



Figure 1 Different gene expressions result in diverse flower colors in *Phalaenopsis* orchids

Patterned flower types represent the highest level of complexity in the *Phalaenopsis* color system and include stripes, spots, veins, blotches, and harlequin patterns. These highly distinctive color forms are often used in specialty cultivar development and high-end markets. Studies have shown that different red pigmentation patterns are regulated by distinct R2R3-MYB transcription factors: PeMYB2, PeMYB11, and PeMYB12 are associated with background coloration, spot formation, and venation patterns, respectively. In harlequin types, the random distribution of spots and blotches is associated with regulatory disruption involving PeMYB11, insertion of the retrotransposon HORT1, and interactions with miR858 and MYB repressors, leading to diverse pigmentation patterns (Lu et al., 2024a). Therefore, patterned coloration fundamentally arises from uneven pigment deposition under specific spatial and temporal gene expression, rather than simple color combination.

## 2.2 Flower form and structural variation

In addition to flower color, floral form and structural characteristics are critical criteria for evaluating ornamental value and cultivar classification in *Phalaenopsis*. The flowers exhibit a typical zygomorphic structure, consisting of three sepals, two lateral petals, and a highly specialized labellum, with a central column. This structure forms the basis of the characteristic “butterfly-like” appearance and defines the primary directions of floral variation. At the level of petals and sepals, significant variation exists among cultivars in terms of length, width, thickness, and curvature, resulting in diverse forms such as flat, cup-shaped, and elongated morphologies (Figure 2) (Indraloka and Rahayu, 2022; Hartati and Samanhudi, 2024). Standard cultivars typically exhibit well-spread petals and strong symmetry, whereas improved cultivars may incorporate wavy margins or increased curvature to enhance visual novelty. Quantitative analyses indicate that sepal and petal dimensions vary significantly among cultivars and serve as important indicators for classification and diversity evaluation.