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Root development in rattans 1. A quantitative study of the roots in two species of *Calamus* L.

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Abstract—The development of root systems of *Calamus thwaitesii* and *C. rotang* was studied for 3 years from seed germination. At the end of the period both species had almost the same number of main roots: *C. thwaitesii* had 28 main roots with a mean length of 45.74 cm and diameter of 3.68 mm and *C. rotang* had 25 main roots with a mean length of 38.70 cm and diameter of 2.8 mm. There were more laterals in *C. thwaitesii* and more sub-laterals in *C. rotang*. A significant difference between the two species was noted with respect to length and diameter of laterals. When there was an increased elongation rate in main roots, there was a decrease in the rate of growth of laterals and *vice versa*. Vertical growth was predominant during the early stages. The root system of a 3-year-old seedling of *C. rotang* showed more horizontal spread compared to *C. thwaitesii*. In *C. rotang* 68% of variation in length and 78% of variation in diameter could be explained by the age of the plant while in *C. thwaitesii* 42% of the variation in root length and 57% of the variation in diameter could be explained by the age of the plant. The age factor influences the root distribution pattern and, hence, determines the area around the plants where soil work needs to be done to open basins to hold water and for manuring. For a 3-year-old *C. rotang* soil work should be done at 45–50 cm around the plant and for a 3-year-old *C. thwaitesii* this would be less, at about 30 cm.

Key words: Root development; rate of growth; spatial distribution; age; silvicultural practices; *C. thwaitesii*; *C. rotang*.

INTRODUCTION

Rattans or canes, belonging to the family Arecaceae, form one of the most useful forest resources, utilized for the manufacture of furniture and handicraft items. They constitute an integral part of the tropical forest ecosystem and include 13 genera and about 600 species in the world [1]. In India, rattans are reported to comprise 60 species in 4 genera [2]. Peninsular India has only one genus, *Calamus*, and in Kerala 15 species of this genus occur [2, 3].

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The economic and social importance of the rattan sector is directly linked to wild rattan resources which are dwindling very fast, due to unscientific extraction and lack of management. The rattan industries in south India are short of raw material and are purchasing it from north-eastern states and the Andaman islands at higher prices. As a remedial measure, the Kerala Forest Department has started cane plantations. Since rattan is a new plantation crop, the silvicultural practices have to be standardized for which a sound knowledge of the pattern and growth of the root system also is required. Knowledge of the structure and development of the root system is essential for a complete understanding of the ecological requirements of each species, which in turn forms the basis for necessary silvicultural practices.

Various aspects of root systems of palms have been subjected to detailed studies by various workers [4–12]. Banik and Ahmed [13] and Lakshmana [14] conducted studies on the root system of rattan species. Not much information is available on the growth pattern, branching pattern or spatial distribution of rattan root systems, especially in the seedling stages. Such information is essential to optimise silvicultural practices in the nursery and early growing stages, e.g. the size of the pit for out-planting, the size of the basin to be opened around each plant, the radius for fertilizer application, etc.

The present study is chiefly concerned with the general form which the root system can attain and its distribution under relatively favourable conditions, with the main objectives being to study and compare the development of root systems and the spatial orientation of roots of selected species of *Calamus* from germination onwards. The early stages of growth are mainly considered because root development at that time is more likely to affect the survival of the plants.

MATERIALS AND METHODS

The study was conducted at the field research station of the Kerala Forest Research Institute (KFRI) at Palappilly. The area selected for the study was more or less undulating and receives an average annual rainfall of 2430 cm. Two commercially important rattans, *Calamus thwaitesii* and *C. rotang*, were selected for this study. *C. thwaitesii* is a large-diameter cane (reaching 3 cm in diameter) and *C. rotang* is a small-diameter one (often less than 1 cm in diameter). Mature seeds were collected from the forest areas in the Western Ghats of Kerala. The voucher specimens were deposited at KFRI herbarium. The fruits, seeds and seedlings were pickled in formalin/acetic alcohol and deposited at KFRI.

To study the germination method, mature fruits of *C. rotang* and *C. thwaitesii* were depulped and put to germination in moist sawdust in plastic trays and kept them in the nursery at the field research station of KFRI. Watering was done once daily. The method of germination was observed. The germinated seeds were used for further field trials.

To study the development of the root system, the experiment was laid out in a randomised block design with the two species replicated five times. Thus, 900 seeds of each species were planted. The plot size was 90 m $\times$ 4.5 m with plants spaced at 1.5 m $\times$ 1.5 m. Thus, in each plot, there were three rows with a total of 180 germinated seeds with 60 seeds in a row. Alternate plants from the central row were selected for recording observations, leaving all the plants in the other two rows to maintain uniform growing conditions throughout the observation period. Initial growth measurements of the root system of the germinated seedlings were made after 2 months. Later on, measurements were taken for both species at intervals of 2 months for 3 years.

To study the morphology of the root system, excavation was carried out, taking care not to damage even the smallest rootlet. Soil around each root was removed carefully after sprinkling adequate water. Before taking the plant out of soil, horizontal and vertical distances the roots had traversed were measured. After excavation, the roots were washed carefully with water to remove all the soil particles. The number, length and diameter of all the main roots and laterals were measured. Here, the first formed root and other roots emerging from the base of the plant are called main roots. The branches of these roots are called laterals and branches from them are referred to as sub-laterals (Fig. 1).

GROWTH CHARACTERS

Number

Numbers of main roots, laterals and sub-laterals were counted. The number of rootlets arising from these main roots and laterals was also recorded. The data were subjected to analysis of variance.

Length

Length measurements of main roots, laterals and sub-laterals were subjected to analysis of variance to find the influence of species on length. This was followed by pair wise comparison of mean values. Rate of increase in length of main roots, laterals and sub-laterals of the two species in each year (from the second year onwards) was calculated using the formula $(l_2 - l_1)/l_1$ where l_2 is the average length of the main/lateral/sub-lateral root in a particular year and l_1 the average length of the main/lateral/sub-lateral root in the previous year. Regression functions were fitted to study the pattern of changes over time.

Diameter

The diameters of main and lateral roots were measured using vernier callipers. The diameter of sub-lateral roots was measured using an ocular micrometer. In order to find variation in the diameter of roots between the two species, the data was subjected to analysis of variance followed by pair-wise comparison of mean values. The rate of increase in diameter of main roots, laterals and sub-laterals of

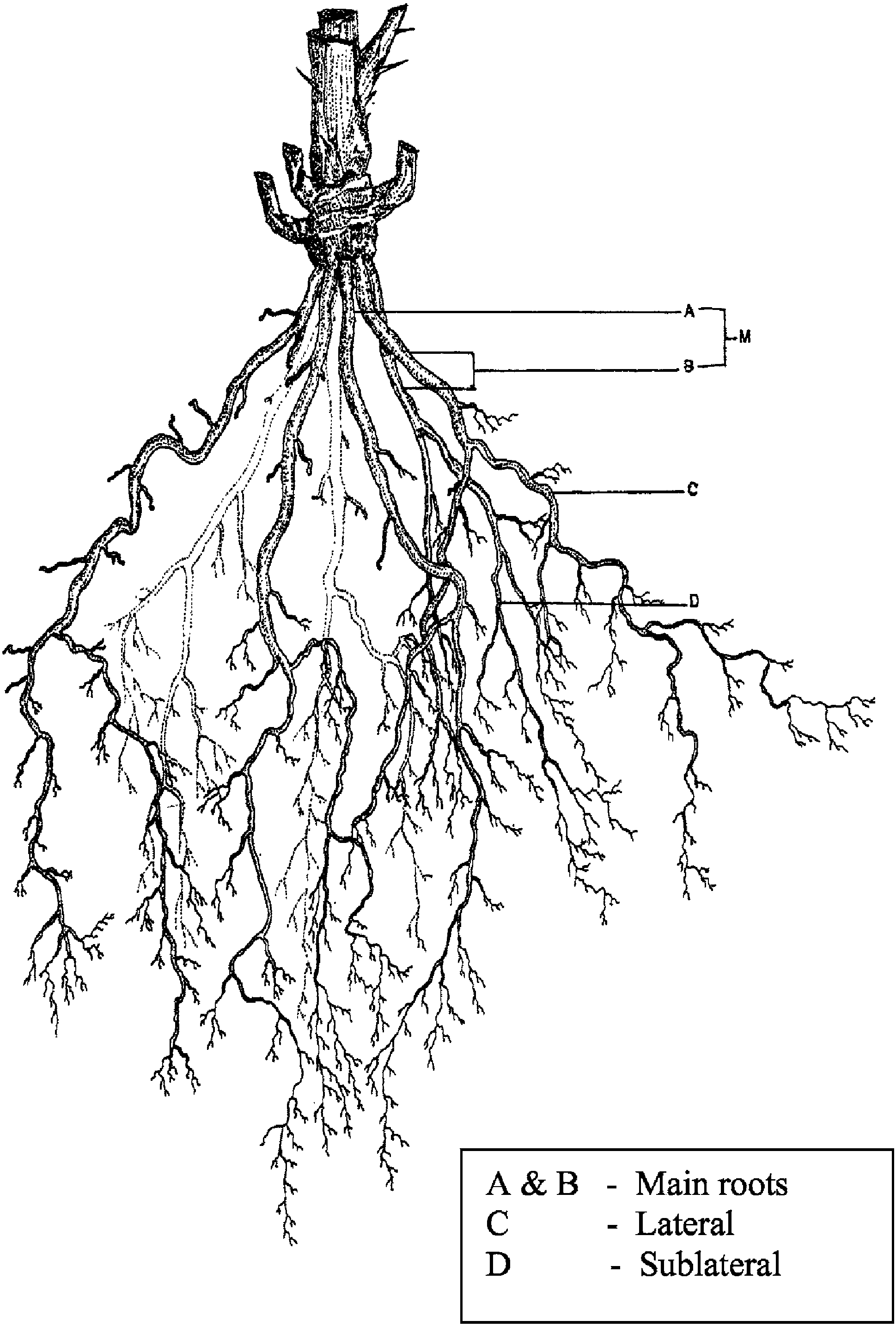

Figure 1. General root morphology.

the two species in each year (from the second year onwards) was calculated using the formula $(d_2 - d_1)/d_1$ where d_2 is the average diameter of the main/lateral/sub-lateral root in a particular year and d_1 the average diameter of main/lateral/sub-lateral root in the previous year. Regression functions were fitted to study the pattern of changes over time.

Root spread

Maximum horizontal distance of the root systems was measured before taking the plant out of the soil and vertical soil depth occupied by each of the main roots was also measured. The data were subjected to analysis of variance followed by comparison of mean values.

RESULTS AND DISCUSSION

Growth characteristics

The germination in both species is adjacent ligular. The growth of the primary root is soon arrested and replaced by adventitious roots produced from the base (Figs 2 and 3). These roots produce laterals and sub-laterals. The same type of development is reported in *Elaeis guineensis* [15] and *Areca catechu* [8].

The base of the stem, developed in the juvenile phase, is commonly bulbous and wider than the distal part, which must offer mechanical advantages as well as a large surface for root development. A large number of adventitious or secondary roots arise from this base as the seedlings grow. Vertical and horizontal roots were observed in both species but no pneumatophores were present as reported in certain species of rattans [9, 14, 15]. Subsequent observations on the two species in the natural rattan-growing areas in the forests also showed that pneumatophores are not produced there.

The number, length and diameter of main roots, as well as laterals, increase with age (Figs 4–9).

A significant difference between *C. rotang* and *C. thwaitesii* with respect to the number of main roots, laterals and sub-laterals is seen only at month 26. In all other instances it is not significant (Table 1).

At the end of the 3-year period, both species had almost the same number of main roots. There were more laterals in *C. thwaitesii* while *C. rotang* had more sub-laterals. A comparative study of the number of roots between species of rattans shows that there is significant difference only in the initial stage. As they grow older all species behave in the same manner. When compared to other palms, the number of roots in *Calamus* is much less, but the roots are very stout and strong [7]. Within the genus *Calamus*, the number of roots developed in the first year is less in the species studied when compared to *C. viminalis* [13]. A 12-month-old *C. rotang* and *C. thwaitesii* had about 5 main roots while *C. viminalis* had 23.

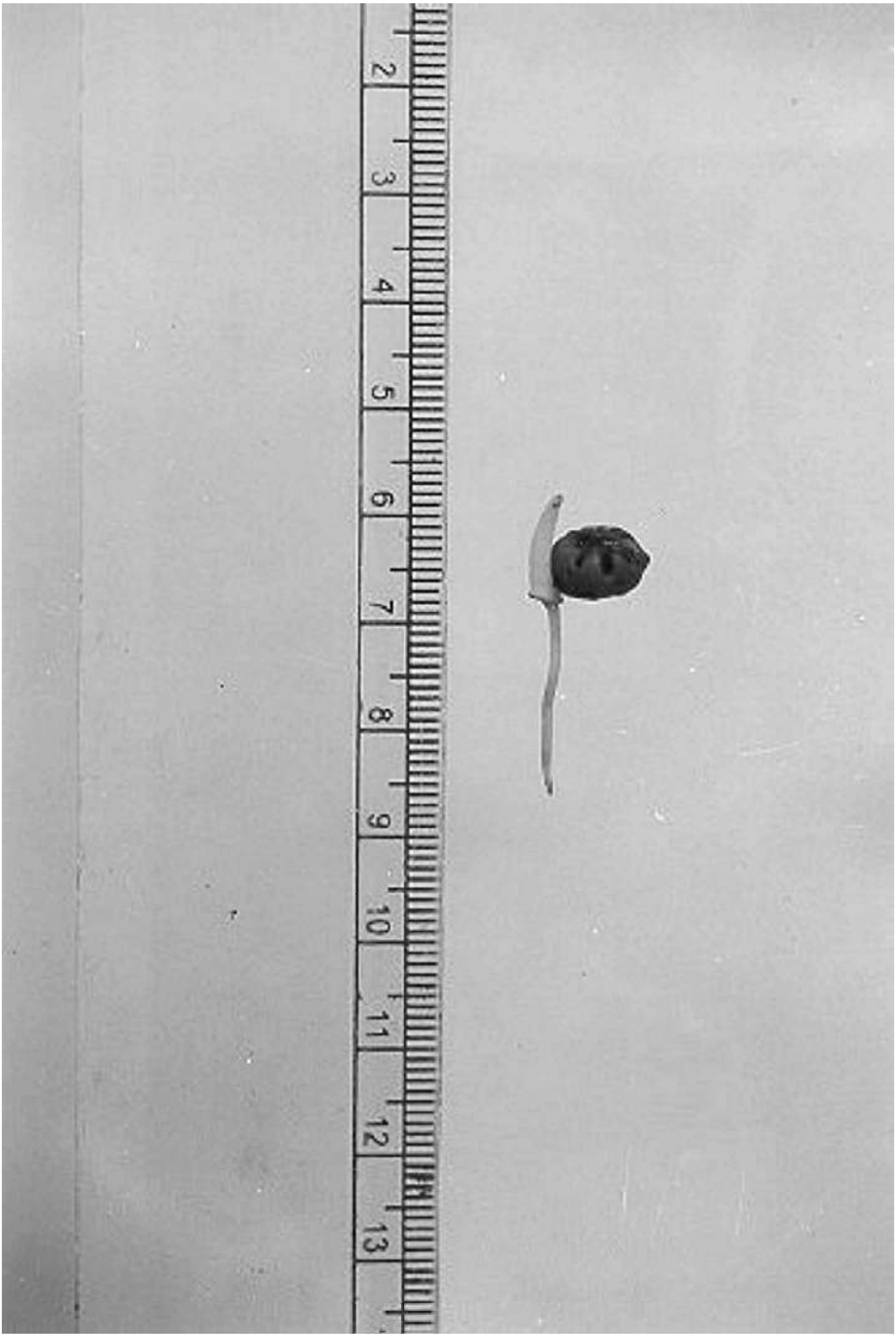

Figure 2. Different stages of root initiation in *C. rotang*.

Figure 3. Different stages of root initiation in *C. thwaitesii.*

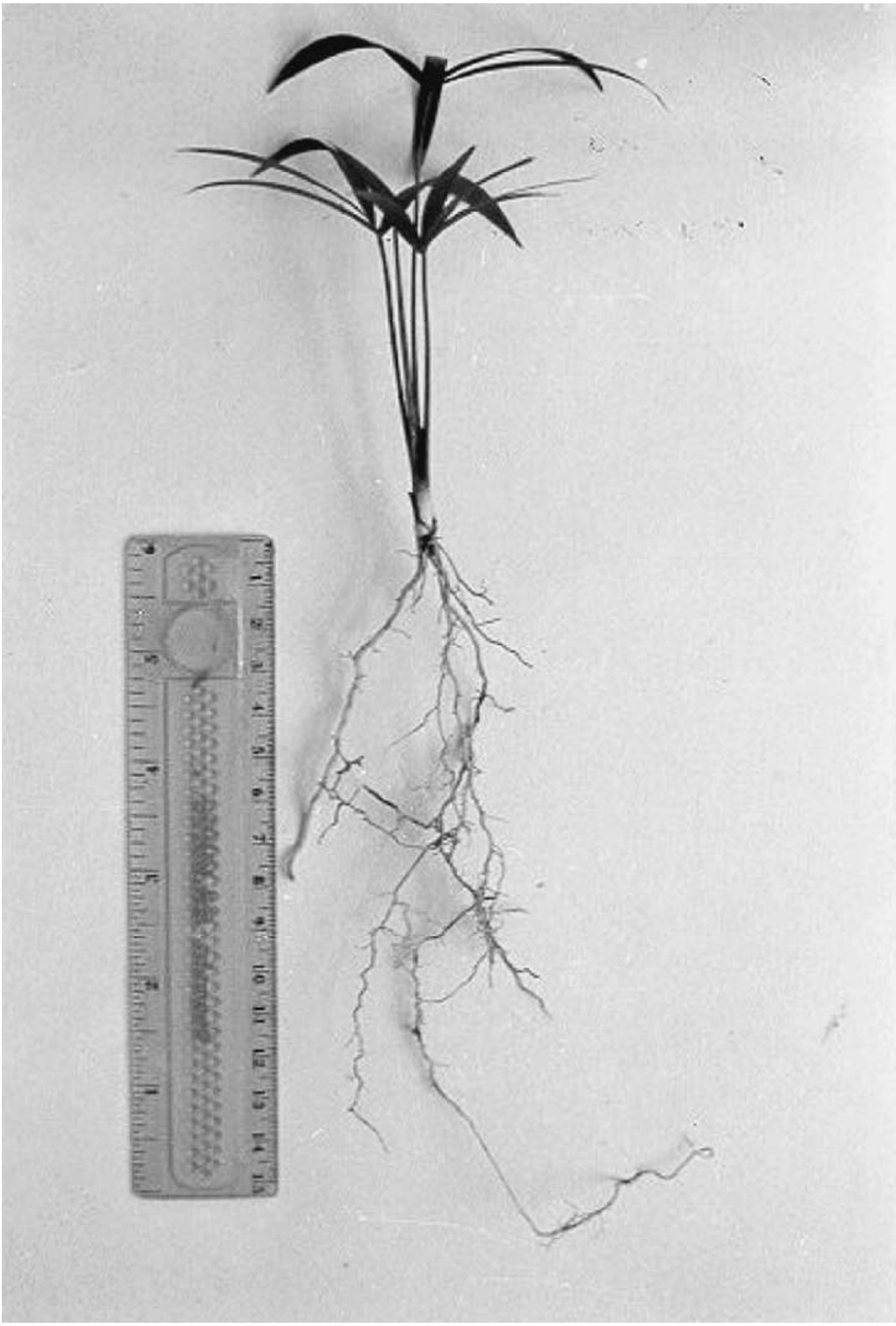

Figure 4. Root system after 6 months in *C. rotang.*

Figure 5. Root system after 6 months in *C. thwaitesii.*

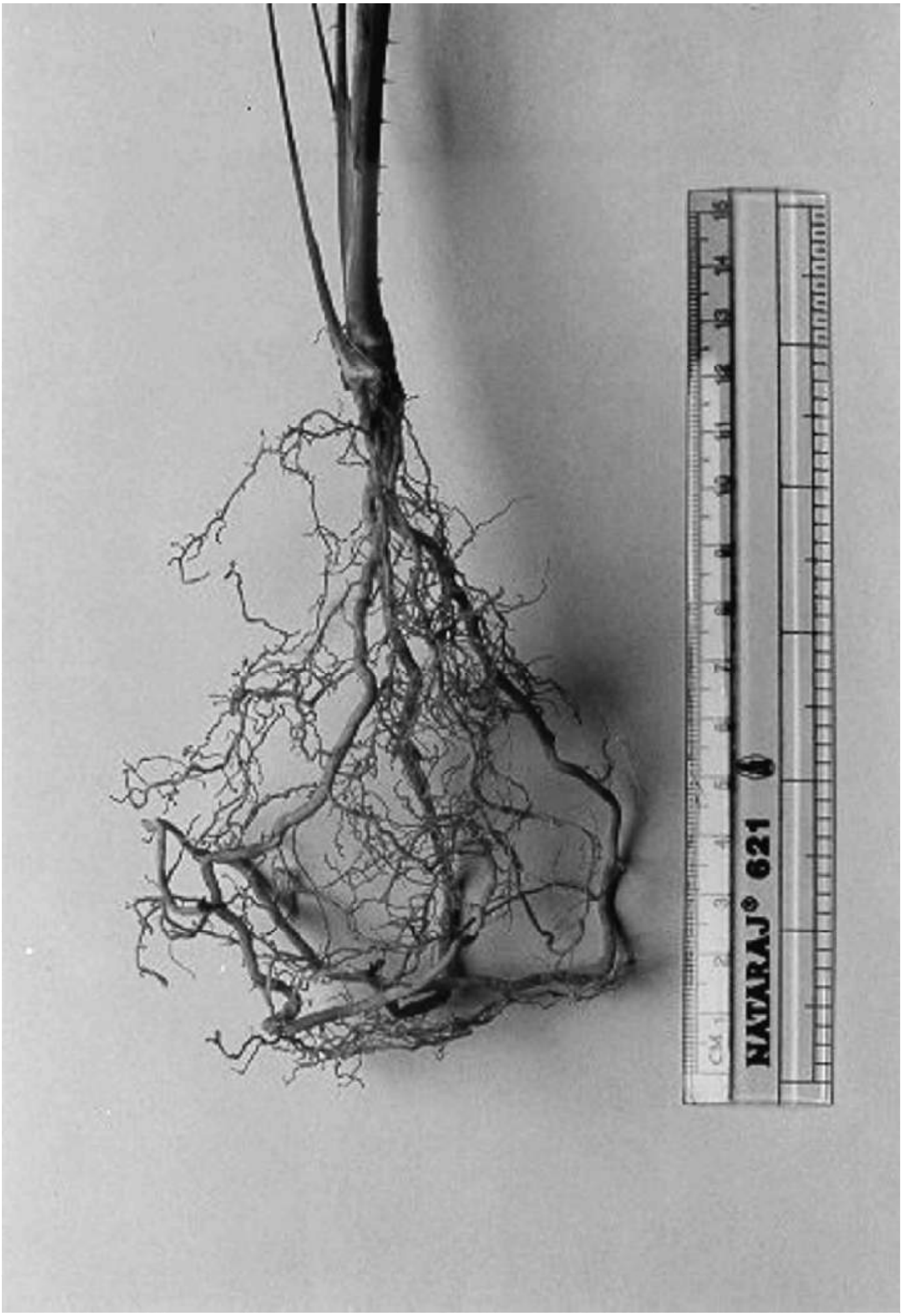

Figure 6. Root system after 12 months in *C. rotang*.

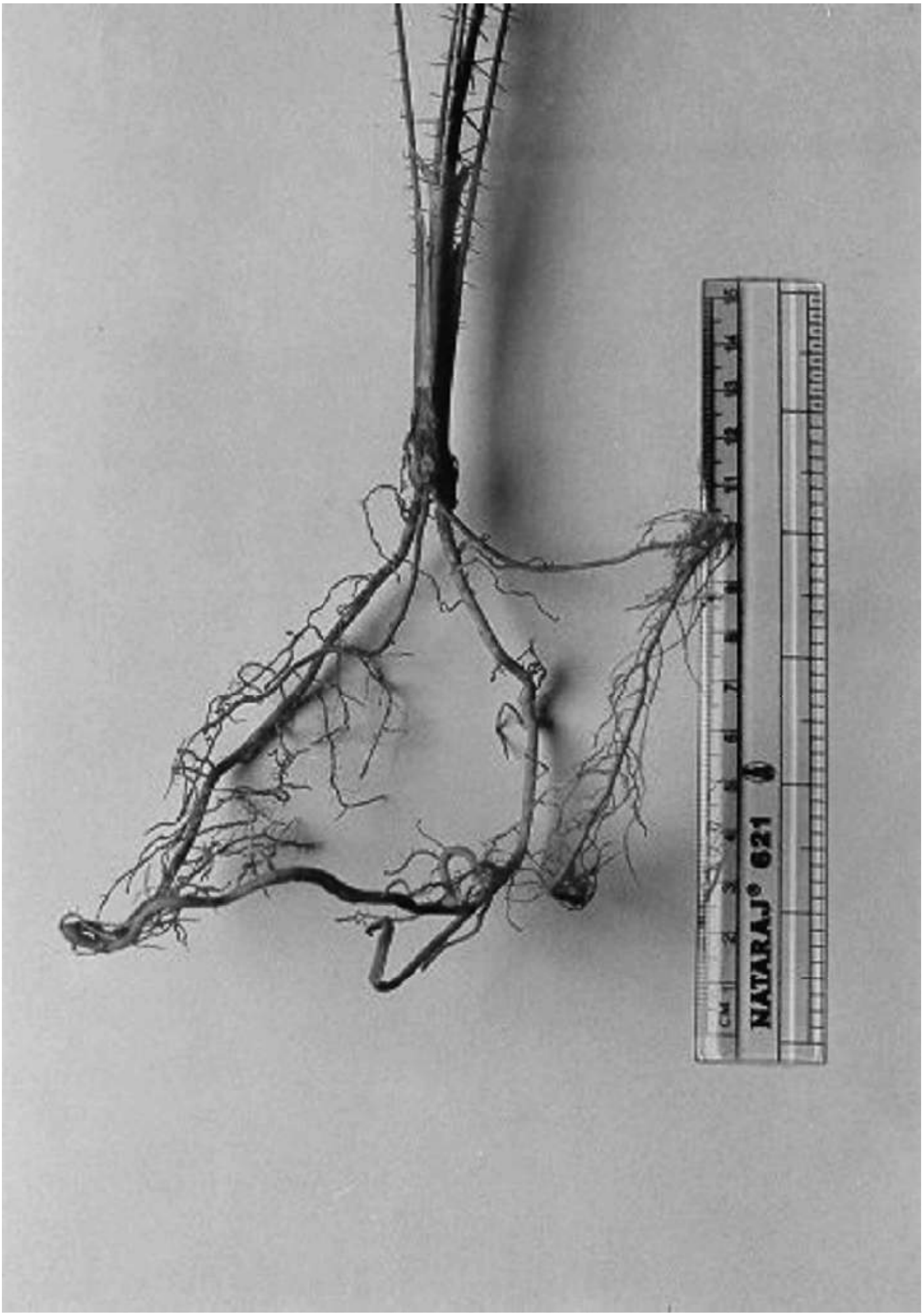

Figure 7. Root system after 12 months in *C. thwaitesii.*

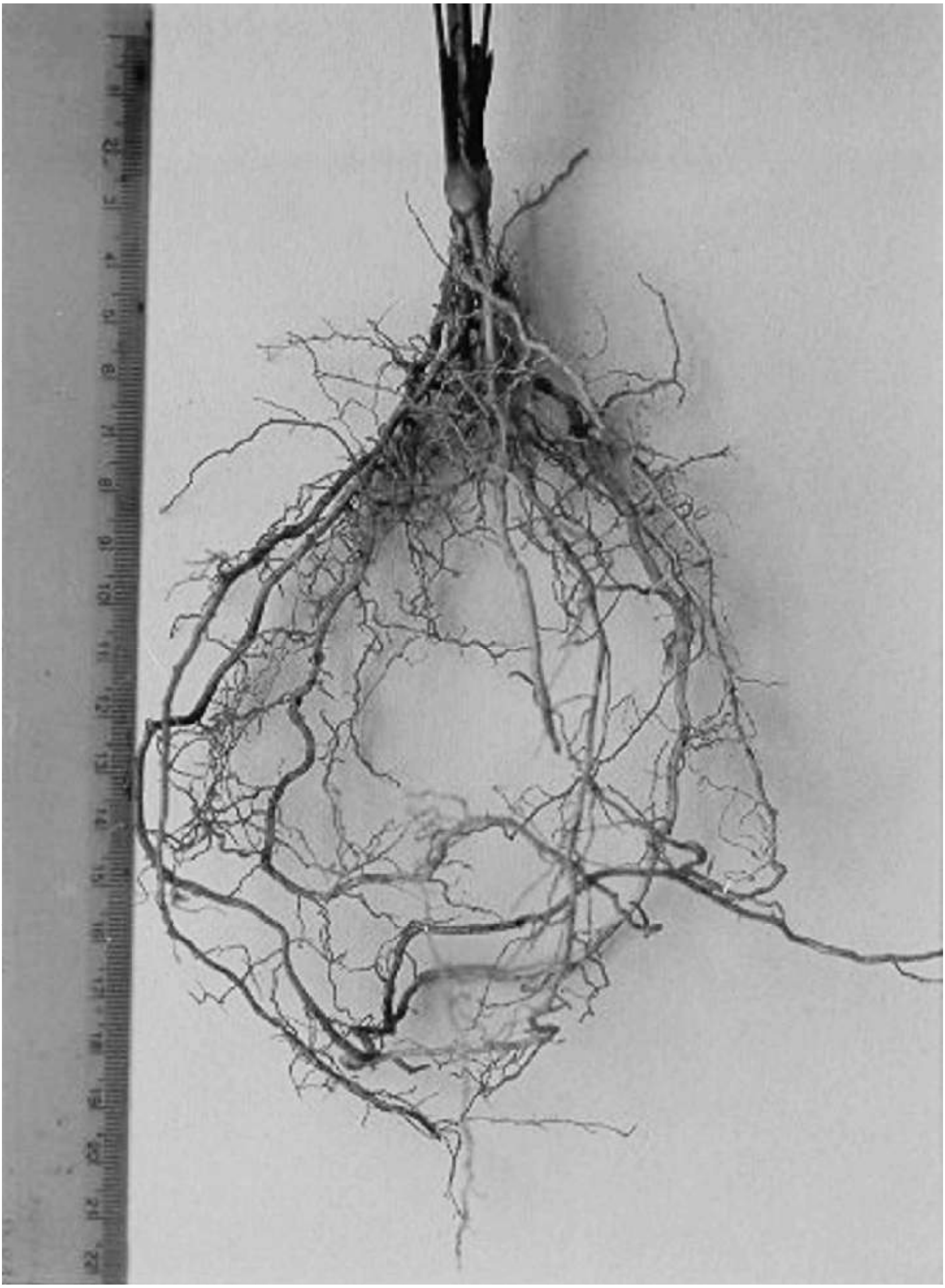

Figure 8. Root system after 26 months in *C. rotang.*

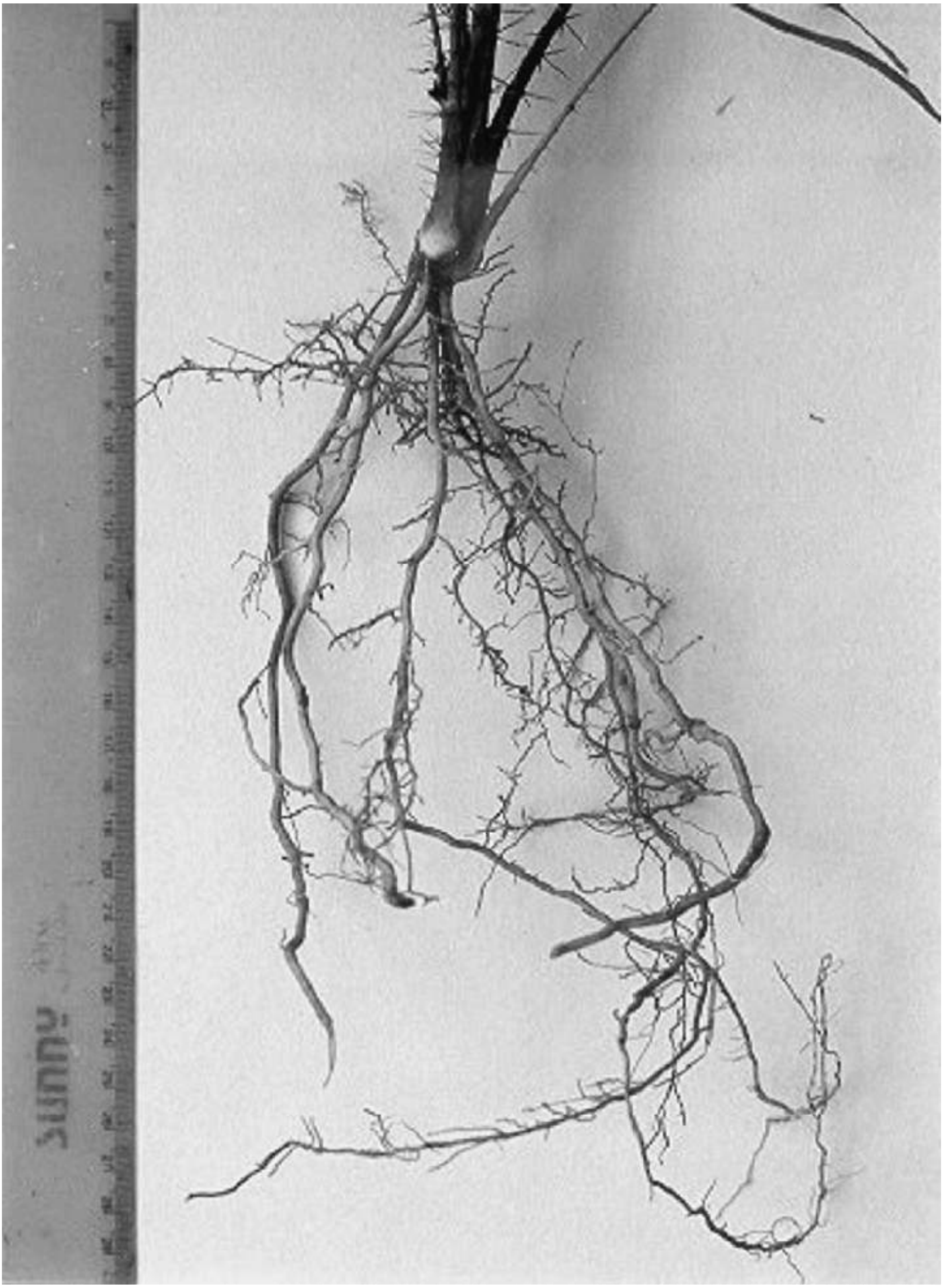

Figure 9. Root system after 26 months in *C. thwaitesii.*

Table 1.
Comparison of mean number of roots, mean length and mean diameter

Period (months)		Main roots			Laterals			Sub-laterals		
		Cr	Ct	R	Cr	Ct	R	Cr	Ct	R
2	number of roots	2	1	ns	—	—	—	—	—	—
	mean length	10.7	14.4	ns	—	—	—	—	—	—
	mean diameter	0.9	1.2	ns	—	—	—	—	—	—
14	number of roots	5	5	ns	9	7	ns	—	—	—
	mean length	13.4	16.4	ns	5.6	4.8	ns	—	—	—
	mean diameter	1.3	1.6	s	0.3	1.2	ns	—	—	—
26	number of roots	15	8	s	119	26	s	39	11	s
	mean length	28.3	19.9	ns	5.8	7.0	ns	3.8	5.5	ns
	mean diameter	2.3	2.8	ns	0.6	0.7	ns	0.4	0.4	ns
38	number of roots	25	28	ns	155	201	ns	43	35	ns
	mean length	38.7	45.7	ns	6.2	5.0	s	4.4	4.1	ns
	mean diameter	2.9	3.7	ns	1.0	0.8	s	0.7	0.5	ns

$n = 5$ replicates. Cr, *C. rotang*; Ct, *C. thwaitesii*; R, result; s, significant; ns, non-significant.

A significant difference between the two species is noticed with respect to length and diameter of laterals at the end of month 38 (Table 1). Similarly significant differences exist with respect to diameter of main roots at the end of 14 months. At the end of the third year *C. thwaitesii* had developed 28 main roots with an average length of 45.74 cm and diameter of 3.68 mm. *C. rotang* had developed 25 main roots with a length of 38.70 cm and diameter of 2.8 mm. Banik and Ahmed [13] reported that *C. vimimalis* developed about 39 main roots with an average length of 94.5 cm and average diameter of 0.41 cm within three years. Here the length is comparatively greater but the diameter is much less.

Kolzova [6] reported that the root system of *Phoenix sylvestris*, *Washingtonia* sp. and *Chamaerops* grew 72–79 cm into the soil in the first year while that of *Trachycarpus* and *Palmetto* grew only 10–15 cm. In rattans, during the first year, the roots grew upto 13–16 cm. A comparison between the two species studied shows that there is no significant difference in the length of main roots in the three-year period. Taylor and Klepper [17] reported that roots deep within the profile extracted water more efficiently. Root length is also important for phosphorus uptake and in a competitive situation, potassium and nitrogen too [18]. The two species studied would appear to be equally efficient in uptake of water and nutrients, when the root length are compared.

The regression equations for root length and diameter were fitted separately for *C. rotang* and *C. thwaitesii* (Table 2). 68% of the variation in the root length of *C. rotang* could be explained by age of the plant. Similarly in the case of *C. thwaitesii*, 42% of the variation in root length could be explained by the age of the plant (Table 2).

Table 2.
Models fitted for different characteristics using regression

Species	Character (Y)	Model	Adj. R^2
C. rotang	Root length	$Y = 1.6491 + 0.0649X$ (0.1172) (0.0046)	0.6836
C. thwaitesii	Root length	$Y = 2.2175 + 0.0396X$ (0.1159) (0.0047)	0.4214
C. rotang	Root diameter	$\ln(Y) = 1.5921 + 0.0537X$ (0.0769) (0.0030)	0.7754
C. thwaitesii	Root diameter	$\ln(Y) = 1.3514 + 0.0337X$ (0.0736) (0.0030)	0.5687

Values in parentheses indicate standard error of the coefficients; X = months.

Table 3.
Rate of elongation and rate of increase in thickness in *C. rotang* and *C. thwaitesii*

Period (year)		Main root		Laterals		Sub-laterals	
		Cr	Ct	Cr	Ct	Cr	Ct
First	Rate of elongation	0.3	0.1				
	Rate of increase in thickness	0.5	0.4				
Second	Rate of elongation	1.1	0.3	0.1	0.5		
	Rate of increase in thickness	0.8	0.8	1.5	−0.4		
Third	Rate of elongation	0.4	1.2	0.1	−0.3	0.2	−0.3
	Rate of increase in thickness	0.3	0.2	0.7	0.2	1.0	0.3

Cr, *C. rotang*; Ct, *C. thwaitesii*.

In *C. rotang* 78 % of the variation in root diameter could be explained by age of the plant whereas in *C. thwaitesii* only 57% of the variation in root diameter could be explained by age of the plant in (Table 2).

Rate of growth with respect to length and diameter (Table 3)

In both species, the elongation rate of main roots was more in the second year than in the first. The root of *C. thwaitesii* elongated more compared to *C. rotang*. The lateral roots of *C. rotang* achieved 5% elongation in the second year and 7% elongation in the third year. The lateral roots of *C. thwaitesii* elongated by 51% in the second year. However, in the third year, when the elongation rate of lateral roots increased from 5% to 7% in *C. rotang*, *C. thwaitesii* showed a negative rate of elongation, meaning that laterals of *C. thwaitesii* showed signs of degeneration in the third year.

For sub-lateral roots, those of *C. rotang* continued to elongate in the third year, but those of *C. thwaitesii* did not.

It can be inferred from the data that when there is an increased elongation rate in the main roots, there is a decrease in the rate of growth of laterals and *vice versa*.

Table 4.
Comparison of horizontal and vertical spread (cm)

Period (months)	Horizontal spread Cr	Ct	R	Vertical spread Cr	Ct	R
2	—	—	—	11.5	14.1	ns
14	9.5	12.3	ns	13.3	15.3	ns
26	48.7	10.3	s	26.4	16.5	s
38	91.8	61.6	ns	29.8	39.1	ns

$n = 5$ replicates. Cr, *C. rotang*; Ct, *C. thwaitesii*; R, result; s, significant; ns, non-significant.

Table 3 provides data on rates of increase in thickness of the three types of roots. These data largely parallel rates of elongation.

Root spread (Table 4)

Whereas the roots spread to all sides from the rooting base, most of the roots remain very close to the palm. In a 3-year-old *C. thwaitesii* the average horizontal spread was 61.6 cm and in *C. rotang* 91.8 cm, i.e. *ca*. 30 cm and 45 cm radius around the stem. Similar results were reported for *Areca* [8, 19] and most of the roots were within 30–60 cm radius in the younger stages but in a 5-year-old areca palm 96% of roots spread was in a zone of 50 cm radius.

A comparison of vertical spread of the roots between *C. rotang* and *C. thwaitesii* was statistically non-significant (Table 4). They grow vertically downward up to a distance of 29.8 cm in *C. rotang* and 39.1 cm in *C. thwaitesii.* Banik and Ahmed [13] reported that in *C. viminalis* most of the roots moved almost parallel to the soil surface.

The age of the plant determines the area where soil work needs to be done and for opening basins to hold water and for manuring. For a 3-year-old *C. rotang* soil work should be done at a radius up to 50 cm. For a 3-year-old *C. thwaitesii* the radial distance for soil work should be 30 cm.

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