Physical Properties of Sacred Lotus (Nelumbo nucifera Gaertn.) Spun Yarns: the Effects of Cultivars and Stem Parts

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ABSTRACT

The objectives of this research were to 1) study the evenness of the sacred lotus spun yarn and 2) study the effects of cultivars and stem parts of the sacred lotus on the physical properties of the lotus spun yarn. The materials used for this study were the stems of two cultivars of sacred lotus flower, namely *Nelumbo nucifera* 'Album Plenum' and *N. nucifera* 'Roseum Plenum', at the age of 3 months. The yarn spinning method applied was jute spinning. The yarns were tested for physical properties according to the method of American Society of Testing Materials Standards (ASTM). It was found that the evenness of the obtained spun yarns was classified as below grade D level. The obtained yarn numbers were 522.65-828.10 tex. The yarns made from 'Roseum Plenum' fibers had higher yarn number than the yarns of 'Album Plenum'. The yarns from upper stem fibers had higher yarn number than the lower stem fibers yarn. The values of tenacity were 1.700-3.020 g/tex. The yarns made from 'Album Plenum' fiber had higher tenacity than the yarns made from 'Roseum Plenum' fibers. Tenacity of lower stem fibers yarn was higher than the yarns made from upper stem fibers. The values of elongation were 1.390-2.098%. The 'Album Plenum' yarns had higher elongation than the yarns made from 'Roseum Plenum' fibers. Lower stem fibers yarn had higher elongation than the yarns made from upper stem fibers. The cultivars of the lotus significantly affected yarn number and tenacity. Parts of lotus stems significantly affected to yarn number, tenacity and elongation. Interaction between cultivars and stem parts of sacred lotus highly influenced to yarn number, tenacity and elongation.

Key words: sacred lotus, spun yarns, physical properties, stem parts

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Introduction

Sacred lotus *(Nelumbo nucifera* Gaertn.) is an ancient aquatic plant that has had connections with human beings since the ancient times and its flower has been used in the Thai society and culture for many centuries especially in Buddhism (Nontapat, 2003). Each part of lotus has some benefits. For example, its petals are used for diuretic and cordial tonic, its pollens for pituitary tonic, and its rhizomes and seeds for treatment of apthous ulcers and thirst (Marja-Sisko, 1995; Nontapat, 2003; Vasuwat, 2005; Karnjanakul, 2008). Since lotus can be planted everywhere in Thailand, there are many agriculturalists who primarily plant it for living. Two cultivars, *Nelumbo nucifera* 'Album plenum' and *N. nucifera* 'Roseum Plenum' have been widely planted in Thailand. After cultivating lotus blossom, fresh stalks would be discarded without further use. The lotus panducle contains a lot of cellulose and consists of 7-8 lenticels arranged in a circle and one big lenticel and a pair of small lenticels (Deangsuwat, 2008). The outer cell contains white latex which will become fiber when it touches the air. Therefore, in some countries, the fresh stalks have been used for producing handmade yarn and fabric. This happens in communities such as the Angta community in Jamkam village in the south of Myanmar, and Battambang in Cambodia (Niyomtham, 2005).

In a previous study, the characteristics of lotus fiber obtained from stretching and retting methods were determined. In terms of the stretching method, it was found that there were a lot of small swirls in the cross section revealed as oval shapes, while the appearance of the longitudinal view was ribbon-like, thin, and waft. The yarn number values were between 3.630-25.360 tex. The yarn tenacity values were between 0.430-1.265 g/tex. The yarn elongation values were between 1.066-2.780 %. In terms of retting method, it was found that the cross-sectional image of the fiber showed clusters of fibers with circular but uneven appearance, while the appearance of the longitudinal view showed that the fibers had an even texture and a nodeless appearance. From the experiment concerning the quantity of fiber, it was found that lotus stalks yielded approximately 3-6% of fibers (Punbua, 2017), which were able to be spun to become a yarn. Lotus yarn obtained from the stretching method yielded less

amounts of fiber and needed more time to produce. Therefore, research on lotus spun yarns made of the lotus fibers obtained from retting method was conducted. This study aimed to determine the evenness of two cultivars of sacred lotus spun yarns and to study the effects of cultivars and stem parts on the physical properties of sacred lotus spun yarns. The selected physical properties determined were yarn number, tenacity and elongation. The results of this research would be to aid the direction of development of lotus fibers in Thailand that will then support the usefulness of by-product of the plant in the future.

Materials and Method

1. Preparing the lotus fibers and spinning the yarn

In this examination, stems of two cultivars of sacred lotus, *Nelumbo nucifera* 'Album Plenum' and *N.* nucifera 'Roseum Plenum' (Figure1), at the age of 3 months from Na-Bua group in Nakorn Pathom province were used. The flower stems were separated into 2 parts: The upper part (0-70 cm measuring from the receptacle), and the lower part, (70-140 cm measuring from the receptacle), retted in clean water for 13 days or until the bark became soft and the inside tissue became rag and then dried in the sun for 3 days (Figure2). The lotus fiber sheets were separated into 2 mm strips and then spun into a yarn utilizing the technique and equipment of hand jute spinning (Figure3).

2 Testing of the yarn evenness and physical properties of the sacred lotus spun yarn

The yarn evenness and physical properties of the sacred lotus spun yarns were determined according to the American Society of Testing and Materials (ASTM) Standards as follows:

1) Yarn evenness was determined according to ASTM D2255 - 02 Standard Test Method for Grading Spun Yarns for Appearance (ASTM International, 2010).

2) Yarn number was determined on a yarn number tester according to ASTM D1059 – 01 Standard Test Method for Yarn Number Based on Short–Length Specimens (ASTM International, 2010).

3) Tenacity and elongation were tested on an Instron tensile tester according to ASTM D 2256 -02 Standard Test Method for Tensile Properties of Yarn by the Single – Strand Method (ASTM International, 2010).

(a) (b)

Figure 1 The two cultivars of sacred lotus: (a) *Nelumbo Necifera* ' Album Plenum' and (b) *N. nucifera* 'Roseum Plenum'

Figure 2 The lotus stem obtained from rotting method

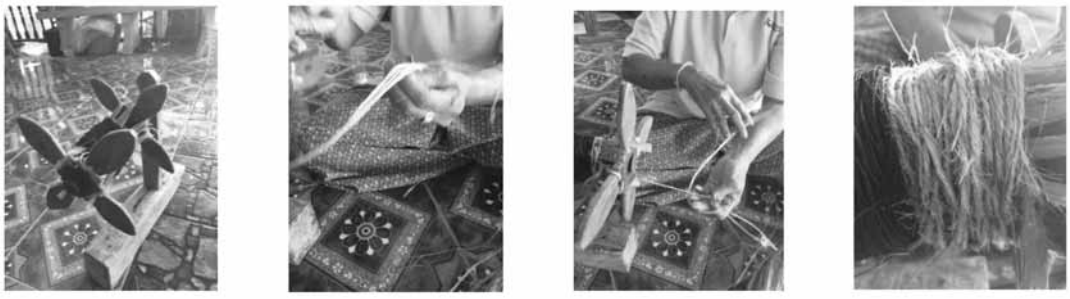

Figure 3 The process of spinning the stem into bundle fibers by hand

3 Experimental design and data analysis

The experiment was performed according to the 2X2 Factorial Experiment in Completely Randomized Design (CRD). Three repeats were conducted. Two factors were studied: 1) the different cultivars of lotus and 2) the upper and

lower parts of the lotus stem. Means and standard deviations were determined and Analysis of Variance (ANOVA) was performed to determine the effects that different cultivars and upper and lower parts of sacred lotus stems have on physical properties of the lotus spun yarns.

Results and Discussion

1 The evenness of the sacred lotus spun yarns

The evenness of the sacred lotus spun yarns is shown in Figure 4. The sacred lotus yarn from the upper part of *Nelumbo nucifera* 'Album Plenum' fibers (a) the sacred lotus yarn from the lower part of *N. nucifera* 'Album Plenum' fibers (b), the sacred lotus yarn from the upper part of *N. nucifera* 'Roseum Plenum' fibers (c), and the sacred lotus yarn from the lower part of *N. nucifera* 'Roseum Plenum' fibers (d) were fuzzy and uneven in texture. All could be categorized as below grade D level. A grade D yarn has some slubs which are more than three times the average diameter of the yarn, and may also have more neps, larger size neps, more thick and thin areas, more fuzz and more foreign matter than Grade C yarn. The appearance of a below grade D yarn has more defects and an overall rougher appearance than Grade D yarn (ASTM International, 2010). The sacred lotus yarns obtained in this experiment could be used to produce different texture fabrics. Therefore, they might be suitable for some household textiles.

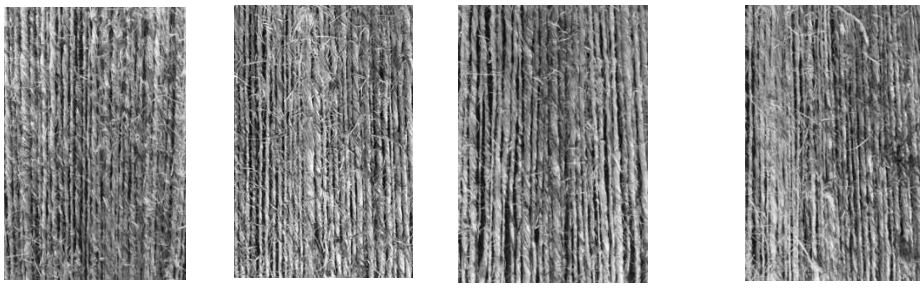

Figure 4 The evenness of the sacred lotus spun yarns from the fibers of different cultivars and stem parts: upper part stem of *Nelumbo nucifera* 'Album Plenum' (a), lower part stem of *N. nucifera* 'Album Plenum' (b), upper part stem of *N. nucifera* 'Roseum Plenum' (c) and lower part stem of *N. nucifera* 'Roseum Plenum' (d)

2 The physical properties of the sacred lotus spun yarn

2.1 Yarn number of the sacred lotus spun yarn

Yarn number values of sacred lotus were ranged from 522.65 to 828.10 tex. (Table 1). According to Sandra (2011), all yarns were classified as heavy yarn. The spun yarn made of the fibers from the upper part stem of *N. nucifera* 'Album Plenum' had the highest yarn number while the spun yarn made of the fibers from the lower part stem of *N. nucifera* 'Album Plenum' had the lowest yarn number. The spun yarns made from *N. nucifera* 'Roseum Plenum' fibers tended to have higher yarn number than the yarns made from *N. nucifera* 'Album Plenum' fibers. Results of Analysis of Variance indicated that the cultivars of lotus affected the mean values of the yarn number with the significance at .05 level. The yarns from *N. nucifera* 'Album Plenum' fibers yielded a lower mean value of the yarn number than those from *N. nucifera* 'Roseum Plenum' fibers (Figure 5). If concerned only about cultivars, it has been suggested that for producing a bigger size yarn, it would be better to use *N. nucifera* 'Roseum Plenum' stem, while the use of the *N. nucifera* 'Album Plenum' stem will produce a smaller size yarn. The lotus stem parts affected the mean values of the yarn number with the significance at .01 level. The yarns made of the fibers from the upper part stem yielded a higher mean value of the yarn number than those made of the fibers from the lower part stem (Figure 6). If concerned only stem parts, it has been suggested that for producing a bigger size yarn, it would be better to use the upper part of lotus stems, and use the lower part for a smaller size yarn. The interaction between cultivars and lotus stem parts affected the mean values of the yarn number with the significance at 1% level by LSD. In case of *N. nucifera* 'Album Plenum', the upper part stem fibers yielded a higher mean value than the lower part stem fibers, while in case of *N. nucifera* 'Roseum Plenum', the upper part stem fibers yielded a lower mean value than lower part stem fibers (Figure 7). Therefore, for producing bigger size yarns, it would be better to use upper part stem of *N. nucifera* 'Album Ple*num*', or lower part stem of *N. nucifera* 'Reseum plenum'. But, for getting smaller size yarns, it would be better to use lower part stem of *N. nucifera* 'Album Plen*um'* or upper part stem of *N. nucifera* 'Roseum Plenum'. When weaving into a fabric, the fabric from the yarn of the upper part stem of *N. nucifera* 'Album Ple*num'* would be more thick, but less soft. On the other hand, the fabric from the yarn of the upper part stem of *N. nucifera* 'Roseum Plenum' would be more thin and soft.

Table 1 Means of yarn number of the sacred lotus spun yarns

Cultivars	Part of stems		
	Upper	Lower	Diff.
N. nucifera ' Album Plenum'	828.10	522.65	305.45**
N. nucifera ' Roseum Plenum'	648.33	744.81	-96.48**
Diff.	179.77*	-222.16*	

CV(%) = 4.23

***** = Significant different at 5% level by LSD

** = Significant different at 1% level by LSD

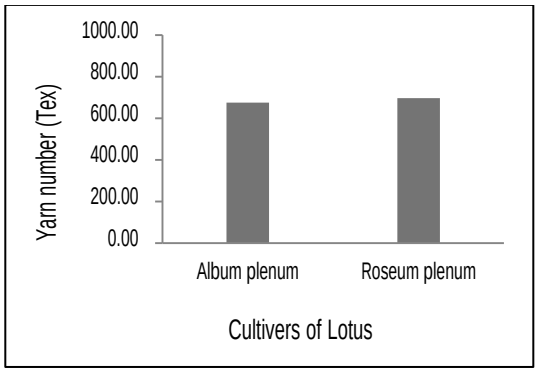

Figure 5 Means of the yarn number of the lotus spun yarns made from the fibers of *N. nucifera* 'Album Plenum' and *N. nucifera* 'Roseum Plenum'

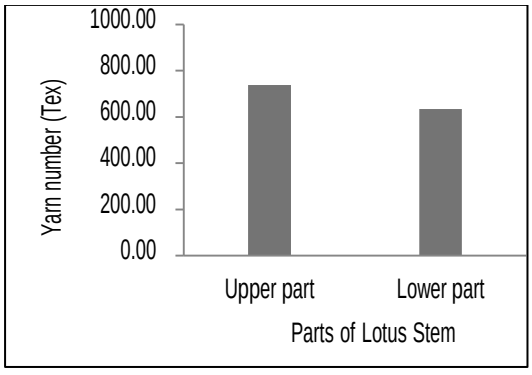

Figure 6 Means of the yarn number of the lotus spun yarns made from the fibers of the upper part and the lower part stems

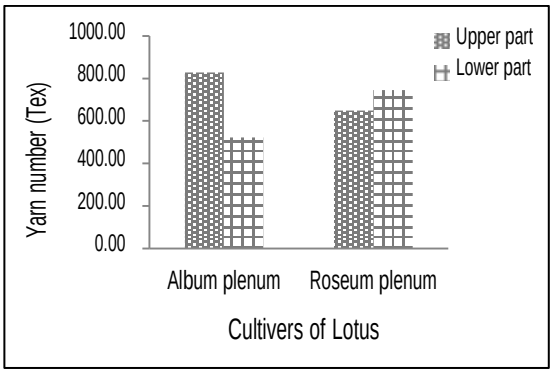

Figure 7 Means of the yarn number of the lotus spun yarns made from the fibers of the upper part and the the lower part stems of *N. nucifera* ' Album Plenum' and *N. nucifera* ' Roseum Plenum'

2.2 Tenacity of the sacred lotus spun yarns

Tenacity values of the sacred lotus spun yarns ranged from 1.70 to 3.02 g/ tex.(Table 2) The spun yarn made of the fibers from the lower part stem of *N. nucifera* 'Album Plenum' had the highest tenacity while the spun yarn made of the fibers from the upper part stem of *N. nucifera* 'Album Plenum' had the lowest tenacity. Results of Analysis of Variance indicated that the cultivars of lotus affected the mean values of tenacity with the significance at 1 % level by LSD. The spun yarns made from the fibers of *N. nucifera* 'Album Plenum' had a higher mean value of tenacity than those made from the fibers of the *N. nucifera* 'Roseum Plenum' (Figure 8). If concerned only about cultivars, it has been suggested that for producing stronger yarns, it would be better to use the fibers from *N. nucifera* 'Album Plenum'. The lotus stem parts affected the mean values of tenacity with statistically significant difference. The yarns made from upper part stem fibers had lower mean value of tenacity than the yarns made from the lower part stem fibers (Figure 9). If concerned only about parts, it has been suggested that for producing stronger yarns, it would be better to use lower part of lotus stems. The interaction between cultivars and lotus stem parts affected the mean value of tenacity with the significant difference at 1 % level . The fibers from the upper part stem of *N. nucifera* 'Album Plenum' yielded a lower mean value of yarn tenacity than the fibers from lower part stem, while the fibers from the upper part stem of *N. nucifera* 'Roseum Plenum' yielded a higher mean value of yarn tenacity than the fibers from lower part stem (Figure 10). Therefore, for producing stronger yarns, it would be better use the lower part stem of *N. nucifera* 'Album Plenum' or the upper part stem of *N. nucifera* 'Roseum Plenum'.

Table 3 Means of tenacity of the sacred lotus spun yarns

Cultivars	Part of stems		
	Upper	Lower	Diff.
N. nucifera ' Album Plenum'	1.70	3.02	-1.32**
N. nucifera ' Roseum Plenum'	2.10	1.79	0.31**
Diff.	-0.30**	1.23**	

CV (%) =5.43

** = Significantly difference at 1% level by LSD

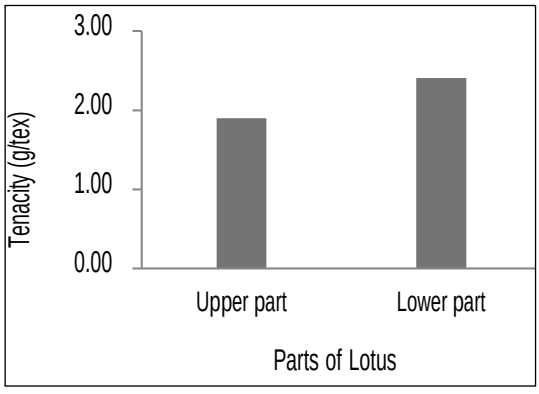

Figure 8 Means of the tenacity of the lotus spun yarns made from the fibers of *N. nucifera* ' Album Plenum' and *N. nucifera* 'Roseum

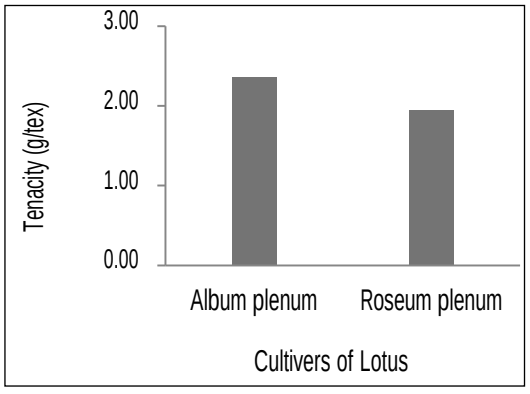

Figure 9 Means of the tenacity of the lotus spun yarns made from the fibers of the upper part and the lower part stems

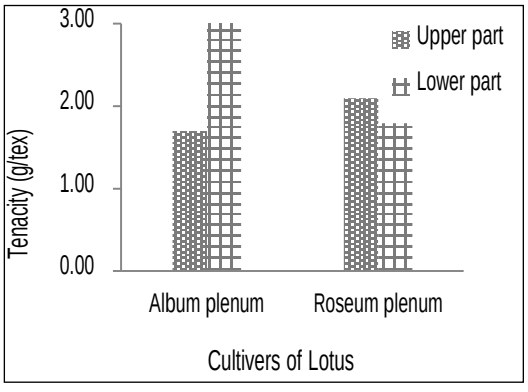

Figure 10 Means of the tenacity of the lotus spun yarns made from the fibers of the upper part and the lower part stems of *N. nucifera* ' Album Plenum' and *N. nucifera* 'Roseum Plenum'

2.3 Elongation of the sacred lotus spun yarn

Table 3 showed that elongation values ranged from 1.39 to 2.09%. The spun yarn made of the fibers from the lower part stem of *N. nucifera* 'Album Plenum' had the highest elongation while the spun yarn made of the fibers from the upper part stem of *N. nucifera* 'Album Plenum' had the lowest elongation. Results of Analysis of Variance indicated that the stem parts affected the mean value of elongation with the significance at .01 level. The spun yarns made from the upper part stem fibers had a lower mean value of elongation than the yarns made from the lower part stem fibers (Figure 11). If concerned only about stem parts, it has been suggested that for producing a higher value of elongation, it would be better to use the

lower part of lotus stems. The interaction between cultivars and stem parts affected the mean value of tenacity with the significance at .01 level. In case of *N. nucifera* 'Album Plenum' yarns, it was found that the fibers of the upper part stems yielded a lower mean value of yarn elongation than the fibers of the lower part stems, while in case of *N. nucifera 'Roseum Plenum'* yarns, the fibers of the upper part stems yielded a higher mean value of yarn elongation than the fibers of the lower part stems (Figure 12). Thus, for producing a yarn with a higher elongation value, it would be better to use the lower part stem of the *N. nucifera 'Album Plenum'* or the upper part stem of the *N. nucifera 'Roseum Plenum'*. The cultivars of lotus did not statistically affect the elongation.

Table 5 Means of elongation of the sacred lotus spun yarns

Cultivars	Part of stems		
	Upper	Lower	Diff.
N. nucifera ' Album Plenum'	1.39	2.10	-0.71**
N. nucifera ' Roseum Plenum'	1.74	1.49	0.25**
Diff.	-0.35^{ns}	0.61^{ns}	

CV(%) = 5.01

ns= not significant

**= Significantly difference at 1% level by LSD

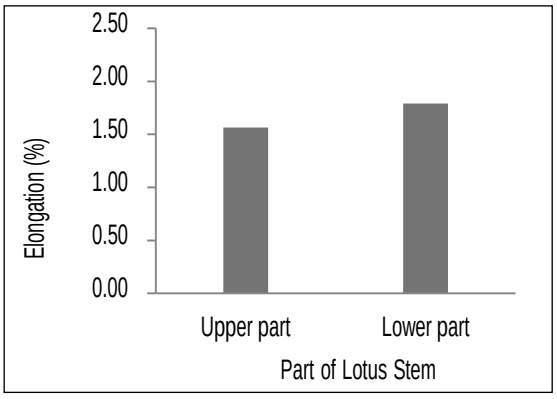

Figure 11 Means of the elongation of the lotus spun yarns made from the fibers of the upper part and the lower part stems

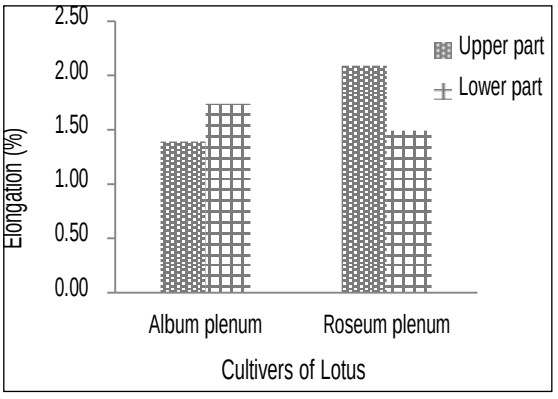

Figure 12 Means of the elongation of the lotus spun yarns made from the fibers of the upper part and the lower part stems of *N. nucifera* 'Album Plenum' and *N. nucifera* 'Roseum Plenum'

Conclusions

In terms of yarn evenness, it was found that the lotus yarns made of the fibers from both the upper and lower part stem and of *Nelumbo nucifera* 'Album Plenum' and *N. nucifera* 'Roseum Pl*enum'* were fuzzy, bumpy and uneven in texture; Therefore they were classified as below grade D level. In terms of yarn number, *N. nucifera* 'Album Plenum' was found that the yarn made of the fibers from the upper part stem had the highest yarn number while the lower part stem of *N. nucifera* 'Roseum Plenum' had the highest yarn number. In addition all yarns were heavy, therefore, It is suggested that these yarns would be suitable for some household fabrics.

In terms of tenacity, *N. nucifera* 'Album Plenum' was found that the fibers from the lower part stem had the highest yarn tenacity whereas the upper part stem of *N. nucifera* 'Roseum Plenum' had the highest yarn tenacity. Since all the yarns had low value of tenacity, they would not be appropriate for durable products such as home textiles or apparels but they would be appropriate for products that need no strength.

In terms of elongation, *N. nucifera* 'Album Plenum' was found that the fibers from the lower part stems had the highest elongation whereas the upper part stems of *N. nucifera* 'Roseum Plenum' was found to have the highest elongation. Since all the yarns had lower values of elongation, they could be used for textile products such as interior decoration and household fabrics.

The results of this research suggested a new concept of producing sacred lotus fiber and yarns for use in textiles. This method is likely suitable for semi-industrial level production. Therefore, further development and innovative use of Thai sacred lotus fibers is encouraging and it would be interesting to try a spinning machine in the textile industry.

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