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Physical properties of *Calamus* species of Arunachal Pradesh

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ABSTRACT

Rattans are spiny climbing palms with solid and flexible stems and are considered as one of the most important non-timber forest products. The present study was carried out on seven species of *Calamus* viz. *C. acanthospathus, C. flagellum, C. floribundus, C. gracilis, C. latifolius, C. leptospadix* and *C. nambariensis* collected randomly from natural forests of Arunachal Pradesh. Of these species, *C. flagellum* and *C. latifolius* belonged to large size diameter class, *C. acanthospathus, C. floribundus*, *C. leptospadix* and *C. nambariensis* had medium size diameter and *C. gracilis* had small size diameter classes. The aim of this investigation was to study the variation of physical properties namely specific gravity, moisture content, longitudinal, radial, tangential, volumetric shrinkages and T/R ratio in selected species along the heights. *C. latifolius* had the largest stem diameter (45.86 mm) and *C. gracilis* had the smallest (8.73 mm). Maximum and minimum specific gravity were observed in *C. acanthospathus* (0.54) and *C. floribundus* (0.28). Specific gravity decreased from bottom to top in all species. The maximum and minimum moisture content were found in *C. leptospadix* (55.62%) and *C. gracilis* (13.15%). Moisture content increased along the height in all species. Longitudinal shrinkage was less than tangential and radial shrinkage in all species. T/R ratio increased from bottom to top position in all species except *C. acanthospathus* and *C. flagellum*. On the basis of present study, *C. acanthospathus and C. nambariensis* were the most suitable species for various end uses as they have more desirable physical properties than other *Calamus* species.

1. Introduction

Rattan is a group of climbing palms and belongs to family ″Arecaceae″. It is considered as one of the most important non-timber forest products. The name rattan is derived from the Malayan word ′rotan′ which means “climbing palm”. Presence of dense spines on stem and scales on fruits distinguish rattans from other palm species (Dransfield 1992) while the presence of solid stem distinguishes them from bamboo. North Eastern states of India are endowed with diverse rattan resources. There are 4 genera and 20 species of rattans in North East India (Raj *et al*. 2014) out of which Arunachal Pradesh alone harbours 18 species of these genera (Haridasan *et al.* 2002). *Calamus* grows over a wide area and has excellent properties as well as numerous commercial applications. *Calamus* is the largest genus with 375 species (Dransfield 1992; Monohara 2007). Of these, 13 species of *Calamus* are reported from Arunachal Pradesh (Haridasan *et al.* 2002). It grows over a wide area and has excellent properties as well as numerous commercial applications. Due to extensive demand for commercial purpose in market, some of the *Calamus* species like *Calamus nambariensis, C. inermis and C. khasiana* have become scarce in Arunachal Pradesh while other species like *Calamus flagellum, C. acanthospathus, C. latifolius, C. gracilis, C. leptospadix* and *C. tenius* are still abundant in this region (Haridarsan *et al.* 2002).The available literature on *Calamus* reveals that potential utilization and grading of rattan mainly depend on the size of stem diameter and internode length (Renuka *et al.* 1987). Mohmod *et al.* (1994) investigated the physical properties and anatomical features of *Daemonorops angustifolia* and *Calamus ornatus* and compared their shrinkage property with *Calamus manan.* They reported the use of both species as an alternative to *Calamus manan.* Kalmia and Jasni (2004) reported *Calamus occidentalis* as a substitute of *Calamus manan* for

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commercial values and possible utilization due to high strength and durability. Bin *et al.* (2014) reported that utilization of different end use products also depends on the physical properties. Ahmed *et al.* (2022) reported that medium diameter of *C. zollingeri* exhibited higher basic density, lower shrinkage and higher dimensional stability and durability than large diameter of *C. zollingeri* and small diameter of *C. ornatus*. Sharma *et al.* (2018) reported that the physical properties for cane processing and utilization are influenced by the species, stem position, diameter, internode length and density. However, there is no information available on the physical properties of *Calamus* species in Arunachal Pradesh. Therefore, the present study is an attempt to study physical properties namely specific gravity, moisture content, longitudinal, radial, tangential, volumetric shrinkages and T/R ratio in *Calamus* species of Arunachal Pradesh and their variation along the stem height for different end use products.

2. Materials and Methods

The seven species of *Calamus* namely *Calamus acanthospathus* Griff., *Calamus flagellum* Griff., *Calamus floribundus* Griff., *Calamus gracilis* Roxb., *Calamus latifolius* Roxb., *Calamus leptospadix* Griff. and *Calamus nambariensis* Becc. were collected from natural forests of Arunachal Pradesh (Fig.1). Geographical coordinates of collected *Calamus* species were given in Table 1. Five stems of each species were randomly selected from the mature clumps. The stems were cut at the height of 20 cm above the ground level. The stem height, diameter of stem, internode length and internode number were taken. Each stem was divided equally into three portions- bottom, middle and top. Three internodes were selected at each height position for investigations of physical properties and samples of 2.5 cm size were cut from the middle portion of the internodes at each height position. Water displacement method (Smith 1955) was used to determine the specific gravity. Longitudinal, radial and tangential shrinkages were taken by calliper and determined as given by Panshin and deZeeuw (1980) method. Moisture content was determined according to Indian standard Method (2008). A total of 45 samples per species were taken to study each physical property. SPSS 16.0 software was used to analyse the data statistically at $\alpha = 0.05$. Tukey's test was carried out to determine the significant differences in physical properties among species at different height positions.

3. Results and discussions

The present study revealed that two species namely *C. flagellum* and *C. latifolius* belonged to large diameter, *C. acanthospathus, C. floribundus, C. leptospadix* and *C. nambariensis* were of medium diameter and *C. gracilis* was of small diameter classes. The stem diameter increased from bottom to top in all species except *C. flagellum* and *C. floribundus* which may be due to increased vigour primary growth in younger part of stem accompanied by frequent and large intercellular spaces in the ground tissue (Bhat *et al*. 1990). Morphological parameters of selected species were tabulated in Table 2. Among all selected species, *C. latifolius* had the longest internode length (34.61cm), while *C. acanthospathus* (20.63 cm) had the shortest. The maximum height was observed in *C. floribundus* (25.52 m) and *C. flagellum* (5.46 m) had the minimum. The maximum number of internodes was present in *C. acanthospathus* (123.40) and the minimum in *C. flagellum* (14.4).

It is well known that specific gravity is one of the important physical properties to determine the strength and flexibility of the cane for different end use products. Maximum specific gravity was observed in *Calamus acanthospathus* (0.54) and minimum in *Calamus floribundus* (0.28). The results presented in Table 3 showed that specific gravity significantly decreased from bottom to top positions in all the species. Similar results were obtained in other rattan species (Renuka *et al.* 1987; Bhat and Vergheese 1991; Ali *et al.* 1995; Roszaini 1997; Wahab *et al.* 2007; Sharma *et al.* 2018; Yang *et al.* 2020). The decrease in specific gravity may be due to the presence of thick-walled fibres and higher concentration of vascular bundle at bottom position as observed anatomically. Moisture content is also responsible to determine the durability of rattan. High moisture content species are highly vulnerable to fungi and insect attack. Moisture content of rattan varies significantly with species and height of the stem (Ali *et al.* 1995). Moisture content increased from bottom to top positions in all species. The increased of moisture content at the top position may be due to the presence of lower parenchyma and more fibre percentage at bottom position. The present result confirms the findings of Abd latif and Norralakmam (1993) and Mohmod *et al.* (1994). Maximum moisture content was observed in *Calamus leptospadix* (55.62%) and minimum in *Calamus gracilis* (13.15%). The shrinkage property acts as an important factor to determine the dimensional stability of the rattan species. Shrinkage occurs due to moisture changes. Longitudinal, radial and tangential shrinkages were given in Table 4. Longitudinal shrinkage was maximum in *C. nambariensis* (1.29%) and minimum in C. *leptospadix* (0.44%). Radial and tangential shrinkages were observed maximum in *C. flagellum* (11.19%) and *C. leptospadix* (16.50%). Minimum radial and volumetric shrinkages were observed in *C. floribundus* (2.21%, 5.81%) and minimum tangential shrinkage was found in *C. nambariensis* (2.89%). The longitudinal shrinkage increased from bottom to top positions in

all species unlike in *C. floribundus* and *C. nambariensis*. Radial shrinkage decreased from bottom to top in all species except in *C. latifolius* and *C. leptospadix*. However, tangential shrinkage also decreased from bottom to top positions whereas, it increased in *C. latifolius* and *C. leptospadix* along the height. Volumetric shrinkage of *C. floribundus, C. latifolius* and *C. leptospadix* were increased from bottom to top and it decreased in *C. acanthospathus*, *C. flagellum*, *C.gracilis* and *C. nambariensis* along the height. *C. floribundus* had the highest T/R ratio (2.47) and *C. nambariensis* had the lowest (1.07). T/R ratio increased along the culm height except in *C. acanthospathus* and *C. flagellum (*Table 5). Among longitudinal, radial and tangential shrinkages, longitudinal shrinkage was less than tangential and radial shrinkage. Tangential shrinkage was more than radial shrinkage in all species which may be due to less shrinkage of parenchyma radially than tangential direction (Abd latif and Mohd. Zin (1992).

In case of physical properties, moisture content of all species showed non-significant variation at different height positions. Whereas, in specific gravity all the species showed significant variation at different height positions except in *C. leptospadix*. No significant variation was observed in longitudinal shrinkage. Radial shrinkage and volumetric shrinkages of *C. acanthospathus* and *C. gracilis* showed highly significant along the heights. Whereas, in tangential shrinkage only *C. acanthospathus* showed significant variation along the culm height. The present study revealed that all *Calamus* species has desirable physical properties. Since *C. acanthospathus* and *C. nambariensis* have higher specific gravity and low moisture content, shrinkage and T/R ratio, therefore these species can be utilized for various end uses.

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C. acanthospathus

C. flagellum

C. floribundus

C. gracilis

C. latifolius

C. leptospadix

C. nambariensis

Figure 1. Clumps of the selected seven species of *Calamus*

Table 1. Geographical co-ordinates of selected *Calamus* species

Species name	Geographical co-ordinates	Locality
C. acanthospathus	28° 28' 18.7"N 94° 80' 26.9"E	Jomo village, Siang district
C. flagellum	27° 97'31.8"N 95° 03'25.3"E	Sido village, East siang district
C. floribundus	27° 97'04.7"N 95° 03'08.8"E	Sido village, East siang district
C. gracilis	28° 26'24.7"N 94° 82'67.4"E	Jomo village, Siang district
C. latifolius	27° 97'33.3"N 95° 02'92.2"E	Sido village, East siang district
C. leptospadix	27° 90'28.5"N 95° 30'00.8"E	Sille village, East siang district
C. nambariensis	27° 94'37.6"N 95° 16'87.8"E	Bilat village, East siang district

Table 2. Morphological parameters of selected *Calamus* species at different height positions

Species	Position	Diameter (mm)	Internode length (cm)	Height (m)	Internode number
		(Mean±S.D)			
C. acanthospathus	Bottom	11.85± 1.34	20.35± 5.13	26.8± 7.79	123.40± 54.77
	Middle	15.04± 4.66	23.58± 24.26		
	Top	18.3± 6.07	17.98± 4.91		
	Average	15.09± 3.49	20.63± 8.92		
C. flagellum	Bottom	31.99± 2.67	30.02± 11.12	5.46± 2.67	14.40± 6.66
	Middle	31.82± 2.88	36.26± 6.88		
	Top	29.74± 6.55	33.65± 5.02		
	Average	31.18± 3.20	32.75± 5.20		
C. floribundus	Bottom	12.91± 1.61	21.90± 3.59	25.52±13.54	43.20± 15.45
	Middle	15.10± 16.75	18.78± 4.62		
	Top	10.24± 1.36	21.25± 21.25		
	Average	12.75± 5.58	20.64± 2.10		
C. gracilis	Bottom	7.15± 1.29	18.97± 6.44	23.30± 2.95	101.6± 16.27
	Middle	9.11± 1.62	23.96± 4.54		
	Top	9.94± 1.82	19.08± 3.49		
	Average	8.73± 1.27	20.67± 2.07		
C. latifolius	Bottom	41.29± 7.89	39.70±10.76	12.15± 1.76	38.20± 5.81
	Middle	46.57± 5.39	35.36± 7.56		
	Top	49.74± 3.13	28.78± 3.35		
	Average	45.86± 4.87	34.61± 4.60		
C. leptospadix	Bottom	16.27± 1.47	26.11± 8.79	5.63± 0.76	25.4± 5.50
	Middle	17.62± 1.29	26.11± 8.79		
	Top	17.88± 1.66	19.67± 3.72		
	Average	17.26± 1.26	22.53± 3.81		
C. nambariensis	Bottom	10.74± 1.37	28.88± 5.51	21.7 ± 2.22	52.4± 23.81
	Middle	14.54± 2.41	25.54± 4.44		
	Top	18.29± 3.79	25.00± 3.62		
	Average	14.52± 2.13	26.47± 3.20		

Table 3. Moisture content and specific gravity of selected *Calamus* species at different height positions

Species	Height position	Moisture content	Specific gravity
		Mean±S.D	
C. acanthospathus	Bottom	15.11±0.94[a]	0.62±0.07[c]
	Middle	14.35±0.63[a]	0.54±0.05[b]
	Top	15.32±1.73[a]	0.47±0.05[a]
	Average	14.93±0.77[a]	0.54±0.04[b]
C. flagellum	Bottom	29.57±18.34[a]	0.52±0.02[c]
	Middle	32.55±12.21[a]	0.47±0.04[b]
	Top	48.57±45.11[a]	0.42±0.06[a]
	Average	36.67±15.89[a]	0.47±0.02[b]
C. floribundus	Bottom	14.29±1.42[a]	0.33±0.03[c]
	Middle	13.84±0.22[a]	0.29±0.02[b]
	Top	14.40±1.18[a]	0.21±0.04[a]
	Average	14.18±0.56[a]	0.28±0.01[b]
C. gracilis	Bottom	12.87±1.81[a]	0.50±0.05[b]
	Middle	13.61±0.63[a]	0.39±0.06[a]
	Top	12.96±2.47[a]	0.39±0.16[a]
	Average	13.15±0.95[a]	0.43±0.06[ab]
C. latifolius	Bottom	39.97± 16.89[a]	0.42± 0.07[c]
	Middle	37.15± 12.02[a]	0.36± 0.04[b]
	Top	47.03± 23.01[a]	0.31± 0.04[a]
	Average	41.38± 8.65[a]	0.37± 0.04[b]
C. leptospadix	Bottom	52.13± 30.81[a]	0.40± 0.03[a]
	Middle	51.93± 27.25[a]	0.37± 0.05[a]
	Top	62.82± 31.53[a]	0.37± 0.06[a]
	Average	55.62± 15.62[a]	0.38± 0.02[a]
C. nambariensis	Bottom	15.36± 1.52[a]	0.50± 0.07[ab]
	Middle	15.45± 2.66[a]	0.52± 0.06[b]
	Top	15.99± 1.89[a]	0.45± 0.05[a]
	Average	15.60± 1.57[a]	0.49± 0.04[ab]

Values with same letter in the same row are not significantly different at 0.05 probability level

Table 4. Shrinkage of selected *Calamus* species at different height positions

Species	Height position	Shrinkage (%)			
		Longitudinal	Radial	Tangential	Volumetric
		Mean±S.D			
C. acanthospathus	Bottom	0.94±0.30[a]	3.91±0.69[b]	4.28±0.81[b]	9.14±1.13[b]
	Middle	1.24±0.72[a]	3.05±0.82[a]	3.00±1.67[a]	7.30±2.46[a]
	Top	1.37±0.59[a]	3.08±0.77[a]	3.05±0.95[a]	7.51±1.31[a]
	Average	1.19±0.32[a]	3.35±0.46[ab]	3.45±0.70[ab]	7.98±1.00[ab]
C. flagellum	Bottom	0.40±0.36[a]	11.85±5.33[a]	16.84±2.08[a]	29.10±6.02[a]
	Middle	0.79±0.74[a]	11.44±5.86[a]	14.87±5.63[a]	27.11±10.51[a]
	Top	0.49±0.46[a]	10.26±3.47[a]	14.74±4.40[a]	25.50±7.42[a]
	Average	0.56±0.34[a]	11.19±2.94[a]	15.49±3.00[a]	27.24±5.50[a]
C. floribundus	Bottom	1.23±1.61[a]	2.70±1.81[a]	4.38±2.21[a]	5.66±2.33[a]
	Middle	0.74±0.36[a]	2.38±1.44[a]	3.90±2.12[a]	5.30±2.17[a]
	Top	1.05±0.89[a]	1.57±0.64[a]	3.83±1.95[a]	6.47±2.15[a]
	Average	1.01±0.47[a]	2.21±1.07[a]	3.88±1.45[a]	5.81±1.52[a]

C. gracilis	Bottom	1.09±0.38[a]	3.88±0.93[b]	3.66±1.21[a]	8.63±1.52[b]
	Middle	1.01±0.39[a]	2.63±1.20[a]	2.99±1.55[a]	6.63±2.36[a]
	Top	1.19±0.43[a]	2.66±0.71[a]	2.64±1.46[a]	6.48±1.67[a]
	Average	1.09±0.32[a]	3.05±0.64[ab]	3.09±0.72[a]	7.25±0.93[ab]
C. latifolius	Bottom	0.83±0.52[a]	8.23±3.16[a]	8.83±3.42[a]	17.90±6.34[a]
	Middle	0.66±0.37[a]	9.31±5.69[a]	11.51±5.09[a]	21.49±10.55[a]
	Top	0.88±0.97[a]	9.69±2.24[a]	11.29±1.02[a]	21.87±2.98[a]
	Average	0.79±0.39[a]	9.08±2.22[a]	10.55±2.23[a]	20.43±4.34[a]
C. leptospadix	Bottom	0.33±0.30[a]	7.54±1.31[a]	16.38±2.50[a]	24.26±3.18[a]
	Middle	0.57±0.66[a]	8.17±1.24[a]	16.42±2.59[a]	25.17±2.60[a]
	Top	0.41±0.40[a]	7.67±1.4[a]	16.71±2.97[a]	24.80±3.59[a]
	Average	0.44±0.30[a]	7.80±0.69[a]	16.50±1.43[a]	24.74±1.71[a]
C. nambariensis	Bottom	1.19±0.76[a]	2.87±0.59[a]	2.69±1.87[a]	6.74±1.54[a]
	Middle	1.13±0.56[a]	3.19±1.58[a]	3.42±2.24[a]	7.74±3.89[a]
	Top	1.07±0.46[a]	2.47±0.73[a]	2.55± 1.40[a]	6.10±1.88[a]
	Average	1.13±0.35[a]	2.84±0.64[a]	2.89±0.90[a]	6.86±1.40[a]

Values with same letter in the same row are not significantly different at 0.05 probability level

Table 5. T/R ratio of selected *Calamus* species at different height position

Height position	***C. acanthospathus***	***C. flagellum***	***C. floribundus***	***C. gracilis***	***C. latifolius***	***C. leptospadix***	***C. nambariensis***
Bottom	1.20	1.70	2.00	0.99	1.07	2.21	1.02
Middle	1.01	1.44	2.15	1.65	1.32	2.05	1.17
Top	1.04	1.50	3.26	1.10	1.24	2.26	1.03
Average	1.08	1.54	2.47	1.24	1.21	2.17	1.07