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The utilisation of Himalayan Nettle (*Girardinia diversifolia)* plant for development of UV protective textiles: A new perspective of a traditionally used plant

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The Himalayan nettle (*Girardinia diversifolia)* plant has been traditionally used to make various fibre-based products such as sack, rope etc. but with this fast-moving technological era, new developments and researches are required to meet the demand of present so that it could also be made commercially viable. Presently UV radiation causes various skin problems including skin cancer. The present study explores the fabric properties of woven fabrics made of Himalayan nettle (*Girardinia diversifolia*) fibre for new end uses to protect the skin from harmful UV radiation. Nettle Yarn was procured from Kraftloom Overseas Private Limited, Dehradun. Twill and crepe weave fabric were prepared using handloom at Kumaon woollens, Haldwani. Physical properties and Ultraviolet Protection Factor (UPF) of the developed woven fabric were studied at textile testing lab of G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. Based on results it was found that properties of nettle woven fabric like thickness, weight, thread count and cover factor affected the UPF of the nettle fabric. It was also found that ultraviolet protection properties of nettle woven fabric could be enhanced through weave variation. Ultraviolet protection properties of fabric made of nettle fibre were explored and reported for the first time which could be utilised for different UV protection products such as curtains, blinds and jackets. Further natural dyeing of developed fabric was also done in another part of the study to maximise the UV protective properties of the fabric.

Keywords: Ultraviolet Protection Factor, *Girardinia diversifolia,* Twill weave, Crepe weave, woven nettle fabric

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Several nettle species in *Urticaceae* produces the textile fibre[1], a particularly known among them is the Himalayan nettle, *Girardinia diversifolia (Link) Fris* (Fig. 1)[2]. The Himalayan nettle has been widely used for extracting bast fibres throughout the Himalayas regions such as Nepal as well as in Uttarakhand[3]. Bast fibres are generally obtained from the stem of the plants by various retting methods and different processing[4]. *G. diversifolia* plant flourishes in the sub-tropical and temperate Himalayas from Kashmir to Sikkim up to 2100 m, in Assam, and the Khasia hills; Burma, Java, and China; and from Marwar and central India to Travancore and Ceylon[5]. While the other fibre producing species of nettle i.e. *Utrica dioica*, flourish in temperate and tropical wasteland areas around the world[6]. The fibres from nettle plant have been utilised for textile for a long time[7]. Various tribal groups are generating livelihood and income by utilising *G. diversifolia* plant for extraction of bast fibre and development of various products such as ropes, porter's tumplines, mats, sacks, and traditional clothing of local community[8]. In

Figure 1 — Himalayan nettle plant

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recent years' considerable attention is being given to these fibres because of the environmental preservation as these fibres do not release any harmful substances and are biodegradable in nature in comparison to man-made fibres. Natural bast fibres are also helpful in reduction of greenhouse gaseous and CO_2 neutral production. Among various natural fibres, *G. diversifolia* bast fibres have a lot of potential because these fibres are biodegradable and require little energy to produce and they are extracted from a renewable source. The nettle plants do not require pesticides and herbicides and even water requirement is also very less in comparison to cotton crop[9].

Various new problems are emerging due to climate change. Therefore, it is necessary to develop new approaches to facilitate the use of these natural fibres for innovative applications besides its regular uses. The harmful effect of UV radiation on Humans such as skin cancer is on rise[10]. Lignin is a natural UV absorber and ensures good UV protection. Many natural bast fibres contain lignin in their chemical structure. Nettle fibre also contains 9.3% lignin which is more in comparison to other bast fibres such as ramie, flax and hemp; however, it is less in comparison to that of jute fibre[11]. Hence, keeping in mind these reviews the present research was aimed at designing textiles using Himalayan Nettle fibres for efficient protection against harmful UV radiation, which is not only good for the protection of human being from UV radiation but also safe for the environment. The study was aimed at improving the UV protection properties of nettle fabric, which is biodegradable and safe for the environment. In another part of this study, natural dyeing was also done on this developed nettle fabric for further improvement of UV protection properties of the fabric.

Methodology

Procurement of yarn of *G. diversifolia*

Study was conducted in the year 2014. Hand spun single yarn made of *G. diversifolia* was procured from Kraftloom Overseas Private Limited, Dehradun, Uttarakhand. The procured nettle yarn was tested for physical properties of yarn. Testing was done at the testing lab of G.B Pant University of Agriculture and technology.

Testing of physical properties of *G. diversifolia* yarn

The physical properties of yarn were tested using standard methods. The samples were conditioned at standard atmospheric conditions i.e. 65 ± 2% RH and 27 ± 2° C temperatures prior to testing. The yarn count of nettle yarn was determined in cotton count (indirect system) by using *digi* COUNT, digital balance with software, Twist per inch (T.P.I) was calculated by Eureka Electronic Twist Tester (E.T.T). Testing of yarn evenness was done by using Uster Evenness tester. Breaking strength of yarn sample was calculated by using the skein strand method as described in book of American Society for Testing and Materials[12].

Weaving of *G. diversifolia* fabric

Two *G. diversifolia* fabric samples were prepared using nettle yarn as warp and weft both. The samples were woven using twill and crepe weave on handloom at Kumaon Woolens, Haldwani, Uttarakhand. Graphical representation of the design of twill weave and crepe weave along with drafting, lifting and tie up plan is presented in Figure 2 and Figure 3, respectively.

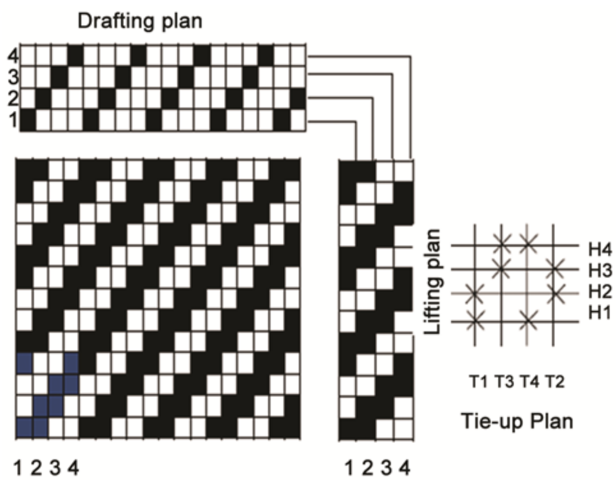

Figure 2 — Graphical representation of twill weave

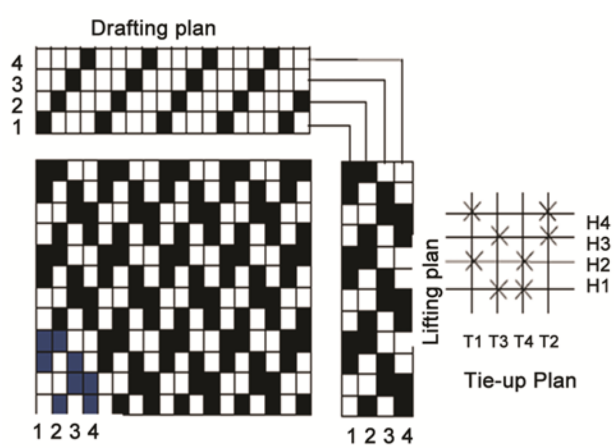

Figure 3 — Graphical representation of crepe weave

During the weaving of fabric primary weaving operations like shedding, picking and beating were followed by secondary weaving operation i.e. taking up and letting off action. Taking up refers to the winding of woven cloth on the cloth beam and letting off is rotating of warp beam for releasing the warp as and when the woven cloth is taken up. After completion of weaving the cloth, the beam was taken off from the loom; the fabric was unwound and folded.

Testing of physical properties and ultraviolet protection factor of woven fabrics

Different fabric properties i.e. fabric count, weight per unit area and thickness and cover factor of the woven nettle fabrics were calculated.

Fabric geometry comprising of fabric count, weight per unit area and thickness and cover factor has a direct and significant effect on UPF. Hence, only these properties of woven nettle fabric were tested. The number of ends and picks per inch of woven fabric i.e. fabric count was counted by using "Pick Glass". The fabric samples were cut with the help of GSM cutter and were weighed on a digital balance, *digi* COUNT for estimating weight per unit area. The thickness of nettle fabric was determined on "Paramount Fabric thickness gauge". The cover factor can be defined as the fraction of the area of the fabric covered by both warp and weft yarns. It is the ratio of the threads per inch to the square root of the cotton count of the yarn. It is calculated from the threads/inch in the fabric and count of the yarn.

The following formula was used to calculate the cover factor

Cover factor, $K = n/\sqrt{N}$,

Where,

n= yarn per inch in warp or weft

N= yarn Count (Cotton count)

In woven fabric, there are two sets of threads and hence two measures of cover factor namely, warp cover factor and weft cover factor can be calculated:

Warp cover factor $K_1 = n_1/\sqrt{N_1}$ weft cover factor $K_2 = n_2/\sqrt{N_2}$

The suffices 1 and 2 are for warp and weft yarns respectively[13]

Hence, cloth cover factor

$K_c = K_1 + K_2 - K_1 . K_2/28$ (ref. 14)

Testing of Ultraviolet Protection Factor (UPF) (AATCC-183: 2006)

UPF of the dyed experimental fabrics was determined by using "SDL UV Penetration and Protection Measurement System (Compsec M 350 UV- Visible spectrometer)". The UPF of each specimen was calculated using the following equation:

$$UPF = \frac{\Sigma E_\lambda \times S_\lambda \times \Delta\lambda}{\Sigma E_\lambda \times S_\lambda \times T_\lambda \times \Delta\lambda}$$

Where,

E_λ = Relative erythemal spectral effectiveness

S_λ = Solar spectral irradiance

T_λ = Average spectral transmittance of the specimen (measured)

$\Delta\lambda$ = Measured wavelength interval (nm)

The UV protection category was determined by the UPF values described by Australian Standards / New Zealand AS/NZS 4399 (1996)[15] given in Table 1.

Results and Discussion

Physical properties of Nettle Yarn

The hand-spun single nettle yarn made of used in the study was tested for various physical properties. Results of the physical properties of the nettle yarn are reported in Table 2.

It is evident from Table 2 that the yarn count of hand spun nettle yarn was found to be 7.22 Ne_c (81.786 tex) which indicates that yarn is finer than the most of the other bast fibres. Madan (2000) reported that the yarn count of single nettle yarn was found to be 154.8 tex that was coarser than the yarn used in this study, as in direct system coarser the yarn, the higher the count.The breaking strength of nettle yarn was 121.66 lb (5400.88 g). The value indicated that the nettle yarn had sufficient strength. Singh (2012)[16] reported that the breaking strength of hemp yarn (bast fibre) was found to be 1963.81g. Yarn evenness was

Table 1 — UPF Classification system

UPF range	UVR Protection category	UPF ratings	% UV radiation blocked
15 – 24	Good protection	15, 20	93.3-95.9
25 – 39	Very good protection	25, 30, 35	96.0-97.4
40 - 50, 50+	Excellent protection	40, 45, 50, 50+	97.5 or more

Table 2 — Physical properties of Nettle Yarn

Yarn properties	Values
Yarn count	7.22 Nec (81.786 tex)
Breaking strength (lb)	121.66
Yarn twist (TPI)	5-6
Yarn evenness (number of neps/km)	6196

measured in terms of number of neps/km length of yarn. It is evident from the Table 2 that number of the neps found per km length of nettle yarn was 6196. More number of neps in nettle yarn may be attributed to the reason that nettle yarn was prepared by hand spinning method and hand spinning is a manual process in which parameters cannot be controlled fully as in case on machine spinning. Hence, yarn showed more number of neps and was not uniform throughout its length. It is clear from Table 2 that nettle yarn had 5-6 turns per inch (TPI). More number of neps in nettle yarn may be attributed to the reason that nettle yarn was prepared by hand spinning method and hand spinning is a manual process in which parameters cannot be controlled fully as in case on machine spinning. Hence, yarn showed more number of neps and was not uniform throughout its length.

Physical properties and UPF of woven nettle fabrics

Numerous studies had focused on different fabric constructional parameters which represent the fabric structure the best and have direct and significant effect on UV protection. Such role has been given to fabric cover factor, fabric open porosity, fabric mass, fabric thickness etc[17].

The fabric samples were prepared on handloom using nettle yarn in twill weave and crepe weave. The woven samples are shown in Sample Sheet 1 (Fig. 4).

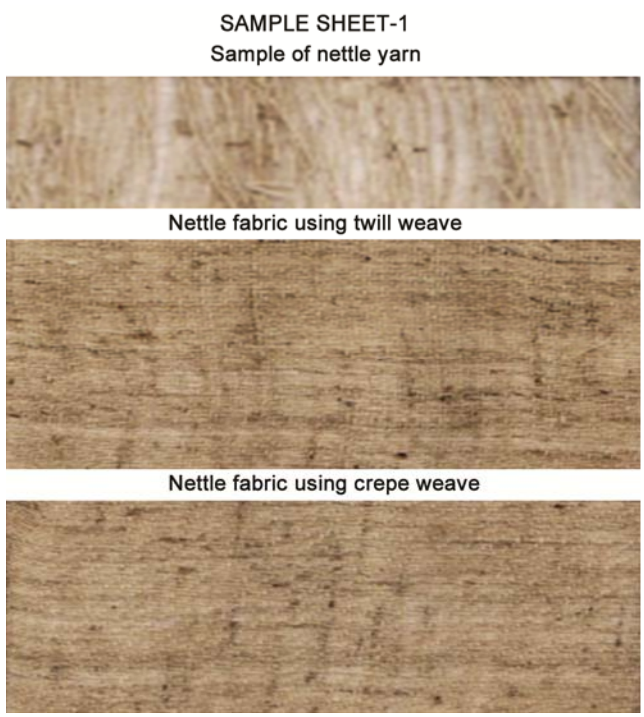

Figure 4 — Sample of nettle yarn and fabric

These woven samples were tested for different fabric properties namely fabric count, weight per unit area, thickness and cover factor. These fabric properties have a direct and significant effect on UPF, hence only these fabric properties of nettle fabric were taken into consideration in the present study. Result of fabric properties is reported in Table 3.

It is clear from Table 3 that twill weave fabric had 22 ends and 25 picks per square inch while crepe weave fabric had 22 ends and 35 picks per square inch. Both the fabrics had an equal number of ends but the number of picks differed. There was a significant difference in picks per inch of woven nettle fabrics at 5% level of significance.

It can be inferred from Table 3 that the crepe weave fabric had more weight i.e. 244.96 g/m^2 as compared to twill weave fabric with a weight of 173.62 g/m^2. There was a significant difference in the values of the weight of woven nettle fabrics at 5% level of significance.

Thickness values given in Table 3 indicate that crepe weave fabric had more thickness i.e. 0.89 mm as compared to twill weave fabric with a thickness of 0.71 mm. There was a significant difference in the thickness of woven nettle fabrics at 5% level of significance

It is clear from the data that the crepe weave fabric had more cover factor i.e. 21.459 as compared to twill weave fabric having cover factor value of 17.728. There was a significant difference in the cover factor of both the woven nettle fabric samples at 1% level of significance

The woven nettle fabric samples were also tested for its ultra violet protection property and the result was obtained in terms of UPF rating. As evident from the results that the crepe weave fabric showed higher UPF rating i.e. 16.9 (good protection category) as compared to twill weave fabric with 13.0 (average protection category) UPF rating. There was a significant difference in UPF of woven samples at 1% level of significance.

The crepe weave fabric had more number of picks per inch though it was made on the same loom setting

Table 3 — Properties of woven *G. diversifolia* fabrics

Properties	Twill weave fabric	Crepe weave fabric
Fabric count (warp X weft)	22 x 25	22 x 35
Fabric weight (GSM)	173.62	244.96
Fabric thickness (mm)	0.71	0.89
Cover factor	17.728	21.459
UPF	13.0	16.9

(drafting plan) as that of twill weave fabric but on varying the weave, the number of picks per inch also changed and found to be increased. The crepe weave fabric found to have more weight and cover factor as compared to twill weave fabric because crepe weave fabric had higher thread count i.e. more no. of threads per unit area which increased the weight and cover factor of the fabric. This nettle fabric with higher thread count have lower porosity hence transmits less ultraviolet radiation through the fabric.

It can be observed from the results that the fabric which had more weight and thickness also had higher UPF. Fabric weight and thickness are regarded as important factors affecting UPF. The results of the present study are also in close conformity with the findings of which points out that thicker fabric with more weight offered more protection from the ultraviolet rays[18].

Good UPF value of crepe weave nettle fabric may also be attributed to its close weave structure. In twill weave, the weave pattern in continues while in crepe weave, the weave pattern is somewhat broken hence less chances to absorb UV radiation, means if the continuity of weave has been broken then there may be less absorbance of UV radiation. Close weave structure relates to high cover factor and crepe weave nettle fabric had more cover factor. Out of two fabrics woven in the present study, the crepe weave fabric was selected for further work based on its higher UPF value.

Conclusion

The crepe weave fabric prepared from hand-spun nettle yarn, had higher values of fabric count, thickness, weight and cover factor as compared to twill weave fabric. UPF rating of crepe weave fabric was also higher (good UPF rating), it can be concluded that fabric weight, thickness and cover factor, influenced the UPF rating. Hence, crepe weave fabric with more thickness and fabric count showed higher UPF rating, which implies that it offers more protection for UV radiation.

Hence, it can be concluded that excellent ultraviolet protection properties were achieved by weave variation. The present study may be useful for designing and development of products such as a hat, curtains and blinds for UV protection using *G. diversifolia* fibre. With the emerging significance and attractiveness of concepts like green, eco-friendly and sustainable, natural fibres seem to have become an obvious choice for progressive producers and consumers of textiles. These products can also help the rural hill population in providing sustainable source of income through commercialization of its products. Further, natural dyeing of developed woven crepe fabric could also be done to increase the UV protection properties of the fabric. This further effort of dyeing would not only protect the human skin against harmful UV rays but also help in diversifying the product range of natural bast fibre.

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Conflict of interest

There is no conflict of interest

Author contribution

DP- writing original draft; MG-supervision and editing

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