Plant growth regulators, particularly gibberellic acid (GA_3), play an important role in regulating berry uniformity. Appropriate GA_3 treatments can promote berry enlargement and improve uniformity, whereas improper applications may exacerbate size variability. Studies have shown that multi-stage GA_3 applications enhance vascular development and sugar transport, thereby promoting berry growth (Cai et al., 2024), while combined treatments of GA_3 and CPPU regulate endogenous hormone levels to influence cell division and expansion in berries (Figure 2) (Choi et al., 2023; Chen et al., 2025). However, such regulation is highly cultivar-dependent. For example, Acharya et al. (2025) reported that low concentrations of GA_3 had limited effects in 'Cabernet Sauvignon', indicating the need for cultivar-specific optimization.

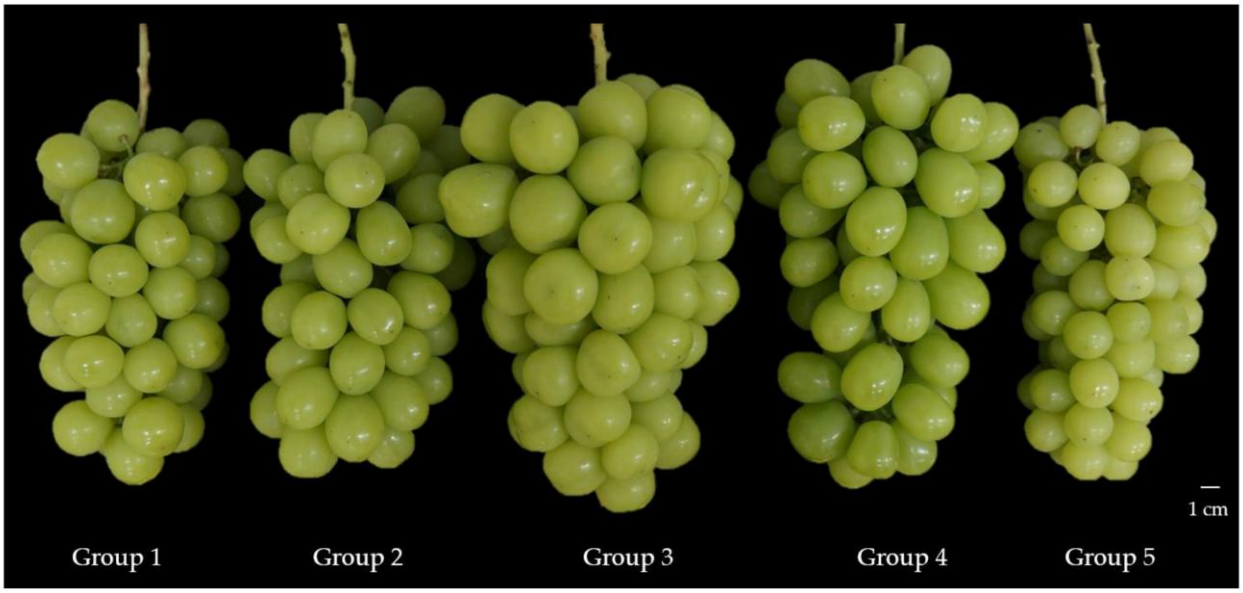

Figure 2 The shape of 'Shine Muscat' grapes at harvest according to PGR treatment (Adopted from Choi et al., 2023)
Image caption: The combinations of PGR treatments applied at full bloom (F) and 12 days after full bloom (DAFB) are as follows; Group 1: F: GA3 12.5+TDZ 2.5, 12 DAFB: GA3 25. Group 2: F: GA3 25 + CPPU 5, 12 DAFB: GA3 25. Group 3: F: GA3 25 + TDZ 5, 12 DAFB: GA3 25. Group 4: GA3 25 + CPPU 5, 12 DAFB: GA3 25+ CPPU 5. Group 5: F: GA3 25 + CPPU 5, 12 DAFB: untreated. The numbers that appear with the PGR are concentrations and their unit is mg/L. Abbreviations: gibberellic acid 3 (GA3), thidiazuron (TDZ), forchlorfenuron (CPPU) (Adopted from Choi et al., 2023)

Water and nutrient management, as well as climatic conditions, also have significant effects on berry uniformity. Stable water and nutrient supply helps maintain synchronized berry growth, whereas water stress or nutrient fluctuations may disrupt developmental balance. Environmental factors such as temperature, light, and precipitation not only affect pollination and seed formation but also influence berry growth rate and cluster structure, leading to inter-annual variation in uniformity. Therefore, improving berry uniformity requires an integrated consideration of genetic background, physiological processes, and cultivation environment, with coordinated regulation of multiple factors to achieve stable optimization.

5 Selection Strategies for Improving Grape Berry Uniformity

5.1 Trait selection

The first step in improving grape berry uniformity is to establish clear, quantifiable, and selection-oriented trait criteria. For table grapes, the combination of large berry size, uniform appearance, and coordinated cluster structure plays a crucial role in consumer preference, commercial grading, and market competitiveness. Therefore, selection should not focus solely on average berry size but should emphasize berry size uniformity, stability of berry morphology, and the coordination of spatial structure within clusters.

At the berry level, the coefficient of variation (CV) of berry size can serve as a key indicator for assessing size uniformity. A lower CV indicates a more concentrated distribution of berry size within a cluster and thus higher uniformity. Consequently, in cultivar screening, germplasm evaluation, and progeny selection, priority should be