



## ANATOMICAL STUDY OF ADVENTITIOUS ROOT DEVELOPMENT IN MASTIC TREE (*PISTACIA LENTISCUS* L. VAR. *CHIA* DUHAM.) CUTTINGS

Murat İsfendiyaroğlu

Ege University, Faculty of Agriculture, Department of Horticulture, 35100 Bornova, İzmir, Turkey,  
Fax: + 90 232 3881865, E-mail: murat.isfendiyaroglu@ege.edu.tr

### Abstract

Mastic tree (*Pistacia lentiscus* L. var. *chia* Duham.) is the unique species valued for gum mastic through the centuries. The tree has been propagated by hardwood cuttings traditionally, but this method is quite difficult because the cuttings are very recalcitrant to root. Rooting of leafy semi-hardwood cuttings seems to be the most proper method to increase the nursery tree productivity. In mastic tree, similar to many other plant species, rooting ability of cuttings was correlated with their own micro-anatomical structure. Our anatomical observations showed that cortex in one-year-old cuttings was separated from phloem tissue by a continuous sclerenchymatic ring. On the 7th day of rooting, cambial activity markedly increased at the proximal end of cuttings. The occurrence of remarkable cellular changes at the rooting zone of cuttings coincided with the 15th day of rooting. A new callus tissue, mostly originated from ray parenchyma cells, developed at the cambial zone of cuttings. Development of callus tissue was more pronounced on the 22nd day. At this time, unorganised xylem elements differentiated in callus tissue, and further accumulated as new trachery nests. The developing callus tissue protruded from cutting base by pushing the sclerenchyma and cortex tissues on the 30th day. Callus xylem or induced tracheids developed into the callus tissue, forming a continuous, narrow strand, where the new root primordium occurred at the endpoint of this structure concurrently. On the 45th day of rooting, new adventitious roots appeared to elongate and about to move out from the callus tissue. Our observations revealed that due to the quite different anatomical structure, mastic tree cuttings showed indirect rhizogenesis and root primordia originated from basal callus tissue.

**Key words:** callus, gum mastic, leafy cutting, rooting, root primordia

### INTRODUCTION

Mastic tree (*Pistacia lentiscus* var. *chia* Duham.) is the main source of gum mastic. It is a small tree, belonging to the Sumac family (Anacardiaceae) (Zohary 1952). Today, mastic resin and mastic oil are the products with high added value and are used in many industrial applications (Paraschos et al. 2012, Pachi et al. 2020). Also, mastic tree is highly resistant to water stress and salinity. Therefore, it seems to be a good landscaping choice in arid regions of the Mediterranean basin as an ornamental plant (Cristiano et al. 2016, Kostas et al. 2021). Mastic tree is a dioecious tree and only male trees have been used through the centuries because of their high-quality resin. So, traditionally mastic tree had been propagated clonally by the hardwood cuttings (İsfendiyaroğlu 2018, Kostas et al. 2021). This method consists of collecting the thick branches from mature trees and planting them in the field, which is quite difficult and laborious. Some alternative propa-

gation methods such as air layering, budding/grafting onto the *Pistacia* seedling rootstocks, and different *in vitro* protocols were developed for clonal propagation of mastic tree. But the methods used to date have drawbacks and are open to discussion. For instance, limited propagation material, nonstandard nursery tree, possible adverse scion/stock interactions besides, unknown genetic stability and gender of new plantlets seemed to be the main constrains of the above-mentioned methods (İsfendiyaroğlu 2018). Leafy cuttings from mature trees of *Pistacia* species are considered very difficult-to-root (Joley and Opitz 1971, Al Barazi and Schwabe 1982, Dunn et al. 1996, Almehdi et al. 2002, Tilkat et al. 2005). In leafy cuttings of the mastic tree (*P. lentiscus* var. *chia*), clonal differences, cutting collection time, type, and concentration of applied auxin, and rooting medium used are the determinant factors on the *in vivo* adventitious rooting. Rooting percentage ranging between 15-80% (varying among clones) was

Received: May 18, 2021

Accepted: July, 29, 2021

obtained from cuttings collected only in mid-winter and treated with high IBA concentrations, and rooted in pure perlite (İsfendiyaroğlu 2003, Kostas et al. 2016, 2021). There have been attempts to correlate anatomy of stem structure with the rooting ability of plant cuttings. Restriction of rooting could occur as a result of obstruction by sclerenchyma bands, secretory and resin canals, or large volumes of induced vascular tissues occupying space in the sub-basal region, which is thus unavailable for root primordium initiation (Beakbeane 1969, Lovell and White 1986). Sclereids occur in stem cuttings of difficult-to-root species such as *Olea europaea* L. (Ciampi 1964), *Hedera helix* L. (Girouard 1967), *Ficus pumila* L. (Davies et al. 1982), *Agathis australis* D. Don (White and Lovell 1984), and *Quercus macrocarpa* Michx. (Amisshah et al. 2008), while easy-to-root types are characterized by a discontinuity or fewer cell layers of this sclerenchyma ring. A negative correlation between the percentage of sclerification and rooting ability was observed in cuttings of *Malus* (Doud and Carlson 1977) and *Quercus macrocarpa* Michx. (Amisshah et al. 2008). In some species, callus formation is a precursor of adventitious root formation. Origin of adventitious roots, particularly from external callus tissue, has been associated with most difficult-to-root species (Lovell and White 1986). The aim of this study was to predict the relationships between stem structure and root formation in mastic tree cuttings. For this reason, anatomical development of adventitious roots in mature cuttings was examined and discussed in this paper.

## MATERIAL AND METHOD

In order to study the adventitious rooting at histological and cellular level in mastic tree (*Pistacia lentiscus* var. *chia* Duham.) cuttings, one-year old, semi-hardwood, terminal leafy cuttings were collected in mid-February. A mature male tree (more than 50 years old), which has been legally protected in Çeşme district of İzmir province, was used as stock plant. Leaf morphology of this plant is identical with 'Maroulitis' clone which is predominant in old plantations (Kostas et al. 2016, 2021). Cuttings with 3-4 leaves and 15-16 cm in length were treated with 20 g l<sup>-1</sup> IBA (dissolved in 50% ethanol) as quick dip for 5 s and planted in coarse perlite. Rooting was conducted in low tunnel misting system with bottom heat (İsfendiyaroğlu 2003). On the 7, 15, 22, 30, and 45th days after planting, 10 cuttings were randomly taken from the rooting medium. Basal portions about 5 cm of cuttings were cut and fixed in FAA [formaldehyde 5% : acetic acid 5% ethanol 90% (70%)] (Purvis et al. 1966). Cross, longitudinal and tangential sections were taken from the proximal portions about 1-1.5 cm of samples taken from the fixative. Cross sections at 25 µm thickness were taken by a sliding microtome (Leitz-Wetzlar). For freezing the samples,

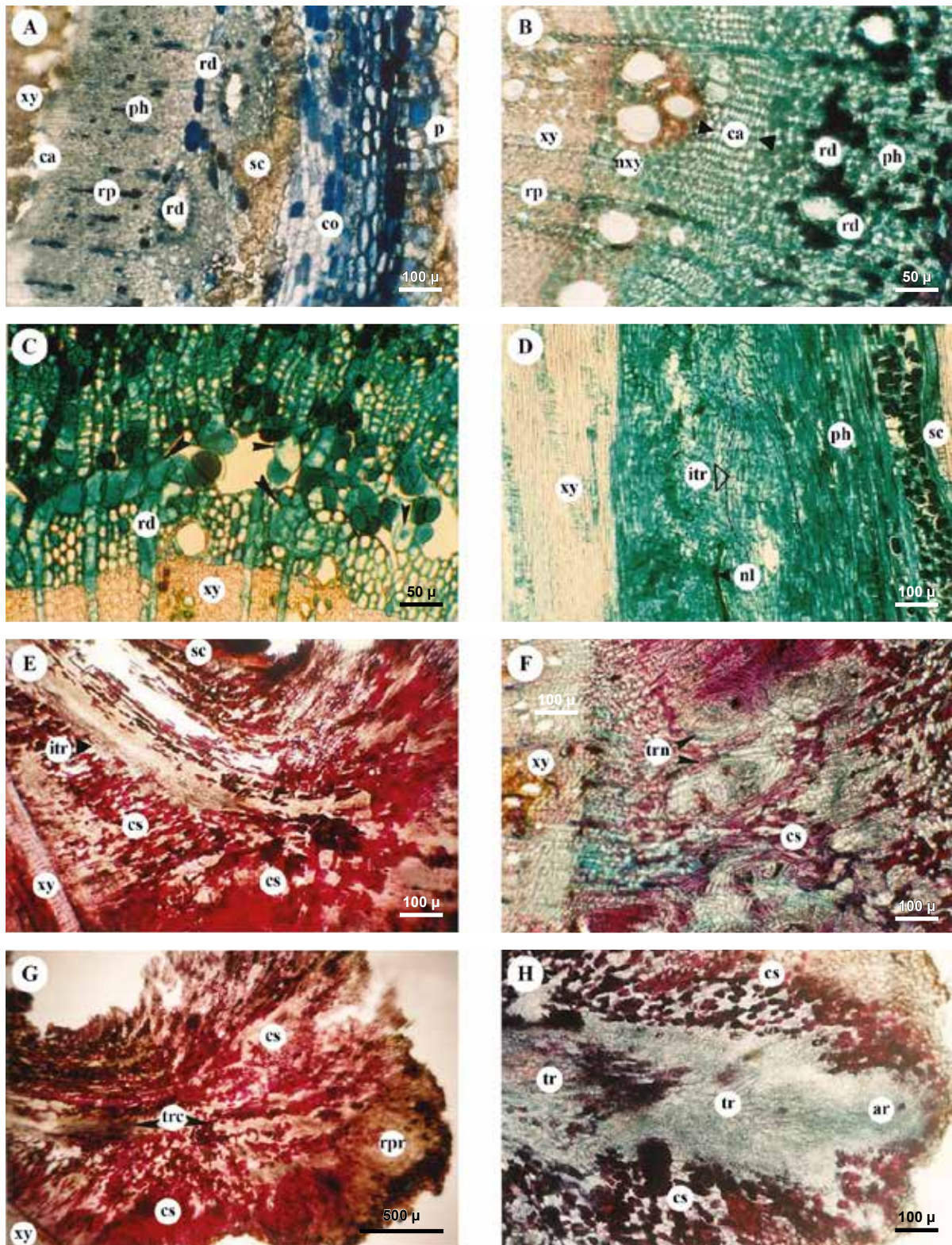
Polyetilenglycol 6000 (PEG) at 5% in water was used as matrix. As for the longitudinal sections, samples were directly embedded to the solid paraffine (Jensen 1962). Sections were taken at about 25-30 µm thickness with a sliding microtome. For microscopic study sections were stained with safranin-fast green double staining technique (Purvis et al. 1966). The cells stained with dark-red or violet tones in double staining sections were also researched, to test whether they comprised poly phenolics or not. For this purpose, cross sections were taken from the fresh material and they were treated with para-dimethylaminocinnamaldehyde (p-DMASA) reagent, which induces a dark-blue colour reaction specific to tannins (Treutter 1989). Anatomical study was performed with a light microscope (OLYMPUS BX50) and documented with a digital camera system.

## RESULTS AND DISCUSSION

Examination of the sections taken from the basal portions of the cuttings showed periderm layer located at the outermost. A continuous sclerenchymatic ring, which was surrounding the vascular cylinder separated the cortex from the phloem. The sclerenchyma layer, which appeared as a continuous ring consisted of sclereids and fibres as formerly reported by Sawidis et al. (2000). Circularly arranged resin ducts occurred at the outermost of the phloem tissue. The resin ducts were reported to be of schizogenous origin (Evert 2006) and their inner walls coated with secretory cells (Sawidis et al. 2000). The phloem was sporadically divided by vascular rays. The vascular rays initiated as single-celled (uniseriate) rows and expanded to the outer part of phloem. Cambium and newly-formed xylem were located at the inner side of the phloem tissue. The old xylem consisted of trachea (xylem vessels) and tracheids and contained primary rays. The pith tissue of parenchymatic cells was at the centre of the stems.

In some places, sclereid layers up to 6-7 cells in thickness were observed in the outer phloem (Fig. 1A). In cross and longitudinal sections, staining of cells in dark red and violet tones suggested they contained tannins. Sections taken from unfixed fresh shoots kept in the tannin reagent p-DMSA showed that many cells of the pit tissue, vascular rays, sieve tubes, phloem parenchyma, epithelial cells and cortex parenchyma respectively, contained tannins (Fig. 1A). Similar findings were also reported by Sawidis et al. (2000) who detected condensed phenolics in all tissues of the mastic tree.

On the 7th day following the cutting insertion, cambial activity at the rooting zone had considerably increased. The cambium, which was not so apparent at the beginning, had divided rapidly and became a distinctive layer composed of 6-9 layers of cells (Fig. 1B). In cuttings of *Ficus pumila* L. (Davies et al. 1982), *Griselinia littoralis* Raoul (White and Lovell 1984), *Malus* rootstocks (Zhou et al. 1992), and *Betula pendula*



**Fig. 1.** A) Tannin containing cells with their dark colour reaction in cross section, B) Increased cambial activity in cross section, C) Active cell divisions in cross section. D) New internal callus tissue and induced tracheid formation in longitudinal section, E) Development of basal callus tissue in longitudinal section, F) Formation of tracheary nests in cross section, G) Root primordium formation and development of tracheid clusters after 22 days as viewed in longitudinal section, H) Adventitious root formation and development in basal callus tissue in longitudinal section.

Abbreviations: ar: adventitious root, ca: cambium, co: cortex, cs: callus, itr: induced tracheids, nl: necrotic layer, nxy: new xylem, p: periderm, ph: phloem, rd: resin duct, rp: ray parenchyma, rpr: root primordium, sc: schlerenchyma, tr: tracheids, trc: tracheid clusters, trn: tracheary nests, xy: xylem.

Roth (Iliev et al. 2001), a distinctive increment was also produced by cambial activity within the first 4-10 days following cutting insertion. The newly-formed layers of phloem consisted of undifferentiated cells. Similar development on the 7th day in mastic tree cuttings despite the high maturity of the stock plant where the cuttings were collected from (Fig. 1B). Besides, in some samples researched, a thin necrotic layer adjacent to the cambium was observed. Previous studies have shown that very high concentrations of IBA gave rise to damage in basal portions of cuttings (Chong 1982, Al Barazi and Schwabe 1982). Similarly, the necrotic layer that we observed in mastic tree cuttings was probably derived from the initial toxic effect of the very high concentration (20 g l<sup>-1</sup>) of IBA.

Significant anatomical changes at the rooting zone of cuttings started on the 15th day after their insertion. At this stage, phloem ray parenchyma cells expressed a meristematic feature and divided into different directions. As a result, a new callus-like tissue consisted of cells without apparent organization, developed at the cambial zone. At the points where the cell divisions were active, some cells became larger with remarkably distinctive nuclei (Fig. 1C). This new internal callus tissue, which originated from the phloem ray parenchyma at the cambial zone and developed outwards, compressed the phloem toward the sclerenchyma layer of the cortex. As a result, completely closed resin ducts were observed. The observed events such as cell enlargement, the distinction of nucleus and condensation of cytoplasm monitored before the mitosis in phloem ray parenchyma cells were indications of dedifferentiation and meristemization that represent the first stage of rooting (Girouard 1967, Smith and Thorpe 1975, Davies et al. 1982). Even in the aerial stems of *Zingiber officinale* Roscoe, the root primordia regenerated from the cells present in meristematic regions (Lincy and Sasikumar 2010). In mastic tree, these cellular changes may not directly result in primordium formation at this stage. However, divisions in the cells of phloem ray parenchyma indicated that meristematic activity started from ray parenchyma in mastic tree cuttings, as formerly observed in mature cuttings of *Hedera helix* L. (Girouard 1967), *Carya illinoensis* K. Koch (Brutsch et al. 1977), *Ficus pumila* L. (Davies et al. 1982), and *Acacia baileyana* F. Muell. (Schwarz et al. 1999). In some samples representing the further stages of anatomical development, some parenchyma cells in the callus tissue showed secondary wall thickness and transformed to induced tracheids or callus xylem (Cameron and Thompson 1969, Brutsch et al. 1977, Kitin et al. 2005, Mitras et al. 2009). These structures that differentiated in the callus, apart from the main xylem, concurrently developed outward and downward toward the cortex (Fig. 1D).

On the 22nd day of rooting, the basal callus tissue

was more developed as it had pushed the phloem tissues outwards (Fig. 1E). At the same time, the presence of protrusions from the cambial zone toward the callus tissue was remarkable. The terminal parts of these protrusions were surrounded by meristematic cells and they also comprised a lot of xylem elements therein. In basal callus of cuttings taken from the mature plants of *Hedera helix* L. (Girouard 1967) and *Ficus pumila* L. (Davies et al. 1982), tracheary elements differentiating by showing secondary wall thickness predicted the places of root primordium formation. In the basal callus tissue formed in mastic tree cuttings, xylem elements differentiating from parenchymatic cells or induced tracheids appeared adjacent to the cells of the callus meristem as reported in *Griselinia littoralis* Raoul. (White and Lovell 1984) and *Malus domestica* Borkh. (MacKenzie et al. 1988). Consequently, the new xylem elements that differentiated in the callus tissue formed distinct tracheary nests with elliptical shapes in the cross sections (Fig. 1F). In cuttings of *Pinus radiata* D. Don (Cameron and Thomson 1969), *Pseudotsuga menziesii* (Mirb.) Franco (Bhella and Roberts 1975), *Carya illinoensis* K. Koch (Brutsch et al. 1977), and *Betula pendula* Roth (Iliev et al. 2001) root primordia formed close to the tracheary nests in the basal callus tissue. In mastic tree cuttings, the tracheary nests could also indicate that root primordium formation will occur at later stages.

The cross and longitudinal sections showed that intense callus development had occurred at the basal portion of cuttings on the 30th day of rooting. The developing callus tissue completely pushed the sclerenchyma and cortex layers outward and reached the outer side of the base of the cuttings. At this stage, callus xylem or induced tracheids were formed as continuous and narrow clusters extending downwards and outwards in the cuttings. The root primordia could be seen at the points where the tracheid clusters reached the outer sides of the cuttings (Fig. 1G). The tracheary nests which were identified in the callus on the 22nd day of rooting sustained their presence also on the 30th day but did not show any development to the direction of primordium formation. At this stage, tracheid clusters that developed toward the primordium were concurrently developing to the adverse direction too and about to contact with the original xylem was observed (Fig. 1G). As a matter of fact, in *Carya illinoensis* K. Koch cuttings the connection between root primordium and main xylem was observed during the outgoing of primordium from callus tissue by elongating (Brutsch et al. 1977). In mastic tree cuttings the occurrence of root primordium quite distant from the main xylem was detected at this stage, as formerly reported in mature cuttings of *Hedera helix* L. (Girouard 1967), *Pinus radiata* D. Don (Cameron and Thomson 1969), *Malus domestica* Borkh. (MacKenzie et al. 1988), and *Prunus*

*cerasifera* Ehrh. (Skolidis et al. 1990). However, a complete vascular connection couldn't be established yet. Nevertheless, the considerable approach of induced vascular strands to the main xylem showed that after the provision of a perfect vascular connection, elongation of primordium and its consequent runout from callus tissue could occur, as formerly predicted in cuttings of *Pseudotsuga menziesii* (Mirb.) Franco (Bhella and Roberts 1975) and *Pinus banksiana* Lamb. (Montain et al. 1983).

On the 45th day of rooting, adventitious roots formed at the bottom of basal callus tissue, notably elongated and ready to grow out of the stem. Besides, induced tracheids or vascular strands developing toward the primordium were in contact with this new tissue (Fig. 1H).

Anatomical observations showed that stem structure had not a direct inhibiting effect on adventitious root formation in mature mastic tree cuttings. From this point of view, root formation can also be controlled by some physiological and biochemical factors, rather than anatomical structure of stem.

#### REFERENCES

- AL BARAZI Z., SCHWABE W. W. (1982). Rooting softwood cuttings of adult *Pistacia vera*. International Journal of Horticultural Science, 57: 247-252.
- ALMEHDI A. A., PARFITT D. E., CHAN H. (2002). Propagation of pistachio rootstock by rooted stem cuttings. Scientia Horticulturae, 96: 359-363.
- AMISSAH J. N., PAOLILLO D. J., BASSUK N. (2008). Adventitious root formation in stem cuttings of *Quercus bicolor* and *Quercus macrocarpa* and its relationship to stem anatomy. Journal of the American Society for Horticultural Science, 133: 479-486.
- BEAKBANE A. B. (1969). Relationships between structure and adventitious rooting. International Plant Propagators' Society, Combined Proceedings, 19: 192-201.
- BHELLA H. S., ROBERTS A. N. (1975). Seasonal changes in origin and rate of development of root initials in Douglas-fir stem cuttings. Journal of the American Society for Horticultural Science, 100: 643-646.
- BRUTSCH M. O., ALLAN P., WOLSTENHOLME B. N. (1977). The anatomy of adventitious root formation in adult-phase pecan (*Carya illinoensis* (Wang) K. Koch) stem cuttings. Horticultural Research, 17: 23-31.
- CAMERON R. J., THOMSON G. V. (1969). The vegetative propagation of *Pinus radiata*: root initiation in cuttings. International Journal of Plant Sciences, 130: 242-251.
- CHONG C. (1982). Influence of high IBA concentrations on rooting. Proceedings of the International Plant Propagator's Society, Combined Proceedings, 31: 453-460.
- CIAMPI C. (1964). Ontogenesi e struttura della guaina sclerenchimatica nelle talee di olivo, paper presented at: Atti Delle Giornate di Studio su la Propagazione delle Specie Legnose (Italia): 94-106 (in Italian).
- CRISTIANO G., MASTRO G. D., FRACCHIOLLA M., LASORELLA C., TUFARELLI V., LUCIA B. D., CAZZATO E. (2016). Morphological characteristics of different mastic tree (*Pistacia lentiscus* L.) accessions in response to salt stress under nursery conditions. Journal of Plant Sciences, 11: 75-80.
- DAVIES F. T. JR., LAZARTE J. E., JOINER J. N. (1982). Initiation and development of roots in juvenile and mature leafbud cuttings of *Ficus pumila* L. American Journal of Botany, 69: 804-811.
- DOUD S. L., CARLSON R. F. (1977). Effects of etiolation, stem anatomy, and starch reserves on root initiation of layered *Malus* clones. Journal of American Society for Horticultural Science, 102: 487-491.
- DUNN D. E., COLE J. C., SMITH M. W. (1996). Timing of *Pistacia chinensis* Bunge. Rooting using morphological markers associated with calendar date and degree days. Journal of the American Society for Horticultural Science, 121: 269-273.
- EVERT R. F. (2006). Esau's plant anatomy: meristems, cells, and tissues of the plant body: their structure, function, and development, 3rd ed. John Wiley & Sons, Inc., New Jersey, USA, 601 pp.
- GIROUARD R. M. (1967). Initiation and development of adventitious roots in stem cuttings of *Hedera helix*: anatomical studies of the mature growth phase. Canadian Journal of Botany, 45: 1883-1886.
- ILIEV I., KITIN P., FUNADA R. (2001). Morphological and anatomical study on *in vitro* root formation of silver birch (*Betula pendula* Roth.). Propagation of Ornamental Plants, 1: 10-19.
- İSFENDİYAROĞLU M. (2003). Effects of some physical and biochemical factors on the rooting of mastic tree (*Pistacia lentiscus* var. *chia* Duham.) cuttings. Journal of Agriculture Faculty of Ege University, 40: 25-32.
- İSFENDİYAROĞLU M. (2018). Propagation of Mastic Tree: From Seed to Tissue Culture. In: Bayram E., Tatar Ö., İştıpliler D. (Eds). 4th International Symposium of Medicinal and Aromatic Plants, Çeşme, İzmir, Turkey: 209-218.
- JENSEN W. A. (1962). Botanical Histochemistry: Principles and Practice. W. H. Freeman and Co., San Francisco, USA, 408 pp.
- JOLEY L. E., OPITZ K. W. (1971). Further experiments with propagation of *Pistacia*. International Plant Propagator's Society, Combined Proceedings, 21: 67-76.
- KITIN P., ILIEV I., SCALTSOYIANNES A., NELLAS C., RUBOS A., FUNADA R. (2005). A comparative histological study between normal and fasciated shoots of

- Prunus avium* generated *in vitro*. Plant Cell, Tissue and Organ Culture, 82: 141-150.
- KOSTAS S., HATZILOUKAS E., HATZILAZAROU S., ECONOMOU A. S. (2016). Efficient vegetative propagation of various clones of mastic tree (*Pistacia lentiscus* 'chia') through rooting of shoot cuttings. Acta Horticulturae, 1242: 735-742.
- KOSTAS S., HATZILAZAROU S., PIPINIS E., VASILEIADIS A., MAGKLARAS P., SMYRNIODIS I., VASILAKIS T., CHAZAKIS M., ANASTASIADI V., ZIOGOU F. T., KOTOULA A., AFENDRA A. S., HATZILOUKAS E., ECONOMOU A. (2021). Propagation of *Pistacia lentiscus* var. *chia* genotypes and determination of their ornamental traits combined with a genetic analysis using ISSR markers. Agronomy, 11: 24 pp.
- LINCY A., SASIKUMAR B. (2010). Enhanced adventitious shoot regeneration from aerial stem explants of ginger using TDZ and its histological studies. Turkish Journal of Botany, 34: 21-29.
- LOVELL P. H., WHITE J. (1986). Anatomical changes during adventitious root formation. In: Jackson M. B. (Ed.). New root formation in plants and cuttings. Springer, Dordrecht, The Netherlands: 111-141.
- MACKENZIE K. A. D., HOWARD B. H., HARRISON-MURRAY R. S. (1988). Anatomical features of rooting in wounded winter cuttings of the apple rootstock M. 26. Acta Horticulturae, 227: 217-223.
- MITRAS D., KITIN P., ILIEV I., DANCHEVA D., SCALTSOYIANNES A., TSAKTSIRA M., ROHR R. (2009). *In vitro* propagation of *Fraxinus excelsior* L. by epicotyls. Journal of Biological Research-Thessaloniki, 11: 37-48.
- MONTAIN C. R., HAISSIG B. E., CURTIS J. D. (1983). Differentiation of adventitious root primordia in callus of *Pinus banksiana* seedling cuttings. Canadian Journal of Forest Research, 13: 195-200.
- PACHI V. K., MIKROPOULOU E. V., GKIOUVETIDIS P., SIAFAKAS K., ARGYROPOULOU A., ANGELIS A., MITAKOU S., HALABALAKI M. (2020). Traditional uses, phytochemistry and pharmacology of Chios mastic gum (*Pistacia lentiscus* var. *chia*, Anacardiaceae): a review. Journal of Ethnopharmacology, 254: 112485, 18 pp.
- PARASCHOS S., MITAKOU L., SKALTSOUNIS A. (2012). Chios gum mastic: a review of its biological activities. Current Medicinal Chemistry, 19: 2292-2302.
- PURVIS M. J., COLLIER D. C., WALLS D. (1966). Laboratory Techniques in Botany. 2nd ed. Butterworths, London, UK, 439 pp.
- SAWIDIS T., DAFNIS S., WERYZKO-CHMIELEWSKA E. (2000). Distribution, development and structure of resin ducts in *Pistacia lentiscus* var. *chia* Duham. Flora, 195: 83-94.
- SCHWARZ J. L., GLOCKE P. L., SEDGLEY M. (1999). Adventitious root formation in *Acacia baileyana* F. Muell. The Journal of Horticultural Science and Biotechnology, 74: 561-565.
- SKOLIDIS K., HARTMANN W., STÖSSER R. (1990). Histologische untersuchung der wurzelbildung an steckhölzern von pflaumenunterlagen und-sorten. Gartenbauwissenschaft, 55: 151-154.
- SMITH D. R., THORPE T. A. (1975). Root initiation in cuttings of *Pinus radiata* seedlings: I. Developmental sequence. Journal of Experimental Botany, 26: 184-18.
- TILKAT E., IŞIKALAN C., ONAY A. (2005). *In vitro* propagation of khinjuk pistachio (*Pistacia khinjuk* Stocks) through seedling apical shoot tip culture. Propagation of Ornamental Plants, 5: 124-128.
- TREUTTER D. (1989). Chemical reaction detection of catechins and proanthocyanidins with 4-dimethylaminocinnamaldehyde. Journal of Chromatography, 467: 185-193.
- WHITE J., LOVELL P. H. (1984). The anatomy of root initiation in cuttings of *Griselinia littoralis* and *Griselinia lucida*. Annals of Botany, 54: 7-20.
- ZHOU J., WU H., COLLET G. F. (1992). Histological study of initiation and development *in vitro* of adventitious roots in minicuttings of apple rootstocks of M 26 and EMLA 9. Physiologia Plantarum, 84: 433-440.
- ZOHARY D. (1952). A monographical study of the genus *Pistacia*. Palestine Journal of Botany, Jerusalem Series, 5: 187-228.