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Ancient Herbal Resources and Their Applications in the Textile Industry: A Sustainable Approach

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Abstract: The combination of ancient herbal knowledge into modern textile applications is a growing trend in sustainable textile manufacturing. This review explores various ancient herbs such as neem, turmeric, tulsi, indigo, aloe vera, and henna, henna, and regional plants like **Arasampattai (Ficus religiosa)** [1], **Thandrikai (Terminalia bellirica)** [2], **Parangipattai (Smilax china)** [3], **Vadhanarayana (Delonix elata)** [4], **Parpadagam (Mollugo cerviana)** [5], and **Vilvam (Aegle marmelos)** [6], highlighting their historical relevance, bio functional properties, and current applications in textile processing. The paper covers antibacterial finishing, dyeing, mothproofing, and UV protection offered by herbal compounds. With increased consumer demand for green and non-toxic products, herbal-based textile processing represents a promising eco-friendly alternative to synthetic chemicals.

Keywords: Herbal textiles, neem, regional herbs, natural dyeing, sustainable textiles, antibacterial finish, ayurvedic textiles.

I. Introduction

The textile industry has been under increasing pressure to adopt sustainable practices, particularly in the area of chemical finishing, which traditionally relies on synthetic agents that may pose risks to human health and the environment. Eco-friendly finishes present a viable alternative, emphasizing the use of natural, biodegradable, and non-toxic substances derived from renewable resources. These finishes aim to impart desirable properties such as antimicrobial activity, UV protection, flame resistance, and wrinkle resistance while minimizing ecological impact.

Eco-friendly finishing agents include herbal extracts, plant-based oils, polysaccharides, and enzymes, which can be applied using conventional methods such as pad-dry-cure, exhaust, and spray techniques. Unlike synthetic finishes, these bio-based treatments are often skin-friendly, non-allergenic, and biodegradable, making them ideal for apparel intended for infants, the elderly, and those with sensitive skin.

In recent years, there has been growing interest in incorporating traditional knowledge systems such as Ayurveda into textile finishing processes. Herbs like **Arasampattai (Ficus religiosa)** [1], **Thandrikai (Terminalia bellirica)** [2], **Parangipattai (Smilax china)** [3], **Vadhanarayana (Delonix elata)** [4], **Parpadagam (Mollugo cerviana)** [5], and **Vilvam (Aegle marmelos)** [6], long valued for their medicinal properties, are now being used to create textiles that promote wellness in addition to functionality. This movement aligns with the global shift toward circular economy models, where product lifecycles are extended, waste is minimized, and ecological balance is maintained.

Moreover, eco-friendly finishes support responsible sourcing and manufacturing, often enabling rural employment through the collection and processing of botanical raw materials. While challenges remain in terms of standardization, shelf life, and industrial scalability, the adoption of green finishing technologies is steadily increasing. Research continues to validate the efficacy and durability of these finishes, ensuring that they meet performance standards comparable to their synthetic counterparts.

As consumers become more conscious of sustainability and health, the demand for textiles treated with eco-friendly finishes is expected to rise, encouraging innovation at the intersection of traditional plant knowledge and modern textile science.

II. Selection of Herbs

From the ancient period, India is the only country having countless herbs available in each places of the country. Some of the herbs were selected and reviewed for the detailed secription for further study in Textile Finishing for Eco friendly and Sustainable finishes in the Textile sector. Safeguard the environment from the harmful hazards chemicals and processing methods.

2.1. Arasampattai (Ficus Religiosa)

Arasampattai, Ficus religiosa, commonly known as Arasampattai or the sacred fig, has antimicrobial and antioxidant properties due to its flavonoids and phenolic compounds [1]. It is traditionally used in Ayurvedic healing and is now being investigated for antibacterial textile finishes and soothing innerwear [1].is a revered tree in Indian tradition and holds deep religious and medicinal significance [1]. It is abundant in bioactive compounds including flavonoids, tannins, phenols, and glycosides, which contribute to its antioxidant and antimicrobial activity [1]. Its bark, leaves, and roots have been widely used in Ayurvedic medicine for treating skin disorders, wounds, and infections [1]. Recent studies have highlighted the antimicrobial properties of Ficus religiosa extract against common textile-related bacteria such as *Staphylococcus aureus* and *Escherichia coli* [1]. This makes it a suitable candidate for natural antibacterial finishing of textiles, especially cotton and other natural fibers [1]. Moreover, the extract from its leaves has shown UV absorption capabilities, indicating its potential as a bio-based UV protective agent in clothing [1].

The application of Ficus religiosa in the textile industry is primarily through aqueous and ethanolic extraction followed by the pad-dry-cure method [1]. Cotton fabrics treated with Ficus religiosa extracts have exhibited noticeable zones of inhibition when tested for antibacterial activity using AATCC 147 and parallel disk diffusion methods [1]. Furthermore, when used as a topical finish on cotton and blended textiles, Ficus religiosa improves the hygiene factor and can reduce the growth of odor-causing microbes [1]. Its natural origin ensures it is non-toxic and skin-friendly, making it ideal for use in babywear, undergarments, and medical textiles [1]. The phytochemicals present in the extract bind well with cellulose fibers, increasing wash durability and reducing the need for synthetic binders [1]. In terms of sensory properties, the finished fabrics retain their softness, suggesting that Ficus religiosa extracts do not negatively affect fabric hand or drape [1].

Besides antibacterial and UV protective applications, there is emerging interest in using Ficus religiosa bark extract as a natural dye [1]. The tannin-rich nature of the bark allows it to impart light brown to greyish hues on cotton fabric, particularly when used in conjunction with bio-mordants like alum or harda (Terminalia chebula) [1]. Although not as vibrant as synthetic dyes, the shades derived are suitable for ethnic, rustic, and eco-fashion products [1]. Moreover, due to its spiritual significance, Ficus religiosa-dyed fabrics are being considered for religious attire and eco-conscious ceremonial garments [1].

Researchers have also experimented with microencapsulation techniques for Ficus religiosa extracts to create slow-release bioactive textiles [1]. This method helps prolong the antibacterial and antioxidant effects of the treatment, making it suitable for wellness and therapeutic wear [1]. With increasing consumer awareness around sustainable and Ayurvedic clothing, textiles finished with Arasampattai extracts could occupy a niche market in Ayurvedic spas, yoga wear, and organic fashion [1]. The challenge remains in standardizing the extraction and application techniques to ensure consistency in finish performance across different fabric substrates [1]. Nonetheless, the overall impact of Ficus religiosa on textile functionality, sustainability, and consumer safety is promising and warrants deeper industrial exploration [1].

2.2. Thandrikai (Terminalia Bellirica)

Terminalia bellirica, one of the three fruits in Triphala, contains tannins and gallic acid [2]. Its extract has shown promise as a natural mordant and UV protective agent in cotton dyeing applications [2].commonly referred to as Thandrikai or Belleric Myrobalan, is a large deciduous tree native to South and Southeast Asia [2]. It is well known in traditional Indian medicine and forms a critical part of the Ayurvedic formulation Triphala, alongside Terminalia chebula and Emblica officinalis [2]. The fruit of Terminalia bellirica is a rich source of phytochemicals such as tannins, gallic acid, ellagic acid, and chebulagic acid, all of which possess significant antimicrobial, astringent, and antioxidant properties [2].

In the textile industry, extracts from Terminalia bellirica have been increasingly studied for their application in natural dyeing and functional finishing [2]. The tannin content of the fruit enables its use as a natural mordant, which enhances the bonding of plant-based dyes to cellulosic fabrics like cotton and linen [2]. When used as a pre-treatment or post-treatment mordant, Terminalia bellirica can improve colorfastness, especially for shades obtained from dyes like turmeric, madder, and indigo [2]. Additionally, the phenolic compounds in the extract contribute to antibacterial properties, which are valuable in apparel, medical textiles, and sportswear [2].

Studies have demonstrated that cotton fabrics treated with Terminalia bellirica extract exhibit notable antibacterial activity against *E. coli* and *S. aureus* when assessed using AATCC 100 and disk diffusion methods [2]. The treated textiles also showed moderate UV resistance, with Ultraviolet Protection Factor (UPF) ratings increasing by 25–30% compared to untreated samples [2]. The extract can be applied using conventional methods like padding, spraying, or exhaustion, making it feasible for both small-scale and industrial textile operations [2].

In terms of aesthetics, Terminalia bellirica imparts a soft beige to brownish hue on fabrics, which aligns with the current trend of organic and earth-toned fashion [2]. The hue intensity can be modified through the use of different mordants, including iron, alum, and harda [2]. Due to its antimicrobial and deodorizing effects, Terminalia bellirica-treated fabrics are well-suited for undergarments, yoga wear, children's clothing, and eco-lifestyle products [2].

Furthermore, the extract's eco-friendly profile makes it a compelling alternative to synthetic mordants, some of which may be harmful to human health or the environment [2]. Recent innovations include the encapsulation of Terminalia bellirica extract in liposomes or nanocarriers, enabling controlled release of its bioactive agents over multiple washes [2]. As consumer awareness continues to grow around sustainable fashion, ingredients like Thandrikai offer an opportunity to align traditional herbal wisdom with contemporary textile science [2]. The main challenge lies in standardizing extraction yields and ensuring uniform application across diverse textile substrates, which will require further collaborative research [2].

2.3. Parangipattai (Smilax China)

Smilax china, commonly known as Parangipattai, is a climbing herbaceous plant extensively used in traditional Asian medicine, particularly in Siddha and Chinese systems [3]. Its roots contain a wide range of phytochemicals including saponins, flavonoids, steroids, and alkaloids, contributing to its strong anti-inflammatory, antimicrobial, and antioxidant properties [3]. Smilax china has traditionally been used for treating skin disorders, rheumatism, urinary tract infections, and as a general detoxifier [3]. These same bioactive compounds have encouraged research into its application in sustainable textiles [3].

The primary method for extracting Smilax china root properties is via aqueous or ethanolic extraction, followed by concentration and filtration [3]. In the textile industry, its application is predominantly for antibacterial and anti-inflammatory finishing on natural fibers like cotton, linen, and viscose [3]. Studies have shown that cotton fabrics finished with Smilax china extracts demonstrate clear zones of inhibition against common bacterial strains such as *Staphylococcus aureus* and *Pseudomonas aeruginosa*, as per AATCC 147 tests [3].

Apart from its antimicrobial function, Smilax china also exhibits notable antioxidant activity, as determined through DPPH assays, which may contribute to fabric stability and prevent oxidative degradation over time [3]. When applied to textiles, the saponins act as natural surfactants, enhancing the wettability and breathability of the fabric, which is especially desirable for wellness and sports apparel [3]. Additionally, early studies indicate that clothing finished with Smilax china may offer soothing effects for individuals with mild skin conditions or sensitivities due to its anti-inflammatory action [3].

Smilax china extract can be applied using the pad-dry-cure or exhaust dyeing techniques, with or without binders depending on the desired wash durability [3]. Fabrics treated with microencapsulated Smilax china formulations have shown prolonged antimicrobial effects even after 15–20 wash cycles [3]. This extends the usability of such fabrics in therapeutic and hospital wear where hygiene and durability are critical [3].

Aesthetic changes to the fabric after treatments are minimal, though a slight herbal aroma may persist, which is often appreciated in aromatherapeutic or holistic clothing [3]. The plant's mild yellow-brown coloration can be used to impart a soft, earthy tint to fabric surfaces when used at higher concentrations, which complements the trend of botanical-dyed garments [3].

Researchers are exploring Smilax china's potential in multifunctional textile applications where a single finish offers antimicrobial, anti-odor, and healing benefits [3]. This makes it a strong candidate for innerwear, socks, babywear, yoga garments, and garments designed for geriatric care [3]. Commercial adoption is still in early stages, but trials by herbal textile start-ups in Tamil Nadu and Kerala have shown consumer interest in Smilax-infused fabric products [3].

Moreover, since the plant is native and abundantly available in southern India and Southeast Asia, it offers a sustainable and economically viable alternative to imported herbal actives [3]. However, challenges such as seasonal variation in phytochemical yield and ensuring consistent extract quality must be addressed through advanced standardization and certification processes [3]. In conclusion, Parangipattai (Smilax china) represents a promising bridge between traditional medicine and modern textile functionality, contributing to a holistic, health-oriented fashion ecosystem [3].

2.4. Vadhanarayana (Delonix Elata)

Vadhanarayana or white gulmohar, is a deciduous tree native to arid and semi-arid regions of India and Sri Lanka [4].It is well-regarded in Ayurveda and folk medicine for its anti-inflammatory, antimicrobial, and wound-healing properties, particularly from its bark, flowers, and seeds [4]. Phytochemical analyses have identified the presence of flavonoids, phenolic acids, saponins, and tannins in various parts of the plant, which lend it potent therapeutic and bioactive capabilities [4].

In the textile domain, Delonix elata is attracting attention for its dual role as both a natural dye and a functional finishing agent [4]. The flowers, in particular, contain natural pigments like flavonoids and carotenoids that yield pale to bright yellowish hues upon dyeing [4]. When applied to cotton fabrics using the exhaust method, these pigments provide consistent shades with moderate light and wash fastness, especially when combined with natural mordants such as alum, myrobalan, or ferrous sulfate [4].

Simultaneously, the bark extract of Delonix elata has been shown to impart antibacterial and anti-inflammatory properties to finished textiles [4]. Studies employing the disk diffusion and AATCC 100 methods have demonstrated zones of inhibition against common textile pathogens such as *Escherichia coli* and *Staphylococcus aureus* [4]. These results suggest that Delonix elata-treated fabrics may be suitable for intimate wear, medical textiles, and clothing intended for individuals with sensitive skin [4].

The application method typically involves aqueous extraction followed by padding, drying, and curing [4].

In formulations where a binder is necessary for wash durability, bio-based fixatives such as gum arabic or soy proteins are preferred to maintain sustainability [4]. Microencapsulation technologies have also been explored, allowing for gradual release of active agents over time, thus enhancing durability and maintaining the therapeutic benefits across multiple laundering cycles [4].

Aside from its antimicrobial capacity, Delonix elata-treated fabrics display antioxidant potential as assessed by FRAP (Ferric Reducing Antioxidant Power) and DPPH (2,2-diphenyl-1-picrylhydrazyl) assays [4]. These antioxidant properties help reduce oxidative stress on fabrics, particularly under prolonged UV exposure or sweaty conditions, thereby extending fabric longevity and comfort [4]. These characteristics are especially valuable in the context of performance wear, healthcare garments, and summer clothing [4].

In terms of consumer perception, the Delonix elata-finished fabrics exhibit a smooth hand and a light floral scent, which enhances the sensory appeal of garments aimed at wellness and aromatherapy markets [4]. Furthermore, since the tree grows in dry regions with minimal agricultural input, its extracts offer a low-carbon, water-efficient alternative to chemically synthesized textile auxiliaries [4]. Its widespread availability and multipurpose utility make it attractive for large-scale commercial use, particularly for eco-conscious apparel brands seeking natural, traceable ingredients [4].

Challenges remain in the form of seasonal variation in pigment yield, extraction efficiency, and color consistency [4]. To address this, researchers are exploring standardization protocols, blending with other plant dyes, and establishing guidelines for fabric pre-treatment to improve uptake and fastness [4]. In conclusion, Vadhanarayana (Delonix elata) offers a versatile solution for sustainable and functional textile finishing, embodying the principles of wellness, ecology, and heritage-based innovation [4].

2.5. Parpadagam (Mollugo Cerviana)

Parpadagam, scientifically known as Mollugo cerviana, is a low-growing herbaceous plant found abundantly in tropical and subtropical regions, especially in India [5]. Traditionally used in Siddha and folk medicine, Parpadagam has been prescribed for fevers, digestive issues, and skin disorders due to its cooling, detoxifying, and antimicrobial properties [5]. Phytochemical screening of the plant reveals the presence of flavonoids, alkaloids, phenolic acids, and saponins, which contribute to its bioactivity [5]. These constituents have recently become the subject of interest in eco-textile applications aimed at merging medicinal value with fabric functionality [5].

One of the primary uses of Mollugo cerviana in textiles is as an antimicrobial finishing agent [5]. Its extracts have demonstrated inhibitory effects against a spectrum of microbes including *Staphylococcus aureus*, *Bacillus subtilis*, and *Candida albicans*, according to agar well diffusion and AATCC 100 test protocols [5]. Cotton fabrics treated with aqueous and ethanolic extracts of the plant showed zones of inhibition ranging from 12 to 18 mm, suggesting its effectiveness as a natural hygiene-enhancing finish [5]. These qualities are especially useful in the production of undergarments, infant wear, and home furnishings such as bedsheets and towels [5].

Apart from antimicrobial properties, Parpadagam extract also exhibits antioxidant activity, as established through DPPH and ABTS assays [5]. This antioxidant action is critical in protecting textiles from oxidative degradation, particularly during prolonged exposure to UV radiation and perspiration [5]. When applied to cotton and linen, the extract not only improves fabric stability but also contributes to skin wellness by minimizing contact irritation and inflammation [5]. This is valuable in wellness and therapeutic garments, such as spa robes and yoga clothing, where skin comfort and hygiene are prioritized [5].

In terms of dyeing, while Parpadagam is not a strong colorant, its extract imparts a faint greenish-brown hue to fabrics when used at high concentrations [5]. Its application is best realized in combination with other plant-based dyes, functioning either as a toner or modifier to influence the final shade and enhance fastness properties [5].

It also functions as a mild mordant due to its tannin content, improving the affinity of natural dyes on cellulose-based textiles [5].

The typical application process involves the extraction of dried whole plant material through boiling in distilled water, followed by filtration and concentration [5]. The extract is then applied to scoured fabric via padding or dipping techniques, followed by drying and curing at moderate temperatures [5]. To improve wash durability, bio-binders like chitosan or guar gum are often included in the formulation [5]. Studies have confirmed the retained activity of the finish even after 10–15 home laundering cycles, confirming its semi-durable performance under standard textile use conditions [5].

Consumer response trials have noted favorable outcomes in terms of softness, breathability, and absence of chemical odor in Parpadagam-treated garments [5]. Its non-toxic nature and hypoallergenic profile make it particularly suitable for sensitive users including children and elderly populations [5]. Additionally, since the plant grows widely as a weed and requires minimal agricultural input, it is an economical and sustainable option for mass-scale herbal textile production [5].

To further industrialize its use, researchers are exploring nano-finishing techniques and encapsulation technologies to improve penetration and long-term release of active compounds [5]. Future directions also include blending Parpadagam with other therapeutic herbs like neem, tulsi, or vetiver for synergistic effects in multifunctional textiles [5]. In summary, Parpadagam (Mollugo cerviana) offers considerable potential as a holistic herbal finish in textile applications, aligning with both health-centric fashion trends and environmental responsibility [5].

2.6. Vilvam (Aegle Marmelos)

Vilvam, known botanically as Aegle marmelos and commonly referred to as bael, is a sacred medicinal tree deeply rooted in Indian tradition, particularly Ayurveda [6]. Its leaves, fruit, and bark have been used for centuries in the treatment of digestive ailments, skin disorders, and respiratory issues [6]. Phytochemical constituents such as marmelosin, tannins, alkaloids, flavonoids, and coumarins contribute to its therapeutic profile and are now being explored for eco-textile applications [6].

In textiles, Vilvam is gaining popularity for its antimicrobial and deodorizing properties, making it suitable for medical, spiritual, and functional wear [6]. Extracts from its leaves and fruit pulp have been used to finish cotton and viscose fabrics through pad-dry-cure and exhaust methods [6]. Studies using AATCC 147 and ASTM E2149 test methods show that Vilvam-treated fabrics inhibit bacterial growth significantly, especially against *S. aureus* and *E. coli* [6]. Its natural antibacterial nature also helps reduce unpleasant odors in apparel and activewear, making it useful in socks, innerwear, and sports clothing [6].

Another important characteristic of Aegle marmelos is its UV-blocking capability, attributed to flavonoids and phenolic compounds [6]. Treated fabrics have shown increased Ultraviolet Protection Factor (UPF), offering an eco-friendly alternative to chemical UV absorbers [6]. The antioxidant content of the extract also provides an anti-aging benefit to textiles, preserving fabric color and integrity during exposure to sunlight and pollutants [6].

Vilvam extracts can impart a subtle golden-green tint when applied at higher concentrations, which may be desirable in ritual garments and spiritual apparel [6]. This aesthetic, combined with its Ayurvedic significance, positions it uniquely in the market of organic religious wear and eco-conscious ceremonial clothing [6]. In addition to its functional finishes, Aegle marmelos has also been studied for use as a dye, although its pigment intensity is modest [6]. When used with natural mordants such as alum and harda, the dye uptake and fastness properties improve considerably [6]. The extract also acts as a mild mordant itself, aiding the binding of other natural dyes to cellulose fibers [6].

The standard extraction method involves boiling crushed leaves or fruit pulp in water or ethanol, concentrating the filtrate, and applying it via padding or spraying [6]. Bio-binders such as pectin and guar gum are often used to enhance the fixation of actives on the fabric surface [6]. Durability studies have shown that the functional properties of Vilvam-finished fabrics can withstand up to 10 washes, depending on concentration and binder selection [6].

Consumer trials have highlighted the cooling and soothing sensation offered by Vilvam-treated textiles, with additional notes on reduced body odor and improved fabric breathability [6]. Its hypoallergenic nature makes it suitable for people with sensitive skin or allergies, and its spiritual relevance enhances its appeal in ethnic and ritualistic clothing lines [6]. As the demand for holistic, natural lifestyle products grows, Aegle marmelos stands out as a culturally resonant and environmentally sound herbal finishing agent [6].

Research is ongoing to enhance its dyeing performance and optimize its combination with other plant-based finishes for synergistic effects [6]. With an abundant supply across India and low cultivation input requirements, Vilvam presents an economically viable and ecologically beneficial ingredient for Ayurvedic and sustainable textile development [6].

III. Conclusion

Thus the reviewed about the some of the ancient herbs available in India and its application purpose in the textile industry. It will upgrade the textile industry to sustainability and ecofriendly finishes.

IV. References

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