

Transplanting management should therefore prioritize root protection, gradual humidity reduction, suitable substrate transition, and early establishment vigor. Evidence across cutting systems indicates that survival after transplanting improves when rooted propagules are moved into clean, aerated substrates and maintained under moderated conditions before full field exposure (Izadi et al., 2022). Physiologically, cutting quality after rooting still depends on leaf vitality, source-sink balance, and uniform root development, and delayed or uneven rooting can impair synchronous later growth among individuals (Druege, 2020). For *T. hemsleyanum*, hardening should thus retain moderate shade and humidity at first, then gradually increase ventilation and reduce protection, while transplanting should use rooted cuttings with intact leaves, healthy white roots, and no basal decay so that establishment management begins from physiologically functional planting stock (Sarolia et al., 2021; Mataruga et al., 2023).

6.2 Seedling quality evaluation, grading, and nursery release standards

Seedling quality evaluation for *T. hemsleyanum* should combine morphological indicators with selected physiological or functional indicators, because morphology remains the operational basis of quality control, but morphology alone does not capture all differences in transplant performance. Reviews of seedling quality practice show that morphological attributes are widely used and often mandatory, while physiological attributes are used less often despite their value for monitoring crop development, nutrient status, viability, and post-planting performance (Grossnickle and Macdonald, 2018). The broader seedling-quality literature also rejects a single universal test: no “silver bullet” applies across nursery, lifting, and pre-planting stages, so quality control must use stage-appropriate indicators and explicit testing purposes. For rooted cuttings specifically, additional quality requirements apply beyond ordinary seedling stock, reinforcing the need for a dedicated standard for clonal *T. hemsleyanum* nursery material.

A practical grading system should be simple enough for nursery use but sufficiently predictive of later medicinal production. In *Panax notoginseng*, unclear seedling sources and uneven quality reduced emergence and acclimatization, and the establishment of a grading standard improved normative industry management. That study found that root length, root diameter, and bud diameter correlated positively with fresh weight, and finally simplified grading to fresh weight plus rootlet number, with higher grades showing better emergence, photosynthetic performance, and medicinal output after transplanting. Similar patterns appear in other medicinal crops: graded transplantation in *Astragalus membranaceus* changed both yield and active component content after transplanting, and licorice seedling grades based on plant weight produced 1.5-2-fold differences in several bioactive constituents in the harvested roots (Li et al., 2023). Accordingly, nursery release standards for *T. hemsleyanum* should classify rooted cuttings into at least premium, standard, and cull grades using easily measured indices such as seedling height, stem thickness, leaf number, root number, root length, root fresh weight, and root system integrity, while excluding seedlings with deformities, weak growth, pest damage, or poor plug development (Grossnickle and Macdonald, 2018; Sarolia et al., 2021).

6.3 Standardized whole-process production and quality traceability for cutting seedlings

Whole-process standardization for *T. hemsleyanum* should begin with the origin control of mother plants and propagules and continue through nursery management, handling, and shipping. Across European systems, control of the origin of seed and vegetative material and pest and disease status are common elements of seedling quality control (Mataruga et al., 2023). Evidence from medicinal-plant production likewise shows that mixed varieties and materials with unclear sources lead to poor field performance, unstable quality, and difficulty in supervision. Standardization also needs explicit nursery protocols for watering, shading, fertilization, growing media, root pruning, weed control, storage, transport, and handling, because these operational steps are already recognized as determinants of seedling quality (Sarolia et al., 2021). This matters especially for cuttings, since quality can decline during storage, shipping, or transition between production environments, and unsuitable transport and handling are a known cause of reduced seedling quality (Druege, 2020).

Traceability should convert that standardized process into a recorded and auditable production chain. Barcode-based in vitro seedling management systems already show that recording medium composition, culture