material for industrial use, including higher average saponin content, stronger in vitro antioxidant activity, and more stable polysaccharide levels, although wild material can contain more alkaloids, amino acids, and coumarins (Peng et al., 2025). These findings support a shift from experience-based planting toward ecology-based, region-specific green cultivation protocols (Cheng et al., 2026).

Figure 2 Morphological images of four *Polygonatum germplasm* resources (Group II) (Adopted from Huang et al., 2026)
Image caption: (A) Fruit of *P. kingianum*; (B) Red flower of *P. kingianum*; (C) Yellow-green flower of P. kingianum; (D) rhizome of *P. kingianum*; (E) rhizome of *P. sibiricum*; (F) Flower of *P. sibiricum* (H58); (G) Flower of *P. sibiricum* (H14); (H) Fruit of *P. sibiricum;* (I) Immature fruit of *P. cirrhifolium*; (J) Mature fruit of *P. cirrhifolium*; (K) Flower of *P. cirrhifolium*; (L) rhizome of *P. zanlanscianense*; (M) Leaf and mature fruit of *P. zanlanscianense* (Adopted from Huang et al., 2026)

The corresponding optimization strategy is to standardize the full chain from nursery to harvest, while building rapid, multi-index quality evaluation. Existing standardized planting patents already cover seed reservation, breeding, seedbed management, greenhouse construction, seedling-stage management, and dormancy management, and show that standardized cultivation can simultaneously secure quantity and quality. Broader medicinal-plant standardization experience further shows the need to define provenance conditions, seed and root standards, seedling techniques, pest control, harvest processing, pesticide and heavy-metal residue limits, active-ingredient thresholds, and storage and transport rules. On the quality side, near-infrared spectroscopy combined with chemometrics enables rapid assessment of polysaccharides and saponins and can support raw-material selection and grading more efficiently than conventional assays (Liao et al., 2023). At the same time,