**Performance of different Amaranthus Varieties for Growth, Yield and Nutritional Quality under Prayagraj Agro-Climatic Conditions**

**Abstract**
The present investigation was undertaken to evaluate the growth, yield and nutritional quality of eight Amaranthus varieties under the agro-climatic conditions of Prayagraj, Uttar Pradesh, India, during the 2023–24 growing season at the Horticulture Research Farm, Department of Horticulture, Naini Agricultural Institute, SHUATS, using Randomized Block Design (RBD) with three replications. The varieties studied included Amaranthus Vlathankara*,* Amaranthus Pink Beauty*,* Arun Red Amaranthus*,* Amaranthus Milky*,* Amaranthus Cholai Green*,* Amaranthus Lalima Red*,* Amaranthus Kashi Cholai IandAmaranthus Kashi Suhaavani*.* Among the varieties evaluated,Arun Red Amaranthus consistently outperformed the best in major parameters, recording the maximum plant height (35.00 cm), number of leaves (33.88), stem diameter (6.23 mm) and root length (7.85 cm) at 45 days after sowing (DAS). It was also the earliest maturing variety, reaching harvestable stage in just 27.25 days and registered the highest herbage yield of 5.59 kg per plot. In terms of nutritional quality, Arun Red Amaranthus showed superior values in Total Soluble Solids (4.99 °Brix), Vitamin C (72.69 mg/100g), β-Carotene (11.01 µg/100g), Fibre (0.83 mg/100g), Calcium (326.56 mg/100g), Iron (22.77 mg/100g), Zinc (0.37 mg/100g) and Protein content (4.87 g/100g). The findings indicated that, the Arun Red Amaranthus is the most suitable variety for cultivation in the Prayagraj region, offering not only higher yields but also enhanced nutritional benefits.

**Keywords:** Arun Red, amaranthus, growth, yield, quality, leafy, evaluation

**Introduction**

Amaranthus, often referred as the "superfood" of the future, has been increasingly recognized for its nutritional and agronomic potential, particularly in regions that experience diverse and challenging climatic conditions (Patil *et al.,* 2024). This fast-growing leafy vegetable is highly valued for its rich nutrient profile, including significant quantities of vitamins (especially Vitamin C), minerals (calcium, iron and zinc), dietary fibers and proteins (Natesh *et al.,* 2017). These attributes make Amaranthus an excellent candidate for combating malnutrition and micronutrient deficiencies in developing countries, especially in rural areas where access to diverse sources of nutrition may be limited (Venu *et al.,* 2019). Furthermore, Amaranthus is naturally rich in bioactive compounds such as β-carotene, which are vital for immune defense, vision and skin health (Randhawa *et al.,* 2015).

Amaranthus belongs to the Amaranthus species, some of which are cultivated as grain crops while others are grown for their leaves (Ruth *et al.,* 2021). This species are mostly cultivated for its edible leaves *viz.,* Amaranthus tricolor, Amaranthus blitum and Amaranthus viridis, all of which are known for their high adaptability and resilience to harsh environmental conditions, including drought, high temperatures and poor soils (Das, 2016). This adaptability makes Amaranthus an excellent choice for cultivation in regions with varying climatic conditions (Mlakar *et al.,* 2010).

India, with its diverse agro-climatic zones, presents an ideal environment for the cultivation of Amaranthus. Among the many agro-climatic zones of India, the Prayagraj region in Uttar Pradesh, with its semi-arid climate and distinct seasons, offers a unique set of conditions for growing a variety of crops, including Amaranthus (Niranjana *et al.,* 2017). This region experiences a mix of hot summers, monsoon season with moderate rainfall and cooler winters. The success of Amaranthus cultivation in such conditions, however, depends on the careful selection of varieties that are not only adapted to these climatic conditions but also capable of delivering high-quality yields with superior nutritional content (Ahmad *et al.,* 2017). Amaranthus has been widely cultivated and studied in several parts of the world, there is a need for region-specific research to identify the most promising varieties for specific agro-climatic conditions (Yeshitila *et al.,* 2024). Different varieties of Amaranthus exhibit considerable variability in growth patterns, yield potential, and nutritional composition, which are influenced by their genetic makeup as well as the environmental conditions in which they are cultivated (Rawat, 2023). Understanding these variations is crucial for maximizing productivity, ensuring sustainable agricultural practices, and enhancing the nutritional value of the crop (Jamalluddin *et al.,* 2022).

The primary objective of this study is to evaluate the growth, yield and quality of various Amaranthus varieties under the Prayagraj agro-climatic conditions. This evaluation focused on the key morphological traits such as plant height, leaf number, stem diameter, and root length, which are critical indicators of plant vigor and overall growth potential. Additionally, the study assessed nutritional parameters, including protein content, Vitamin C, β-carotene, and essential minerals like calcium, iron, and zinc, which are vital for human health. By evaluating these factors, the study aims to identify the best-performing Amaranthus varieties for the Prayagraj region, based on both agronomic and nutritional considerations. Varieties that perform well in terms of early maturity, high herbage yield and superior nutritional composition could significantly contribute to improving the dietary intake of local populations and provide a valuable crop for farmers looking to diversify their production systems. This research will not only help bridge knowledge gaps in Amaranthus cultivation but also pave the way for future breeding programs aimed at developing high-yielding, nutrient-rich varieties tailored to the specific needs of farmers in Prayagraj and similar agro-climatic zones.

**Materials and methods**

The study titled "Performance of Different Varieties of Amaranthus on Growth, Yield and Quality under Prayagraj Agro-Climatic Conditions" was conducted during the 2023-24 growing season at the Horticulture Research Farm, Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology, and Sciences (SHUATS), Prayagraj, India. The experiment aimed to evaluate the growth, yield and nutritional quality of eight distinct Amaranthus varieties, *viz.,* Amaranthus Vlathankara, Amaranthus Pink Beauty, Arun Red Amaranthus, Amaranthus Milky, Amaranthus Cholai Green, Amaranthus Lalima Red, Amaranthus Kashi Cholai I and Amaranthus Kashi Suhaavani, under the specific agro-climatic conditions of the region. A **Randomized Block Design (RBD)** with three replications was used for the experiment, by assessing the growth parameters, including plant height, number of leaves per plant, stem diameter and root length, which is measured at 45 days after sowing (DAS). Yield parameters such as days to first harvest and herbage yield per plot were recorded, while nutritional quality was assessed by analyzing Total Soluble Solids (TSS), Vitamin C, β-Carotene, Fibre, Calcium, Iron, Zinc and Protein content. The collected data were subjected to statistical analysis using ANOVA to determine significant differences between the varieties.

**Results and Statistical Analysis**

The following section outlines the findings from the evaluation of eight Amaranthus varieties under the agro-climatic conditions of Prayagraj. The data focus on key growth, yield and quality parameters, providing insights into varietal performance and statistical reliability, which are represented in Table 1, Table 2 and are illustrated on Figure 1.

Plant height is the primary indicator of vegetative vigour and biomass accumulation. The recorded heights among the eight varieties studied ranged from 19.61 cm (**Amaranthus Pink Beauty**) to 35.00 cm (**Arun Red Amaranthus**). The significant superiority of **Arun Red Amaranthus** in plant height suggests a strong inherent genetic potential for vertical growth, which likely supports better light interception and enhanced photosynthetic activity (Barwal, 2007). This varietal performance aligns with the findings of Ochieng *et al.* (2019), who reported that taller plants typically exhibit more robust growth and improved yield potential of amaranthus.

**Figure 1. Graphical representation on the growth performance of different Amaranthus varieties**

Number of leaves per plant is directly linked to the photosynthetic capacity and growth rate of leafy vegetables (Evans, 1989). **Arun Red Amaranthus** again dominated recording the highest number of leaves (33.88), followed by **Amaranthus Lalima Red**(30.72) and **Amaranthus Cholai Green**(28.51). A higher leaf number reflects the enhanced vegetative growth and a greater potential for assimilate production, which translates into improved biomass and yield (Osei-Kwarteng *et al.,* 2022). In contrast, **Amaranthus Pink Beauty** and **Amaranthus Green** produced minimum number of leaves, suggesting limited vegetative expansion, which could impact overall productivity. Stem diameter is a structural trait that contributes to the stability and transport efficiency within the plant (Zanne and Falster, 2010). The maximum stem thickness was observed in **Arun Red Amaranthus**(6.23 mm), followed by **Amaranthus Lalima Red**(5.83 mm) and **Amaranthus Cholai Green** (5.43 mm), demonstrating a substantial girth and the minimum was observed in Amaranthus Pink Beauty (4.63mm). The thick stems generally correlate with improved nutrient and water transport, resistance to lodging and overall plant robustness (Yeshitila *et al.,* 2024).

Root length plays a fundamental role in water and nutrient acquisition (Chapman *et al.,* 2012). **Arun Red Amaranthus**exhibited the longest roots (7.85 cm), closely followed by **Amaranthus Lalima Red** (7.60 cm) and **Amaranthus Cholai Green** (7.26 cm). These results suggest that these varieties are better adapted to extract resources from the soil, particularly under sub-optimal conditions (Jomo *et al.,* 2015). Shorter root systems, such as in **Amaranthus Pink Beauty** (5.34 cm), may restrict access to deeper soil nutrients and moisture, contributing to reduced plant growth. Early maturity is a valuable trait for ensuring quick turnover and potential for multiple harvests within a growing season (Baturaygil *et al.,* 2021). **Arun Red Amaranthus**reached marketable stage in just 27.25 days, making it the earliest among the evaluated varieties, followed by **Amaranthus Lalima Red** (27.67 days) and **Amaranthus Cholai Green** (28.33 days). This early maturity gives growers a competitive advantage in terms of earlier market supply and economic returns. **Amaranthus Pink Beauty**, with a harvesting period of 34.54 days, was the slowest maturing and may be less suited for intensive cropping systems. Similar findings were observed in amaranthus by Ozimede *et al.,* 2019.

Herbage Yield is a cumulative reflection of all physiological and morphological traits (Garnaik, 2021). **Arun Red Amaranthus**again led this category with a herbage yield of 5.59 kg/plot, signifying its overall superior performance. **Amaranthus Lalima Red** (5.03 kg/plot) and both **Amaranthus Cholai Green**and Amaranthus Kashi Suhaavani(4.78 kg/plot each) also showed promising results and the difference in the results are illustrated in Figure 2. The lowest herbage yield was recorded in **Amaranthus Pink Beauty**(2.26 kg/plot), consistent with its weaker performance in vegetative and root traits. These outcomes support the conclusion that higher herbage yield is linked to better vegetative growth, root system development, and early maturity (Gomes, 2023). Studies by Sarker *et al.,* 2014, affirm that genetic diversity significantly affects biomass accumulation and herbage yield potential.

#### Table 1: ****Morpho-Physiological and Yield Performance of Amaranthus Varieties****

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Varieties** | **Plant Height (cm)** | **No. of Leaves** | **Stem Diameter (mm)** | **Root Length (cm)** | **Days to 1st Harvest** | **Herbage** **Yield (kg/plot)** |
| V1: Amaranthus Vlathankara | 27.19 | 24.40 | 5.13 | 6.48 | 30.66 | 3.52 |
| V2: Amaranthus Pink Beauty | 19.61 | 18.49 | 4.63 | 5.34 | 34.54 | 2.26 |
| V3: Arun Red Amaranthus | 35.00 | 33.88 | 6.23 | 7.85 | 27.25 | 5.59 |
| V4: Amaranthus Milky | 21.79 | 20.79 | 4.77 | 5.84 | 31.33 | 2.51 |
| V5: Amaranthus Cholai Green | 32.98 | 30.72 | 5.83 | 7.60 | 27.67 | 4.78 |
| V6: Amaranthus Lalima Red | 31.82 | 28.51 | 5.43 | 7.26 | 28.33 | 5.03 |
| V7: Amaranthus Kashi Cholai I | 25.86 | 22.18 | 4.83 | 6.25 | 31.27 | 2.87 |
| V8: Amaranthus Kashi Suhaavani | 28.56 | 27.20 | 5.30 | 6.97 | 29.55 | 4.78 |
| **F-Test** | **S** | **S** | **S** | **S** | **S** | **S** |
| **SE(d)** | **1.29** | **0.67** | **0.22** | **0.16** | **1.33** | **0.09** |
| **CD0.05** | **2.80** | **1.45** | **0.48** | **0.35** | **2.89** | **0.21** |
| **CV** | **5.89** | **3.19** | **5.19** | **2.97** | **5.45** | **3.04** |

**Figure 2. Graphical representation on the performance of different Amaranthus varieties on Herbage** **Yield per plot (kg/plot)**

#### ****Nutritional Quality Parameters****

Nutritional attributes are critical for evaluating the dietary value of leafy vegetables like Amaranthus (Sarker *et al.,* 2020). The present study evaluated Total Soluble Solids (TSS), Vitamin C, β-Carotene, Fibre, Calcium, Iron, Zinc and Protein contents across eight **Amaranthus** varieties and the results are depicted in Figure 3 and Figure 4. The varietal differences were significant and can be attributed to genetic makeup and their ability to synthesize, store, and translocate various nutrients (Chakrabarty *et al.,* 2018). TSS serves as a key quality determinant for palatability in leafy greens, reflecting sugar concentration and overall taste (Nyonje, 2022). The highest TSS was recorded in **Arun Red Amaranthus** (4.99 °Brix), indicating superior sweetness and flavor, likely due to efficient carbohydrate accumulation. **Amaranthus Lalima Red** and **Amaranthus Cholai Green**followed closely, further suggesting good metabolic activity. **Amaranthus Pink Beauty**, which recorded the lowest TSS (3.61 °Brix), may possess lower enzymatic activity or slower carbohydrate metabolism.

As an antioxidant, Vitamin C enhances immunity, iron absorption and collagen formation (Akinola, 2021). **Arun Red Amaranthus** led with 72.69 mg/100g, reflecting its biosynthetic potential and photoprotection efficiency. High vitamin C content in **Amaranthus Cholai Green** and **Amaranthus Lalima Red** also highlights their nutritional superiority. The lower concentration in **Amaranthus Pink Beauty** suggests weaker oxidative defense, reducing its appeal as a nutritionally dense variety. This pigment is the precursor of Vitamin A, vital for vision, skin health, and immune defense (Singhania *et al.,* 2023). **Arun Red Amaranthus** exhibited the highest β-carotene content (11.01 µg/100g), followed by **Amaranthus Lalima Red** and **Amaranthus Cholai Green**, indicating better carotenoid biosynthesis. Lower β-carotene in **Amaranthus Pink Beauty** (8.55 µg/100g) points to its reduced capacity for Vitamin A enrichment, affecting its nutraceutical value.

**Figure 3. Graphical representation on the quality performance of different Amaranthus varieties**

Dietary fibre plays a vital role in regulating digestion, blood sugar levels, and cholesterol (Kongdang *et al.,* 2021). **Arun Red Amaranthus** (0.83 mg/100g) again showed prominence, suggesting superior structural and cell wall development. Varieties **Amaranthus Lalima Red**and **Amaranthus Cholai Green** also contained considerable fibre, while **Amaranthus Pink Beauty** had the lowest (0.38 mg/100g), potentially offering less digestive benefit. Calcium supports skeletal structure, enzymatic functions, and signal transduction (Kumar *et al.,* 2010). **Arun Red Amaranthus**excelled with 326.56 mg/100g, followed by **Amaranthus Lalima Red** and **Amaranthus Cholai Green**, emphasizing their mineral richness. In contrast, **Amaranthus Pink Beauty** (253.27 mg/100g) had the lowest value, indicating its limited potential for supporting bone health.

Iron deficiency remains a global concern, making its content crucial in leafy vegetables (Nyonje, 2022). **Arun Red Amaranthus** had the highest iron level (22.77 mg/100g), supporting its role in hemoglobin synthesis and cognitive function. **Amaranthus Lalima Red** and **Amaranthus Cholai Green** followed closely. The low iron concentration in **Amaranthus Pink Beauty** may limit its usefulness in combating anemia. Zinc is essential for enzymatic functions, DNA synthesis, and immune competence (Soriano-García and Aguirre-Díaz, 2019). **Arun Red Amaranthus** had the highest (0.37 mg/100g), showcasing its role in cellular repair and immunity. **Amaranthus Pink Beauty** recorded the lowest zinc content (0.12 mg/100g), possibly affecting its overall physiological utility. Protein is a macronutrient necessary for tissue repair and enzyme synthesis. **Arun Red Amaranthus** (4.87 g/100g) again ranked highest, followed by **Amaranthus Lalima Red**and **Amaranthus Cholai Green**. Their high protein content enhances their value as a nutrient-rich vegetable source. **Amaranthus Pink Beauty**, with the lowest (3.45 g/100g), may offer lesser nutritional returns per serving.

**Figure 4. Graphical representation on Vitamin C and Calcium content of different Amaranthus varieties**

### ****Conclusion****

Based on a thorough evaluation of morphological characteristics, yield performance, and nutritional quality, Arun Red Amaranthus proved to be the most superior variety under the agro-climatic conditions of Prayagraj. It consistently outperformed all other tested varieties in key growth parameters such as plant height, number of leaves, stem diameter, root length, and early maturity, reflecting its strong vegetative vigor and adaptability. Moreover, Arun Red Amaranthus recorded the highest herbage yield per plot and excelled in essential nutritional components including Total Soluble Solids (TSS), Vitamin C, β-Carotene, Fibre, Calcium, Iron, Zinc and Protein content, confirming its potential as a nutrient-dense leafy vegetable. The variety's robust physiological traits and early harvest capability make it particularly well-suited for intensive cropping systems and profitable cultivation in the region.

#### Table 2: ****Nutritional Quality Attributes of Amaranthus Varieties****

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Varieties** | **TSS (°Brix)** | **Vit. C (mg/100g)** | **β-Carotene (µg/100g)** | **Fibre (mg/100g)** | **Calcium (mg/100g)** | **Iron (mg/100g)** | **Zinc (mg/100g)** | **Protein (g/100g)** |
| V1: Amaranthus Vlathankara | 4.05 | 59.21 | 9.83 | 0.57 | 292.48 | 16.53 | 0.20 | 3.94 |
| V2: Amaranthus Pink Beauty | 3.61 | 50.25 | 8.55 | 0.38 | 253.27 | 11.32 | 0.12 | 3.45 |
| V3: Arun Red Amaranthus | **4.99** | **72.69** | **11.01** | **0.83** | **326.56** | **22.77** | **0.37** | **4.87** |
| V4: Amaranthus Milky | 3.79 | 54.44 | 9.03 | 0.45 | 275.51 | 12.21 | 0.15 | 3.62 |
| V5: Amaranthus Cholai Green | 4.54 | 67.74 | 10.65 | 0.68 | 312.67 | 19.64 | 0.28 | 4.23 |
| V6: Amaranthus Lalima Red | 4.82 | 69.45 | 10.87 | 0.75 | 320.34 | 20.84 | 0.31 | 4.55 |
| V7: Amaranthus Kashi Cholai I | 3.85 | 56.67 | 9.56 | 0.51 | 282.80 | 14.23 | 0.17 | 3.86 |
| V8: Amaranthus Kashi Suhaavani | 4.36 | 64.08 | 10.46 | 0.63 | 303.17 | 17.02 | 0.25 | 4.09 |
| **F-Test** | **S** | **S** | **S** | **S** | **S** | **S** | **S** | **S** |
| **SE(d)** | **0.06** | **1.36** | **0.67** | **0.01** | **6.72** | **1.36** | **0.06** | **0.06** |
| **CD0.05** | **0.13** | **2.94** | **7.03** | **0.03** | **14.46** | **2.96** | **0.13** | **0.14** |
| **CV** | **1.75** | **2.69** | **8.24** | **3.34** | **2.78** | **9.95** | **3.02** | **2.01** |

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