Effect of Gauge Length on Tensile Properties of Veldt Grape Fibre

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Abstract. This research used digital image processing methods to assess the real cross-sectional area of veldt grape fibre (VGF) and examine the impact of fibre gauge length on the tensile behaviour of VGF. Five different gauge lengths are used to evaluate the tensile characteristics of single fibre VGF: 10, 20-, 30-, 40-, and 50-mm. Tensile modulus, stresses to failure, and ultimate tensile strength are measured separately. To precisely forecast the tensile characteristics, the VGF tensile test is performed 100 times under each gauge length. In order to do the Weibull distribution analysis, 500t tensile test data with various gauge lengths are reported. The length of the fibre gauge and the fiber's tensile strength were shown to be significantly correlated. It was found that as the gauge length rises, the fibre strength and strain values drop. The single fibre failure was analysed using the two-way ANOVA statistical computation. The probability of failure, or the weak point, rises with time. Existing research using the Weibull distribution supports this claim. By using a different technique, in this case correlation, the others are also getting the same result.

Keywords: Veldt grape fibre, Sustainable Fibre Materials, tensile strength, tensile modulus, strain, ANOVA.

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1 Introduction

The utilisation of natural fibres is on the rise in numerous engineering applications due to their exceptional properties and biodegradability. The environment is being polluted by all of the synthetic fibres at the conclusion of the service. The presence of polymer in synthetic fiber-based polymer materials causes them to not degrade in the environment, whereas this is not the case with natural fibre material. Natural fibres are, by and large, the preferred choice for the production of ecological composite materials [1-3]. Nevertheless, the natural fibres have some disadvantages, including a lack of long-term durability in damp environments, weak wettability, and acid corrosion. The strength of polymer composite materials is contingent upon the strength of the fibre. The single fibre failure mechanism will cause the fiber-reinforced polymer composites materials to enter the weakening stage if the strength of the single fibre is insufficient. An analysis of the solitary fibre strength is necessary prior to the reinforcement of the fibre into the polymer to determine its suitability. The cellulose content of the fibre is a determining factor in its strength. The strength of the fibre is also increased in comparison to low-cellulose content fibres when the alpha cellulose content is higher [4-6]. The length and diameter of all natural filaments are not homogenous. The tensile strength and modulus of polymer composite materials are significantly influenced by the diameter and length of the fibres. The tensile properties and actual cross-sectional area of a single fibre must be analysed prior to the fabrication of polymer composite materials [7-8]. This research aims to provide a concise overview of how the tensile strength, modulus, and strain of veldt grape plant fibres are affected by the length of the fibre gauge. Furthermore, a statistical method is used to forecast the actual cross-sectional area of VG fibre.

2 Materials and Experimental Procedure

2.1 Materials

The scientific name of the plant known as the Veldt grape (VG) is Cissus quadrangularis, and the species belongs to the Vitaceae family of plants. Naturally this plant is growing node by node with long stem branches. The length of internodes branches is 8-10cm as shown in fig 1a. This plant grows in dirt that drains well and on empty land. The veldt grape plant is also known as the devil's backbone and the adamant vine. The name for this plant in Tamil is Pirandai. The plant is growing in green and pale-yellow colour. The native of the plant is Asia, Africa and Arabia. The veldt grape plant is collected from around the area of Kadayam, south Tamilnadu.

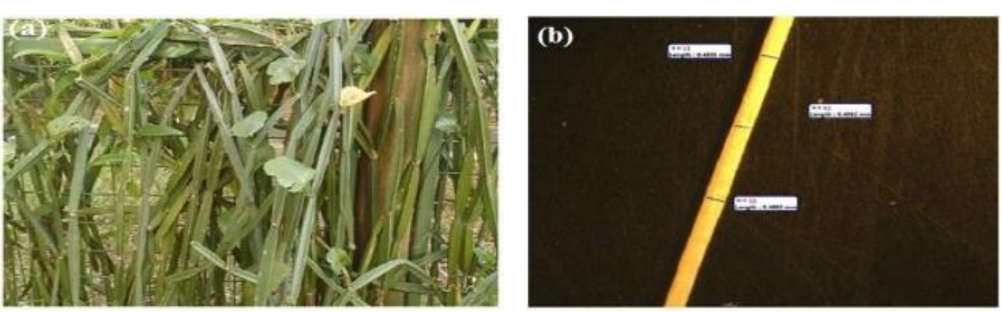


Fig. 1 (a) Veldt grape plant, (b) Apparent diameter measurement using Motic 2.0 image software

2.2 Fibre Extraction Method

The VGF long plant is used to extract the natural fibres. The plant is manually pulverised using a mallet. After the plant is crushed, it undergoes the retting process to decompose the green plant inundation. The retting procedure is conducted using standard potable water. Underwater, the plant is maintained. The retting procedure is conducted for three days using the same water to facilitate the removal of fibres from the discharge. After being immersed, the plants were subjected to a hand extraction method to extract the fibre. The cleansed fibre is stored in a tray and deposited in a hot air furnace at a temperature of 100°C for a duration of two hours [8].

2.3 Tensile testing

The tensile behaviour of retted veldt grape fibre was examined. The tensile behaviour of natural fibres is significantly influenced by the amount of chemical composition. The tensile properties of veldt grape stem fibre, including tensile strength, modulus, and breaking strain, were determined through one hundred tensile tests of individual single fibres for gauge lengths ranging from 10 to 50mm. The UTM (INSTRON-55OOR) machine was employed, employing a 10N load cell. The single fibre is attached to a single paper at both ends to improve traction, and the central portion of the paper is torn. A machine is then used to bind the fibre ends with paper. All tensile measurements on VG fibres are conducted in accordance with the ASTM standard D2256. Table 1 illustrates the diverse tensile property measurements, and the load deflection contours were represented in a graph for the corresponding readings.

2.4 Apparent Diameter

The rudimentary single-lens optical microscope was employed to determine the apparent diameter of the fibre. The fibre was divided into five distinct lengths (10mm, 20mm, 30mm, 40mm, 50mm). For each length, ten fibres were selected, and the diameter of the VG fibre was measured at ten distinct locations. The fibre was initially positioned in a stage beneath the lens at a 1x magnification. The focus adjustments were altered to obtain precise images, which were then displayed on a monitor. The apparent diameter of the fibre was measured using Motic Image Plus 2.0 software (Fig 1b), and the resulting images were stored.

2.5 Determination of Fibre Cross Sectional Area

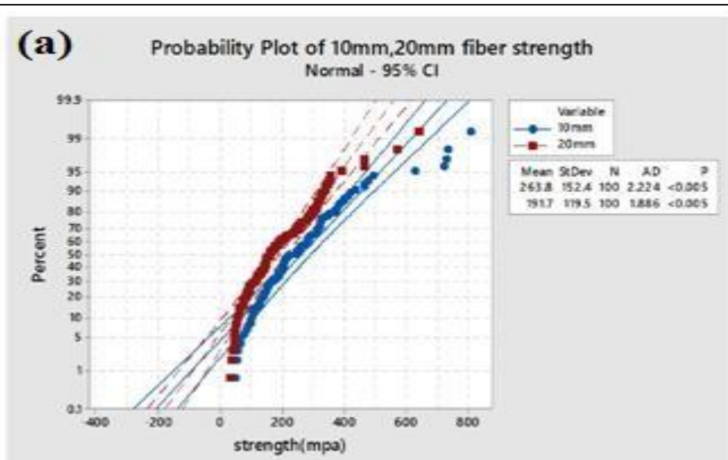
The cross-sectional area of the fibre is a critical physical property that is utilised to determine the mechanical properties. The following experimental procedures were employed to determine the precise cross-sectional area of the fibre. The veldt grape fibre was moulded using a wax medium. The wax is initially solid, but it is heated to a specific temperature (70-80°C) in a heater until it becomes liquid. This liquid is then poured into a simple rectangular mould, and the fibre is positioned in the centre. The fibre is allowed to solidify for 10 minutes, after which the solidified rectangular bar is sliced using a microtome. The microtome divides the material into extremely thin pieces with a thickness of 10 microns. These sliced pieces, which contain cross-sectional fibres, are deposited on a glass plate that has been coated with a mixture of glycerol and egg white to ensure that the fibres adhere to the glass plate. Next, the glass plate was heated with the heater, causing the wax to dissolve and be collected with the assistance of a cotton swab. Consequently, only filaments remain attached to the plate. Subsequently, they employed a multi-lens optical microscope to acquire clear, magnified images of the cross-sectional fibres. The glass plate was positioned on the microscope's stage under a 10x magnification, and the clear images of the fibres were displayed on a computer display that was connected to the microscope. After this process, the digital image processing software was employed to ascertain the precise cross-sectional area of 100 veldt grape filaments. The images displayed were captured and saved. The procedure's detailed processing is illustrated in Figure 2a and Figure 2b.

Fig .2 a) Microscope analyser (b) Microscope image of cross-sectional area of VGF

3. Results and Discussions

3.1 Probability Distribution of veldt grape fibre

The probability distribution graph between the number of fibres and tensile strength was depicted for five distinct gauge lengths (10-50mm), as illustrated in Figure 3(a-c). This graph is displayed to ascertain the extent to which the strength is distributed in relation to the probability of failure, as illustrated in Figures 3a, b, and c. The tensile strength is uniformly distributed across the graph for gauge lengths ranging from 10 to 50mm, as illustrated in Figure 3. The frequency distribution is normal, and the tensile strength varies across all gauge lengths, as illustrated in Figure 3. The tensile strength of the fibre decreases as the gauge length of the fibre increases, as confirmed by this statistical approach model.



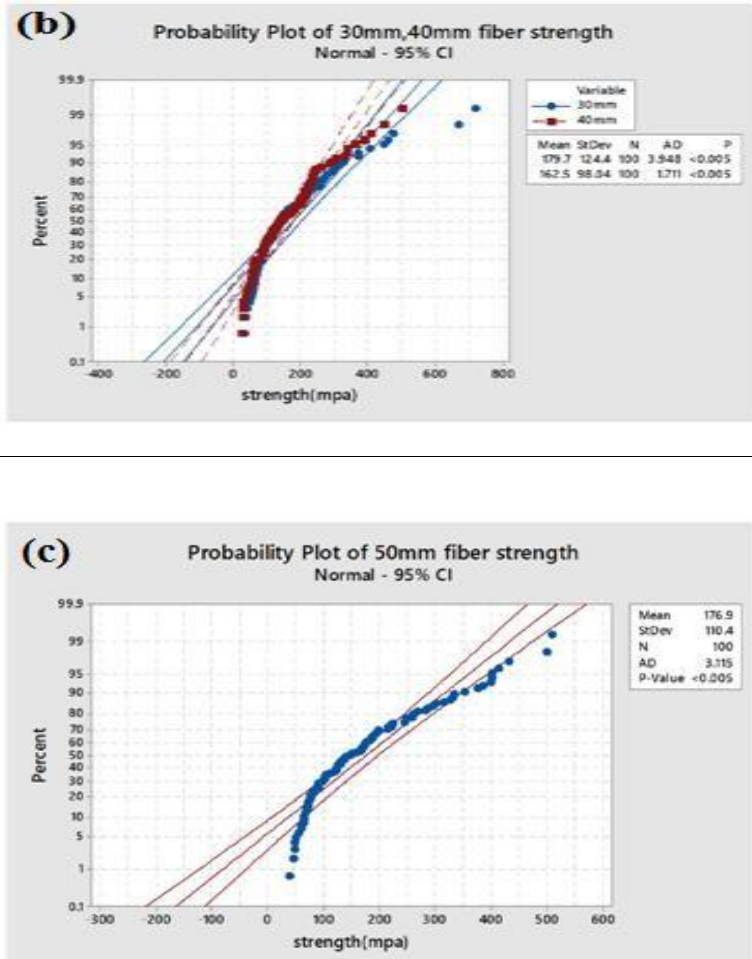


Fig 3. Probability distribution of tensile strength (a) 10mm and 20mm fibre length, (b) 30mm and 40mm fibre length and (c) 50mm fibre length.

3.2 Frequency Distribution of Veldt Grape Fibre

The mechanical properties of the veldt grape fibre exhibit an anticipated natural variation; however, the juvenile modulus does not experience a substantial change across the tested fibre range. The ultimate strength and strain distributions for all gauge lengths (10mm, 20mm, 30mm, 40mm, 50mm) are illustrated below. The figure 4 plainly demonstrates that the frequency distribution is more numerous in the 50-100 MPa range, with a total of 108 single fibres, exceeding 100. The average tensile stress frequency distribution is between 200 and 250 MPa, as illustrated in Figure 5. The tensile strain frequency distribution has a maximum value of 4-8% and a minimum value of 20-28%. The average tensile strain of VGF is between 7.1 and 11.28%. In reality, the true cross-sectional area of VGF, which is derived through image processing, is used to calculate the fibre tensile properties for a variety of gauge lengths. The genuine cross-sectional area of the VGF fibre is within the range of 0.00479-0.01923mm2. The average true cross-sectional area of VGF is 0.009361 mm2. The average apparent diameter is 0.251 ± 0.1 mm^2. The tensile modulus of VGF is measured within the range of 0.247 GPa to 15.719 GPa. The irregular dimensions of the VGF fibre are the cause of the variation in the cross-sectional area and tensile properties of VGF. This is the case for all natural fibres [3-5].

3.3 Determination of Signification of length and tensile properties using two-way Anova calculation

The average reading of tensile properties is listed on table 1. The two-way analysis of variance (ANOVA) of variance is a statistical extension of the one-way ANOVA that looks at how two independent categorical variables affect the dependent one-way variable. In table 1 we can see the mean value of the tensile characteristics.

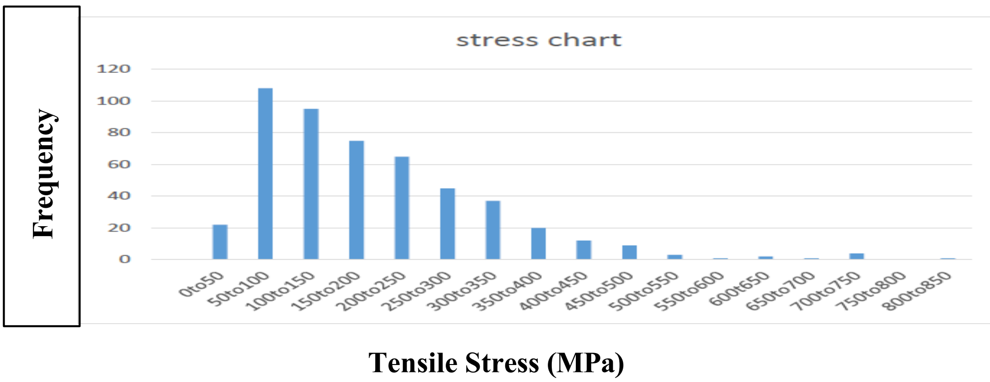


Fig 4. Frequency distribution of tensile stress

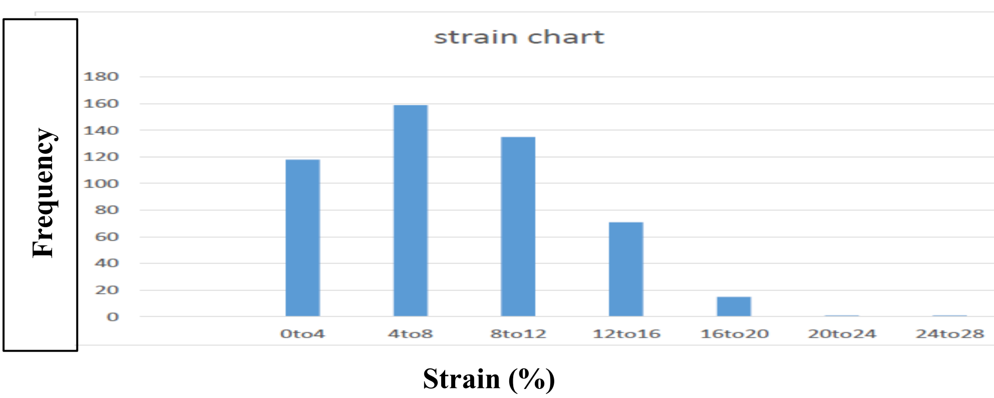


Fig 5. Frequency distribution of tensile strain

3.4 Determination of Signification of length and tensile properties using two-way Anova calculation

The two-way analysis of variance (ANOVA) is a statistical method that builds upon the foundation of the one-way ANOVA by investigating the impact of two distinct categorical independent variables on a single continuous dependent variable. Two-way analysis of variance (ANOVA) is a statistical test that may be used to evaluate not only the main impact of each independent variable on the dependent variable but also whether or not there is a significant interaction effect between the independent variables. We have used the two-way analysis of variance (ANOVA) to ascertain whether or not there is a significant discrepancy between the fibre lengths. We have also used it to discover whether or not there is a significant difference between the tensile properties (which include strength, strain, and modulus) and to determine how the variation in fibre length will affect the tensile characteristics. As seen in Table 2, the cases that have to be anticipated for two-way ANOVA

Case1:
H01: The lengths of the fibres are not significantly different.
H02: In terms of tensile strength, there is little variation.

Case2:
H11: The lengths of the fibres are significantly different from one another.
H12: The tensile characteristics vary significantly from one another.

Table.1 The average readings of tensile properties

length	**Avg. stress MPa**	**Avg. modulus (GPa)**	**Avg. strain (%)**
10	263.813±4.3	2.54287±0.5	11.2808±0.9
20	191.721±4.1	2.27307±0.5	10.0157±0.6
30	179.698±3.2	3.61575±0.6	5.6374±0.8
40	162.471±4.1	3.73144±0.3	5.7503±0.4
50	176.893±2.8	11.2972±0.7	7.1406±0.4

When F value<F- critical value, case1 is accepted.
When F value>F- critical value, case1 is rejected and case2 is accepted.
In our case, the tensile properties exhibit a significant difference, while the fibre lengths do not exhibit any significant difference, as indicated by the calculated values.

Table 2: ANOVA for fibre length and tensile properties

Source of variation	**Degree of freedom**	**Sum of squares**	**Main sum of squares**	**F-Ratio**
Fibre length	4	2230.28	557.57	F01=1.05645
Tensile properties	2	118562.567	59281.284	F02=112.414
Errors	8	4220.622	527.58	
Total	14	125013.469	60366.434	

Table Value (5%) of statics data.
If 1.05645< 3.83785: Accept H01. The length of the fibres is not significantly different. If 112.414 > 4.45897: Reject H12. The tensile characteristics vary significantly from one another. Table Value (1%)
If 1.05645 < 11.3: Accept H01.The length of the fibres does not vary much.
If 112.414 >8.567: Reject H12. The tensile characteristics vary significantly from one another.

3.5 Relationship between length and tensile characteristics

Correlation method there are two types of correlation is possible

- There is a positive relationship between length and tensile qualities, meaning that when length grows, tensile characteristics also increase, or vice versa.

- Tensile characteristics will either increase or decrease with increasing length, a phenomenon known as negative correlations.

The correlation is calculated for modulus, strength and strain using the following relation and the value is listed on table 3.

$$\text{Correl}(X,Y) = \frac{\sum(x-\ddot{x})(y-\ddot{y})}{\sqrt{\sum(x-\ddot{x})^2 \sum(y-\ddot{y})2}} \quad (1)$$

where the sample means average (array1) and average (array2) are denoted by X and Y.

Table 3. Correlation table for modulus, strength and strain

Length	Modulus	Strength	Strain
10	2.543	263.8125	11.281
20	2.273	191.7205	10.016
30	3.616	179.698	5.637
40	3.721	162.4707	5.75
50	11.297	176.8929	7.14
Corr.Result	0.799636	-0.80492	-0.77509

The readings for our case show negative correlation for strength and strain values (increase in length and decrease in strength &strain), and positive correlation for modulus value (increase in length and increase in modulus)

4. Conclusions

Five hundred single fibre tensile experiments were effectively conducted with five distinct gauge lengths (10mm, 20mm, 30mm, 40mm, and 50mm) to predict the exact tensile strength of VGF. For every gauge length, one hundred tensile tests were performed; the results are shown in a table. With a tensile modulus ranging from 0.247 GPa to 15.719 GPa, the veldt grape single fibre tensile test was successfully completed. As the length expanded from 10mm to 50mm, the ultimate strength and strain dropped from 263.8125 MPa to 176.8929 MPa and 11.2808% to 7.1406%, respectively. The VGF's real cross-sectional area is measured between 0.00479 and 0.01323 mm². To ascertain if there is a significant difference between the fibres' length and tensile characteristics, the two-way ANOVA approach was used. The findings showed no discernible relationship between the fibres' length and tensile characteristics. The effect of the variation on the tensile characteristics as the fibre length grew was then ascertained using the correlation approach. The findings showed that although the modulus grew with length, the ultimate strength and strain dropped.

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