

predictive modeling, simulation, and robotic execution in a closed loop, with more than 90% localization accuracy reported in greenhouse operations. For *T. hemsleyanum*, future development should therefore combine protected facility propagation with digital traceability, environmental monitoring, automated irrigation and mist control, and eventually intelligent transplanting and grading, so that cutting seedling production becomes not only standardized but also scalable, auditable, and less dependent on manual experience.

Conflict of Interest Disclosure

The author affirms that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

References

- Abass M.M.M., Thabet R.S., Lasheen F.F., Abdelhamid A.N., Hassan K.M., Saady H.S., and Boghdady M.S., 2024, Modulating the rhizosphere medium and indole-3-butyric acid supply influence rooting, nutrients and biochemical constituents and histological features of *Pedilanthus tithymaloids*, *Journal of Soil Science and Plant Nutrition*, 24(4): 6880-6892.
<https://doi.org/10.1007/s42729-024-02011-5>
- Abshahi M., Garcia-Morote F.A., Zarei H., Zahedi B., and Nejad A.R., 2022, Improvement of rooting performance in stem cuttings of Savin Juniper (*Juniperus sabina* L.) as a function of IBA pretreatment, substrate, and season, *Forests*, 13(10): 1705.
<https://doi.org/10.3390/f13101705>
- Campbell S.M., Anderson S.L., Brym Z.T., and Pearson B.J., 2021, Evaluation of substrate composition and exogenous hormone application on vegetative propagule rooting success of essential oil hemp (*Cannabis sativa* L.), *PLOS ONE*, 16(7): e0249160.
<https://doi.org/10.1371/journal.pone.0249160>
- Choudhary S., Kumar S., Yadav S., and Saini S., 2026, Effect of plant growth regulators on root development of dragon fruit cuttings (*Hylocereus costaricensis* Britton & Rose), *Plant Archives*, 26(1): 681-686.
<https://doi.org/10.51470/plantarchives.2026.v26.no.1.093>
- Choudhary S., Rana V.S., Choudhary M., Choudhary K., Choudhary R., and Choudhary J., 2024, Evaluation of hardwood and semi-hardwood cuttings for rooting performance in exotic kiwifruit cultivars, *Journal of Scientific Research and Reports*, 30(10): 368-374.
<https://doi.org/10.9734/jsrr/2024/v30i102464>
- De Almeida M.R., Aumond M. Jr., Da Costa C.T., Schwambach J., Ruedell C.M., Correa L.R., and Fett-Neto A.G., 2017, Environmental control of adventitious rooting in Eucalyptus and Populus cuttings, *Trees*, 31(5): 1377-1390.
<https://doi.org/10.1007/s00468-017-1550-6>
- Druege U., 2020, Overcoming physiological bottlenecks of leaf vitality and root development in cuttings: a systemic perspective, *Frontiers in Plant Science*, 11: 907.
<https://doi.org/10.3389/fpls.2020.00907>
- Druege U., Hilo A., Pérez-Pérez J.M., Klopotek Y., Acosta M., Shahinnia F., Zerche S., Franken P., and Hajirezaei M.R., 2019, Molecular and physiological control of adventitious rooting in cuttings: phytohormone action meets resource allocation, *Annals of Botany*, 123(6): 929-949.
<https://doi.org/10.1093/aob/mcy234>
- Dumani A., Silwana T.T., Egbichi I., Oyediji A.O., Mpambani B., and Seepe H.A., 2026, Effects of cutting position and leaf area retention on rooting and growth of vegetatively propagated *Cannabis sativa*, *Journal of Applied Horticulture*, 28(1): 92-97.
<https://doi.org/10.37855/jah.2026.v28i01.13>
- Essahibi A., Benhiba L., Oussouf F.M., Ait Babram M., Ghoulam C., and Qaddoury A., 2017, Improved rooting capacity and hardening efficiency of carob (*Ceratonia siliqua* L.) cuttings using arbuscular mycorrhizal fungi, *Archives of Biological Sciences*, 69(2): 291-298.
<https://doi.org/10.2298/abs160307100e>
- Feng Y., Zhi L., Pan H., Chen Y., and Xu J., 2023, Shade improves seedling quality of ornamental *Cyclocarya* species under plastic greenhouse cultivation, *Ornamental Plant Research*, 3: 13.
<https://doi.org/10.48130/opr-2023-0013>
- Gautam R.D., Kumar A., Kumar R., Chauhan R., Singh S., Kumar M., Kumar D., Kumar A., and Singh S., 2021, Clonal propagation of *Valeriana jatamansi* retains the essential oil profile of mother plants: an approach toward generating homogenous grade of essential oil for industrial use, *Frontiers in Plant Science*, 12: 738247.
<https://doi.org/10.3389/fpls.2021.738247>
- Ghimire B.K., Kim S.H., Yu C.Y., and Chung I.M., 2022, Biochemical and physiological changes during early adventitious root formation in *Chrysanthemum indicum* Linné cuttings, *Plants*, 11(11): 1440.
<https://doi.org/10.3390/plants11111440>
- Grossnickle S.C., and MacDonald J.E., 2018, Seedling quality: history, application, and plant attributes, *Forests*, 9(5): 283.
<https://doi.org/10.3390/f9050283>
- Guan L., Tayengwa R., Cheng Z., Peer W.A., Murphy A.S., and Zhao M., 2019, Auxin regulates adventitious root formation in tomato cuttings, *BMC Plant Biology*, 19(1): 435.
<https://doi.org/10.1186/s12870-019-2002-9>