

4 Quality Formation and Quality Control

4.1 Accumulation patterns and influencing factors of active components in *Anoectochilus roxburghii*

The medicinal quality of artificially cultivated *Anoectochilus roxburghii* is determined by the accumulation of multiple active components, chiefly kinsenoside, flavonoids, polysaccharides, phenolic acids, and nucleosides, rather than by any single compound (Zou et al., 2025). Kinsenoside is especially important because *A. roxburghii* is its exclusive medicinal source, but its content varies substantially among varieties, production areas, and cultivation periods (Zou et al., 2025). Variety effects are clear: among nine varieties, Hongxiadaye had the highest kinsenoside content, while Xiaoyuanye uniquely contained both kinsenoside and its isomer (Figure 2) (Wang et al., 2025). Regional heterogeneity is equally strong, with targeted and untargeted metabolomics showing large differences in flavonoid profiles among Fujian habitats, and Youxi samples having higher average levels of eight quantified flavonoids despite Yongchun showing the richest unique-metabolite diversity (Lyu et al., 2024).

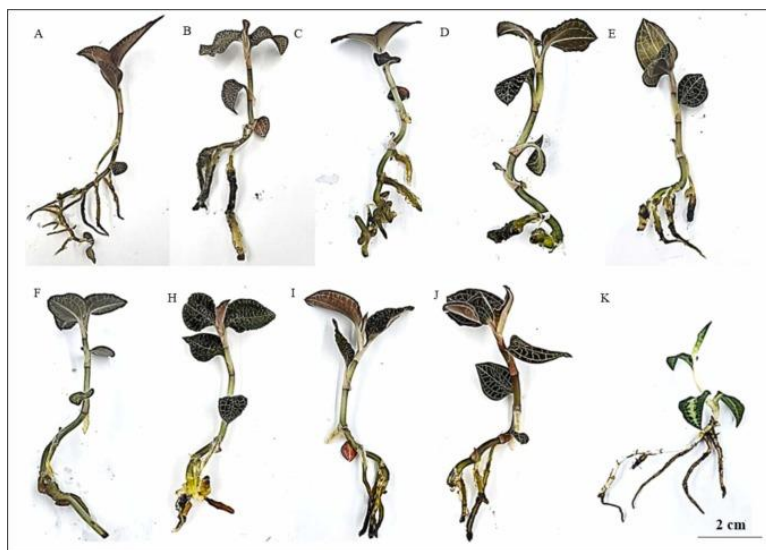


Figure 2 Whole plants of 10 genuine and counterfeit *A. roxburghii* (Adopted from Wang et al., 2025)

Image caption: (A) Caixia, (B) Jianye, (C) J6 Gong, (D) J6 Mu, (E) Dayuanye, (F) Xiaoyuanye, (G) Jinmai, (H) Hongxia, (I) Hongxiadaye, and (J) *G. schlechtendaliana* (Adopted from Wang et al., 2025)

Active-component accumulation is also shaped by developmental stage and culture system. In greenhouse-acclimatized plants from floral-bud-derived propagules, whole-plant kinsenoside rose with cultivation time and peaked at 2.591% after 12 months (Zou et al., 2025). In hydroponic systems, ex vitro cotton-layer and cocopeat systems supplied with 1/2 SH nutrient solution produced higher whole-plant kinsenoside accumulation of 1.24%~1.32% dry weight (Luan et al., 2025). Rhizome bioreactor culture showed that biomass, kinsenoside, and polysaccharide accumulation peaked at 30 days, reaching 2980.5 mg/L and 5 672.9 mg/L for kinsenoside and polysaccharides, respectively, under optimized inoculum, aeration, and light conditions (Wei et al., 2020). At the mechanistic level, transcriptomic analysis linked higher kinsenoside accumulation to elevated expression of *ACAA*, *Hbd*, *CoAT*, *PaaH*, and *UGT* genes, while light-regulation studies further showed that red-blue light activates phenylpropanoid, flavonoid, and kinsenoside biosynthetic pathways (Wang et al., 2025; Luo et al., 2025).

4.2 Regulatory effects of cultivation environment on the medicinal quality of *Anoectochilus roxburghii*

Among environmental factors, light quality is the most consistently validated regulator of medicinal quality in cultivated *A. roxburghii*. Blue film increased fresh weight, leaf area, chlorophyll, antioxidant enzyme activities, polysaccharides, and flavones, whereas red film promoted plant height and phenolic accumulation. Supplemental blue light likewise increased biomass, total flavonoids, and total polyphenols, while yellow light preferentially increased soluble sugars and polysaccharides (Wang et al., 2018). More precise orthogonal optimization showed that light intensity, red:blue ratio, and photoperiod all significantly affect growth and metabolite accumulation, with 60 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$, 2:1 red:blue, and a 10 h photoperiod favoring growth and polysaccharides, while 100 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$, 1:1 red:blue, and a 14 h photoperiod favored flavonoids (Chen et al., 2021). Recent metabolomic