

At the same time, the best substrate remains species-dependent, so standardization for *T. hemsleyanum* should define a preferred range of structure rather than assume one universal medium (Zheng et al., 2020; Mello et al., 2025). Some species root best in highly aerated coarse media, as grape cuttings rooted best in pure perlite and in other large-particle substrates such as coarse sand mixtures (Zheng et al., 2025). Others favor alternative materials, such as Kanuma soil in *Apocynum lancifolium*, which gave the highest survival and rooting rate among the tested substrates (Seo et al., 2023). Substrate design also has to consider later plug quality, because stratifying peat-based media with coarse amendments did not clearly improve root growth but reduced plug structural stability in herbaceous cuttings (Hoover et al., 2025). For *T. hemsleyanum*, the most defensible standard is therefore a clean, moderately fine but aerated substrate, with perlite-based or peat/cocopeat-perlite mixtures prioritized for rooting trials and plug integrity evaluated together with rooting percentage, root length, and root biomass (Abshahi et al., 2022).

4.2 Types, concentrations, and application methods of plant growth regulators

Among plant growth regulators, IBA is the most consistently effective rooting auxin across cutting systems, although the optimum dose varies by species, cutting type, and physiological state (Quan et al., 2022; Seo et al., 2023; Saini et al., 2025). IBA improved rooting percentage, root number, root length, and root quality in juniper, chrysanthemum, guava, bottle brush, dragon fruit, and *Solanum procumbens*, with species-specific optima ranging from 500 to 3 000 ppm (Abshahi et al., 2022; Marappan et al., 2026). In *T. hemsleyanum*, the direct evidence points to 1 000 mg/L IBA for 10 s as the best tested treatment, which is notably consistent with the 1 000 ppm optima reported in juniper, catalpa, and bottle brush (Quan et al., 2022; Muniandi et al., 2025). Mechanistically, exogenous auxin promotes cell division, assimilate mobilization, root primordium differentiation, and favorable endogenous hormone ratios such as higher IAA/ABA and IAA/ZR, which together accelerate root initiation and improve uniformity (Abass et al., 2024).

However, more auxin is not always better, and several studies show a threshold beyond which rooting declines or root systems become short and coarse (Ghimire et al., 2022). In carnation, rooting percentage did not increase with increasing auxin concentration, and higher concentrations inhibited rooting (Zheng et al., 2020). In *Apocynum lancifolium*, Rootone gave the highest rooting rate, while 500~1 000 mg/L IBA reduced survival relative to lower-dose or control treatments, despite 1 000 mg/L producing more roots (Seo et al., 2023). By contrast, some species require higher IBA doses, including 3 000 ppm in dragon fruit and 3 000 ppm in guava single-node cuttings, while ivy gourd responded best to 1 500 ppm IBA and *Solanum procumbens* to 500 ppm (Jayaganesh et al., 2025; Choudhary et al., 2026). Combined auxin treatments can also be useful in some systems, since IBA+NAA improved rooting in carnation and dragon fruit, but IBA alone still outperformed NAA in catalpa and bottle brush (Quan et al., 2022; Marappan et al., 2026). For *T. hemsleyanum*, the present evidence supports adopting a short basal dip in IBA as the standard core treatment, then refining concentration by cutting age and season rather than broadly increasing dose (Saini et al., 2025).

4.3 Regulation of cutting time, planting depth, and density

The timing of cutting collection should match periods of high physiological activity but moderate stress, because season strongly affects rooting capacity, sprouting, and subsequent seedling growth (Seo et al., 2023). Across species, spring and early autumn repeatedly perform well: juniper rooted best in spring, tea cuttings performed best when collected from early September to late October, bamboo rooted best in spring-summer, and camellia showed higher survival and bud sprouting in spring and autumn than in summer or winter (Abshahi et al., 2022; Kumar et al., 2022). Caucasian whortleberry also showed its highest rooting in September with semi-hardwood cuttings, while cerrado pitaya performed better in spring and was not recommended for autumn preparation (Yazar et al., 2025; Mello et al., 2025). Reviews of fruit-cutting propagation similarly conclude that early planting, especially February-March, often enhances rooting because carbohydrate accumulation is more favorable (Saini et al., 2025). For *T. hemsleyanum*, this supports scheduling propagation in spring or early autumn and avoiding periods of extreme summer heat or deep winter dormancy.