

Vegetative Propagation of Sandalwood (*Santalum album* L.): A Review

Abstract

Vegetative propagation is a fantastic way to improve the quality of the forest tree planting stock. It is often used in seed orchards and clone banks as a method of genotype preservation. Vegetative propagation is the greatest option when low quality seed and poor germination rates limit the availability of planting stock and quality. This review article discusses different vegetative propagation methods, including macro-propagation by cuttings, micropropagation through tissue culture, and grafting. Having insufficient knowledge and experience is the biggest obstacle to employing vegetative propagation. Therefore, an effort was made to outline several techniques together with their history and significance.

Keywords: grafting, tissue culture, cutting, planting and yield

Introduction

Due to its high economic worth and reputation, sandalwood (*Santalum album* L.) is one of the fancy wood species and luxury good in Indonesia (Pareira *et al.*, 2019). This plant is a source of essential oils and a potential non-timber forest product; due to the particular quality of its core wood and its aroma-specific. Sandalwood oil may be made from the hardwood of sandalwood trees' trunks, roots, and branches. Sandalwood's uniquely fragrant oil content gives the wood its economic significance (santalol). The sesquiterpenoid chemical family that comprises α -santalol and β -santalol makes up sandalwood essential oil (Ariyanti & Asbur, 2018). Since sandalwood has desirable properties, it has been over-harvested without regard for sustainability, causing a sharp fall in its population. Since its number has dropped, sandalwood has been designated as an endangered species (Kumar *et al.* 2019) and has been listed as vulnerable wood that has to be preserved and protected on the International Union for the Conservation of Nature (IUCN) Redlist since 1998. There hasn't been enough focus on establishing sandalwood plantations because there were fewer adult individuals and the sandalwood's mating system, which had previously been dominated by outcrossing and later growing inbreeding in some populations, underwent alterations (Indrioko *et al.* 2015), (Nurchahyani *et al.* 2017), (Ratnaningrum *et al.* 2021). For instance, a decline in the genetic quality of the seeds produced, inbreeding depression, and even reproductive failure might result from it (Ratnaningrum *et al.* 2015). As a result, a new technique for vegetative propagation is required to produce more certified seedlings in less time. Different outcomes were seen in earlier sandalwood vegetative propagations. While root sucking, grafting, and tissue culture techniques show promise, air layering and stem cutting were not very successful (Das *et al.* 2021)

advanced techniques and an aseptic environment are needed for the tissue culture (Swamy *et al.* 2021), whereas root suckers require more time to create new seedlings (Batabyal *et al.* 2015).

Grafting is a form of vegetative growth that involves joining sections of plant tissue (the scion) with other plant part (the rootstock). As the newly created parenchyma cells intermingle, interlock, and fill the gap between the rootstock and scion (Hartmann *et al.* 2014). Successful grafting propagation depends on compatibility. Thus, they are able to develop into a single plant. Grafting is often used to conserve certain genetic resources or to grow better plants in clonal seed orchards rather than to produce forest tree seedlings in large quantities. (Sukendro *et al.* 2010). It is reported to improve plant resistance, productivity, and fruit quality (Kumar *et al.* 2017). Since the planting program for sandalwood is currently only available in a small area, the rate of sandalwood harvest from wild populations typically exceeds the rate of planting. Thereby, rescuing sandalwood is a big issue that requires assistance from efficient culture techniques as a step toward broad regeneration. (Herawan *et al.*, 2015). Due to the incapacity of forest plants to regenerate naturally, human intervention is required to create artificial regeneration, which may be achieved by environmental modification or vegetative propagation.

Vegetative propagation through tissue culture

Growing plant parts namely protoplasts, cells, cell groups, tissues, and organs in sterile or aseptic conditions is known as tissue culture or micropropagation. The development of plant cultivation technology calls for the use of tissue culture for vegetative propagation. (Jayusman, 2015). This method offers the advantages of yielding plants that are mature relatively quickly, using the least amount of land possible, and not being impacted by the time of year. (Harahap *et al.*, 2019; Mastuti, 2017). The axillary branches of sandalwood plants can therefore be stimulated as a way to quickly accomplish mass regeneration. The advantage of axillary shoot proliferation is related to no genetic diversity and the shoots are genetically more stable. (Ngezahayo & Liu, 2014). The success of tissue culture is greatly influenced by regulated substances, namely auxins and cytokinins often utilized as growth regulators. The cytokinin family member benzyl amino purine (BAP) is easily available, moderately priced, and particularly effective at promoting shoot and leaf production. (George *et al.*, 2007). The auxin group, NAA promotes callus formation, cell division, and elongation in plants. (Wattimena, 1988).

Vegetative propagation through Grafting

Grafting aims to preserve the genes of superior and/or unique plants. (Page *et al.* 2020, 2021), RATNANINGRUM *et al.* 2022– Sandalwood grafting compatibility in Gunung Sewu, Indonesia enhanced stem performance (Huang *et al.* 2019), accelerated the development of sexual maturity and delivered mature plants ready to blossom for breeding purposes (Page *et al.* 2020; Pullaiah *et al.* 2021). Grafting is also said to increase plant productivity, tolerance, and fruit quality. (Kumar *et al.* 2017; Belmonte-Urena *et al.* 2020). Grafting has a substantial impact on the parameters of *Solanum* spp. survival, plant morphology, plant growth, reproductive, and yield in India. (Kumar *et al.* 2017). In the developed grafting, various characteristics were reported to have been passed from rootstock to scion in the Greek *Solanum melongena* plant. In addition to passing on their resistance to fusarium wilt to the fruits, rootstocks control the nutrient deposition that influenced the composition and nutritional content of the fruits. (Krommydas *et al.* 2018). The genotypes, age, and size of the rootstocks and scions both had a significant impact on the survival rate in the grafted sandalwood. (Page *et al.* 2012, 2020; Pullaiah *et al.* 2021). The first study on sandalwood grafting in Wanagama Gunung Sewu revealed that the seedlings grown from a red-big flower variant are the healthiest for rootstock. (Prastyo *et al.* 2022). Wild saplings and root-suckers are commonly used as rootstock materials in numerous Pacific Island locations. (Page *et al.* 2012, 2021). In Tanzania, the *Allanblackia stuhlmannii* grafting technique may also be used with *in-situ* rootstocks, either on farms or in the open countryside. (Munjuga *et al.* 2013). The survival rate, plant morphology, plant growth, reproductive and yield parameters of *Solanum* spp. in India were significantly affected by grafting (Kumar *et al.* 2017). Within the developed graftings, several traits were transferred by rootstock to scion, as was reported in *Solanum melongena* in Greece. Rootstocks controlled the nutrient deposition which affected the composition and nutritional value of the fruits; as well as transferred the resistance of fusarium wilt from the rootstocks to the fruits (Krommydas *et al.* 2018). The survival rate in the grafted sandalwood was mostly affected by the genotypes, as well as the age and size of both rootstocks and scions (Page *et al.* 2012, 2020; Pullaiah *et al.* 2021). The initial study on sandalwood grafting in Wanagama Gunung Sewu showed that the seedlings raised from a red-big flower variant are the best for rootstock (Prastyo *et al.* 2022). In several sites on Pacific Islands, wild seedlings and root-suckers are also common for rootstock materials (Page *et al.* 2012, 2021). In Tanzania, the *Allanblackia stuhlmannii* grafting might also be applied using *in situ* rootstocks, both on-farm or in the natural environment (Munjuga *et al.* 2013). establishing an Indonesian breeding facility for premium sandalwood while protecting the chosen genotypes of sandalwood (n=27) grafted onto two different rootstock types. (YENI *et al.*, 2022).

Vegetative propagation through cuttings

Any piece of the parent plant that is taken and intended for regeneration is referred to cutting. (Parthiban *et al.*, 2016). Cutting germination and root growth are regulated by ecophysiological, biochemical, and anatomical elements during the complicated process of cutting germination and rooting. (Uniyal *et al.* 1993). Cutting position was a critical factor in rooting success. (Diego Wassner and Damia'n Ravetta 2000). The most well-known method of encouraging roots in all types of cuttings is undoubtedly the administration of auxin to draw assimilates to the cutting base and to encourage meristematic differentiation. IBA has a significant role in the growth of adventitious roots, increasing the proportion of cuttings that take root, enhancing the quality of the roots, and ensuring consistency in cutting rooting. (Nagesh, 2002; Teklehaimanot *et al.*, 2004; Husen and Pal, 2007a; Opuni-Frimpong *et al.*, 2008).

Stem cuttings, root cuttings, leaf cuttings, and leaf bud cuttings are the four main forms of cuttings. (Parthiban *et al.*, 2016). Stem cuttings for vegetative propagation allow for the speedy generation of plants that are true to type and the availability of superior individuals for large-scale commercial plantations with rapid productivity improvements. (Pratap Chandra Panda *et al.*, 2019). The simplest and most affordable form of vegetative propagation used in many tree species is rooting stem cuttings. (Babu *et al.*, 2018). To build industrial plantations, seed orchards, nutritional experiments, etc. and increase forest productivity, macro propagation by induction of rooting in stem cuttings is a recommended practical alternative. (Aslam and Rather 2008). with hardwood, semi-hardwood, and soft wood cuttings. (Evans, 1999). From mature, dormant stems (<year old), hardwood cuttings are extracted. Typically, semi-hardwood cuttings are made from partially mature wood from the current season's growth, whereas softwood cuttings are made from the soft, succulent new growth of woody plants. (Evans, 1999; Leakey *et al.*, 1982). The vegetative plant propagation method of root cutting is semi-artificial. Only a few species may be grown, using cuttings obtained from roots. (Rosie Lerner and Mary Welch-Keesey 2002). Leaf cutting by remove one leaf from the plant. (Rosie Lerner and Mary Welch-Keesey 2002). Most plants' leaf cuttings won't grow into a new plant; instead, they often merely develop a few roots or decompose. Only plants with the ability to develop adventitious buds may be propagated via leaf cuttings since they lack an axillary bud. (Ervin Evans and Frank Blazich 1999). For many trailing vines and when there is a lack of space or cutting material, leaf bud cuttings are employed. A stem's nodes can all be thought of as cuttings. This particular cutting comprises of a leaf blade, petiole, and a short stem segment with an axillary bud attached. (Ervin Evans and Frank Blazich 1999).

Conclusion

Vegetative propagation has a great potential to produce high-quality planting material with better phenotypic and genotypic traits in a very short period of time. In this overview, the various vegetative growth techniques are described. All observed sandalwood variation rootstock-scion pairs showed compatibility with various results. The average grafting survival rate with Red as the rootstock and scion was 35.8%. Therefore, the grafting strategy of propagation shows promise for the deployment and conservation of sandalwood variants. Grafting is necessary to establish the stool plant in the hedge orchard, to copy the genetic material for the clonal test, and to establish a clonal seed orchard. Tissue culture or micropropagation is needed for vegetative propagation as plant cultivation technology advances. process of growing plant from a stem or root, that has been cut from another plant is called cutting

References

Ariyanti, M., & Asbur, Y. (2018). Cendana (*Santalum album* L.) sebagai tanaman penghasil minyak atsiri. *Kultivasi*, 17(1), 558-567.

Arunkumar A N, Dhyani A and Joshi G 2019 *Santalum album* The IUCN Red List of Threatened Species e T31852A2807668.

Indrioko S and Ratnaningrum Y W N 2015 Habitat loss caused clonality, genetic diversity reduction and reproductive failure in *Santalum album* (Santalaceae), an endangered endemic species of Indonesia *Procedia Environ Sci* 28 657–64.

Nurchahyani Y W, Indrioko S, Faridah E and Syahbudin A 2017 The effects of population size on genetic parameters and mating system of sandalwood in Gunung Sewu, Indonesia *Indones J Biotechnol* 20 182–201 .

Ratnaningrum Y W N, Indrioko S, Karrin A, Kurniawan A and Putri A D C 2021 The genetic diversity and reproductive dynamics of sandalwood in Gunung Sewu (Java, Indonesia) in 2012- 2019 designing conservation strategies in a continuous versus fragmented landscape *Biodiversitas J Biol Divers* 22 3219–29

Ratnaningrum Y W N and Indrioko S 2015 Response of flowering and seed production of sandalwood (*Santalum album* Linn., Santalaceae) to climate changes *Procedia Environ Sci* 28 665–75

Das S C 2021 *Silviculture, Growth and Yield of Sandalwood* Sandalwood: silviculture, conservation and applications ed T Pullaiah, S C Das, V A Bapat, M K Swamy, V D Reddy and K S R Murthy (Singapore: Springer) pp 111–38

Swamy M K 2021 Tissue culture studies in sandalwood (*Santalum album* L.) Sandalwood: silviculture Conservation and applications ed T Pullaiah, S C Das, V A Bapat, M K Swamy, V D Reddy and K S R Murthy (Singapore: Springer) pp 209–41

Batabyal S 2015 Growth variability of *Santalum album* L. in different edaphic conditions and formulation of protocols for its propagation (The University of Burdwan, West Bengal, India.)

Hartmann H T, Kester D, Davies F T and Geneve R L 2014 Hartmann & kester's plant propagation, principles and practices (Harlow: Pearson)

Sukendro A, Mansur I and Trisnawati R 2010 Studi pembiakan vegetatif Intsia bijuga (*Colebr*) O K melalui grafting [Vegetative propagation studies of Intsia bijuga (*Colebr*) O K through grafting] J Silvikultur Trop 01 6–10

Flick, C.E., D.A. Evans, dan W.R. Sharp. (1983). Organogenesis in Y. Yamada (ed). Handbook of Plant Cell Culture. Vol. 1: Techniques for Propagation and Breeding. New York: Macmillan Publishing Company

George, E.F., Hall, M.A., & De Klerk, G.J. (2007). Plant Propagation by Tissue Culture: Volume 1. The Background. Springer Netherlands. https://books.google.co.id/books?id=55X_Wjct7f0C

Harahap, F., Diningrat, D.S., Poerwanto, R., Nasution, N.E.A., & Hasibuan, R.F.M. (2019). In vitro Callus Induction of Sipahutar Pineapple (*Ananas comosus* L.) from North Sumatra Indonesia. Pak J Biol Sci, 22(11), 518-526. <https://doi.org/10.3923/pjbs.2019.518.526>.

Herawan, T., Na'iem, M., Indrioko, S., & Indrianto, A. (2015). Kultur jaringan cendana. Jurnal Pemuliaan Tanaman Hutan, 9(3), 177–188. <https://doi.org/10.20886/jpth.2015.9.3.177-188>.

Jayusman. (2015). Biotechnologi Propagasi Vegetatif Tanaman Hutan: Keuntungan Dan Risiko (Benefit and risk biotechnology in forest tree vegetative propagation-a review). Prosiding SNPBS (Seminar Nasional Pendidikan Biologi dan Saintek). 248–257. <https://proceedings.ums.ac.id/index.php/snpbs/article/view/40>.

Mastuti, R. (2017). Dasar-dasar kultur jaringan tumbuhan. Universitas Brawijaya Press.

Ngezahayo, F., & Liu, B. (2014). Axillary Bud Proliferation Approach for Plant Biodiversity Conservation and Restoration. International Journal of Biodiversity, 2014, 1–9. <https://doi.org/10.1155/2014/727025>.

Pareira, M.S., Mansur, I., & Wulandari, D. (2019). Pemanfaatan FMA dan Tanaman Inang untuk Meningkatkan Pertumbuhan Bibit Cendana (*Santalum album* Linn). *Journal of Tropical Silviculture*, 9(3), 151–159. <https://doi.org/10.29244/jsiltrop.9.3.151-159>.

Salisbury & Ross. (1995). *Fisiologi Tumbuhan* Jilid 3. Bandung : ITB Bandung

Wattimena, G.A. (1991). *Zat Pengatur Tumbuh Tanaman*. PAU Bioteknologi Tanaman. Direktorat Jenderal Pendidikan Tinggi. Bogor Wardani (2022)

Wattimena. (1998). *Bioteknologi Tanaman*. DEPDIKBUD, Direktorat Jenderal Pendidikan Tinggi Pusat Antar Universitas Bioteknologi, IPB, Bogor.

Page T, Doran J, Tungon J, Tabi M. 2020. Restoration of Vanuatu sandalwood (*Santalum austrocaledonicum*) through participatory domestication. *Aus For* 83 (4): 216-226. DOI: 10.1080/00049158.2020.1855382.

Ratnaningrum YWN, Indrioko S, Faridah E, Syahbudin A. 2015. The effects of population size on genetic parameters and mating system of sandalwood in Gunung Sewu, Indonesia. *Indo J Biotech* 20 (2): 182201. DOI: 10.22146/ijbiotech.24347

Page T, Meadows J, Kalsakau T. 2021. *Sandalwood Regional Forum - proceedings of a regional meeting held in Port Vila, Vanuatu, 11–13 November 2019*. ACIAR Proceedings 150, Australian Centre for International Agricultural Research, Canberra. ACIAR Proceedings Series No. 150 (PR150). ISSN 1447-0837. ISBN 978-1-922635-75-4.

Page T, Tate H, Tungon J, Tabi M, Kamasteia P. 2012. *Vanuatu Sandalwood: Growers Guide for Sandalwood Production in Vanuatu*. Australian Centre for International Agricultural Research. Canberra.

Prastyo B, Indrioko S, Faridah E, Ratnaningrum YWN. 2022. Grafting compatibility between variants of sandalwood (*Santalum album* Linn.) in Gunungkidul, Indonesia. *Proceeding of The 5th International Conference on Agriculture, Environment and Food Security held in Medan, 18 November 2021*. Universitas Sumatera Utara, Medan.

Pratiwi WA. 2019. *Keragaman Genetik Cendana Hasil Reproduksi Tiga Tipe Induk di Desa Petir, Kecamatan Rongkop. Kabupaten Gunungkidul*. [Thesis]. Faculty of Forestry, Universitas Gadjah Mada, Yogyakarta. [Indonesian]

Pullaiah T, Das SC, Bapat VA, Swamy MK, Reddy VD, Murthy KSR (eds). 2021. Sandalwood: Silviculture, Conservation and Applications. Springer Nature Singapore Pte Ltd. 152 Beach Road 21-01/04 Gateway East Singapore 189721. DOI: 10.1007/978-981-16-0780-6.

Putri YR, Indrioko S, Ratnaningrum YWN. 2020. Genetic diversity of Sandalwood in Imogiri, Gunung Sewu. IOP Conf. Series: Earth and Environmental Science 914: 012028. DOI: 10.1088/17551315/914/1/012028.

Krommydas K, Mavromatis A, Bletsos F, Roupakias D. 2018. Suitability of CMS-based interspecific eggplant (*Solanum melongena* L.) hybrids as rootstocks for eggplant grafting. *J Agric Ecol Res Intl* 15 (1): 1-15. DOI: 10.9734/JAERI/2018/42320.

Kumar BA, Pandey AK, Raja P, Singh S, Wangchu P. 2017. Grafting in Brinjal (*Solanum melongena* L.) for growth, yield and quality attributes. *International Journal of Bio-resource and Stress Management* 8 (5): 611-616. DOI: 10.23910/IJBSM/2017.8.5.1840a.

Munjuga M, Kariuki W, Njoroge JBM, Ofori D, Jamnadass. 2013. Effect of rootstock type, scion source and grafting methods on the healing of *Allanblackia stuhlmannii* grafts under two nursery conditions. *Afr J Hort Sci* 7: 1-10

RATNANINGRUM, Y. W., FARIDAH, E., UTAMA, I. N., & PRASTYO, B. (2022). Establishing breeding house of superior sandalwood in Gunung Sewu, Indonesia: preserving the 27 selected genotypes grafted onto two types of rootstocks. *Biodiversitas Journal of Biological Diversity*, 23(7).

Uniyal, R. C., Prasad, P. and Nautiyal, A. R. (1993). Vegetative propagation in *Dalbergia sericea*: Influence of growth hormones on rooting behaviour of stem cuttings. *Journal of Tropical Forest Science*, 21-25.

Parthiban, K. T., Sudhagar, R. J., Kanna, S. U., Vennila, S., Sekar, I. and Baranidharan, K. (2016). *Forestry: A Subjective Guide for IFS Aspirants*. Scientific Publishers-Competition Tutor.

Wassner, D. and Ravetta, D. (2000). Vegetative propagation of *Grindelia chiloensis* (Asteraceae). *Industrial Crops and Products*, 11(1), 7-10.

Nagesh, L. (2002). Successful vegetative propagation techniques for the threatened African pencil cedar (*Juniperus procera* Hochst. ex Endl.). *Forest ecology and management*, 161(1-3), 53-64

- Teklehaimanot, Z., Mwang'Ingo, P. L., Mugasha, A. G. and Ruffo, C. K. (2004). Influence of the origin of stem cutting, season of collection and auxin application on the vegetative propagation of African Sandalwood (*Osyris lanceolata*) in Tanzania. *The Southern African Forestry Journal*, 201(1), 13-24
- Hausman, J. F. (1993). Changes in peroxidase activity, auxin level and ethylene production during root formation by poplar shoots raised in vitro. *Plant Growth Regulation*, 13(3), 263-268.
- Opuni-Frimpong, E., Karnosky, D. F., Storer, A. J. and Cobbinah, J. R. (2008). Key roles of leaves, stockplant age, and auxin concentration in vegetative propagation of two African mahoganies: *Khaya anthotheca* Welw. and *Khaya ivorensis* A. Chev. *New Forests*, 36(2), 115-123.
- Aslam, M. and Rather, M.S. (2008). Macropropagation of *Taxus baccata* Linn.: A novel method for conserving a critically endangered medicinal plant. *Indian Forester*; 134:1058-66.
- Babu, B. H., Larkin, A. and Kumar, H. (2018). Effect of Plant Growth regulators on rooting behavior of stem cuttings of *Terminalia chebula* (Retz.). *Int. J. Curr. Microbiol. App. Sci*, 7(8), 2475- 2482.
- Evans, E. and Blazich, F. A. (1999). *Plant Propagation by layering: Instructions for the Home Gardener*. North Carolina Cooperative Extension Service.
- Leakey, R. R. B. (2014). Plant cloning: Macropropagation (Clonación de plantas: Macropropagación) *Encyclopedia of Agriculture and Food Systems*, 4, 349-359.
- Welch-Keesey, M. and Lerner, B. R. (2002). *New plants from cuttings*.
- Warschefskey, E. J., Klein, L. L., Frank, M. H., Chitwood, D. H., Londo, J. P., von Wettberg, E. J. and Miller, A. J. (2016). Rootstocks: diversity, domestication, and impacts on shoot phenotypes. *Trends in plant science*, 21(5), 418-437
- Evans, E. and Blazich, F. A. (1999). *Plant Propagation by layering: Instructions for the Home Gardener*. North Carolina Cooperative Extension Service. Google Scholar Evans, E. and Blazich, F. A. (1999). *Plant Propagation by Leaf, Cane, and Root Cuttings: Instructions for the Home Gardener*. North Carolina Cooperative Extension Service.