

Amaranthus as a Climate Resilient Leafy Vegetable: A Pragmatic Pathway for Sustainable Nutrition and Production

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ABSTRACT

Amaranthus is a climate-resilient leafy vegetable with high nutritional value and adaptability to heat, drought and marginal soils. Its short duration and low input needs make it suitable for smallholder and urban farming. Promoting its cultivation can enhance sustainable production and address nutritional security under climate stress.

INTRODUCTION

Leafy vegetables occupy a pivotal position at the interface of agriculture, nutrition and public health. Among them, *Amaranthus* (commonly referred to as amaranth greens) stands out as an underexploited yet exceptionally promising crop for climate-resilient agriculture. Cultivated widely across tropical and

subtropical regions, *Amaranthus* species have long been part of traditional diets, particularly in Asia, Africa and Latin America. However, in the context of accelerating climate variability manifested through erratic rainfall, rising temperatures and soil degradation the crop is gaining renewed scientific and agronomic attention (Jimoh *et al.*, 2022).

From a decade of research and field engagement with *Amaranthus*, it is evident that this genus possesses a rare combination of physiological hardiness, nutritional richness and agronomic flexibility. These attributes make it not merely a supplementary vegetable, but a strategic crop for ensuring food and nutritional security under climate stress conditions.

Botanical overview and diversity

The genus *Amaranthus* belongs to the family Amaranthaceae and comprises over 60 species, many of which are adapted to diverse agro-ecological conditions. The commonly cultivated leafy types include *Amaranthus tricolor*, *Amaranthus dubius*, *Amaranthus blitum* and *Amaranthus viridis*. These species exhibit remarkable variability in leaf colour, growth habit and maturity duration.

Amaranth is a C₄ plant, a trait that confers high photosynthetic efficiency, especially under conditions of high light intensity and temperature. This physiological advantage is central to its climate resilience, enabling sustained productivity where many conventional leafy vegetables fail.



Amaranthus seeds



Inflorescence



Green Amaranthus



Red Amaranthus

Climate resilience: physiological and agronomic dimensions

1. Heat tolerance and photosynthetic efficiency

One of the defining features of *Amaranthus* is its exceptional tolerance to elevated temperatures. Unlike cool-season leafy vegetables that exhibit reduced growth and bolting under heat stress, amaranth maintains active growth due to its C₄ photosynthetic pathway. This allows efficient carbon fixation and minimal photorespiration, even at temperatures exceeding 35°C. Field observations consistently demonstrate that *Amaranthus* sustains biomass accumulation during peak summer months, making it a reliable crop in regions experiencing heat waves (Nazeer *et al.*, 2022).

2. Drought adaptability and water-use efficiency

Water scarcity is an increasingly limiting factor in vegetable production. Amaranth exhibits moderate drought tolerance, supported by its deep root system and efficient stomatal regulation. Although optimal moisture enhances yield, the crop can withstand short dry spells without significant yield penalties. Moreover, its short growth cycle (20–30 days for leafy harvest) reduces cumulative water demand, making it suitable for low-input and rainfed systems (Riggins, 2021).

3. Soil adaptability and marginal land utilization

Amaranth thrives across a wide range of soil types, including low-fertility and slightly saline soils, where many vegetables perform poorly. Its adaptability to suboptimal conditions allows cultivation in marginal lands, thereby expanding the productive base of vegetable farming. Research trials have shown satisfactory yields even under reduced fertilizer inputs, highlighting its potential for resource-poor farmers.

4. Rapid growth and short duration

The crop's rapid growth cycle is a critical advantage under climate uncertainty. With harvestable greens available within 3–4 weeks of sowing, amaranth enables quick returns and flexible cropping schedules. This short duration also allows multiple cropping cycles within a season, enhancing land-use efficiency.

Nutritional significance: addressing hidden hunger

Beyond its agronomic resilience, *Amaranthus* is a nutritional powerhouse. The leaves are rich in:

- High-quality proteins with a balanced amino acid profile
- Dietary fibre
- Essential vitamins (A, C, folate)
- Minerals such as iron, calcium and magnesium
- Bioactive compounds including phenolics and antioxidants

In regions where micronutrient deficiencies often termed “Hidden hunger” are prevalent, amaranth serves as an affordable and accessible dietary component. Its inclusion in daily diets can significantly contribute to improved nutritional outcomes, particularly among vulnerable populations.

Role in sustainable and climate-smart agriculture

1. Integration into cropping systems

Amaranth fits seamlessly into diverse cropping systems. It can be grown as:

- A main crop for leafy production
- An intercrop in orchards and wide-spaced vegetables

- A catch crop between major cropping cycles

Its compatibility with mixed and intercropping systems enhances biodiversity and reduces risk under uncertain climatic conditions.

2. Suitability for urban and peri-urban agriculture

With increasing urbanization, the demand for fresh, locally produced vegetables is rising. Amaranth is ideally suited for urban agriculture, including terrace gardens, container cultivation and vertical systems. Its fast growth and minimal input requirements make it a preferred choice for household-level production.

3. Organic and low-input farming systems

Amaranth responds well to organic manures and biofertilizers, making it compatible with organic farming systems. Its relatively lower pest and disease incidence further reduces dependence on chemical inputs, aligning with environmentally sustainable practices (Mulaudzi *et al.*, 2025)

Challenges and research opportunities

Despite its advantages, certain constraints limit the widespread adoption of *Amaranthus*:

- Perishability of leaves, leading to post-harvest losses
- Limited availability of improved varieties tailored to specific regions
- Presence of anti-nutritional factors such as oxalates, which require proper processing
- Inadequate market structure and value chains

From a research perspective, there is significant scope for:

- Breeding high-yielding, nutrient-dense and stress-tolerant varieties
- Developing post-harvest technologies to extend shelf life
- Exploring biofortification and functional food applications
- Standardizing agronomic practices under climate variability

Farmer perspectives and field realities

Long-term field interactions reveal that farmers appreciate amaranth for its low risk and quick returns. Even under erratic weather conditions, the crop provides a dependable source of income. Its role as a “buffer crop” during adverse seasons cannot be overstated. In many cases, amaranth cultivation has enabled smallholders to maintain cash flow when other crops failed due to drought or heat stress. This resilience at the farm level translates into broader livelihood security (Macías-Naranjo *et al.*, 2026).

CONCLUSION

In an era where climate change poses unprecedented challenges to agricultural systems, *Amaranthus* emerges as a robust, versatile and nutritionally significant leafy vegetable. Its inherent resilience to heat, moderate tolerance to drought, adaptability to marginal conditions and rapid growth make it a strategic crop for future farming systems. Elevating amaranth from a traditional vegetable to a mainstream component of climate-smart agriculture requires concerted

efforts in research, extension and market development. By integrating scientific advancements with traditional knowledge, *Amaranthus* can play a transformative role in achieving sustainable food and nutritional security.

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