

Research Insight

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Improving Berry Uniformity in Grape (*Vitis vinifera*): Trait-Based Evaluation and Selection Perspectives

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Abstract This study explores the conceptual framework and evaluation methods of grape berry uniformity, elucidating its multidimensional nature arising from the coordinated contributions of berry size, shape, and cluster structure. Quantitative evaluation approaches based on the coefficient of variation, composite multi-trait indices, and high-throughput phenotyping technologies are systematically summarized. On this basis, key factors influencing berry uniformity are further analyzed, including genetic background, pollination and fertilization processes, berry developmental dynamics, plant growth regulator treatments, and water-nutrient environmental conditions. Integrating breeding strategies with production practices, a framework for improving berry uniformity is proposed, centered on “multi-trait selection, marker-assisted selection, and cultivation regulation.” Meanwhile, with the advancement of machine vision, high-throughput phenotyping, and multi-source data integration technologies, the evaluation of berry uniformity is shifting toward automation, precision, and intelligence. However, challenges remain in the standardization of evaluation systems, elucidation of molecular mechanisms, and integration of multi-source data. Future research directions toward data-driven precision improvement are discussed. This study aims to provide theoretical foundations and technical support for enhancing the quality and standardized production of table grapes.

Keywords Grapevine; Berry uniformity; Phenotypic evaluation; Cluster architecture; Precision breeding

1 Introduction

Grapevine (*Vitis vinifera* L.) is one of the most widely cultivated fruit crops worldwide, and its table grapes are highly favored by consumers due to their attractive appearance and desirable flavor. In the quality evaluation system of table grapes, in addition to intrinsic attributes such as soluble solids content, flavor, and taste, external traits also play a central role. Previous studies have shown that consumers are highly sensitive to visual characteristics such as berry size, shape, color, and overall cluster architecture, among which visual uniformity often plays a dominant role in purchasing decisions (De Oliveira et al., 2026). In this context, berry uniformity, as an important composite indicator reflecting the visual harmony of grape clusters, directly influences consumers' first impressions and product acceptance, and is therefore a key trait for assessing the commercial quality and market value of table grapes.

Clusters with high uniformity typically exhibit consistent berry size, orderly arrangement, and well-coordinated structure, which not only significantly enhance visual quality but also reflect the combined effects of genetic traits and cultivation management practices (Dobrei and Sala, 2025). In contrast, uneven berry size or irregular distribution is often regarded as an indicator of reduced commercial quality and may negatively affect market evaluation, even when intrinsic quality remains high (De Oliveira et al., 2026). In production practice, such heterogeneity is relatively common and results from the combined influence of genetic factors and environmental regulation. For example, different cultivars show significant variation in fruit set, berry enlargement capacity, and cluster architecture, while seed number, floral characteristics, and cultivation practices (such as thinning, application of plant growth regulators, and water and nutrient management) also affect berry development (Gharate et al., 2025; Milišić et al., 2025). In addition, trade-offs among cluster compactness, berry number, and individual berry size further exacerbate differences in uniformity within and between clusters (Meneses et al., 2025; Sharma et al., 2025).