

## The Silent Guardians: Antioxidants and Plant Resilience

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Plants exist in environments that constantly challenge their survival. Extreme temperatures, water scarcity, soil salinity, pollution, and disease pressure are part of their daily reality. Unlike animals, plants cannot relocate when conditions become hostile. Instead, they depend on an internal protective network dominated by antioxidants. These substances—both enzymatic and non-enzymatic—play a crucial role in neutralising reactive oxygen species (ROS), preserving cell structures, and regulating stress responses. This article discusses how antioxidants function in plants, explains their dual defence system, highlights examples from wheat and moringa, and connects plant antioxidant activity with agricultural sustainability and human health. By understanding these natural defence strategies, we gain insight into how plant survival is closely linked to human well-being.

**Keywords:** Antioxidants, Reactive Oxygen Species, Stress Tolerance, Wheat, Moringa, Plant Physiology

### Introduction

Consider what it would be like to endure intense heat, polluted air, or dehydration without any protection. For plants, this is not a hypothetical challenge—it is a daily reality. Rooted in one place, plants must cope with environmental stressors where they stand. Their survival depends on an invisible but powerful defence system operating inside their cells: antioxidants. Antioxidants are biologically active compounds that protect plants from oxidative damage. During normal metabolic activities, plants produce reactive oxygen species (ROS). At controlled levels, these molecules act as important signals involved in growth and defence. However, stressful conditions such as drought, heat, or salinity cause excessive ROS accumulation, which can damage proteins, lipids, and DNA. Antioxidants act as emergency responders, controlling ROS levels and preventing cellular injury.

### Understanding Antioxidants

Plant antioxidants can be grouped into two major categories based on their mode of action:

**Enzymatic antioxidants** include specialized proteins such as superoxide dismutase (SOD), catalase (CAT), and ascorbate peroxidase (APX). These enzymes actively convert toxic ROS into harmless molecules like water and oxygen.

**Non-enzymatic antioxidants** consist of compounds such as vitamin C, vitamin E, carotenoids, flavonoids, glutathione, and proline. These molecules support membrane integrity, protect photosynthetic pigments, and shield plant tissues from ultraviolet radiation.

### The Dual Defence System in Plants

#### Enzymatic Antioxidant Mechanisms

- **Superoxide dismutase (SOD):** Transforms superoxide radicals into hydrogen peroxide.
- **Catalase (CAT):** Rapidly decomposes hydrogen peroxide into water and oxygen.
- **Ascorbate peroxidase (APX):** Uses ascorbate to neutralize hydrogen peroxide.

- **Glutathione peroxidase (GPX):** Detoxifies hydrogen peroxide and lipid peroxides.
- **Regenerating enzymes (GR, DHAR, MDHAR):** Maintain antioxidant pools by recycling glutathione and ascorbate.

### Non-Enzymatic Antioxidant Components

- **Vitamins:** Ascorbate (vitamin C) and tocopherols (vitamin E) protect membranes and photosystems.
- **Carotenoids:** Pigments such as beta-carotene and lutein prevent photooxidative damage.
- **Phenolic compounds:** Flavonoids and tannins act as radical scavengers and natural UV filters.
- **Amino acids:** Proline helps maintain osmotic balance and stabilises proteins during stress.
- **Minerals:** Elements like zinc, manganese, and selenium support antioxidant enzyme function.

### Antioxidants at Work: Practical Examples

**Heat Stress Response in Wheat:** Research comparing two wheat varieties—one heat-tolerant (C 306) and one heat-sensitive (PBW 343)—demonstrated the importance of antioxidant defences. Under high temperatures, the tolerant genotype sustained higher activity of enzymes such as SOD, CAT, and APX. This helped regulate hydrogen peroxide levels and protected cell membranes. In contrast, the susceptible variety showed weakened antioxidant activity, resulting in increased oxidative damage and reduced productivity.

**Salinity Tolerance in Moringa:** Moringa oleifera, often referred to as a “miracle tree,” shows impressive adaptability to saline conditions. Under moderate salt stress, the plant increased antioxidant enzyme activity and boosted the production of health-promoting compounds. Even at higher salt concentrations, moringa intensified its antioxidant response, highlighting its potential value as a resilient crop and a source of nutraceuticals.

### Why Plants Invest in Antioxidants

Plants increase antioxidant production for several key reasons:

- To cope with environmental stresses such as drought, heat, salinity, and pollution
- To strengthen defences against pests and pathogens
- To regulate growth, ageing, and programmed cell death through controlled ROS signalling

### Links Between Plant Antioxidants and Human Health

The antioxidant compounds that protect plants also benefit humans when consumed. Fruits, vegetables, teas, and whole grains provide vitamins, carotenoids, and polyphenols that support immunity, protect vision, and reduce the risk of chronic diseases. In this way, plant survival strategies have a direct impact on human health and nutrition.

### Future Directions

- **Crop development:** Enhancing antioxidant capacity through breeding or biotechnology can improve stress tolerance and yield stability.
- **Functional foods:** Cultivating antioxidant-rich plants like moringa can support health-focused agriculture.
- **Traditional knowledge integration:** Combining indigenous plant-based practices with modern research can unlock new antioxidant applications.

### Conclusion

Antioxidants serve as quiet yet powerful protectors of plant life. By carefully balancing reactive oxygen species, plants allow themselves to grow, adapt, and survive under harsh conditions. Their role extends beyond plant physiology—by sustaining crops and enriching human diets, antioxidants connect plant resilience with human resilience. Every leaf, grain, and pod carries a hidden story of survival shaped by these remarkable molecules.

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