

**PRINCIPAL COMPONENT ANALYSIS IN  
BIOMETRIC, PULP QUALITY AND ANATOMICAL  
PROPERTIES OF THRONLESS BAMBOO  
(*Bambusa balcooa*)**

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**ABSTRACT**

**Aims:** To estimate the impact, connection and association among the biometric attributes, pulping qualities and anatomical characters in *Bambusa balcooa*

**Place and Duration of Study:** The study was conducted across the agro climatic regions viz., North Eastern Zone, Northern Zone, Western Zone, Cauvery Delta Zone and Southern Zone of Tamil Nadu, India during 2017-2018.

**Methodology:** The Principal Components Analysis (PCA) was examined to establish the numbers of clusters using Statistical Package for Social Studies (SPSS) version 16.0.1 software in order to identify the patterns of variation (PCA). The principal component analysis was computed using the equation  $PCA = \sum a_j X_j$

**Results:** The PCA separated into three cluster principal components among the nineteen parameters studied. Out of nineteen principal components generated, twelve principal components had contributed positively on pulp yield. Among these twelve traits, maximum contribution to the pulp yield was observed by the traits viz., numbers of culms, hollocellulose, kappa number, tear index, burst index, fibre wall thickness and vessel diameter with respect to *Bambusa balcooa*.

**Conclusion:** The results showed some relationships between the biometric attributes, pulping qualities and anatomical characters in *Bambusa balcooa*. PCA was shown to be a useful tool for assessing the impact and connection for further research.

**Keywords:** *Thornless bamboos, PCA, Impact & Connection, biometric attributes, pulping qualities, anatomical characters, Bambusa balcooa*

**1. INTRODUCTION**

India is the second richest country in bamboo genetic resources after China. These two countries together have more than half the total bamboo resources globally. Bamboos are aptly called the poor man's timber and are found in great abundance. Their strength, straightness and lightness combined with extraordinary hardness, range in sizes,

21 abundance, easy propagation and the short period in which they attain maturity make them  
22 suitable for a variety of purposes <sup>[1]</sup>. Deo Kumar Tamang *et al.*, <sup>[2]</sup> reported 136 species of  
23 bamboos occurring in India. Fifty-eight species of bamboo belonging to 10 genera are  
24 distributed in the north eastern states alone. The forest area, over which bamboos occur in  
25 India is approximately 9.57 million hectares, which constitutes about 12.8% of the total area  
26 under forests <sup>[3]</sup>. The general consumption pattern of bamboo in India indicates that 8.4% of  
27 bamboo is being consumed by pulp and paper industries while, cottage, furniture and  
28 implements industries consume 65% bamboo <sup>[4]</sup>. In earlier days, more than 70% bamboo  
29 was used for paper and paperboard production. In Bamboo, pulp yield is an important trait.  
30 This trait is more complex as it depends on the action and interaction of various component  
31 traits *viz.*, growth attributes, pulp quality and anatomical characters. In the integrated  
32 structure of Bamboo, most of the traits are inter-related with one another. Understanding of  
33 such association between traits is very essential for any genetic **improvement program**.  
34 Moreover, the Principal Component Analysis enables easier understanding of impacts and  
35 connections among the different traits by finding and explaining them<sup>[5]</sup>. Such studies are in  
36 infant stage in *Bambusa balcooa*. Keeping the above perspectives, the investigation on the  
37 impact and connection of different traits on *Bambusa balcooa* has been determined and  
38 presented hereunder.

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## 2. MATERIAL AND METHODS

### 2.1 Materials

43 The thorn less bamboos species *Bambusa balcooa* grown in five agro climatic *viz.*,  
44 Western Zone, Northern Zone, North Eastern Zone, Cauvery Delta Zone and Southern Zone  
45 were chosen as the experimental material for the present study. From the each agro climatic  
46 regions, five year old plantations of *Bambusa balcooa* were selected. From each plantation,  
47 25 clumps in three replications were selected for recording the biometric observations. In  
48 order to carry out pulp quality analysis of, selected single culm were felled from a clump and  
49 billets of 1 m length were extracted and chipped for pulp quality analysis. Five culm samples  
50 each of dimension 2 x 2 x 2 cm<sup>3</sup> were sliced out separately to study the anatomical  
51 properties in this species. The growth attributes, pulp quality and anatomical characters *viz.*,  
52 Height, Diameter, Number of culms, Internodal length, Bulk density, Basic density, Acid  
53 insoluble lignin, **Holocellulose**, Kappa number, Pulp yield, Tensile index, Tear index, Burst  
54 index, fiber wall thickness, fiber diameter, fiber length, Lumen diameter, Vessel length and  
55 Vessel diameter recorded at five years old *Bambusa balcooa* were subject to Principal  
56 Component Analysis.

### 2.2 Principal Component Analysis

58 A large number of variables are often measured by breeders, some of which may  
59 not be of sufficient discriminatory power for evaluation, characterization, and management.  
60 In such case, Principal Component Analysis (PCA) may be used to reveal patterns and  
61 eliminate redundancy in data sets [6] [7] as any variations routinely occur in any species.  
62 Analysis of variance using descriptive statistics such as mean, standard deviation and  
63 coefficient of variation and correlation coefficient for each of the studied traits were  
64 calculated. Clustering of genotypes into similar groups was performed using Ward's  
65 hierarchical algorithm based on squared Euclidean distances. For the three groups of traits  
66 viz., biometric attributes (height, diameter, number of culms and internodal length), pulping  
67 qualities (bulk density, basic density, acid insoluble lignin, holocellulose, kappa number, pulp  
68 yield, tensile index, tear index and burst index) and anatomical characters (wall thickness,  
69 diameter, and length of the fibers, lumen diameter, vessel length and vessel diameter), the  
70 data were standardized to have a mean of zero and a variance of one prior to squared  
71 Euclidean distance calculation. The pseudo F statistic and the pseudo T2 statistic [8] were  
72 examined to establish the numbers of clusters using Statistical Package for Social Studies  
73 (SPSS) version 16.0.1 software [9]. In order to identify the patterns of variation, (PCA) was  
74 conducted.

75 Those Principal Components with Eigen values greater than one were selected as  
76 proposed by Jeffers [10]. Correlations between the original traits and the respective Principal  
77 Components were calculated. Data were processed using statistical program Statistical  
78 Package for Social Studies (SPSS) version 16.0.1 software [9]. The principal component  
79 analysis was computed using the following equation:

$$80 \quad PC = \sum a_j X_j$$

81 Where: PC = Principal component,

82  $a_j$  = Linear coefficient

83  $X_j$  = Eigen vectors

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### 85 3. RESULTS AND DISCUSSION

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87 The Principal Component Analysis, is one the multivariate analysis method and  
88 provides easier understanding of impacts and connections among different traits [11]. There is  
89 a certain number of criteria for selecting the number of principal components (PC) to be  
90 included in the future analysis, and mostly these are based on the height of Eigenvalues  
91 Principal Components or needed Summary communality in percentage [11]. In most cases the  
92 number of principal components rotated depends on the number principal components  
93 chosen for the next analysis [12].

94 The present investigation was carried out in five agro climatic regions of Tamil Nadu  
 95 viz., North Eastern Zone, Northern Zone, Western Zone, Cauvery Delta Zone and Southern  
 96 Zone with thorn less bamboo species viz., *Bambusa balcooa* across different age gradations  
 97 in order to elucidate the suitability of thorn less bamboos based on their growth performance,  
 98 pulping qualities as well as wood anatomy. The results of Principal Component Analysis are  
 99 presented here under. Number of Principal Components calculated from correlation matrix  
 100 was 19. It is similar to the number of observed traits viz., biometric attributes, pulp quality  
 101 traits and anatomical characters of *Bambusa balcooa*. Principal Component Analysis  
 102 concentrated variability in first principal components. Total variance explained with the first  
 103 Principal Component was 38.99 per cent followed by second principal component (32.578 %),  
 104 third principal component (18.159 %) and fourth principal component (10.273 %). With these  
 105 four principal components hundred per cent of total variability had been accounted.  
 106 Variances explained by the rest of fifteen principal components were irrelevant (Table 1).

107 The first four principal components explained were based on rotated values. Among  
 108 the three groups of traits viz., biometric traits, pulping qualities and anatomical characters,  
 109 Significant correlation was exhibited by vessel diameter (0.997) followed by number of culms  
 110 (0.987), holocellulose (0.815), burst index (0.612), tear index (-0.695), fiber wall thickness  
 111 (0.805) and kappa number (0.936) in the first principal component. In the highest significant  
 112 correlation with second principal component were lumen diameter (0.950) followed by fiber  
 113 diameter (0.891), acid insoluble lignin (0.845) and basic density (0.865). These first and  
 114 second principal components comprised of quality parameters that relates to pulp yield and  
 115 paper and hence these principal components could be named as pulp and paper quality  
 116 (Table 2).

117 **TABLE 1 Eigenvalues and variability of rotated values of Principal components in *Bambusa***  
 118 ***balcooa***

<i>Principal components</i>	<i>Initial Eigenvalues</i>		
	<b>Total</b>	<b>% of Variance</b>	<b>Cumulative %</b>
Height	7.408	38.990	38.990
Diameter	6.190	32.578	71.568
Number of culms	3.450	18.159	89.727
Internodal length	1.952	10.273	100.000
Bulk density	4.910	2.584	100.000
Basic density	4.244	2.234	100.000

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Acid insoluble lignin	3.331	1.753	100.000
Holocellulose	2.848	1.499	100.000
Kappa number	1.969	1.036	100.000
Pulp yield	1.061	5.584	100.000
Tensile index	6.289	3.310	100.000
Tear index	1.662	8.750	100.000
Burst index	-1.585	-8.343	100.000
Fiber wall thickness	-8.391	-4.416	100.000
Fiber diameter	-1.240	-6.525	100.000
Fiber length	-2.065	-1.087	100.000
Lumen diameter	-2.812	-1.480	100.000
Vessel length	-3.916	-2.061	100.000
Vessel diameter	-6.598	-3.473	100.000

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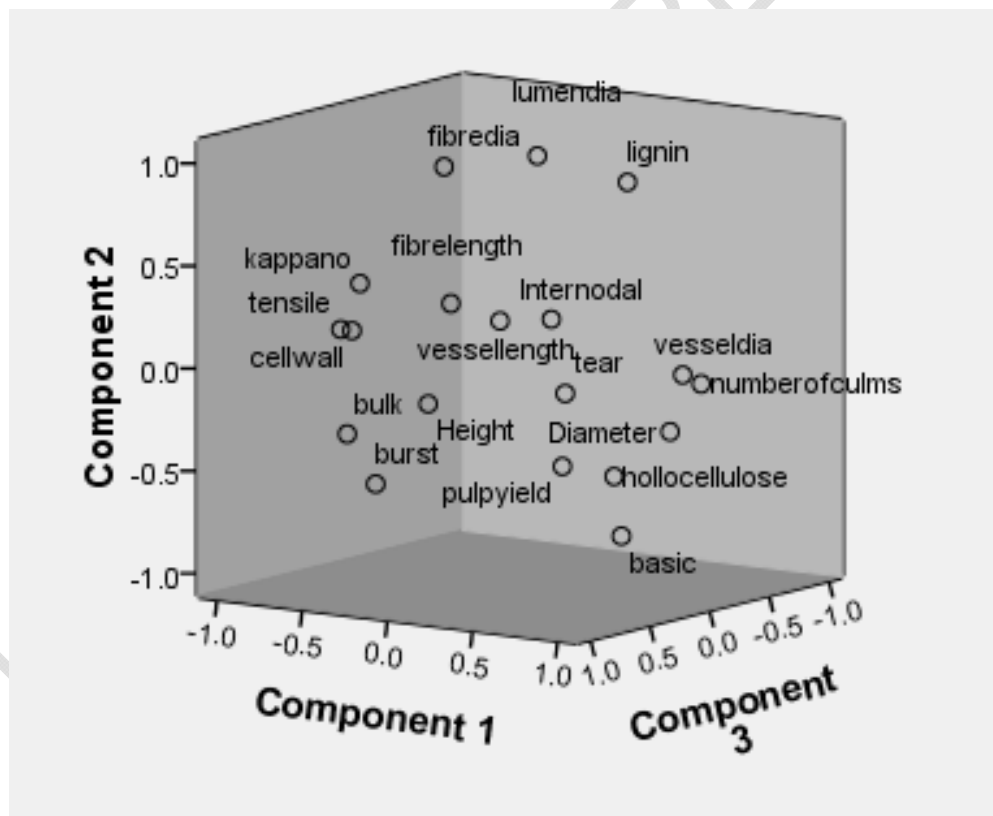
TABLE 2. Principal Component analysis of *Bambusa balcooa*–rotated values

<i>Traits</i>	<i>Principal components</i>			
	Component 1	Component 2	Component 3	Components 4
Height	0.151	-0.064	<b>0.986</b>	-0.002
Diameter	0.487	-0.389	<b>-0.563</b>	0.542
Number of culms	<b>0.987</b>	-0.040	-0.110	-0.110
Internodal length	-0.043	0.141	-0.324	<b>0.935</b>
Bulk density	-0.487	-0.309	<b>0.754</b>	-0.315
Basic density	0.405	<b>-0.865</b>	-0.272	0.120
Acid insoluble lignin	0.375	<b>0.846</b>	-0.365	0.104
Hollocellulose	<b>0.815</b>	-0.439	0.376	0.045
Kappa number	<b>-0.936</b>	0.072	0.167	0.303
Pulp yield	<b>0.625</b>	-0.033	0.514	-0.586
Tensile index	-0.306	-0.532	<b>0.773</b>	-0.159
Tear index	<b>-0.695</b>	0.347	0.350	0.524
Burst index	<b>0.612</b>	-0.390	0.518	-0.453
Fibre wall thickness	<b>-0.805</b>	0.092	0.260	-0.525
Fibre diameter	-0.442	<b>0.891</b>	0.005	0.101
Fibre length	0.083	0.378	<b>0.698</b>	-0.602
Lumen diameter	-0.058	<b>0.950</b>	-0.228	0.205
Vessel length	-0.100	0.176	0.024	<b>0.979</b>
Vessel diameter	<b>0.997</b>	0.030	0.059	0.045

124 The third principal component explained 18.15 percentage of total variance recorded  
125 maximum significant correlation with the pulp yield in the order of height (0.986), tensile index  
126 (0.773), bulk density (0.754), fibre length (0.698) and diameter (-0.563). Vessel length (0.979)  
127 and internodal length (0.935) recorded the maximum significant correlation with pulp yield in  
128 fourth principal component which explained 10.273 per cent of total variance. Hence the third  
129 and fourth principal components could be named as components productivity (Table 2).

130 In the present investigation, with respect to *Bambusa balcooa*, out of nineteen  
131 principal components generated, twelve principal components viz., height, diameter, number  
132 of culms, internodal length, bulk density, basic density, acid insoluble lignin, holocellulose,  
133 kappa number, tensile index and tear index had contributed positively on pulp yield. Among  
134 these twelve traits, maximum contribution to the pulp yield was observed by the traits viz.,  
135 numbers of culms, holocellulose, kappa number, tear index, burst index, fibre wall thickness  
136 and vessel diameter. (Figure 1).

137 **FIGURE 1. Principal Component analysis for *Bambusa balcooa*–rotated values**



138 Similar to the present study PCA had also been used as an effective tool to confirm  
139 the impacts and connections among different traits in *Eucalyptus*<sup>[13]</sup>, *Casuarina equisetifolia*  
140<sup>[14]</sup><sup>[15]</sup> and *Azadirachta indica*<sup>[16]</sup> which fall in line with the findings of the current investigation.

142 **4. CONCLUSIONS**

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Holistically, out of nineteen principal components generated, twelve principal components viz., height, diameter, number of culms, internodal length, bulk density, basic density, acid insoluble lignin, holocellulose, kappa number, tensile index and tear index had contributed positively on pulp yield. Among these twelve traits, maximum contribution to the pulp yield was observed by the traits viz., numbers of culms, holocellulose, kappa number, tear index, burst index, fibre wall thickness and vessel diameter with respect to *Bambusa balcooa*.

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152 **COMPETING INTERESTS**

153 Authors have declared that no competing interests exist.

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