

Feature Review

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Trait Basis and Management Strategies for Stable High Yield in Greenhouse Tomato Production

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Received: 15 Jan., 2026

Accepted: 14 Feb., 2026

Published: 22 Feb., 2026

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Preferred citation for this article:

Lin X.X., and Luo M.T., 2026, Trait basis and management strategies for stable high yield in greenhouse tomato production, Plant Gene and Trait, 17(1): 36-55 (doi: [10.5376/pgt.2026.17.0004](https://doi.org/10.5376/pgt.2026.17.0004))

Abstract This study explores the key agronomic trait basis, physiological-ecological mechanisms, and regulatory pathways underlying high and stable yield formation in protected tomato production. Protected tomato cultivation plays an important role in ensuring year-round vegetable supply and increasing yield per unit area; however, yield stability is often affected by environmental fluctuations, suboptimal canopy structure, and mismatched management practices. Based on a systematic review of recent studies, this study summarizes the major trait foundations associated with high and stable yield from the perspectives of plant growth, flowering and fruit set, fruit development, and root characteristics. It focuses on the roles of plant architecture, internode length, the balance between vegetative and reproductive growth, inflorescence number and pollen viability, single fruit weight and fruit enlargement dynamics, as well as root vigor and health in determining yield and its stability. Meanwhile, the effects of environmental factors such as temperature, light, humidity, and CO₂ on tomato growth and fruit set are reviewed, and the contributions of integrated management practices-including optimal planting density, pruning, fertigation, supplemental lighting, pollination techniques, and grafting-are discussed. Finally, future trends in intelligent environmental control, breeding of high-yield and stress-resistant varieties, and green efficient production systems are highlighted, achieving high and stable yield in protected tomato production depends on the coordinated optimization of traits, environment, and management.

Keywords Protected tomato; High and stable yield; Cultivation traits; Environmental regulation; Integrated water and fertilizer management

1 Introduction

Protected agriculture, as an important component of modern agriculture, plays a crucial role in ensuring the year-round stable supply of vegetables, improving land-use efficiency, and enhancing agricultural productivity. Tomato (*Solanum lycopersicum* L.), owing to its high nutritional value, strong adaptability to processing, and stable market demand, has become one of the most widely cultivated and economically valuable vegetable crops worldwide (Banoo et al., 2024; Avasiloaiei et al., 2025). With the intensification of climate change and increasing constraints on arable land resources, traditional open-field vegetable production is facing growing uncertainties. In contrast, protected cultivation can partially control crop growth conditions by regulating environmental factors such as temperature, humidity, and light, thereby extending production cycles and increasing yield per unit area (Banoo et al., 2024). Within global protected horticulture systems, tomato is not only one of the crops with the largest planting areas but is also regarded as a representative model crop for production intensification and technological innovation in controlled-environment agriculture.

However, compared with open-field production, protected environments provide controllable cultivation conditions while simultaneously creating a more complex growth regulation context. Environmental factors such as temperature, light, humidity, and vapor pressure deficit (VPD) are highly coupled across spatial and temporal scales, which can easily lead to microclimatic variations and consequently affect plant growth and fruit development (Dewapriya et al., 2024; Šalagovič et al., 2024). In practical production, protected tomatoes often exhibit fluctuations in fruit set and uneven fruit expansion, resulting in unstable yields and marketable fruit rates. In addition, extreme climatic events, particularly heat stress, can significantly reduce fruit set and the number of fruits per plant. Even in high-tech greenhouse systems, yield losses under extreme high-temperature conditions