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Nettle Fiber: The eco-friendly resurgence in sustainable fashion

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Abstract
Sustainable fibres are the need of the present and future. A number of alternative fibre options have been explored in recent times to enhance the sustainability quotient of the textile industry. While some of the sustainable plant fibres have been in use in the past, they had lost out to more commercially viable fibres. The environmental crisis has brought many of these traditional fibres into limelight. However, not all of them are ready for commercial scale use. This review paper covers the present status and future prospects of nettle, which not only has all the qualities of an environmentally friendly material but also has recently caught the attention of the fashion industry. The review aims at providing an overview of the recent developments in the cultivation, extraction and value addition of nettle fibres with special reference to the Indian context.

Keywords: Nettle fibre, sustainable plant fibre, stinging nettle, Himalayan nettle

1. Introduction
Plant fibres are sustainable because of the renewable nature of their crop cycles. Nettle fiber, which falls under the category of Bast Fibres, are located in clusters situated just beneath the external bark of the nettle plant [3]. It is an abundant and sustainable plant that provides useful fibrous materials. Nettle fiber, comprising 19-21% of the stem, is finer, more flexible, pleasant, and stronger compared too many other bast fibers [2].

1.1 Main Varieties of Nettle and their habitats
Nettle fiber belongs to the *Urticaceae* family and is derived from two textile-producing species, namely *Urtica dioica L.* and *Girardinia diversifolia*, among the 63 species within the genus *Urtica*. *Urtica dioica L.*, also known as the European nettle or stinging nettle, due to the presence of small hairs or spikes on its leaves that cause discomfort upon contact with the skin, is found naturally growing in Europe, Africa, Asia, and North America [23]. The name "Nettle" may have originated from the Anglo-Saxon word "*noedl*," meaning needle, while "*Urtica*" comes from the Latin term meaning "to burn," referring to the burning sensation caused when touching the plant. The name "*Dioica*" signifies that male and female flowers are found on separate plants [34]. All of these species yield fiber from their stems, and interestingly, there is no remaining sting in the extracted fiber. The plants typically grow to heights ranging from 1 to 3 meters [24]. The fibers extracted from Stinging Nettle were utilized by Native Americans and Europeans to make sailcloth, sacks, ropes, and fishing nets. Furthermore, these fibers were also made into fabrics with a silky linen like feel [26].
Girardinia diversifolia, another nettle species, also known as Himalayan nettle, is abundantly present in the Himalayan region - from Uttarakhand to Sikkim in India [32]. It is also found in Nepal, Bhutan, China, Indonesia, Korea, Malaysia, Sri Lanka – in Asia, and Africa. This wide distribution reflects the adaptability and prevalence of the Himalayan nettle in diverse geographical regions [24, 34].
The Himalayan nettle plant is known by various names: Bichchhoo in Hindi, Indian stinging nettle in English, Bhangre sisnu and Allo sisnu in Nepali, and Kuju in Lepcha. It thrives in a variety of habitats, including forest margins, shady moist areas, along streams, ecologically disturbed places, near villages, waste grounds, and shrubberies. It is naturally found at altitudes ranging from 300 to 2800 meters above sea level [34]. Local communities primarily use Himalayan Nettle fiber for making ropes or fabric using hand-spun yarns [23].

Fig 1: Nettle Plant

1.2 Composition and Morphology of Nettle Fibre

Fibre constitutes 19-21% of the stem of the Nettle plant, with 70% of these being primary long fibers [28]. However, on a dry weight basis, the fibre content of the stem drops to 3.5-13.2%. Like other plant fibers, Nettle fiber is composed of cellulose, hemi cellulose, lignin, fats, waxes, pectin, and ash. Since lignin and hemicellulose considered detrimental to textile processing, they are eliminated through the process of degumming [24]. After degumming, the fibre has 11% moisture, 67% cellulose, 8% hemicelluloses, 4% lignin and 3% ash. The Indian fiber consists of 7% moisture, 90% cellulose, and 1.5% ash [23, 26].

The fiber bundles, visible as a thin layer of less than 100mm, are situated on the outer perimeter of the stem [4]. The morphology of nettle fiber features a hollow cavity with a wide lumen in the middle of a cross-section varying from polygonal to kidney shape, with thin walls. The surface of the fiber contains micro-grooves connected with the hollow center through holes that enhance its surface area. The hollow core of nettle fiber makes nettle a versatile fibre suitable for both warm and cold conditions [4, 23, 24]. The average diameter of the fibre is 19.9 µm (± 4.4) [4], and have lengths of 5-75 cm. Other properties include a moisture content of 12.3%, dry tenacity of 0.4-0.6 N/tex, and a breaking extension of 2.0-2.5% [28].

1.2 Brief History of Nettle Fiber

Nettle has a long history of being used as a fiber source worldwide. Archaeological findings, such as burial shrouds made of nettle fabrics in Denmark, date back to the Bronze Age (3000-2000 BC). Notably, nettle cloth was discovered in the Voldtofte grave in Denmark, where it was used to wrap human bones, dating back to between 900 and 750 BC [24, 26].

There is evidence of nettle cloth production in Scandinavia, Poland, Germany, and Russia. However, nettle fiber and textile production were not as widespread as flax and hemp, except in northern, central, and Eastern Europe. Nettle's popularity declined with the arrival of cotton in the 16th century, as cotton was easier to harvest and spin. In Poland, up until the 17th century, nettle thread was commonly used before silk took its place. Meanwhile, nettle fabric remained in production in Scandinavia and Scotland until the 19th century, where it was referred to as Scotch cloth [25].

During World War I, the German Empire used nettle fabric as a substitute for cotton due to textile shortages. Captured German uniforms were found to be made of 85% nettle fiber. However, nettle processing facilities were destroyed during World War II, and other cost-effective fibers became more available [25]. Germany and Austria pioneered commercial nettle farming during the 19th century. In the early 20th century, Germans found that a blend of nettle with 10 percent cotton, resulted in creating superior quality fabric, underclothes, stockings, and tarps. Fishing nets were also largely constructed from nettle twine [30].

The properties inherent in nettles have sparked a renewed interest in their usage for fiber production in the 21st century. They are relatively simple to grow in temperate climates that receive adequate rainfall and are found naturally in diverse regions around the globe. Their perennial life cycle eliminates the necessity for repeated sowing and plowing. Moreover, nettles have the capability to flourish even on lands that are marginal and polluted with organic or inorganic contaminants. This potential for growth in challenging environments could help minimize hazards to humans, water sources, and ecosystems, thus establishing nettles as an eco-friendly option for fiber production [19, 33].

2. Research Objectives

Keeping in view the importance of Nettle as a sustainable textile fibre option, this review paper aims to provide an overview of the emerging trends in this area, with the following specific objectives:

- To explain the importance of Nettle in enhancing the eco-friendliness of textiles.
- To review the different fibre extraction and property enhancement processes.
- To highlight the special significance of Nettle fibre in the Indian context.
- To describe the trends in the adoption of Nettle in the fashion industry.

3. Methods and Materials

This review paper makes use of 34 scholarly articles and documents, sourced from various research databases like Research Gate, Open Science, Science Direct, Academic.edu, Core, Google Scholar, and Search engines. Search for research papers was done using key words such as sustainable plant fibre, Nettle fibre, Nettle fibre in India, Stinging nettle, Himalayan Nettle, Nettle fibre properties, Netlle garments. Included in this review are a number of previously conducted review articles on the topic, effectively expanding the scope of the current review to encompass more than 300 papers. The 34 articles were carefully chosen from a larger collection of 42, based on their relevance and alignment with the research objectives.

A significant feature of the current review is the focus on the importance of Nettle in the Indian context. These papers cover contrasting settings of Stinging Nettles of Europe and Himalayan Nettle of India. The retrieved research papers were also further grouped based on their research goals keeping in view the specific research objectives of this review paper.

4. Survey of Results and Discussion

The different studies included in this review have covered a wide variety of important themes around sustainable nettle fibers. The salient aspects are discussed below.

4.1 Importance of Nettle in enhancing the eco-friendliness of textiles

Nettle fibers are anticipated to be a key player in the upcoming green economy, which emphasizes energy efficiency, lower carbon emissions, and recyclable materials to cut down on waste. As natural fibers, they are renewable and carbon-neutral, as they absorb the same amount of CO_2 as they emit. Nettle provides a sustainable, eco-friendly, and biodegradable alternative for textile production. It also consumes less energy during its manufacturing process [9, 24].

Stinging nettle, a versatile perennial plant, requires minimal fertilizer and pesticide, flourishes in diverse climates and

supports local biodiversity. The growth of this plant could answer the increasing call for sustainable plant fiber substitutes in sectors such as textiles. The emphasis on nettle is motivated by the search for eco-friendly crops and concern about the environmental consequences of cotton farming, which is highly dependent on water resources and chemicals [33]. Recent research indicates that nettle fibers, due to their outstanding and appropriate textile qualities, can serve as substitutes for cotton fibers in a range of applications [1].

From the late 1990s, stinging nettle has experienced a resurgence in attention, with initiatives taking place in countries such as Germany, Austria, Finland, France, Italy, Lithuania, and Luxembourg. The ERA-NET SusCrop NETFIB project has set its sights on developing innovative methods of producing nettle fiber on less fertile lands. SusCrop is an initiative under the Horizon 2020 program, operating as an ERA-Net Cofund Action. Its primary goal is to bolster the European Research Area (ERA) in sustainable crop production. This aims to cater to the increasing need for sustainable fibers and alleviate strain on agricultural land [33].

Nettle plants are recognized not just for their utility as fibers, but also for their diverse applications, including their notable medicinal qualities. The objective is to take advantage of the entire plant in adherence with the no-waste principles of sustainability, investigating various uses to optimize resource efficiency [3]. The multifaceted nettle plant indeed has a broad spectrum of uses. Its wooden stem is employed in the paper industry, while its leaves and flowers are used as vegetables. It is also used as fodder for livestock, a material for bedding, and a fuel source (Table 1). Furthermore, its unique properties allow it to be used in dye production as well [11]. Nettles can be utilized as a source of dye, with the roots yielding a yellow color and the leaves producing a yellowish-green tint [28].

During World War II, the British government made a requisition for 100 tons of Nettle fiber. This was primarily intended for the production of green dye used in camouflage [26].

Table 1: Uses of the various parts of Nettle plant [24]

Material	Uses
Long bast fibre of exceptional strength	Textile manufacturer
Wood fibres	Paper making
Leavulose	Sugar that can be used in food
Chlorophyll	Medicinal purposes
Powdered leaves	Cattle feed

Nettle offers both economic and ecological benefits by providing top-quality textile fibers and food in one harvest. Traditional fiber processing yields soft, flexible fibers suitable for fine textiles. Additionally, the wastewater produced during this process can be a source of natural colorants, which can successfully dye cotton and wool in various shades, from beige to green, depending on the mordant used. Ultimately, nettle processing can promote recycling and sustainability in farming, creating diverse production and livelihood opportunities [20].

4.2 Fibre Extraction and Property Enhancement Processes

Nettle plants typically grow once a year, with growth starting from July-August and ready for collection from October-January [23]. Nettle stems, which are harvested three to five months after germination, are left to dry in the sunlight for 10 days. However, this drying period cannot be excessively long, as sunlight can damage the fibers and decrease their strength. Moreover, the chemical composition of nettle plant parts changes as they mature [2].

The overall process of extracting nettle fibers can be broken down into five main steps: Harvesting, retting, decortication, separation, and refining [33]. The nettle fiber extraction process involves manual or machine harvesting, followed by retting to separate fiber bundles from the core. Bast fibers, which are found inside the stem, are often held together with pectin, a type of carbohydrate. These fibers can be extracted via a process called retting, which breaks down the pectin, allowing the fibers to be separated from the surrounding plant material [28]. Retting is a carefully controlled decomposition process designed to dissolve the gummy substances that bind fibers together. This can be achieved in a number of ways. In water retting, stalks are immersed in a body of water such as a pond or river, where bacteria naturally degrade the adhesive components. Dew retting involves leaving the stalks in a field for about six weeks for fungi to carry out the decomposition. Chemical retting involves placing the stalks in chemical solutions, often alkali ones. This requires a pretreatment stage, or bioscouring, to remove any impurities in the fiber and a bio softening stage to reduce the fiber's stiffness [25]. Using sodium hydroxide extraction enhances mechanical interlocking, surface roughness, cellulose content of the fiber and the tensile strength, besides reducing water absorption in fibrous materials [13]. Some nettles are processed without retting [34]. A 2016 study reports the development of a cost-effective, energy-efficient, environmentally friendly wet process for degumming nettle fibers and spinning them at room temperature, without requiring the need for scraping, scrubbing, or pounding, yields finer, cellulose-rich nettle fibers that can be spun into fine yarn (60 tex and below), making it an attractive option for potential users [22].

Decortication involves manual or machine methods to separate the outer skin from the inner wooden material of the stem [33]. Initially, the stalks are broken, followed by scraping or scotching to remove the fibers. Hackling, which involves combing, is employed to further separate the long fibers from the short ones and to eliminate any remaining woody material. These processes result in purified nettle fibers ready for various applications in textile production or other industrial uses [2, 25, 28, 33]. Once separated, fibres can be spun in to yarns and woven into textiles, or overlaid to make high quality pulp [2].

Nettle blended with organic cotton and bamboo, in varying ratios, can create fabric suitable for a range of applications such as home textiles, technical uses, fiber composites, and handmade goods. Compared to control fabrics made solely from either 100% organic cotton or bamboo, their blends with nettle showed enhancements in properties like abrasion resistance, strength, and elongation [25]. Blending Himalayan Nettle fiber with Viscose enhances the softness of both the resultant yarns and fabrics, although a slight decrease in strength is noticed due to the introduction of viscose. The 25/75 nettle/viscose blend showcases satisfactory overall properties. This suggests the nettle plant's potential as a viable source of fiber for apparel textile production [21]. Nettle fiber has the potential to be blended with other fibres such as wool, cotton, flax, ramie and viscose, among others. These blends can be used in the creation of sustainable fashion apparel and luxury textiles products [25].

The use of natural dyes cutch (*Acacia catechu)* and madder (*Rubia cardifolia)* offers woven nettle fabric superior protection against UV rays, even in the absence of mordanting [18]. Another research explored the enhancement of antibacterial and wrinkle-resistant attributes of 100% nettle fabrics via specific finishing processes. 1, 2, 3, 4-

butanetetracarboxylic acid (BTCA) and sodium hypophosphite (SHP) were employed for wrinkle resistance, while chitosan enhanced antibacterial properties. Optimum results were achieved with 6% BTCA, which also improved fabric softness when combined with chitosan, albeit with minor strength loss [1].

4.3 Special Significance of Nettle Fibre in the Indian context

India has recognized the significance and potential of the naturally occurring nettle plant found in the Himalayan region as a valuable natural fibre resource [19]. The Himalayan Giant Nettles, *Girardinia diversifolia* are abundantly present in the Himalayan foothills, extending from Uttarakhand to Sikkim [32].

Uttarakhand has been recognized as an Indian state which has significant potential for Nettle [26]. The traditional Nettle fibre craft, thrives among the Bhotiya community of Uttarakhand [8]. The nettle fiber continues to be utilized by local villagers residing near the available areas to create and cherish the handcrafted products using age-old traditional methods [32]. Nettle as a traditional craft of Uttarakhand is also emerging as employment generating activity now [8].

Based on initial surveys conducted by the Uttarakhand Bamboo and Fiber Development Board and other NGOs like the Himmothan Society, it was found that three blocks in Chamoli district, Uttarakhand, have approximately 770 square kilometers of naturally growing Himalayan Nettle, *Girardinia diversifolia*. This abundant resource can potentially yield 24,704.26 tons of raw dried fiber annually [26]. Despite receiving orders for fiber or yarn from both Indian and international design houses, the order amounts often fall short of expectations. As of now, there is a need to improve processing and grading fiber [8]. Current techniques for extracting Himalayan nettle fiber are labor-intensive and complex, involving challenging harvesting due to the plant's stinging hairs and time-consuming retting and degumming processes. This makes traditional nettle fiber production strenuous [32].

Under the secure Himalaya project, the Uttarakhand Bamboo and Fiber Development Board initiated a collaborative research project to explore and optimize the potential of nettle fiber. It found that hand combing yielded around 50-60% fiber, a figure that could be significantly increased by using appropriate machinery. Although enzymes were used to soften the fiber, they inflated the cost, indicating room for substitutions. The study recommends applying the same processing methods to other unconventional fibers, reducing environmental impact through reuse and recycling, and introducing value-additions such as dyeing fibers with natural dyes. It also highlighted the benefits of training local communities, NGOs, and Self-Help Groups in optimized fiber processing [32]. A Swiss company seeking to produce nettle-based goods has requested the Uttarakhand Bamboo and Fibre Development Board for a supply of six tonnes of raw Himalayan nettle grass annually. This potential collaboration could offer significant employment opportunities for youth and women in the nettle production sector [7].

An Awareness Workshop with a focus on Nettle Fibres, organized in 2021, by the Indian Council for Agricultural Research (ICAR)-National Institute of Natural Fibre Engineering and Technology in collaboration with the Raybaar Samiti emphasized the need for technological interventions to enhance fibre extraction, yarn making, coloration, and product development [10]. Maheshwari Khati, a skilled artisan from Bhimtala, Chamoli District, Uttarakhand, manages a weaving center specializing in handloom products. Her center crafts items using both wool and nettle fiber, in addition to producing carpets [14].

The Lepchas, as the indigenous people of Sikkim, possess remarkable technical knowledge of the Nettle plant and have been used as a source of fibre for making clothing and accessories. In Sikkim, the harvesting period mostly falls during October and November months. It is during this time that the stems are at the appropriate stage for extracting the fibers effectively [34].

The Lepchas use a traditional method to extract and soften nettle fibers. The process begins with harvesting semi-matured stems, peeling off their green bark, and drying them until they become breakable. The dried bark is then washed until creamy white fibers are exposed. To soften the fibers, they are treated with local white soil and dried again. A degumming process involving boiling the bark with soap or wood ash follows. The fibers are then treated with a wooden paddle to remove any remaining bark before spinning them into yarn and transforming them into fabric. The nettle yarn is used to create various products like bags, shawls, and stoles [34].

Recent skill development programs organized by the Khangchendzonga Landscape Conservation and Development Initiative (KLCDI)-India focused on nettle fiber product creation and value addition. Fifteen women from Self Help Groups (SHGs) in Dzongu were trained in nettle fiber making, yarn making, and fabric production by the local expert [34].

Mixing nettle yarn with other materials such as cotton, sun hemp, angora, or yak wool can lead to a diversified range of textiles. These enhanced products, promoted as handicrafts from the Lepcha community, can tap into the thriving tourism industry of the region, resulting in socio-economic advantages for the local communities engaged in the production of these handicrafts. Training from Nepalese women has also revitalized the craft, introducing new designs and eco-friendly extraction methods, which has generated supplementary income for the women, selling popular nettle bags and hats as souvenirs to tourists in Sikkim [12].

In order to increase the visibility of nettle yarn-based products and empower female entrepreneurs, NIHE-SRC, with the backing of various organizations, displayed these fabrics at events like the Asian Rural Tourism Festival and World Mountain Day celebrations. Despite receiving positive feedback, additional efforts are required to mainstream their market use. While nettle yarn fabrics form a part of Sikkim's traditional dress, effective marketing is key to their commercial success [34].

A significant development which shows the way forward for substantial increase in nettle fibre use in India is the Enterprise development Project. As part of the project, 80 kg of nettle seeds were collected and sown across 95 hectares in Van Panchayat and community lands within 8 clusters. A remarkable 75% seed germination rate was observed. Subsequently, a total of 17,508 kg of nettle, hemp, and bhimal fibers were harvested and processed as a result of the project's efforts [31]. This project clearly establishes the feasibility of growing nettle as a commercial crop and creating a sustainable supply chain for the textile and clothing industry.

4.4 Trends in the Adoption of Nettle by the Fashion Industry

The global textile industry is seeking alternative and

sustainable natural fiber sources to reduce its dependency on cotton, jute, hemp, flax and silk. Designers, manufacturers and retailers are looking out for new raw materials and processes that will entice the consumers to walk into their retail outlets [19]. Recent trends in the fashion industry clearly point to the renewed interest in the use of nettle as a fashion fibre.

In 2019, British designers vin + Omi were gifted 3000 nettle plants from Prince Charles' royal gardens at Highgrove to create eco-conscious, high-end clothing. Showcased at London Fashion Week in spring 2020, their Sting collection included garments made from these nettles. Vin + Omi used traditional methods of making woven material from nettles while introducing an eco-friendly mercerization to lighten the fibers. The collection revealed the potential of nettles as a sustainable, versatile textile for the fashion industry [33].

Fig 2: Nettle dress by Vin + Omi [33]

Camira Fabrics, a British textile company has developed a range of nettle fabrics, StingPLUS in collaboration with De Montfort University under a project of the Department for Environment, Food and Rural Affairs in the United Kingdom. This collection comprises recycled, renewable, compostable, or climate-neutral fabrics, suitable for upholstery applications. The project encompassed research on nettle cultivation, fiber extraction, processing, blending, weaving, and dyeing, as well as technical performance evaluation and life cycle assessment [5, 15].

In the new millennium, several International fashion labels and brands have joined the nettle bandwagon. Netl, a fashion brand from the Netherlands, joined forces with designer Rianne de Witte to release their first collection, showcasing clothing with vibrant colors and geometric patterns, made from a blend of 75 percent cotton and 25 percent nettle yarns [27]. Fashion designer Gesine Jost created a collection from nettles, resulting in garments that are both soft and lustrous [16]. In 2004, the Florence-based fashion brand Corpo Nove debuted jeans made from nettle yarn, which were enthusiastically received at Selfridges, a renowned retail store [27]. Pangaia, a New York based Lifestyle brand unveiled a nettle denim collection in collaboration with Candiani Denim and Himalayan Wild Fibers in October 2021. The collection created used a fabric blend of Indian organic cotton and Himalayan nettle, exemplifying slow fashion with its long-lasting garments woven on slower shuttle looms. Comprising a unisex '90s-style denim jacket, unisex straight-leg jeans, and women's high-rise jeans, the line was produced utilizing a water-conserving dyeing process [6].

The community in Khar, Dharchula district, Nepal, produces high-end Himalayan Nettle products like mufflers, stoles, bags, and mats, which are sold in local and international markets. These products, often blended with ramie, cotton, or wool, have garnered significant attention [11]. Several Online stores in India (biswabangla.com, gocoop.com, vrittidesigns.com, aslee.com) and abroad (Knokkon.com, Etsy.com, kiron.com, ehun-naturalak.com, kalamulur.com) are also already selling nettle yarns, fabrics as well as finished products like dress, shawl, scarf, Cardigan, t-shirts, ponchos, skirt, tunics, sweater, nettle-linen saree, Jackets online. Nettle based accessories sold online include Pencil case, tote bag, cushion cover, bedlinen and towels. Biswabangla online store is operated by the Govt. of west Bengal under the Department of Micro, Small and Medium Enterprises and Textiles to facilitate market linkage for products, handmade or otherwise traditionally produced by the different indigenous communities. Their nettle products are also available in other online ecommerce stores.

A moving tribute to the resurgence of nettle is paid by the documentarian Dylan Howitt who has captured the journey of Textile artist Allan Brown, who devoted seven years to make a dress solely from the fiber of locally acquired stinging nettles, in a 2023 documentary film, “The Nettle Dress” [29].

5. Conclusion

What the foregoing review suggests is that the nettle fibre has proved its credentials as a completely sustainable and eco-friendly fibre, which is also knocking at the doors of the fashion industry. The abundant availability of Himalayan nettle provides an opportunity to India to accelerate the adoption of nettle as a commercially viable alternative to popular fibres, that are not so eco-friendly. The biggest challenge is however, in taking forward the sporadic initiatives already taken by a few states and organisations and promote large scale cultivation. What is to be noted is that the technological processes already developed are at the lab stage or applied only on a small scale. It is time to give the nettle, a big push to facilitate its, mass cultivation, production and marketing.

6. References

1. Arık B, Yavas A, Avinc O. Antibacterial and Wrinkle Resistance Improvement of Nettle Biofiber Using Chitosan and BTCA. Fibres and Textiles in Eastern Europe. 2017;25, 3(123):106-111.
2. Asmare Tadele. Effect of maturity on fundamental properties of Nettle fibre. Journal of Textile and Fashion Technology (JTFT). 2012;3(1):1-10.
3. Barlow Claire Y, Neal Daniel. Fibre from stinging nettles.

https://www.ifm.eng.cam.ac.uk/uploads/News/Fibrefrom stingingnettles.pdf
4. Bodros E, Baley Christophe. Investigation of the use of stinging nettle fibres (Urtica Dioica) for polymer reinforcement: Study of single fibre tensile properties. 2008;
5. Camira Sting - environmental fabric made from nettles. https://cms.esi.info/Media/documents/Camira_sting_ML.pdf
6. Candiani Denim and PANGAIA launch the first nettle denim. https://www.candianidenim.com/en/hub-activism/candiani-denim-e-pangaia-lanciano-il-primo-denim-in-fibra-di-ortica/14
7. Eye on European market, Uttarakhand promotes Himalayan nettle grass goods
8. Hindustan Times, Dehradun. Roy Suparna. 17 Sep 2017. https://www.hindustantimes.com/dehradun/eye-on-european-market-uttarakhand-promotes-himalayan-nettle-grass-goods/story-22rvjhotKE8pQPmjxhUp3I.html
9. Ganeshgudi Abhishek, Patel Bhavin. Understanding Reasons of Slow Growth in Development of Traditional Fibre Craft "NETTLE" Industry of Uttarakhand. International Journal of Research in Engineering, Science and Management. 2019;2(9):23-27.
10. Garg Neha, Saggu Harinder, Brar Kanwaljit. Physical and mechanical properties of cotton/nettle union fabrics. Asian Journal of Home Science. 2018;13(1):261-264.
11. ICAR-NINFET organized workshop on Potential of Natural Fibres in Uttarakhand.
12. http://www.nirjaft.res.in/Newsboard/views/327/1 23 October 2021.
13. Joshi Nidhi. Himalayan Nettle –Amazing Wild Plant from Sub-Himalayan Region. Just Agriculture. 2023;3(4):1-5.
14. Kangchenjunga Landscape Conservation and Development Initiative, How a cross-border exchange helped revive a traditional craft.
15. https://www.icimod.org/how-a-cross-border-exchange-helped-revive-a-traditional-craft. 23 Dec 2018.
16. Kumaresan K, R Deepa, K Kumaresan, K Saravanan. Effect of surface chemical treatment of himalayan nettle and investigation of surface, physical and mechanical characteristics in treated nettle fibre. Archives of Metallurgy and Materials. 2023;68(2):571-578.
17. Nettle Fabric Craft Traditions From Uttarakhand, https://artsandculture.google.com/story/nettle-fabric-craft-project-fuel/ZAURke4dMAguqQ?hl=en
18. Nettles for Cloth and Sustainable Texiles by Rebecca Alexander. https://arboretumfoundation.org/wp-content/uploads/alexander_nettles-for-sustainable-textiles.pdf. Winter 2022.
19. Nettles instead of cotton - designers are looking for new fibers. https://fashionunited.de/v1/leads/brennnesseln-statt-baumwolle-designer-suchen-neue-fasern/20141118449218 Nov 2014
20. Nettle plant (Girardinia diversifolia) fibre extraction and yarn making – Technical Manual. July 2020. https://lib.icimod.org/record/34867
21. Pargaia Deepti, Gahlot Manisha, Rani Anita. Ultraviolet protection properties of nettle fabric dyed with natural dyes. Indian Journal of Fibre & Textile Research. 2016;41:418-425
22. Radhakrishnan Shanthi. Development of Fabric from Girardina Diversifolia Stem Fibres and its Blends. International Journal of Innovative Research in Science, Engineering and Technology. 2015;4(11):1111-1118.
23. Sadik S, Toukola P, Räisänen R. Zero waste nettle: Process optimization to refine nettle (Urtica dioica) into multi-purpose materials. Textile Fibres and Colorants. Acta Hortic. 1361, 181-188
24. Samanta Kartick, Roy Alok, Baite Haokhothang, Debnath Sanjoy, Ammayappan Lakshmanan, Nayak L, *et al.* Properties of Himalayan Nettle Fiber and Development of Nettle/Viscose Blended Apparel Textiles. Journal of Natural Fibers. 2023;20(1):1-17.
25. Sett Sunil, Ghosh Bijay, Banerjee A, Ray Deb, Mukherjee P. Studies on the Extraction and Properties of Himalayan Giant Nettle. Textile Research Symposium at Indian Institute of Technology, Delhi; c2016.
26. Sett Sunil, Ray Sadhan, Mukherjee A. Processing of Himalayan Giant Nettle (*Girardinia Diversifolia*) and its Potential use in Textile Products. International Conference on Natural Fibres; c2014.
27. Sinha Sujit, Sharma Akshay, Maity Subhankar. Thermal Resistance and Moisture Management Behaviour of Nettle/Polyester Nonwoven Fabrics. Tekstilec. 2019;62(4):258-268.
28. Singha Atul, Nayak L, Ammayappan Lakshmanan, Roy Alok, Samanta Kartick, Baite Haokhothang. Applications of Nettle Fibre in Textile: A Brief Review. International Journal of Bioresource Science. 2021;08(01):39-45.
29. Srivastava Nupur, Rastogi Deepali. Nettle fiber: Himalayan wonder with extraordinary textile properties. International Journal of Home Science. 2018;4(1):281-285.
30. Sustainable Textile Innovations: Nettle Fibres. Simone Press. https://fashionunited.uk/news/business/sustainable-textile-innovations-nettle-fibres/2017080725413 7 Aug 2017.
31. Tadele G. A. Separation and Characterization of Ethiopian Origin Nettle Fiber. International Journal of Engineering Research & Technology (IJERT). 2016;5(3):259-262.
32. The Nettle Dress. https://www.nettledress.org/
33. Two Burning Houses: A Natural History of Stinging Nettle, https://blog.ncascades.org/naturalist-notes/two-burning-houses-a-natural-history-of-stinging-nettle/ 20 October 2015.
34. Uttarakhand Bamboo & Fiber Development Board Dehradun Annual Report 2019-20.
35. https://ubfdb.org.in/uploads/annual-reports/annual-report-2019-20.pdf
36. Uttarakhand Bamboo & Fiber Development Board Dehradun Annual Report 2020-21.
37. https://ubfdb.org.in/uploads/annual-reports/Administrative-Report-2020-21.pdf
38. VIN + OMI. An exploration of new UK plant based textiles produced by Studio VIN + OMI https://www.vinandomi.com/ss20-sting
39. Viotti Chloé, Albrecht Katharina, Amaducci Stefano, Bardos Paul, Bertheau Coralie, Blaudez Damien, *et al.* Nettle, a Long-Known Fiber Plant with New Perspectives. Materials. 2022;15(4288):1-35.