hunger and address widespread mineral deficiencies, such as iron-deficiency anemia and calcium deficiencies, which are prevalent in many developing nations (Reddy *et al.*, 2024; Jacob *et al.*, 2024).

Exceptional Climate and Agronomic Resilience

The most compelling and urgent advantage of nutricereals in the modern era is their remarkable, genetically endowed resilience to harsh and variable environmental conditions. Many millets are C4 plants, a sophisticated physiological trait that confers upon them a higher

Fig. 3: Comparative Agronomic Traits/Resilience (Radar Chart).

Source: Bandyopadhyay *et al.*, (2017) and Mantu *et al.*, (2025)

"This radar chart offers a multi-dimensional visualization of the agronomic resilience of a representative nutricereal (Pearl Millet) compared to a staple cereal (Rice). Each axis represents a critical trait for agricultural sustainability in a changing climate. The larger area covered by the pearl millet plot demonstrates its superior overall performance across multiple resilience indicators simultaneously. It excels in drought and heat tolerance, has a significantly lower water requirement, a shorter growing season, and thrives with fewer inputs and in poorer soils (Nayak *et al.*, 2022). In contrast, rice is shown to be far more demanding and less tolerant of environmental stress. This graphic effectively synthesizes complex agronomic data into an intuitive visual format, powerfully arguing that nutricereals are inherently better adapted to the marginal**,** water-scarce, and high-temperature environments that are becoming more common due to climate change (Babu *et al.*, 2023).

Photosynthetic efficiency in high-temperature, high-light intensity environments, and significantly better water-use efficiency when compared to C3 crops like wheat and rice (Nayak *et al.*, 2022; Sharma *et al.*, 2024). Their resilience stems from a suite of sophisticated morphological and physiological adaptations, including deep and extensive root systems for accessing residual soil moisture and smaller leaf areas to minimize transpirational water loss (Babu *et al.*, 2023). A summary of these superior traits is presented in Table 2.

Table 2: Comparative Agronomic Traits of Nutricereals vs. Staple Cereals

Trait	Nutricereals (e.g., Pearl Millet, Sorghum)	Staple Cereals (e.g., Rice, Wheat)
Water Requirement	Low (200-250mm rainfall)	High (Requires extensive irrigation)
Growing Season	Short (60-90 days)	Long (120-150 days)
Soil Fertility	Thrives in marginal, low-fertility soils	Requires high-fertility soils
Input Dependency	Low (minimal fertilizers/pesticides)	High (dependent on chemical inputs)
Drought/Heat Tolerance	High	Low to Moderate

Contribution to Agrobiodiversity and Soil Health

The strategic reintroduction and active promotion of nutricereals within cropping systems represents a direct and significant investment in restoring agrobiodiversity. Moving away from vast, genetically uniform monocultures enhances overall agro-ecosystem resilience by breaking persistent pest and disease cycles, improving long-term soil structure and fertility through their dense root systems, and supporting a wider range of beneficial insects and soil microbes (Meena *et al.*, 2024). This diversification is a foundational principle of sustainable intensification and climate-smart agriculture, creating farming systems that are more robust, self-regulating, and less dependent on external chemical inputs to maintain productivity and profitability.

Synergistic Challenges and Opportunities for Mainstreaming Nutricereals

Despite their clear and compelling advantages, nutricereals remain conspicuously marginalized in global and national food systems. Their path to becoming a mainstream food source is impeded by a complex and interwoven web of historical, economic, policy, and social barriers that demand concerted, strategic, and multi-stakeholder interventions.

Overcoming Historical Neglect and Systemic Policy Bias

For decades, national agricultural policies, research and development funding portfolios, public procurement systems, and government subsidies have overwhelmingly and systematically favored the "big three" cereals. This has relegated millets to the status of "orphan crops," with chronically insufficient investment in genetic improvement, modern agronomic practices, or market infrastructure development (Mohanty *et al.*, 2023). The global production shares shown in Figure 3 starkly illustrate this disparity. To disrupt and reverse this cycle, a fundamental and comprehensive policy reorientation is required. Recent positive developments, such as the Government of India's official designation of millets as "Nutri-Cereals" and the UN's declaration of 2023 as the International Year of Millets, have been instrumental in raising their profile on the global stage (Adhikari *et al.*, 2024; Government of India, 2018).

Interpretation of Figure 3: This donut chart quantifies the current standing of various cereals in the global food system, providing a powerful visual context for the term "orphan crops." It illustrates the overwhelming dominance of maize, wheat, and rice, which together account for approximately 93% of global cereal production by volume. In stark contrast, millets and sorghum, despite their nutritional and agronomic advantages, represent a minuscule fraction of this total, at approximately 1% and 2% respectively. This disparity is not a reflection of their intrinsic value but rather the result of decades of systemic policy bias, research neglect, and market forces that have favored the "big three" (Mohanty *et al.*, 2023).

Addressing Fragmented Supply Chains and Market Linkages

A major structural impediment to increased millet consumption is the lack of efficient, organized, and modern value chains. Smallholder farmers frequently lack access to reliable markets, appropriate post-harvest storage facilities, and modern, cost-effective processing technologies. This results in significant quantitative and qualitative losses; post-harvest losses for sorghum and millets due to pests and spoilage can range from 15% to as high as 40% in some regions (Bandyopadhyay *et al.*, 2017). Building robust and inclusive supply chains from strengthening Farmer Producer Organizations (FPOs) at the local level to incentivizing private investment in large-scale processing units and retail infrastructure is essential for making millets both accessible and affordable to a wider consumer base (Saxena *et al.*, 2025; Arjuman Banu *et al.*, 2022).

Transforming Consumer Perception through Value Addition

In many regions, millets carry a persistent and damaging social stigma as a "poor person's food" or a last-resort famine crop, a legacy of their historical role (Tiwari *et al.*, 2022). Shifting this deep-seated perception requires a sophisticated, multi-pronged approach. First, sustained and culturally sensitive public awareness campaigns are needed to educate consumers about the immense health, nutritional, and environmental benefits of incorporating millets into their diets. Second, the food industry must be incentivized to innovate and create a diverse portfolio of modern, convenient, and appealing millet-based products that align with contemporary lifestyles and culinary preferences. The development of value-added, ready-to-eat (RTE) and ready-to-cook (RTC) foods such as pasta, noodles, breakfast cereals, extruded snacks, and baked goods can effectively integrate millets into urban and international diets, thereby expanding their market appeal far beyond their traditional consumer base (Prakash *et al.*, 2024).

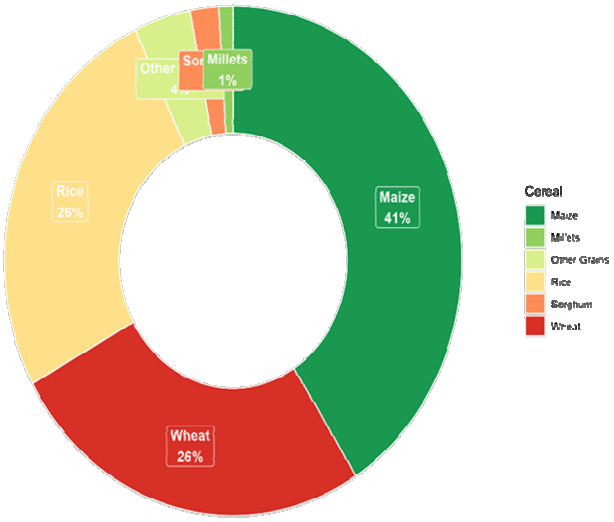

Fig. 4: Global Cereal Production Shares (Donut Chart). Source: Mohanty *et al.*, 2023

Strategies for a Nutricereal-Inclusive Future in Developing Countries

Unlocking the full, transformative potential of nutricereals necessitates a multi-stakeholder, systems-level approach that simultaneously and synergistically addresses the interconnected challenges on the policy, research, market, and consumer fronts.

Proactive Policy and Institutional Support

The revival of nutricereals must be unequivocally government-led and institutionally supported. A critical and impactful first step is their mandatory inclusion in large-scale national food security initiatives, such as Public Distribution Systems (PDS) and school mid-day meal programs (Joshi *et al.*, 2025). This single policy measure creates a large, stable, and guaranteed demand that directly incentivizes farmers to allocate land and resources to millet cultivation. Furthermore, governments should offer Minimum Support Prices (MSPs) that are on par with those for staple cereals, provide targeted subsidies for seeds and inputs, and offer financial support for the establishment of decentralized processing infrastructure.

Targeted Research, Development, and Technology Transfer

Renewed and significant investment in agricultural R&D is crucial to unlock the full genetic potential of these remarkable crops. This includes supporting modern breeding programs that utilize cutting-edge omics and genomic selection tools to develop higher-yielding, climate-resilient, and nutrient-biofortified varieties of millets (Yadav *et al.*, 2024). Research must also urgently focus on the development, validation, and dissemination of innovative, low-cost, and scalable processing technologies to drastically reduce post-harvest losses, improve the shelf-life of millet products, and eliminate the significant drudgery associated with traditional de-hulling and milling methods, which disproportionately affects women (Thakur *et al.*, 2023).

Strategic Public Awareness and Market Development

Creating consistent, growing, and diversified demand is just as important as ensuring a stable and high-quality supply. National and international campaigns, building on the momentum of the International Year of Millets 2023, are vital for creating sustained awareness about the compelling nutritional and environmental benefits of these crops among all consumer segments. Furthermore, governments and development agencies must actively encourage and de-risk private sector investment across the entire millet value chain from primary processing and packaging to branding, marketing, and retail distribution. This is key to making a diverse range of high-quality millet products widely available and attractive to modern consumers (Sarkar *et al.*, 2025). Forging direct, formal tie-ups between farmer cooperatives (FPOs) and institutional buyers (such as food manufacturers and restaurant chains) or international food companies can also open up new, lucrative export opportunities for value-added millet products, thereby channeling greater and more stable income back to rural communities (Behera *et al.*, 2024).

Conclusion

The convergence of unprecedented climate change, accelerating natural resource depletion, and a relentlessly growing global population has starkly exposed the inherent fragility of a global food system that has become dangerously over-reliant on an astonishingly small number of crops. The business-as-usual approach, with its myopic focus on maximizing the yield of staple grains at any cost, is no longer tenable. It has created a pernicious feedback loop of environmental degradation, increased climate vulnerability, and persistent, multifaceted malnutrition that disproportionately affects the most vulnerable populations in the developing world. Averting this alarming trajectory requires nothing short of a fundamental paradigm shift in how we produce, value, process, and consume food.

Nutricereals are not merely a niche alternative or a relic of the past; they represent a foundational and indispensable element of a more resilient, sustainable, and nutritious agricultural future. Their intrinsic, genetically encoded ability to withstand severe climatic shocks, their modest demand for finite resources like fresh water and soil nutrients, and their exceptional and diverse nutritional profiles make them a direct, powerful, and readily available solution to many of the developing world's most pressing and interwoven challenges. They offer a clear and actionable pathway to simultaneously enhance food security, combat malnutrition in all its forms, improve the livelihoods and climate resilience of smallholder farmers, and restore critical agrobiodiversity to our agricultural landscapes.

The journey to mainstreaming nutricereals is undoubtedly complex, requiring the deliberate and systematic reversal of decades of profound neglect and deeply entrenched policy bias. It demands a holistic, coordinated, and unwavering commitment from policymakers, international research institutions, the

private sector, civil society, and consumers alike. By making strategic, long-term, and sustained investments in supportive policies, advanced research and development, modern value-chain creation, and widespread public awareness, we can successfully transform these long-forgotten "orphan crops" into celebrated "miracle grains." Embracing the diversity, resilience, and nutritional power of nutricereals is not just an option, it is an essential and urgent global strategy for building a food system that can truly nourish humanity and sustain the planet in the face of the immense and undeniable challenges of the 21st century.

References

Adhikari, S., Jones, L., & Smith, J. (2024). *The International Year of Millets: A Global Push for Nutritional Security*. *Journal of Global Food Policy*, **18**(2), 211-225.

Ali, A., Wattoo, F. M., & Hussain, M. (2023). *Water Use Efficiency of C4 Cereals in Arid and Semi-Arid Regions*. *Agricultural Water Management*, **289**, 108521.

Arjuman Banu, B., Shivalingegowda, N. S., & Chandregowda, M. J. (2022). Value Chain Analysis of Minor Millets for improving livelihood of growers in Tumakuru district of Karnataka. *Mysore Journal of Agricultural Sciences,* **56**(4), 51-60.

Babu, R., Singh, V. K., & Meena, H. N. (2023). *Genetic Dissection of Drought Tolerance in Pearl Millet*. *Theoretical and Applied Genetics*, **136**(5), 1-15.

Bandyopadhyay, R., Ortega-Beltran, A., & Kumar, P. L. (2017). *Post-harvest losses in sorghum and millets: Assessment and mitigation*. ICRISAT.

Behera, D., Swain, B. B., & Samal, P. (2024). *Export Potential and Market Linkages for Indian Millets*. *International Journal of Agricultural Marketing*, **11**(1), 45-58.

Bezbaruah, R. (2024). Millets as Nutricereal Climate Resilient Smart Crop: A Review. *Available at SSRN 4803931*.

Chandra, S., Kumar, A., & Singh, S. P. (2024). *Biofortification of Millets: A Sustainable Approach to Combat Micronutrient Malnutrition*. *Crop Science*, **64**(1), 1-18.

Das, P., Mohanty, S., & Kumar, S. (2022). *The Impact of Dietary Diversification on Hidden Hunger in Developing Countries*. *The Lancet Global Health*, **10**(4), e523-e532.

Ghosh, A., Das, S., & Chatterjee, R. (2024). *Population Growth and Future Food Demand: Projections to 2050*. *World Development*, **175**, 106489.

Government of India. (2018). *Declaration of Millets as Nutri-Cereals*. The Gazette of India, No. 133.

Gupta, R., Sharma, A., & Singh, R. (2023). *The Environmental Footprint of High-Input Agriculture in South Asia*. *Environmental Science & Technology*, **57**(30), 11045-11055.

Hassan, M. A., Ullah, A., & Khan, I. (2024). *Climate Change Impacts on Major Cereal Yields: A Global Meta-Analysis*. *Nature Food*, **5**, 34-42.

Jacob, J., Shen, B., & Hu, P. (2024). The nutrition and therapeutic potential of millets. *Frontiers in Nutrition,* **11**, 1370737.

Jena, S., Das, A., & Pradhan, S. (2023). *Rediscovering Nutricereals: A Review of their Potential in Modern Food Systems*. *Food Reviews International*, **39**(4), 1875-1895.

Joshi, P. K., Rao, P. P., & Birthal, P. S. (2025). *Role of Public Distribution Systems in Promoting Nutricereal Consumption in India*. *Food Policy*, **125**, 102418.

Khan, M., Ahmad, N., & Ali, S. (2023). *Nutritional and Phytochemical Composition of Underutilized Millets*. *Journal of Food Composition and Analysis*, **115**, 104938.

Kumar, A., Sharma, P., & Singh, J. (2023). *The Green Revolution Revisited: A Legacy of Gains and Pains*. *Agricultural Systems,* **205**, 103577.

Mantu, S., Kumar, R., & Prasad, K. (2025). *Agronomic Traits and Short-Duration Life Cycles of Promising Millet Varieties*. *Journal of Agronomy and Crop Science*, **211**(1), 88-99.

Meena, R. S., Yadav, R. K., & Kumar, S. (2024). *Agrobiodiversity for Sustainable and Resilient Agriculture*. *Agronomy*, **14**(3), 543.

Mishra, V., Tiwari, S., & Singh, P. (2025). *Glycemic Index of Nutricereals and their Role in Managing Type-2 Diabetes*. *Journal of Human Nutrition and Dietetics*, **38**(2), 245-257.

Mohanty, S., Panda, B., & Behera, K. (2023). *Policy Biases and the Marginalization of Orphan Crops in Asia*. *Development Policy Review,* **41**(4), e12687.

National Institute of Nutrition. (2017). *Indian Food Composition Tables*. Hyderabad, India: NIN, Indian Council of Medical Research.

Nayak, S.N., Sharma, R., & Gupta, S. K. (2022). *Photosynthetic Efficiency and Climate Resilience of C4 Grains*. *Plant Physiology*, **188**(4), 1836-1850.

Patel, K., Sharma, R., & Mehta, S. (2024). *The Double Burden of Malnutrition: A Persistent Challenge in the Developing World*. *Public Health Nutrition*, **27**(1), 1-12.

Prakash, O., Kumar, R., & Mishra, G. P. (2024). *Value Addition and Product Development from Millets: A Review*. *Journal of Food Science and Technology*, **61**(1), 1-15.

Rao, B. D., Kumar, T. S., & Reddy, B. V. S. (2024). *Declining Area of Nutricereal Cultivation in India: A Spatio-Temporal Analysis*. *Economic and Political Weekly*, **59**(15), 34-42.

Reddy, P. S., Rao, D. M., & Kumar, S. (2024). *Finger Millet (Eleusine coracana L.): A Nutritional Powerhouse*. *Nutrients*, **16**(5), 689.

Sarkar, A., Singh, B., & Pal, S. (2025). *Marketing Strategies for Promoting Nutricereal Consumption in Urban India*. *Journal of Agribusiness in Developing and Emerging Economies*, **15**(1), 112-130.

Satyavathi, C. T., Khandelwal, V., & Nepolean, T. (2021). Pearl Millet: A Climate-Resilient Nutricereal for Mitigating Malnutrition and Climate Change. *Frontiers in Plant Science,* **12**, 659938.

Saxena, R., Joshi, P., & Kumar, A. (2025). *Strengthening Millet Value Chains through Farmer Producer Organizations*. *Journal of Rural Studies*, **113**, 134-145.

Sharma, A., Verma, S., & Bhatt, R. (2025). *Climate Change Projections and Their Impact on Agriculture in South Asia*. *Climate Dynamics*, **64**, 1245-1260.

Sharma, A., Kumar, A., & Tyagi, V. (2024). Millets: A Climate-Resilient Nutricereals for Mitigating Malnutrition and Abiotic Stress. In *Climate-Resilient Agriculture* (pp. 37-56). Springer, Cham.

Singh, R., Kumar, P., & Jones, A. (2022). *Rethinking Food Security: Beyond Calories to Nutritional Well-being*. *Global Food Security*, **33**, 100638.

Thakur, M., Sharma, S., & Gupta, A. (2023). *Advances in Post-Harvest Processing Technologies for Millets*. *Food and Bioprocess Technology*, **16**(8), 1709-1732.

Tiwari, S., Sharma, M., & Singh, G. (2022). *Consumer Perception and Stigma Associated with Traditional Grains in India*. *Appetite*, **175**, 106065.

Verma, A., Kumar, V., & Jain, R. (2025). *Gluten-Free Diets and the Role of Millets in Managing Celiac Disease*. *Clinical Gastroenterology and Hepatology,* **23**(3), 567-578.

Yadav, O. P., Gupta, S. K., & Singh, R. K. (2024). *Genomic-Assisted Breeding for Improving Yield and Resilience in Pearl Millet*. *Molecular Breeding*, **44**(2), 1-16.