Study of stinging nettle fibers as a reinforcing of composite materials based on its growing region

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Abstract. Stinging nettle is a perennial herbaceous plant belonging to the Urticaceae family, in Bali Indonesia called jelatang. This species is considered a weed in intensive agriculture as its fast vegetative growth and high densities enable increased spread and soil coverage. In Tabanan Bali Indonesia several places to grow are in Denbantas altitude 200-500 meters and in Bedugul altitude 1000 - 1500 meters above sea level. Nettle fibers are natural fibers that can be utilized as reinforcement for composite materials. Natural fibers have been used worldwide as a potential replacement for glass fiber reinforced composites, over the last few years has been applied in the automotive sector, aircraft interior and interior of the building. Properties of the natural fiber is lighter, easier to handle, not abrasive, and low cost. The objective of this study was to compare the composition and the tensile strength of the fiber nettle based growing areas from Bedugul and Denbantas. The method used is a fiber tensile test equipment, fourier transformer infrared red (FTIR), thermo-gravimetric analysis (TGA) and scanning electron microscope (SEM). From the research of nettle fibers that stinging nettle from Denbantas has a better tensile strength than Bedugul nettle. The TGA test the visible fiber from Denbantas is superior when used as a composite reinforcement.

1. Introduction

Stinging nettle plants thrive in Tabanan-Bali, Indonesia, of which its stem, leave and fiber are used by the people. Journals which discuss the use of nettle plants are; multipurpose of nettle plants for medicine, biomass and material [1]. Nettle plants are studied as antioxidant, antimicrobial, antiulcer and analgesic [2]. Nettle plants are studied as utility of its in layer diets as a natural yellow colorant for egg yolk [3]. Nettle plants are studied as adding its haylage to a total mixed ration on performance and rumen function of lactating dairy cows [4]. Nettle fiber is a natural fiber which is very strong with young’s modulus 87 (±28) GPa, tensile strength 1594 (±640) MPa, strain fracture 2.11 (±0.81) % [5].

Method and the way of taking the fiber from the nettle stem highly influence the mechanical characteristic of the fiber, of which have been studied the method; decortication, chemical retting, enzymatical treatment and chelating agent [6-7].

Nettle plants are covered by fine hairs especially at the leave and stem. If it is touched, these plants will release chemical substance, stinging and triggering inflammation which causes redness, itching and irritation of the skin. Wild nettle plants are considered as weeds (disturbing plants) in farm industry, which easily grow and seize food from the parent plant.

The average height of one dried sample of nettle stem taken from Bedugul was 54.2 cm and 49.4 cm from Denbantas. The average weight of one dried sample of nettle stem from bedugul was 16.45 gram and give fibers was 2.46 gram but sample Denbantas average weight was 11.31 gram and give fibers was 1.28 gram.
2. Method

2.1. Material

Stinging Nettle is harvested in Denbantas and Bedugul of Tabanan-Bali, Indonesia. Denbantas is located in altitude 200 – 500 meter above sea level, 008° 27' 40" S – 115° 08' 18" E with average humidity 83.12%, and rainfall 215.43 mm/month. Bedugul is located in altitude 1000 -1500 meter above sea level 008° 15' 40" S – 115° 09' 49" E, with rainfall 248.85 mm/month calculated in 5 years. Average temperatures in Bedugul are 22 °C at daylight and 16 °C nighttime, while average temperatures in Denbantas are 30 °C at daylight and 21 °C at nighttime.

The harvested stem of nettle plant was cut and dried for 3-5 days before it was rooted in a water for 4 days in the end of January 2017. Fiber of nettle plant was dried in a room temperature and kept in weeks. The fiber was extracted manually without damaging the fiber.

2.2. Measurements

The surface of fibers was coated with gold and then examined using a JOEL JSM-651OLA analytical scanning electron microscope (SEM) made in Japan.

Infrared spectra of fiber samples (4000-400 cm-1) were recorded using a Fourier Transformer Infrared (FTIR) Spectrophotometer (IRPrestige-21) Shimadzu.

Instrument of TGA701 LECO made in USA was used for thermogravimetric analysis of fibers samples from room temperature to 600 °C at a heating rate of 10 °C/min under nitrogen gas flowing at 60 mL/min. About 1 g of sample was used in each test.

3. Result and Discussion

Characterization of nettle plants is a search of characteristic and basic nature of nettle fiber so the typical value can be discovered. In Fig. 1 and Fig. 2, it can be seen the nettle fiber from Bedugul and Denbantas respectively taken from one stem.

Table 1 – Table 4 are be authority by Badan Meteorologi, Klimatologi dan Geofisika Tuban Bali Indonesia. Physical environment such as rainfall, temperature, humidity and sunlight intensity highly influence the growth of nettle plants.

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Des | Mean |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 2012 | 1,056.5 | 622.5 | 1,510.5 | 434.5 | 189.5 | 5.5 | - | 2.0 | - | 61.5 | 313.5 | 661.5 | 404.79 |
| 2013 | 542.0 | 766.0 | 244.0 | 293.5 | 177.0 | 111 | 62.0 | 10.0 | 6.0 | 133.0 | 307.1 | 587.0 | 269.93 |
| 2014 | 449.0 | 207.8 | 158.0 | 322.5 | 91.0 | 10.5 | 108.5 | 18.0 | - | 37.5 | 312.0 | 252.0 | 163.90 |
| 2015 | 210.0 | 254.0 | 351.0 | 355.0 | 41.0 | 22.0 | 8.0 | - | - | 11.0 | 110.0 | 106.0 | 122.33 |
| 2016 | 307.0 | 557.0 | 302.0 | 184.0 | 221.0 | 150 | 145.0 | 58.0 | 39.0 | 389.0 | 340.0 | 707.5 | 283.29 |
Table 2. Monthly Rainfall in Denbantas Tabanan (millimeter).

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Des | Average |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|---------|
| 2012 | 538.0 | 307.5 | 405.5 | 185.0 | 200.0 | 11.0 | 182.5 | 20.0 | - | 225.0 | 136.0 | 330.0 | 211.71 |
| 2013 | 516.5 | 200.5 | 186.0 | 265.5 | 418.0 | 161.5 | 124.0 | 40.0 | 34.0 | 19.0 | 333.0 | 555.0 | 237.75 |
| 2014 | 396.0 | 103.0 | 171.0 | 121.0 | 6.0 | 177.0 | 15.0 | 5.0 | 27.0 | 248.0 | 494.0 | 165.08 |
| 2015 | 356.0 | 243.0 | 218.0 | 90.0 | 162.0 | 174.0 | 68.0 | 10.0 | 2.0 | 11.0 | 289.0 | 555.0 | 146.25 |
| 2016 | 201.5 | 551.0 | 286.0 | 272.0 | 186.0 | 318.0 | 17.0 | 400.0 | 226.0 | 476.0 | 541.0 | 316.38 |

Table 3. The Average Humidity in Denbantas Tabanan (%).

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Des | Average |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|---------|
| 2012 | 85 | 86 | 83 | 83 | 84 | 83 | 83 | 81 | 80 | 81 | 82 | 84 | 82.9 |
| 2013 | 85 | 84 | 84 | 85 | 87 | 88 | 85 | 83 | 81 | 77 | 82 | 85 | 83.8 |
| 2014 | 84 | 83 | 83 | 84 | 84 | 82 | 81 | 78 | 79 | 79 | 86 | 82.3 |
| 2015 | 82 | 83 | 84 | 84 | 85 | 84 | 83 | 81 | 80 | 78 | 81 | 82.5 |
| 2016 | 79 | 88 | 82 | 85 | 85 | 84 | 83 | 82 | 85 | 85 | 84.1 |

Table 4. Duration of Sunlight in Denbantas Tabanan (%).

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Des | Average |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|---------|
| 2012 | 44 | 63 | 53 | 76 | 70 | 74 | 69 | 76 | 90 | 84 | 73 | 57 | 69.1 |
| 2013 | 52 | 57 | 70 | 54 | 63 | 58 | 72 | 77 | 81 | 92 | 64 | 47 | 65.6 |
| 2014 | 53 | 59 | 78 | 80 | 85 | 76 | 70 | 83 | 95 | 97 | 84 | 48 | 75.7 |
| 2015 | 58 | 66 | 66 | 60 | 79 | 82 | 82 | 79 | 89 | 93 | 85 | 61 | 75.0 |
| 2016 | 69 | 48 | 70 | 66 | 74 | 71 | 66 | 76 | 81 | 64 | 60 | 45 | 65.8 |

Table 1 shows the average of monthly rainfall in Bedugul within 5 years was 215.43 mm/month. Meanwhile, Table 2 shows the average of monthly rainfall in Denbantas within 5 years was 248.85 mm/month. Table 3 shows the average of humidity within 5 years in Denbantas was 83.12%. Meanwhile, Table 4 shows the average of sunlight duration within 5 years in Denbantas was 70.23%.

3.1 TGA Test

TGA (Thermogravimetric analysis) is a heat analysis method in which the change in term of physical and chemical nature from the sample is measured in high precision. The measurement is conducted by the constant temperature escalation upon time function by calculating the mass loss.
Figure 3. TGA fibers from Bedugul.

Figure 4. TGA fibers from Denbantas.

The drying of nettle stem from Bedugul took 4-5 days, while the Denbantas nettle stem took 3-4 days. The result of nettle stem TGA showed almost the same moisture values, because it was similarly conditioned that was dried under the sun until the nettle stem had the same weight after and before the drying.
Volatile value of Bedugul nettle stem was higher than from Denbantas. It showed Bedugul nettle stem had more volatile substance. Denbantas fibers has a higher fixed carbon that is 15, this is potential fiber.

Ash value of Denbantas nettle stem was higher than from Bedugul. It means that Denbantas nettle stem had more organic and anorganic materials. TGA showed the fiber of Denbantas nettle stem had better physical and chemical characteristic if it is used to strengthen composite material.

3.2 FTIR Test

FTIR (Fourier Transform Infra Red) is an infrared radiation through the sample. Some infrared radiation was absorbed by the sample and some of them passed the sample. The resulting spectrum is absorption and transmission molecule, creating traces of sample molecule, there will be two unique marks, absorbing sample molecule and sample molecule which was passed by infrared radiation.

![Figure 5. FTIR fibers from Bedugul.](image.png)
Figure 6. FTIR fibers from Denbantas.

FTIR test on the two samples of Bedugul and Denbantas nettle fiber, the absorption pattern and infrared radiation channel showed the same pattern, and it could be assured that both samples of the fiber came from the same element and compound.

Analysis on Denbantas nettle fiber was based on the biggest area so the occurred clusters were in wave number 3302.13 cm\(^{-1}\) which showed cluster NH\(_2\), for wave number 2899.01 cm\(^{-1}\) showed cluster NH\(_3\), for wave number 1645.28 cm\(^{-1}\) showed cluster CO and for wave number 1105.21 cm\(^{-1}\) showed cluster CH\(_3\). These clusters were appropriate with chemical compounds for cellulose fiber.

### 3.3 Tensile Strength Test

Fiber tensile strength is the power of fiber to withstand the load up to break for each unit area. Single nettle fibers were glued onto a slotted paper holder (10 mm gap equal to L0 the nominal length of the fiber). Tensile tests were carried out on a MTS Tensile Manuals. Tensile test each number (code) is 30 samples.

| Code | Average (Mpa) | Standard Deviation |
|------|---------------|--------------------|
| DB   | 886.0         | 275                |
| 4B   | 193.0         | 80                 |
| DD   | 900.7         | 247                |
| 4D   | 525.4         | 411                |

Table 5. Tensile strength of fibers.

Code of fiber retting with decortication on the nettle stems which is harvested in Bedugul is symbolized by DB. Code of fiber ratting of nettle stems harvested in Bedugul with a soaked in water for 4 days is symbolized by 4B. Code of fiber retting with decortication on the nettle stem which is harvested in Denbantas is symbolized by DD. Code of fiber ratting from nettle stems harvested in Denbantas with soaked in water for 4 days is symbolized by 4D.
Tensile test result of Bedugul fiber on Table 5 shows the fiber taking with decortication method had averagely higher tensile strength with 866.0 MPa. Meanwhile, Denbantas fiber on Table 5 shows fiber taking with decortication method had averagely higher tensile strength with 900.7 MPa than soaked in water. If it is compared to the growth area, Denbantas fiber had higher tensile power.

4. Conclusion
The potency of stinging nettle to be used as reinforcement of composite materials is highly recommended as it can be seen from the result of the characterization. From the research of nettle fibers that stinging nettle from Denbantas Tabanan has a better tensile strength, from the TGA test the visible fiber from Denbantas is superior when used as a composite reinforcement.

Acknowledgments
The authors thank the Ministry of Research, Tech., and Higher Education of the Republic of Indonesia and LPPM (Lembaga Penelitian dan Pengabdian Masyarakat) University of Udayana for supporting this research and paper through The Grant.

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