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SCREENING OF POTENTIAL TANNIN YIELDING TREE SPECIES FOR INDUSTRIAL AND COMMERCIAL APPLICATIONS

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ABSTRACT
The tannins are naturally occurring polyphenolic compounds valued for their antioxidant, antimicrobial, astringent, and protein-binding properties, with applications in the leather, pharmaceutical, food, cosmetic, and wood-based industries. The study aimed to estimate the tannin content of selected tree species and identify promising natural sources for commercial exploitation. A literature survey covering 100 tannin-producing species from more than 30 botanical families revealed that the Fabaceae family was the most dominant. Condensed tannins were the predominant type, while bark was the principal plant part used for tannin extraction. Ten tree species were selected for experimental evaluation, and tannin content was determined using the Folin - Ciocalteu colorimetric method following solvent extraction with 70% aqueous acetone. The results showed significant variation in tannin content among the species, ranging from 7.0% to 37.5%. *Eucalyptus camaldulensis* recorded the highest tannin content (37.5%), followed by *Acacia nilotica* (36.0%) and *Butea monosperma* (35.5%). Moderate tannin levels were observed in *Terminalia arjuna*, *Casuarina equisetifolia*, *Cassia fistula*, *Emblica officinalis*, *Pterocarpus santalinus*, and *Mangifera indica*, while *Ficus religiosa* exhibited the lowest tannin content (7.0%). The study identified *Eucalyptus camaldulensis*, *Acacia nilotica* and *Butea monosperma* as promising tannin-rich species with potential for sustainable extraction and commercial applications in leather processing, wood adhesives, pharmaceuticals, natural antioxidants, and other value-added industrial products.

KEYWORDS: Tannin, Extraction, Bark tannins, Polyphenols and Commercial utilization

INTRODUCTION
Forests provide a wide range of timber and non-timber forest products (NTFPs), including tannins, which are important raw materials for the leather, pharmaceutical, food, cosmetic, adhesive, and water treatment industries (Saxena *et al*., 2013). With growing concerns over environmental pollution caused by synthetic chemicals, natural tannins have gained attention as renewable, biodegradable, and eco-friendly alternatives (Pizzi, 2008). Tannins are naturally occurring polyphenolic compounds found in the bark, wood, leaves, fruits, seeds, and roots of many tree species. They function as secondary metabolites that protect plants against herbivores and microbial pathogens and possess strong protein-binding properties that make them valuable for industrial applications (Haslam, 1989; Scalbert, 1991). Based on their chemical structure, tannins are classified into hydrolysable and condensed tannins, each having distinct industrial uses (Haslam, 1989). Several tree species, including *Acacia nilotica, Senegalia catechu, Terminalia* spp., and *Quercus* spp., are recognized as rich sources of tannins. However, only a limited number of species are commercially utilized, while many indigenous species remain unexplored (Kumar & Vaithiyanathan, 1990). Since tannin content varies with species, plant part, age, and environmental conditions, systematic screening is essential to identify high-yielding and sustainable sources (Makkar *et al*., 1997). Natural tannins also possess antioxidant, antimicrobial, anti-inflammatory, and other bioactive properties, expanding their applications in pharmaceuticals, nutraceuticals, and food preservation (Chung et al., 1998). Consequently, identifying tannin-rich tree species can support sustainable forest resource management, reduce dependence on synthetic chemicals, and promote value-added utilization of non-timber forest products. The present study was therefore undertaken to screen selected tree species for tannin content and identify promising species with potential for industrial and commercial applications.

MATERIALS AND METHODS

The information on tannin-yielding tree species was collected through an extensive review of published scientific literature. The literature survey was undertaken to identify tree species reported as natural sources of tannins and to compile information on their tannin content, tannin type, plant parts used for tannin extraction, and potential industrial and commercial applications. The Scientific names and taxonomic classification of the selected species were verified using standard botanical references and internationally recognized plant databases to ensure nomenclatural accuracy. Duplicate records and studies lacking adequate experimental details or reliable references were excluded from the compilation. The final dataset consisted of 100 tannin-producing plant species belonging to more than 30 botanical families. The collected information was organized systematically in tabular form under the following headings: serial number, common name, scientific name, botanical family, plant part used for tannin extraction, tannin type (condensed or hydrolysable), reported tannin content (%), and literature reference. The compiled database was subsequently used for comparative analysis of taxonomic distribution, tannin types, plant parts used, tannin concentration, and identification of commercially and medicinally important tannin-yielding tree species. This literature-based compilation served as the foundation for selecting representative tree species for the experimental estimation of tannin content and for evaluating their suitability for industrial and commercial applications.

Estimate the tannin content of selected tree species

The bark samples of ten tree species *viz*., *Acacia nilotica, Eucalyptus camaldulensis, Casuarina equisetifolia, Mangifera indica, Emblica officinalis, Cassia fistula, Ficus religiosa, Pterocarpus santalinus, Butea monosperma* and *Terminalia arjuna* were collected from healthy, mature trees based on their reported tannin-producing potential. The samples were cleaned, shade-dried, oven-dried at 60 ± 2°C, powdered, and stored in airtight containers until analysis.

Tannin Extraction

Tannins were extracted following the solvent extraction method using 70% aqueous acetone (70:30 acetone: water, v/v). One gram of dried bark powder was mixed with 50 mL of the solvent and shaken for 2 hours at room temperature. The mixture was then heated at 50-60°C for 20 minutes, cooled, filtered through Whatman No. 1 filter paper, and the extract volume was adjusted to 50 mL. The extracts were stored in amber bottles at 4°C until analysis.

Estimation of Total Tannin Content

Total tannin content was determined using the Folin - Ciocalteu colorimetric method. An aliquot (0.5 mL) of the extract was mixed with 2.5 mL of 10% Folin - Ciocalteu reagent, followed by 2.0 mL of 7.5% sodium carbonate after 5 minutes. The reaction mixture was incubated in the dark for 30 minutes, and absorbance was measured at 700 nm using a UV–Visible spectrophotometer. Tannic acid was used to prepare the standard calibration curve, and tannin content was expressed as tannic acid equivalents (TAE).

The tannin concentration was calculated using the following equation:

$$\text{Tannin content (mg TAE g}^{-1}\text{ dry sample)} = \frac{C \times V \times DF}{W}$$

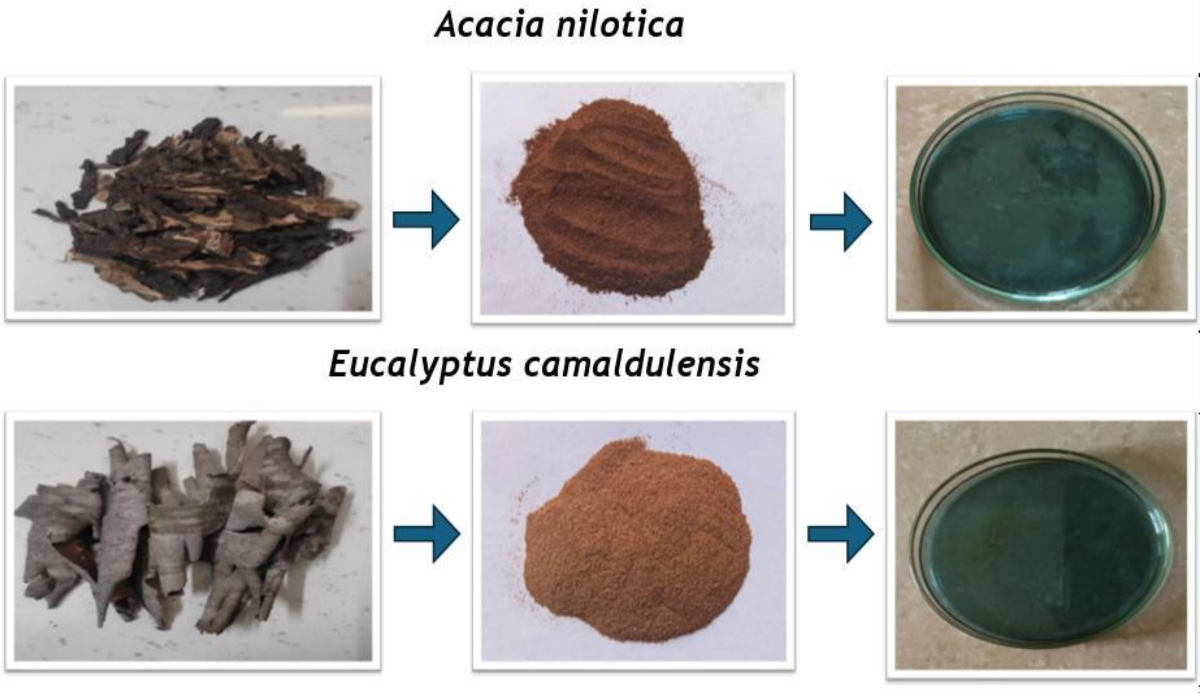
where,
C = Concentration obtained from the tannic acid calibration curve (mg mL^{-1})
V = Total volume of the extract (mL)
DF = Dilution factor
W = Weight of the dried bark sample (g)

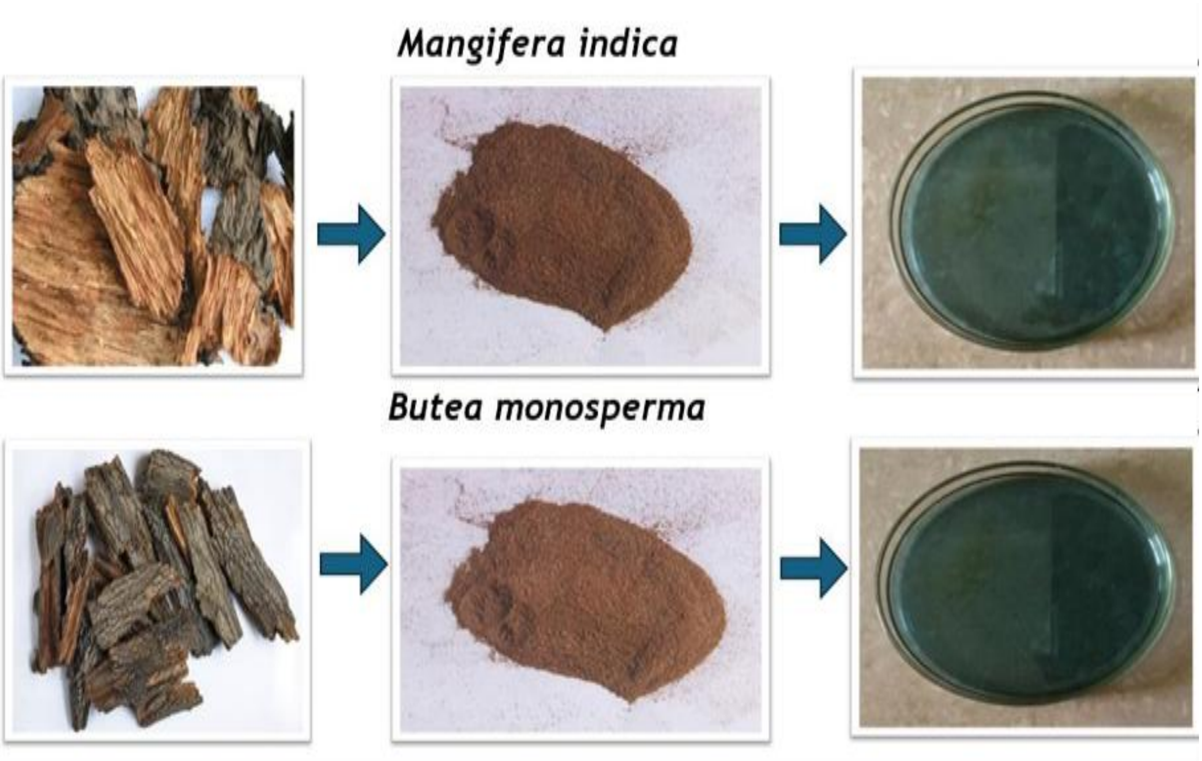
The tannin content was expressed as a percentage using the following equation:

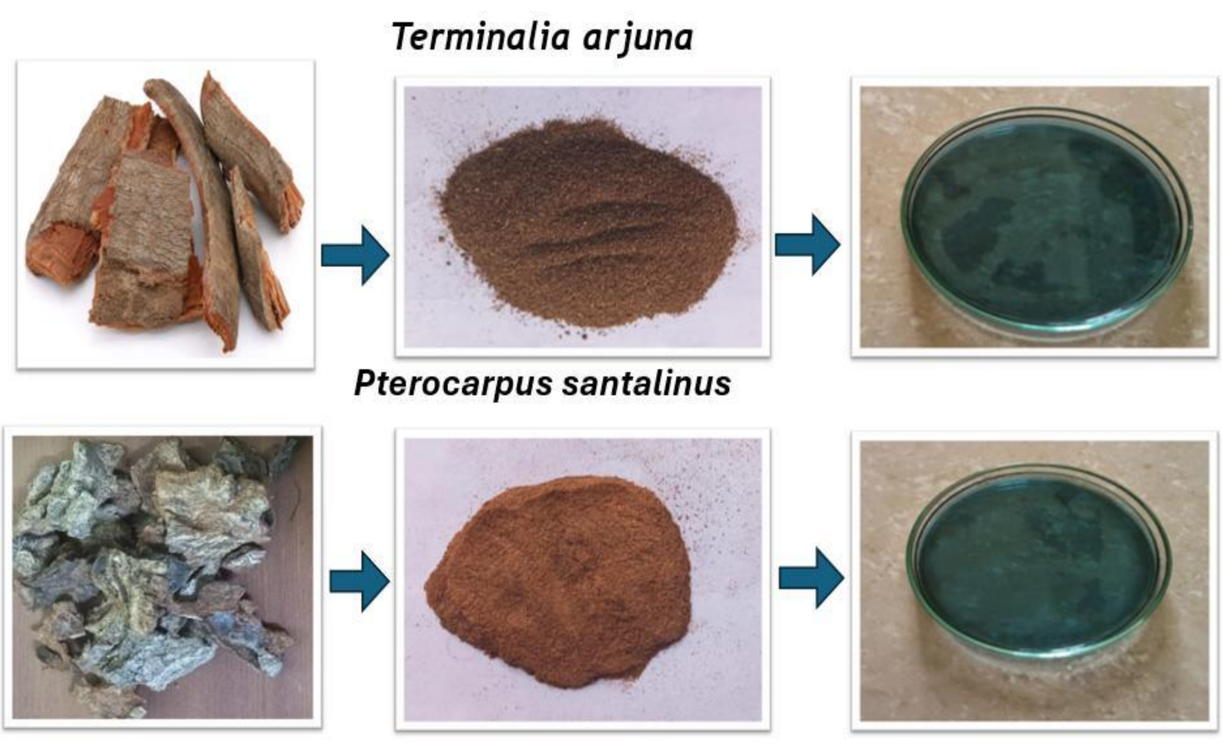
$$\text{Tannin (\%)} = \frac{\text{Tannin (mg g}^{-1}\text{)}}{10}$$

The data were analyzed using Analysis of Variance (ANOVA) under a Completely Randomized Design (CRD) as described by Panse *et al*., (1978). Statistical analysis was performed using AGRES software, and the results were expressed as mean tannin content with significance tested among the tree species.

Tannin Extraction from different tree species




Mangifera indica
Butea monosperma


Terminalia arjuna
Pterocarpus santalinus

RESULT AND DISCUSSION

The documented tannin-yielding plant species, their botanical family, plant parts used, tannin type, reported tannin content, and corresponding references are presented in Table 1. The literature survey compiled 100 tannin-producing plant species belonging to more than 30 botanical families, demonstrating the widespread occurrence of tannins among higher plants. The documented species included economically important forest trees, medicinal plants, horticultural crops and agroforestry species that have been reported as potential sources of vegetable tannins. Among the documented species, members of the Fabaceae family constituted the largest group, represented by species such as *Acacia nilotica, Acacia mearnsii, Acacia catechu, Senegalia catechu, Caesalpinia spinosa, Albizia lebbeck, Dalbergia sissoo, Pterocarpus marsupium, Tamarindus indica* and *Cassia fistula*. The predominance of Fabaceae is attributed to its ability to accumulate high concentrations of condensed tannins in bark, heartwood, pods, and seeds. Similar observations have been reported by Hagerman (2002), CSIR (2007) and Singh *et al*., (2014), who recognized Fabaceae as one of the richest sources of commercial vegetable tannins. The documented tannin content varied widely among plant species, ranging from 3% to 60%, indicating considerable interspecific variation. The highest tannin concentrations were reported in *Schinopsis balansae* (40–60%), *Caesalpinia spinosa* (35–50%), *Acacia mearnsii* (30–45%), *Camellia sinensis* (35–40%), *Senegalia catechu* (25–40%) and *Acacia decurrens* (25–40%). These species are widely recognized as major commercial sources of vegetable tannins and are extensively utilized in leather tanning, wood adhesives, natural dyes, and pharmaceutical industries (Pizzi, 2008; De la Cruz *et al*., 2004; Ferreira *et al*., 2002; CSIR, 2007). Conversely, medicinal tree species such as A*cacia nilotica, Terminalia arjuna, Terminalia chebula, Mangifera indica, Phyllanthus emblica, Pterocarpus marsupium, Ficus religiosa* and *Syzygium cumini* contained moderate tannin concentrations ranging between 10% and 25%. Although these species possess comparatively lower tannin contents than commercial species, they are well known for their antioxidant, antimicrobial, anti-inflammatory, and wound-healing properties, largely attributed to the presence of tannins and other polyphenolic compounds (Dwivedi, 2007; Scartezzini and Speroni, 2000; Berardini *et al*., 2005; Ayyanar and Subash Babu, 2012). The wide variation observed in tannin content among species may be attributed to differences in genetic makeup, plant age, environmental conditions, geographical location, plant part used, extraction procedure, and analytical method employed. Similar variations have been reported by Hillis (1987) and Scalbert (1999), who emphasized that both biological and methodological factors significantly influence the estimation of plant tannins.

Taxonomic Distribution of Tannin-Producing Plant Species

The taxonomic distribution of the documented tannin-producing species is presented in Table 2. The compiled dataset consisted of 100 species distributed among more than 30 botanical families, indicating the widespread occurrence of tannins across angiosperms. Among these families, Fabaceae was the most dominant, contributing 20 species, followed by Rosaceae (10 species). Moraceae and Myrtaceae each contributed five species, while Combretaceae, Lauraceae, Betulaceae, and Fagaceae were represented by four species each. Pinaceae and Rubiaceae contributed three species each, whereas the remaining 38 species belonged to several other families. The predominance of Fabaceae reflects the abundance of tannin-rich genera such as *Acacia*, *Senegalia*, *Caesalpinia*, *Albizia*, *Dalbergia* and *Pterocarpus*, which have long been recognized as important commercial sources of condensed tannins (Ferreira et al., 2002; Hagerman, 2002; CSIR, 2007). Likewise, members of Combretaceae, especially *s* species, are rich sources of hydrolysable tannins and possess considerable medicinal value (Dwivedi, 2007). These findings indicate that tannin-producing species are taxonomically diverse, although a few plant families contribute disproportionately to global tannin resources. Such information is useful for selecting promising species for industrial utilization and conservation.

Distribution of Plant Parts Used for Tannin Extraction

The distribution of plant parts used for tannin extraction is presented in Table 3. Among the various plant organs, bark was the most frequently utilized source of tannins, accounting for approximately 35-40% of the documented species. This was followed by leaves (20-25%), fruits and pods (15-18%), seed coats (8-10%), heartwood/wood (6-8%), and peels or husks (6-s8%). Flowers, rhizomes, and roots contributed only a small proportion of the reported sources. The predominance of bark as a tannin source can be attributed to its protective function against insects, herbivores, fungi, and microbial pathogens. Consequently, bark tissues accumulate high concentrations of polyphenolic compounds that enhance plant defense mechanisms (Hillis, 1987; Scalbert, 1999). Important bark-derived tannin species include *Acacia mearnsii, Acacia nilotica, Terminalia arjuna, Quercus robur, Eucalyptus globulus* and *Senegalia catechu*. Leaves represented the second most important plant part because they contain appreciable amounts of tannins involved in defense against herbivory and oxidative stress.

Species such as *Camellia sinensis, Psidium guajava, Terminalia catappa,* and *Lawsonia inermis* are notable examples of leaf-based tannin sources. Fruits and pods of *Terminalia chebula, Punica granatum, Caesalpinia spinosa* and *Tamarindus indica* also serve as valuable sources of tannins for medicinal and industrial applications.

Comparative Tannin Content of Documented Plant Species

The classification of plant species according to reported tannin content is presented in Table 4. The reported tannin concentrations ranged from 3% to 60%, indicating substantial variability among plant species. Species exhibiting the highest tannin contents included *Schinopsis balansae* (40-60%), *Caesalpinia spinosa* (35-50%), *Acacia mearnsii* (30-45%), *Camellia sinensis* (35-40%), *Senegalia catechu* (25-40%) and *Acacia decurrens* (25-40%). These species constitute the principal commercial sources of vegetable tannins because of their high extraction efficiency and industrial demand (Ferreira et al., 2002; Pizzi, 2008; De la Cruz et al., 2004). Moderate tannin concentrations (15-30%) were reported in *Terminalia chebula, Terminalia catappa, Psidium guajava, Punica granatum, Lawsonia inermis,* and *Musa paradisiaca*, making these species suitable for medicinal and nutraceutical applications. Species such as *Curcuma longa, Zingiber officinale, Rosa damascena, Tagetes erecta,* and *Nelumbo nucifera* contained comparatively lower tannin concentrations (<10%), suggesting that tannins are not their principal bioactive constituents. The considerable variation in tannin concentration among species is consistent with previous reports that indicate tannin biosynthesis is influenced by species characteristics, environmental conditions, plant maturity, extraction methods, and analytical procedures (Scalbert, 1999; Hillis, 1987). These findings highlight the importance of selecting species with high tannin content for commercial extraction while recognizing that moderate tannin concentrations may still provide valuable medicinal and biological activities.

Estimation of Tannin Content in Selected Tree Species

The tannin content of ten selected tree species was estimated using the solvent extraction method followed by the Folin - Ciocalteu assay. The results presented in Table 5 revealed significant variation in tannin content among the selected tree species, indicating considerable interspecific differences in the accumulation of tannins. The average tannin content ranged from 7.0% to 37.5%**,** with an overall mean value of 22.45%**.** Statistical analysis showed significant differences among species, with a critical difference at 5% of 9.79, and CD at 1% of 18.26, confirming that the observed variations were statistically significant. Among the species evaluated, Eucalyptus camaldulensis recorded the highest average tannin content **(**37.5%**),** followed by *Acacia nilotica* **(**36.0%**)** and *Butea monosperma* **(**35.5%**).** These values indicate that these species possess a high potential as natural sources of vegetable tannins suitable for industrial utilization. Previous studies have also reported that species of Acacia are rich in condensed tannins, particularly in the bark, which is extensively used in leather tanning and adhesive manufacturing (Singh *et al*., 2014). Similarly, Eucalyptus bark has been recognized as an important source of polyphenolic compounds and condensed tannins with antioxidant and antimicrobial properties (Santos *et al*., 2012). Although *Butea monosperma* has been primarily valued for its medicinal properties, its bark contains appreciable quantities of tannins that contribute to its therapeutic and industrial significance (Harborne, 1998).

A comparatively high tannin content was also observed in *Terminalia arjuna***,** which recorded an average value of 26.5%**.** This finding is consistent with earlier reports indicating that the bark of *T. arjuna* contains hydrolysable tannins responsible for its antioxidant and cardioprotective properties (Dwivedi, 2007). Moderate tannin concentrations were recorded in *Casuarina equisetifolia* (19.0%), *Cassia fistula* (18.0%), *Emblica officinalis* (16.5%), and *Pterocarpus santalinus* (15.0%). These results agree with previous reports that these species contain moderate quantities of tannins and possess important medicinal properties associated with antioxidant, antimicrobial and anti-inflammatory activities (Scartezzini and Speroni, 2000; Kirtikar and Basu, 1999). Among the tested species, *Mangifera indica* **e**xhibited a relatively lower average tannin content (13.5%)**,** while *Ficus religiosa* recorded the lowest tannin content (7.0%)**.** Although these species contained lower tannin concentrations compared with Acacia and Eucalyptus, their tannins still contribute significantly to their medicinal value. Mango bark and leaves contain condensed tannins together with mangiferin and other phenolic compounds that exhibit strong antioxidant activity (Berardini *et al.,* 2005). Likewise, *Ficus religiosa* bark contains lower concentrations of tannins but remains an important medicinal resource because of its antimicrobial and wound-healing properties (Singh *et al.,* 2011). The observed variation in tannin content among species may be attributed to genetic differences, species-specific metabolic pathways, plant age, environmental conditions, bark maturity, geographical location, extraction efficiency, and analytical methods. Similar variations have been reported by Hagerman (2002), who emphasized that tannin biosynthesis is influenced by both genetic and environmental factors.

Overall, the present study demonstrates that *Eucalyptus camaldulensis*, *Acacia nilotica* and *Butea monosperma* are promising tannin-rich tree species with considerable potential for commercial extraction and industrial applications, including leather processing, wood adhesives, pharmaceuticals, natural dyes, and antioxidant formulations.

Table 1. Tannin-yielding Species and their tannin content

S.No	Common Name	Species	Family	Part Used	Tannin type	Tannin content (%)	References
1	Babul	*Acacia nilotica*	Fabaceae	Bark, pods	Condensed	12-20	Singh *et al*., 2014
2	Black Wattle	*Acacia mearnsii*	Fabaceae	Bark	Condensed	30-45	Ferreira, *et al*.,2002
3	Catechu	*Acacia catechu*	Fabaceae	Heartwood, bark	Condensed	20-25	CSIR, 2007
4	Mimosa	*Acacia decurrens*	Fabaceae	Bark	Condensed	25-40	Hagerman, 2002
5	Oak	*Quercus robur*	Fagaceae	Bark	Hydroysable	8-15	Scalbert,1999
6	Chestnut	*Castanea sativa*	Fagaceae	Wood, bark	Hydrolysable	20-40	Vázquez *et al*.,2008
7	Myrobalan	*Terminalia chebula*	Combretaceae	Fruits	Hydrolysable	15-30	Sale *et al*., 2002
8	Beleric Myrobalan	*Terminalia bellirica*	Combretaceae	Fruits	Hydrolysable	12-24	Nadkarni, 1976
9	Arjun	*Terminalia arjuna*	Combretaceae	Bark	Hydrolysable	10-22	Dwivedi, 2007
10	Indian Almond	*Terminalia catappa*	Combretaceae	Leaves, bark	Hydrolysable	25-30	Lin *et al.,* 2001
11	Pomegranate	*Punica granatum*	Lythraceae	Rind	Hydrolysable	20-25	Gil *et al.,* 2001
12	Sumac	*Rhus coriaria*	Anacardiaceae	Leaves	Condensed	18-30	Kossahet, 2009
13	Mangrove	*Rhizophora mucronata*	Rhizophoraceae	Bark	Condensed	8-15	Bandaranayake, 2002
14	Hemlock	*Tsuga canadensis*	Pinaceae	Bark	Condensed	10-18	Hillis, 1987
15	Spruce	*Picea abies*	Pinaceae	Bark	Condensed	8-12	Holmbom, 1999
16	Willow	*Salix alba*	Salicaceae	Bark	Condensed	7-12	Nahrstedt and Schmidt, 2002
17	Birch	*Betula pendula*	Betulaceae	Bark	Hydrolysable	20-35	Häggblom, 1982
18	Amla	*Phyllanthus emblica*	Phyllanthaceae	Fruit	Condensed	10-18	Scartezzini and Speroni 2000
19	Guava	*Psidium guajava*	Myrtaceae	Leaves	Condensed	15-30	Arim and Danno, 2002
20	Tea	*Camellia sinensis*	Theaceae	Leaves	Condensed	35-40	Cabrer *et al.,* 2006
21	Gambier	*Uncaria gambir*	Rubiaceae	Leaves	Condensed	20-35	Anggraini, *et al.,* 2011
22	Quebracho	*Schinopsis balansae*	Anacardiaceae	Heartwood	Hydrolysable	40-60	Pizzi, 2008
23	Tara	*Caesalpinia spinosa*	Fabaceae	Pods	Hydrolysable	35-50	De la Cruz *et al.,* 2004
24	Divi-divi	*Caesalpinia coriaria*	Fabaceae	Pods	Condensed	10-18	Ortega *et al.,* 2011
25	Siris	*Albizia lebbeck*	Fabaceae	Bark	Condensed	8-15	Kirtikar & Basu, 1999

26	Neem	*Azadirachta indica*	Meliaceae	Bark, leaves	Hydrolysable	12-20	Biswas *et al.*,2002.
27	Jamun	*Syzygium cumini*	Myrtaceae	Bark, seeds	Hydrolysable	12-20	Ayyanar & Subash babu 2012
28	Mango	*Mangifera indica*	Anacardiaceae	Bark, leaves	Condensed	8-15	Berardini *et al.*, 2005
29	Jackfruit	*Artocarpus heterophyllus*	Moraceae	Bark	Hydrolysable	15-25	Swami *et al.*, 2012
30	Walnut	*Juglans regia*	Juglandaceae	Hulls	Condensed	8-15	Amarl *et al.,* 2004
31	Hazel	*Corylus avellana*	Betulaceae	Bark	Condensed	10-20	Alasalvar *et al.,* 2003
32	Pine	*Pinus roxburghii*	Pinaceae	Bark	Condensed	8-18	Singh & Rawat, 2010
33	Eucalyptus	*Eucalyptus globulus*	Myrtaceae	Bark	Condensed	12-20	Santos *et al.*, 2012
34	Cashew	*Anacardium occidentale*	Anacardiaceae	Bark	Condensed	10-18	Trevisan *et al.*, 2006
35	Arecanut	*Areca catechu*	Arecaceae	Nut husk	Condensed	8-15	Bha and Karim, 2010
36	Coconut	*Cocos nucifera*	Arecaceae	Husk	Hydrolysable	10-22	DebMandal & Mandal, sss2011
37	Henna	*Lawsonia inermis*	Lythraceae	Leaves	Condensed	15-25	Ali *et al*., 1995
38	Grape	*Vitis vinifera*	Vitaceae	Seeds, skins	Condensed	8-15	Shi *et al*., 2003
39	Rosemary	*Rosmarinus officinalis*	Lamiaceae	Leaves	Condensed	8-15	Borras *et al.*, 2014
40	Sage	*Salvia officinalis*	Lamiaceae	Leaves	Hydrolyzable	10-18	Lu & Foo, 2001
41	Blackberry	*Rubus fruticosus*	Rosaceae	Leaves	Hydrolysable	8-16	Kaume *et al*., 2012
42	Raspberry	*Rubus idaeus*	Rosaceae	Leaves	Hydrolysable	8-15	Beekwilder *et al*., 2005
43	Strawberry	*Fragaria* × *ananassa*	Rosaceae	Leaves	Condensed	5-12	Aaby *et al*., 2007
44	Cranberry	*Vaccinium macrocarpon*	Ericaceae	Fruit	Condensed	6-15	Howell, 2002
45	Blueberry	*Vaccinium corymbosum*	Ericaceae	Fruit	Condensed	8-15	Prior *et al*., 1998
46	Lotus	*Nelumbo nucifera*	Nelumbonaceae	Leaves	Condensed	5-10	Mukherjee *et al*., 2009
47	Banana	*Musa paradisiaca*	Musaceae	Peel	Condensed	15-25	Someya *et al.*, 2002
48	Tamarind	*Tamarindus indica*	Fabaceae	Seed coat	Condensed	10-18	Sudjaroen *et al.* ,2005
49	Peepal	*Ficus religiosa*	Moraceae	Bark	Condensed	10-12	Singh *et al*., 2011
50	Banyan	*Ficus benghalensis*	Moraceae	Bark	Condensed	5-10	Joseph & Raj, 2010
51	Indian Kino	*Pterocarpus marsupium*	Fabaceae	Bark, heartwood	Condensed	15-30	Harborne 1998
52	Khair	*Senegalia catechu*	Fabaceae	Heartwood	Condensed	25-40	Council of Scientific and Industrial Research. 2007

53	Shisham	*Dalbergia sissoo*	Fabaceae	Bark	Condensed	10-18	Orwa *et al*., 2009
54	Rosewood	*Dalbergia latifolia*	Fabaceae	Bark	Condensed	10-20	Gamble, 1935
55	Prosopis	*Prosopis juliflora*	Fabaceae	Bark	Condensed	8-15	Pasiecznik *et al*., 2001
56	Mesquite	*Prosopis glandulosa*	Fabaceae	Pods	Condensed	6-12	Felker, 2009
57	Babchi	*Psoralea corylifolia*	Fabaceae	Seeds	Condensed	8-15	Khare, 2007
58	Cassia	*Senna siamea*	Fabaceae	Bark	Condensed	10-18	Duke, 2002
59	Golden Shower	*Cassia fistula*	Fabaceae	Bark	Condensed	15-25	Kirtikar & Basu,1999
60	Tendu	*Diospyros melanoxylon*	Ebenaceae	Leaves	Condensed	10-20	Troup, 1921
61	Persimmon	*Diospyros kaki*	Ebenaceae	Fruit peel	Condensed	8-15	Morton, 1987
62	Mahua	*Madhuca longifolia*	Sapotaceae	Bark	Condensed	10-18	Parrotta, 2001
63	Sapota	*Manilkara zapota*	Sapotaceae	Bark	Condensed	8-15	Morton, 1987
64	Clove	*Syzygium aromaticum*	Myrtaceae	Flower buds	Condensed	10-15	Peter, 2004
65	Rose Apple	*Syzygium jambos*	Myrtaceae	Leaves	Condensed	8-15	Lim, 2012
66	Bay Leaf	*Cinnamomum tamala*	Lauraceae	Leaves	Condensed	6-12	Ravindran *et al*., 2004
67	Cinnamon	*Cinnamomum verum*	Lauraceae	Bark	Condensed	8-15	Jayaprakasha *et al*., 2003
68	Avocado	*Persea americana*	Lauraceae	Seed, peel	Condensed	10-18	Dreher & Davenport, 2013
69	Laurel	*Laurus nobilis*	Lauraceae	Leaves	Condensed	12-20	Simon *et al*., 1984
70	Mulberry	*Morus alba*	Moraceae	Leaves	Hudrolysable	12-22	Butt et al., 2008
71	Fig	*Ficus carica*	Moraceae	Leaves	Hydrolysable	10-12	Solomon *et al.,* 2006
72	Breadfruit	*Artocarpus altilis*	Moraceae	Bark	Condensed	8-5	Ragone, 2006
73	Elm	*Ulmus minor*	Ulmaceae	Bark	Condensed	10-14	Mabberley, 2017
74	Beech	*Fagus sylvatica*	Fagaceae	Bark	Condensed	8-14	Packham *et al.,* 2012
75	Cork Oak	*Quercus suber*	Fagaceae	Bark	Condensed	10-20	Pereira, 2007
76	Red Oak	*Quercus rubra*	Fagaceae	Bark	Hydrolysable	10-16	Burns & Honkala, 1990
77	Alder	*Alnus glutinosa*	Betulaceae	Bark	Condensed	8-15	Claessens *et al.,* 2010
78	Hornbeam	*Carpinus betulus*	Betulaceae	Bark	Hydrolysable	10-18	Mitchell, 1974
79	Apple	*Malus domestica*	Rosaceae	Peel	Hydrolysable	12-20	Boyer & Liu, 2004
80	Pear	*Pyrus communis*	Rosaceae	Peel	Hydrolysable	10-18	Salta*, et al*., 2010
81	Peach	*Prunus persica*	Rosaceae	Leaves	Condensed	5-10	Gil et al., 2002
82	Plum	*Prunus domestica*	Rosaceae	Fruit skin	Condensed	8-14	Kim *et al*., 2003

83	Cherry	*Prunus avium*	Rosaceae	Bark	Condensed	6-5	Serradilla *et al*., 2011
84	Apricot	*Prunus armeniaca*	Rosaceae	Seed coat	Hydrolysable	8-15	Leccese, 2008
85	Rose	*Rosa damascena*	Rosaceae	Petals	Condensed	4-8	Boskabady *et al*., 2011
86	Hawthorn	*Crataegus monogyna*	Rosaceae	Leaves	Condensed	8-14	Rigelsky and Sweet, 2002
87	Coffee	*Coffea arabica*	Rubiaceae	Beans	Hydrolysable	8-15	Farah and Donangelo, 2006
88	Noni	*Morinda citrifolia*	Rubiaceae	Fruit	Condensed	10-18	Wang *et al.* ,2002
89	Madder	*Rubia tinctorum*	Rubiaceae	Roots	Hydrolysable	6-12	Bechtold and Mussak, 2009
90	Olive	*Olea europaea*	Oleaceae	Leaves	Hydrolysable	5-10	Vinha *et al*., 2005
91	Jasmine	*Jasminum sambac*	Oleaceae	Leaves	Hydrolysable	8-16	Green, 2003
92	Sesame	*Sesamum indicum*	Pedaliaceae	Seed coat	Condensed	10-20	Namiki, 2007
93	Sunflower	*Helianthus annuus*	Asteraceae	Seed hull	Condensed	6-12	Seiler and Jan, 2007
94	Marigold	*Tagetes erecta*	Asteraceae	Flowers	Condensed	4--10	Piccaglia, 1998
95	Lettuce	*Lactuca sativa*	Asteraceae	Leaves	Condensed	5-12	Nicolle *et al.* 2004
96	Turmeric	*Curcuma longa*	Zingiberaceae	Rhizome	Hydrolysable	3-8	Prasad *et al*., 2014
97	Ginger	*Zingiber officinale*	Zingiberaceae	Rhizome	Condensed	4-5	Ali *et al*., 2008
98	Cardamom	*Elettaria cardamomum*	Zingiberaceae	Pods	Condensed	4-8	Ravindran and Madhusoodanan. 2002
99	Black Pepper	*Piper nigrum*	Piperaceae	Fruits	Condensed	6-12	Srinivasan, 2007
100	Betel	*Piper betel*	Piperaceae	Leaves	Hydrolysable	8-15	Guha, 2006

Table 2. Taxonomic Distribution of documented Tannin-Producing Plant Species

Family	Approximate Number of Species
Fabaceae	20
Rosaceae	10
Moraceae	5
Myrtaceae	5
Fagaceae	4
Lauraceae	4
Betulaceae	4
Rubiaceae	3
Combretaceae	4
Pinaceae	3
Others	38

Fig 1: Approximate number of species by plant family

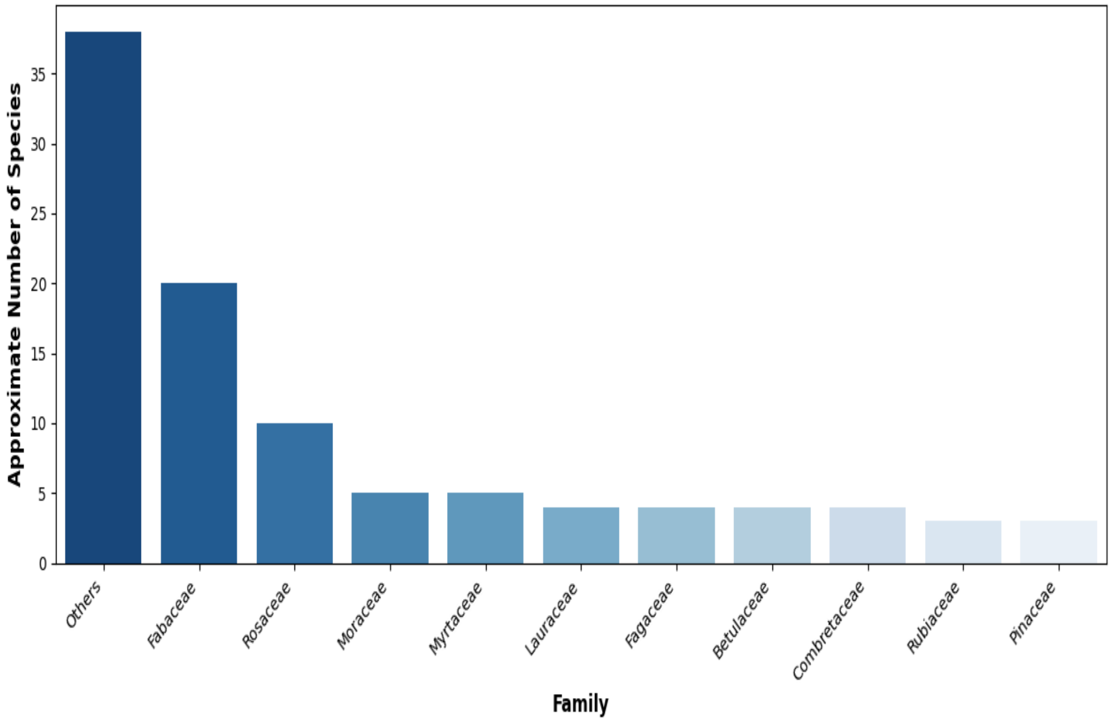


Table 3. Distribution of Plant Parts Used for Tannin Extraction

Plant Part	Approximate Number of Species	Percentage (%)
Bark	35–40	35–40
Leaves	20–25	20–25
Fruits/Pods	15–18	15–18
Seeds/Seed coat	8–10	8–10
Heartwood/Wood	6–8	6–8
Peel/Husk/Hulls	6–8	6–8
Flowers	3–4	3–4
Rhizomes	2	2
Roots	1–2	1–2

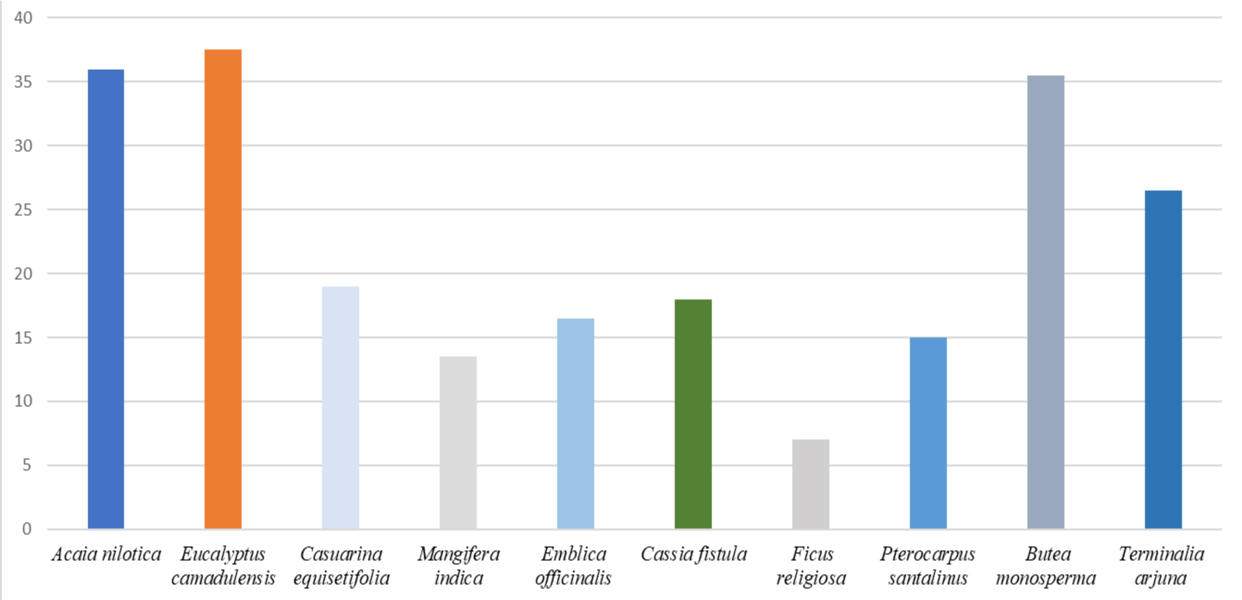
Table 4. Tannin content of various species

Species	Tannin (%)
Highest tannin contents (>40%)	
Schinopsis balansae (Quebracho)	40–60
Caesalpinia spinosa (Tara)	35–50
Acacia mearnsii (Black Wattle)	30–45
Senegalia catechu (Khair)	25–40
Acacia decurrens	25–40
Camellia sinensis (Tea)	35–40
Moderate tannin contents (15–30%)	
Terminalia chebula	15-30
Terminalia catappa	25-30
Pterocarpus marsupium	8-18
Psidium guajava	15-30
Punica granatum	15-25
Banana peel	15-20
Henna	15-25
Chestnut	8-15
Lower tannin contents (<10%)	
Turmeric	3-8
Ginger	4-5
Rose petals	2-8
Marigold	2-6
Lotus	5-10
Peach leaves	4-10

Table 5. Estimation of Tannin Content in Selected Tree Species

Species	Average (%) tannin content
Acaia nilotica	36.0*
Eucalyptus camaldulensis	37.5*
Casuarina equisetifolia	19.0
Mangifera indica	13.5
Emblica officinalis	16.5
Cassia fistula	18.0
Ficus religiosa	7.0
Pterocarpus santalinus	15.0
Butea monosperma	35.5*
Terminalia arjuna	26.5
Mean	**22.45**
SEd	4.24
CD (5%)	9.79
CD (1%)	18.26

Fig 2: Estimation of tannin content in selected tree species



CONCLUSION

The present investigation, "Screening of Potential Tannin-Yielding Tree Species for Industrial and Commercial Applications," aimed to document tannin-producing tree species through a literature review and estimate the tannin content of selected tree species. The literature survey covered 100 tannin-producing species belonging to over 30 botanical families, with Fabaceae being the most dominant family. Condensed tannins were the predominant type (70–75%), while hydrolysable tannins accounted for 25–30%. Bark was identified as the primary source of tannins, followed by leaves, fruits, pods, and seeds. Reported tannin content ranged from 3% to 60%, with species such as *Schinopsis balansae*, *Acacia mearnsii*, *Senegalia catechu*, *Caesalpinia spinosa*, and *Castanea sativa* recognized as major commercial sources. The laboratory analysis of ten selected tree species revealed significant variation in tannin content. *Eucalyptus camaldulensis* recorded the highest tannin content (37.5%), followed by *Acacia nilotica* (36.0%) and *Butea monosperma* (35.5%). Moderate tannin levels were observed in *Terminalia arjuna* (26.5%), *Casuarina equisetifolia* (19.0%), *Cassia fistula* (18.0%), *Emblica officinalis* (16.5%), *Pterocarpus santalinus* (15.0%), and *Mangifera indica* (13.5%), while *Ficus religiosa* recorded the lowest tannin content (7.0%). Statistical analysis confirmed significant differences among the species, identifying *Eucalyptus camaldulensis*, *Acacia nilotica*, and *Butea monosperma* as promising sources of tannins for industrial and commercial applications.

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