

杜仲中反式聚异戊二烯分布和积累的组织化学研究

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摘要: 探究杜仲叶、皮和籽壳中杜仲胶 (EUR) 的分布和积累规律, 分析不同器官 EUR 的理化性质、橡胶颗粒和含胶细胞与组织的关系以及不同位置 EUR 积累情况。2022 年 4—10 月, 在杨凌西北农林科技大学, 以杜仲基地的杜仲乔林和叶林为研究对象, 对叶、皮和籽壳进行 EUR 提取, 含胶细胞原位观测与分离, 以及组织切片与化学染色, 使用 GPC、DSC、FTIR 和 ¹H-NMR 对 EUR 进行表征, 利用 FM、SEM、TEM、CLSM 对组织切片进行观察, 测量不同位置杜仲含胶细胞 (EC) 和橡胶颗粒 (RP) 的特征参数, 同时测量不同部位的 EUR 密度和大小, 分析 EC 形成和发育规律, 建立 EC 中 RP 积累模型。结果表明: 1) EUR 在杜仲叶、皮和籽壳中差异在细胞尺度上主要体现在密度, 横截面大小, 分布位置上, 一般情况下密度和横截面: 籽壳>皮>叶。2) 在亚细胞尺度上主要体现在橡胶粒子形状上的差异, 其中杜仲叶中的 RP 主要以球型和椭球型为主, 而在杜仲皮和籽壳中是胶囊状, 球状, 椭球状共存的状态。3) EUR 在成熟的杜仲叶、皮和籽壳中一般是两端膨大, 中间细长的丝状形状, 少数 EUR 丝中间有单个膨大点。而在发育中的杜仲叶、皮和籽壳中, 除上述两种形状外还可见具有多个膨大点的胶丝, 这些胶丝通常未填充 RP 或 RP 未填充满。在 EUR 的发育过程中, 一般会经历三个阶段, 第一阶段是少量 RP 在橡胶管中生成, 第二阶段是大量 RP 在橡胶管中生成, 且 RP 和橡胶管会逐渐变大, 皮和籽壳中的 RP 可能会从球形或椭球形发育为胶囊形。第三阶段则是 RP 高度聚合, 形成一个主体, 此时 EC 完全成熟。而 RP 有中间含多个空洞和没有空洞两种形式。少部分 RP 会因为中间空洞没有完全填充而导致成熟 EC 内部有空洞。在叶林模式不同位置的叶和树皮中, 树皮中 EC 的数量和面积与树皮厚度和位置密切相关, 而叶中 EC 的数量和面积与叶的大小密切相关。杜仲叶中 EUR 分子量双峰是由于高分子量集中于主叶脉, 而低分子量聚集于分叶脉。

Histochemical study on the distribution and accumulation of trans-polyisoprene in *Eucommia ulmoides*

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Abstract: The distribution and accumulation of *Eucommia ulmoides* rubber (EUR) in the leaves, barks, and fruit coatings of *Eucommia ulmoides* were investigated. The physicochemical properties of EUR in different organs, the relationship between rubber particles (RP) and *Eucommia ulmoides* rubber-containing cells (EC) with tissues, as well as the spatial localization of EUR accumulation were analyzed. From April to October 2022, in Northwest A&F University, Yangling, arbor forest model of *Eucommia* planting and using leaf model of *Eucommia* planting Base were studied. EUR was extracted from leaves, barks and fruit coatings, and the EC were observed and separated in situ, as well as histological sections and chemical staining. The EUR was characterized by GPC, DSC, FTIR and ¹H-NMR, and the tissue sections were observed by FM, SEM, TEM and CLSM. The characteristic parameters of EC and RP at different locations were measured, and the density and size of EUR at different locations were measured to analyze the formation and development of EC. Establish RP accumulation model in EC. The results show that 1) The difference of EUR in the leaves, barks, and fruit coatings of *Eucommia ulmoides* at the cellular scale is mainly reflected in the density, cross section size and distribution location. The density and cross section of the fruit coating generally exceed those of the bark, which in turn exceed those of the leaf. 2) The differences in the shape of rubber particles are mainly reflected in the subcellular scale. The RP in the leaves of *Eucommia ulmoides* is mainly spherical and ellipsoidal, while the RP in the skin and seed shell of *Eucommia ulmoides* is capsules, spheroids and ellipsoids. 3) EC in mature *Eucommia ulmoides* leaves, barks, and fruit coatings is generally enlarged at both ends, with a slender filamentary shape in the middle, and a few ECs have a node in the middle. In the developing *Eucommia ulmoides* leaves, barks, and fruit coatings, in addition to the above two shapes, there are also ECs with multiple expanded points, which are usually filled with little or no RP. In the development process of EC, it generally goes through three stages, the first stage is a small amount of RP generated in the EC, the second stage is a large amount of RP generated in the EC, and the RP and the EC will gradually grow larger, and the RP in the bark and fruit coating may develop from a spherical or ellipsoidal shape to a capsule shape. In the third stage, the RP is highly polymerized to form a main body, at which point the EC is fully mature. RP has two forms including multiple voids in the middle and no voids. A small number of RPs may have cavities inside mature ECs because the intermediate cavities are not completely filled. The number and area of EC in barks were closely related to the thickness and location of bark, while the number and area of EC in leaves were closely related to the size of leaves. The double-peak EUR molecular weight in *Eucommia ulmoides* leaves is due to the high molecular weight concentration in the main vein and the low molecular weight concentration in the branch vein.