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RHIZOME AND ROOT MORPHOLOGY OF RATTANS

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CONTENTS

Abstract

Root system of tropical plants varies greatly in their form. A wide variation is observed in the distribution of root length, dominance of main roots, relative dimensions the number of root systems and their branching pattern. When grown in soil, the spatial orientation of root members is of considerable importance and the orientation of root axes determines the ability of the root system to retain the plant in an upright position. Besides, the extent of root spread should be taken into consideration when silvicultural operations are carried out. Quantitative information on root morphology is of importance in the study of soil ecosystem. Therefore the present study on root and rhizome morphology of rattans is undertaken.

Three species *C. thwaitesii, C. pseudotenuis* and C. *rotang* were investigated. In all the species studied, the germination of the seeds was of adjacent ligular type. The growth of primary root stopped about four months after germination and subsequently more roots were produced from the basal portion of the plant. These roots produced the first and second order laterals after about 5 months. Within one year, 5-8 main roots were produced in *C. rotang* and *C. thwaitesii* whereas in *C. pseudotenuis* only 3-4 roots produced. *C. pseudotenuis* did not show any consistent growth and the end of 19 months all the plants perished. *C. rotang* recorded a faster growth in the second year and *C. thwaitesii* during the third year. By the end of third year both the species had almost the same number of main roots. The lateral roots were also produced earlier in C. *rotang* than in *C. thwaitesii.*

The initial growth was almost similar for all the species studied. The general morphology and developmental pattern were similar for *C. rotang* and *C. thwaitesii.* But the rate of growth in terms of length and diameter of roots was higher for *C. rotang* as compared to the other two species.

For *C. rotang* the average vertical depth of root was 29.84 cm and the horizontal distance traversed by roots was 91.80 cm at the end of three years. In *C. thwuitesii* the vertical depth was 39.05 cm and the hortizontal distance 61.60 cm.

Even though the shoot of the rattan remained in the rosette stage, the biomass increased because the basal portion of the plant increased in diameter until the potential maximum diameter for the particular species was reached. Hence it is concluded that methods which help to speed up the vegetative growth will shorten the period of the rosette stage.

Rhizome production in all the species of rattans studied began only after the primary shoot reached its potential maximum diameter, characteristic of the species . Each new shoot developed from an axillary bud located near the base of the stem. As each shoot again produced a new axillary shoot in turn, a clustered habit resulted. The lateral suckers developed their own root system early and therefore became less dependent on the parent axis. The study showed that *Calamus* does not fit into any of the root system models described for

1. INTRODUCTION

Root system of tropical plants is little investigated. The existence of morphological and anatomical diversity in the roots oftropical plants has long been known, but attention was inevitably focussed on the more obvious aspects of root morphology oftropical trees, such as the development of aerial roots, especially in mangrove species (Troll, 1937, Lyford and Wilson, 1966).

The root system anchors the plant in the soil, absorbs water and minerals and serves as a storehouse for carbohydrates. On its size, type and efficiency depends the competitive ability of an individual and the success of a species in a given habitat. Knowledge of the structure and development of root system is essential for a complete understanding of the ecological requirements of each forest species which in turn forms the necessary basis for silvicultural practices.

Individual roots in soil vary greatly in size, longevity and activity and their interaction with other organisms will depend on these variables, many of which are determined by the relationship of the root to the whole root system. Study of root morphology is therefore important in understanding the interaction and dynamics within the soil system.

The most striking characteristics of plant root systems are their total length and the number of their component members. The study of root system is extremely important for the explanation of many vegetational phenomena. In spite of the fact that a detailed knowledge of plant roots is useful from the academic as well as applied standpoints, investigations in this direction have been rather neglected due to various reasons.

Root morphology and methods for its study

In general, there are two types of root systems, sympodial or fibrous root system, characteristsic in grasses and palms, and monopodial root system with a central tap root and secondary ramifications usually seen in dicots.

While describing the roots of monocots a rigid distinction is usually drawn between two types of root members, the ‘primary roots’ (also called seminal roots) which develop from the germinating seed, and ‘adventitious or secondary roots (also called nodal roots) which arise subsequently from the shoot. These two classes of roots differ in internal structure (Russel, 1977). For example, in small grained cereals the arrangement of xylem vessels contrasts between seminal and nodal root axes.

When roots are growing in soil, the spatial orientation of root members is of considerable importance as it can influence the efficiency with which the soil is exploited. It has also been suggested that the orientation of root axes in cereals can influence their ability to retain the plant in an upright position, if the axes susbtend a wide angle the stability of the plant and its resistance to ‘root lodging’ may be greater (Pinthus, 1967).

Quantitative information on root morphology is important for understaning their importance to soil ecosystem. The two attributes most commonly determined in studies of root growth are length and weight. Root diameter is also an important character when used in conjunction with a generalised system of ordering root system members.

The main problem in studying the behaviour of roots in nature is that it is impossible to observe a root growing in soil. Most of the studies are conducted in water culture and other artificial media or through rhizotrons, where the behaviour of roots, although easily observed, may have little bearing on their actual behaviour in soil. Studies on roots in soil involve tedious and destructive sampling, making it difficult to study their actual dynamics in soil. Because of this difficulty, it is probable that more energy has been spent in developing the techniques rather than carrying out studies on the subject.

Three main approaches can be used to assess root growth and morphology.

1. Root system extraction
2. Observation methods
3. Indirect methods

Each system has it own merits and demerits.

In rattans, no detailed study on root system has been carried out so far and hence no information is available on the growth pattern, the nature or branching pattern and the spatial distribution of roots. Hence the method of the total excavation of the root system was chosen for the present study.

The length and branching of an intact root system, after a few months growth, can be so complex that a detailed morphological description would be a formidable task. The changes in the environmental factors markedly affect the root form (Weaver, 1926). The present study deals with the general form which root system can attain and distribution under relatively favourable conditions. The early stages of growth are mainly considered because root development at that time is more likely to affect the survival of the plant.

2. MATERIALS AND METHODS

Three species naturally occurring in three different habitats were selected. The species were *Calamus thwaitesii, C. pseudotenuis* and *C. rotung. C. thwaitesii* occurs naturally in evergreen, semi-evergreen and moist deciduous forests between 75 to 900 m. of altitude *C. pseudotenuis* is seen only at higher elevations, between 700-1000 m, in the evergreen forests. *C. rotung* naturally occurs in marshy areas and is also seen in sacred groves at 50 m. elevation.

The species were planted in a randomised block design with five replications. In each plot of one speices, 120 seedlings were planted in 3 rows, with 40 plants in a row. Alternate plants from the central row were selected for making observations, leaving all the marginal plants, to maintain uniform growing conditions throughout the observation period. Observations were made once in two months for 3 years, ie, 18 x 5 observations were recorded for each species.

For recording observations, the whole root system was excavated, taking care not to damage even the smallest rootlet. Soil around each root was removed carefully and slowly after sprinkling adequate water. Before taking the plant out of the soil, horizontal and vertical distances the roots had traversed were measured. After taking out, the roots were washed carefully with water to remove all the soil particles. The length and diameter of all the main roots and laterals were measured. Here, the first formed root is called as primary root and other roots emerging from the base of the plant are called secondary roots. The primary and secondary roots are considered as main roots. The branches of these roots are called as first and second laterals (Fig. 1).

For comparing the biomass of root and shoot produced per year, four species; *Calamus thwaitesii, C. pseudotenuis, C. rotung* and *C. hookerianus* were selected. The species were planted in a randomised block design with five replications. In each plot of one species 27 seedlings were planted in 3 rows, with 9 plants in a row. Alternate plants from the central row were selected for the estimation of dry weights. Observations were made once in an year for 3 years.

The root systemwas separated from shoot system and both were weighed separately to get the fresh weight. The plant parts were dried in an oven and the dry weights were recorded. In order to find out the variations in total number of roots, length and diameter of roots between species, the data were subjected to analysis of variance. This was followed by comparison of means by the method proposed by Calinski and Corsten (1985). Regression functions were fitted for two species separately for mean total length and mean diameter of root to study the pattern of changes in the above two characters separately with the period.

3. RESULTS

3.1. Origin of root system

The type of germination and the nature of origin of roots were similar for all the three species studied. While the seed germinated a white columnar plug emerged first. The plug elongated and the plumule emerged from one side of the plug. After 2-3 days radicle developed on the opposite side of the plumule. The plumule gradually turned green in colour while the radicle remained white. The radicle grew out to become the primary or seminal root of the seedling. The primary root at this stage had a fully developed root cap, Numerous rootlets were produced from the primary root. Within 2-3 weeks, lateral roots emerged from the primary root and this root system remained functional for about 2 months. During this stage the seed remained attached to the plant (Plate 1, Figs. 2-5.).

3.2. Development of secondary and lateral roots.

About 2 months after germination, the base or axis of the plant elongated obconically and form the lower end of the axis secondary roots (adventitious roots) began *to* emerge. First, a root emerged from near the base of the primary root and elongated producing several laterals simultaneously Several rootlets were produced on these laterals. (Plate 2, Figs.6-8). About 4-5 months after germination, the primary root gradually stoped its activity At this stage 2-5 main roots were present in a seedling. All of them produced laterals which again produced 2nd order laterals When any of the main branches was broken or damaged, secondary laterals were produced immediately behind the injury (Plate 2; Fig. 7).

The number of secondary roots gradually increased as the plants grew. The diameter of these roots also increased with age. (Plate 3, Figs. 9-11; Plate 4; Figs. 12-13). The lateral roots had an endogenous origin. The 1 st order laterals were produced from the first year itself while the 2nd order laterals were produced from the second year onwards. When the root apex was destroyed, it was usually replaced by one or more branch roots, which grew out immediately behind the dead apex.

3.3. Root growth : A comparison between the species

Out of the 3 species studied, *C.pseudotenuis* did not show consistant growth and by the end of 1 1/2 years all the plants perished. Hence comparison was possible only for 1 1/2 years for the 3 species, and for the rest of the study period only 2 species could be compared.

3.3.1. The number of roots:

In the initial stages one or two main roots were found. At the end of 14 months, C. *rotang* and *C. thwaitesii* developed 5-8 main roots and *C. pseudotenuis* developed about 2-4 roots. At the end of 26 months *C. rotang* had 14-27 main roots while *C. thwaitesii* had only 8-10 roots. At the end of 38 months both the species had almost the same number of main roots (Table 1).

In *C. pseudotenuis* the first order laterals were produced 4th month onwards while in *C. rotang* and *C. thwuitesii* they were produced respectively 6 and 8 months onwards. The second order laterals started to develop from 10th month in *C. rotang* while they started to develop from 16 and 18 months in C. *pseudotenuis* and *C. thwaitesii.*

The number of main roots and their laterals increased with age. Analysis of variance revealed significant differences between species with regard to number of main roots at 14th and 26th months. The analysis also showed that the species differ with respect to the number of first laterals at the 26th month. Pair-wise comparison between the species with respect to the main roots at the 14th month showed that *C. pseudotenuis* is siguficantly different from *C. rotang* and *C. thwaitesii,* but not between *C. rotang* and *C. thwaitesii;* at 26th month, there is significant difference between *C. rotang* and *C. thwaitesii* with respect to the number of main roots and first order lateals (Table 1). In all other instances it is nonsignificant.

Table 1. Comparison of mean number of roots

Period	Main roots			1st order laterals			2nd order laterals		
	CP	CR	CT	CP	CR	CT	CP	CR	CT
2 months	1	1.80	1.40	--	--	--	--	--	--
14 months	2.60^a	5.40^b	5.0^b	0.20	9.20	6.80	--	--	--
26 months	--	15.20^a	8.4^b	--	119.40^a	26.40^b	--	38.8	10.8
38 months	--	24.6	28.4	--	154.8	201.4	--	43.00	34.8

CP = C. pseudotenuis; CR = C. rotang: CT = C. thwaitesii

Figures superscribed by the same letter in a row for each character indicates non-significance.

3.3.2. The length and diameter of roots:

Roots of *C. pseudotenuis* did not show any stable trend in length and thickness increment (Fig. 14). In other two species the length of roots increased with age. Statistical analysis showed that the species are significantly different (P=0.01) with respect to the length of main roots at 14th month. Pair-wise comparison between species with respect to the length of the root showed that the species differed significantly from each other at the 14th month (Table 2).

A comparison of mean values of length showed that during the early stages the growth the primary root of all the three species was almost similar. But, a highly significant variation was found between species with regard to the length of the main and also lateral roots at the end of 14 months. All plants of *C. pseudotenuis* perished by 16th month. Second order laterals started developing from the second year onwards for the other two species and statistical analysis showed that there is no significant difference between these two species. They show almost the same length at the end of 26th month and this trend continued in the third year also (Table 2).

Diameter of roots also increased gradullay with age. Analysis of variance showed that the difference in diameter of main roots is mainly attributable to the highly significant (P<0.01) influence of species at the 14th month. Pair-wise comparison between species showed that *C. pseudotenuis* is significantly different from the other two species whereas between *C. thwaitesii* and *C. rotang* there is no significant difference (Table 3).

Table 2. Comparison of mean values of length (cm)

Period	Main roots			1st order laterals			2nd order laterals		
	CP	CR	CT	CP	CR	CT	CP	CR	CT
2 months	11.70	12.37	17.31	--	--	_	_	--	--
14 months	6.28^a	13.77^b	17.08^c	0.60^a	7.24^c	4.69^b	--	--	-
26 months	--	28.48	20.08	--	6.05	5.71	--	3.96	2.76
38 months	--	40.52	46.44	--	6.22^a	4.86^b	--	4.25	3.22

CP = C. pseudotenuis; CR = C. rotang: CT = C. thwaitesii

Table 3. Comparison of mean values of diameter (mm)

Period	Main roots			1st order laterals			2nd order laterals		
	CP	CR	CT	CP	CR	CT	CP	CR	CT
2 months	1.00	0.92	1.33	--	--	--	--	--	--
14 months	0.72^a	1.25^b	1.58^b	--	0.08	1.02	_	--	--
26 months	--	2.21	2.27	--	0.62	0.57	--	0.38	0.22
38 months	--	2.92	3.70	--	1249.4	2066.4	--	0.75^a	0.44^b

CP = C. pseudotenuis; CR = C. rotang: CT = C. thwaitesii

Table 4. Comparison of mean values of horizontal and vertical spreads (cm)

Period	Horizontal spread			Vertical spread		
	CP	CR	CT	CP	CR	CT
2 months	--	_	--	11.0	11.45	14.13
14 months	2.60^a	9.26^b	12.50^c	6.84^a	13.33^b	15.34^b
26 months	_	48.70^a	10.30^b	--	26.55^a	16.51^b
38 months	--	91.80	61.60	_	29.84	39.05

CP = C. pseudotenuis; CR = C. rotang: CT = C. thwaitesii

Figure superscribed by the same letter in a row for each character indicates cance. Figure which are not superscribed by any letter indicate the nonsignificance between the species.

A comparison of mean values of diameter of roots showed highly significant variation at the end of 14th month only. After that the correlation is nonsignificant in case of the main roots. Statistical analysis showed that the speices, *C. rotung* and *C. thwaitesii* are significantly different with respect to diameter of 2nd laterals at 38th month (Table 3).

The regression equations fitted for length are given in Table 5.

Table **5. Models fitted for different characters using regression.**

Species	Character	Model	Adj. R^2
C. rotang	Root length	$Y = 1.64914 + 0.064928X$ (0.117228) (0.004670)	0.68364
C. thwaitesii	Root length	$Y = 2.217534 + 0.039625X$ (0.115958) (0.004754)	0.42143
C. rotang	Root diameter	$\ln (y) = 1.592164 + 0.053794X$ (0.076918) (0.003064)	0.7754
C . thwaitesii	Root diameter	$\ln (y) = 1.35149 + 0.033754X$ (0.073652) (0.003020)	0.56871

Figures in paranthesis indicate standard error.
X = months

Root development with respect to length was found to be nonsignificant. But the rate of growth in length was higher for *C. rotang* than for *C. thwaitesii* (Fig. 15).

Root development pattern of two species viz. *C. rotang* and *C. thwaitesii* with respect to diameter was found to be significant and the rate of growth in diameter was higher for *C. rotang* as compared to *C. thwaitesii* (Fig. 16).

3.3.3. Spaital orientation

In the early stages the vertical growth was prominant in rattan root systems. Within two months the primary root grew upto about 14 cm in *C. thwaitesii.* In the other two species it reached upto about 11 cm. By the end of 14 months the roots spread to a horizontal distance of about 12.5 cm and a vertical distance of about 15.34 cm in *C. thwaitesii.* In *C. rotang* the horizontal distance was 9.26 cm and vertical distance, 13.33 cm. In the 2nd year of growth this trend reversed and more horizontal and vertical spread were shown by *C. rotang.* In the 3rd year *C. rotang* traversed horizontally much faster than *C. thwaitesii* but the vertical growth was more in *C. thwaitesii.* (Table 4)

3.3.4. Root-shoot relationship

In rattans, the shoot system remains in the rosette stage for the first 3-4 years of their seedling stage without showing much growth in length. In order to see whether the roots develop faster than the shoot at early seedling years, a comparative study of the dry weight of shoot and root was conducted. When the correlation coefficients were computed between the shoot weight and root weight year-wise, a highly significant positive correlation was obtained (Table 6). This indicated to the simultaneous increase of biomass of shoot and root. Eventhough the shoot remains in the rosette stage its biomass increases (Fig. 17)

Table 6. Correlation coefficients between dry weight of shoot and root for 4 periods.

	DS1	DS2	DS3	DS4
DR1	.7207*			
DR2		.8602**		
DR3			.9070**	
DR4				.9607**

**denote significance at 0.01 level

DS - Dry weight of shoot

DR - Dry weight of root

3.3.5. Rhizome

Calamus is a clustering palm. In the three species selected, clustering was relatively close, not exceeding 10 cm lateral distance from the parent axes. Suckers were produced from the very base. The proximal lateral buds developed into suckers. Among the species selected, *C. rotang* started clustering first. All plants of *C. pseudotenuis* perished before clustering.

In the species studied, the rhizome development started with the development of multiple stems. Seedling leaves had vegetative buds in their axils which grew out penetrating the supporting leaf sheaths, splitting it into two at the base. The suckers repeated the growth characteristics of the parent stem. These lateral suckers, developed root system early and so became less dependent on the parent axis (Plate 5, Figs 18-21).

In *C. rotang* the primay shoot started elongation before the production of suckers. But in *C. thwaitesii,* 3-4 suckers were produced before the primary shoot elongated.

4. DISCUSSION

In all the three species of rattans investigated, the germination of the seeds is of adjacent ligular type, which is the general type reported in palms (Tomlinson, 1961). The primary root stops its growth about four months after germination. This is also a common feature among palms. The primary root in most palms is small, developing and functioning for only a short period in the seedling. Subsequently main roots are produced from the obconical base. These roots produce the first and second laterals as they grow.

The seedling axis is massive and obconical, reflecting its primary development by addition of successively wider internodes. In this phase the type of growth has been referred to as establishment growth (Tomlinson, 1970). 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 large surface for root development. A large number of adventitious or secondary roots arises from this base, as the seedling grows.

The number of main roots as well as laterals and the length and diameter of the roots increase with age. More laterals and secondary laterals are produced second year onwards. A comparative study of the number of roots between the species shows that there is significant difference only in the initial stage. As they grow older, all species behave in the same manner.

The rate of growth in the length and in diameter is higher for *C. rotang* when compared to *C. thwaitesii.*

The initial growth in length is almost similar for the 3 species. By the end of the 14th month, highly significant variation is seen between species, mainly because of the slower growth of roots shown by *C. pseudotenuis* The same trend is seen for growth in diameter also. *C. pseudotenuis* does not perform well in the experiment site, because it is a high altitudinal species growing naturally at about 1000m elevation and the species is not able to withstand the environmental conditions at a lower altitude.

The degree of occupation of soil volume by roots which depends on the branching and distribution of minute roots serves as a criterion for distinguishing intensive and extensive types of root systems. In *Calamus* there is an initial faster vertical growth. After an year when more number of roots are produced they spread more horizontally than vertically (Table 4).

The vertical and horizontal spread of the root system is an important aspect to be considered while carrying our silvicultural operations. For *C. rotang* the average vertical depth is 29.84 cm and the horizontal distance traversed by roots is 91.80 cm. In *C. thwaitesii* the vertical depth is 39.05 cm and the horizontal distance is 61.60 cm. In *C. viminalis* the roots were reported to be growing more or less parallel to the soil surface (Banik, 1986). But none of the species in the present study is found to behave in that way.

With regard to the root-shoot relationship, highly significant positive correlation was found between the dry weights of root and shoot, revealing that the biomass of shoot and root increases simultaneously even though the shoot remains in the rosette stage. This is because the base of the plant increases in diameter over a long period of time, before the stem elongates. In *Calamus* this is about 4 years and this period differs with the diameter of the stem. Among the species studied *C. rotang* started stem elongation first, since it is a slender stemmed species. If the growth in diameter in the basal portion can be accelarated by any treatment, the length of the period of rosette stage can be shortened.

In *Calamus,* a great range of clustering types can be found, from closely clustering species to open colonies produced by stolons (Dransfiled, 1978). In this study, all the three species showed close-clustering.

The rhizome production begins only after building up the base of the primary shoot of potential maximum diameter for that species. This is a common feature of clustering palms. *C. rotang* started rhizome production first because this is a small diameter rattan, ie., less than 1 cm, when compared to the other two speices (1.5 to 3 cm.).

Calamus exhibits a sympodial habit which is charactersitic of monocotyledons (Holtum, 1955). Each new shoot is developed from an axillary bud located near the base of the stem. As each shoot again produces a new axilary shoot in turn, a clustered habit results. Rhizome production starts with the development of multiple stems. The lateral suckers develop their own root system early and so become less dependent on the parent axis. Jenik (1978) classified the monoct root systems into 5 models based on the morphology, but the root systems of *Calamus* do not fall under any of these categories.

5. CONCLUSIONS

The productivity of plants depends largely on the development of a root system adequate to support them. Among the species studied *C. rotang* is the best performer followed by *C. thwaitesii*. In *C. pseudotenuis* the root system does not develop well after an initial growth for about 6 months. Thus its survial rate is also low.

The general morphology and growth pattern of the root system are similar in *C. rotang* and *C. thwaitesii*. The rate of growth in length and diameter is higher for *C. rotang* than for *C. thwaitesii.*

During rosette stage, the base of the plant enlarges in diameter until the potential maximum diameter for the particular species is reached; only then only the growth in elongation of stem starts. Hence any method which will help to speed up the growth in diameter in the basal portion will shortern the period of the rosette stage.

Although rhizomatous habit is developed in *Calamus*, it differs from other palms like *Rhapis*, *Serenoa*, *Phylelephas* etc. where the rhizome is of creeping type. It differs from Nypa also where the rhizome branches in distinctive ways. Hence as suggested by Tomlinson (1970) the simple term 'rhizome' cannot cater the multiplicity of creeping or subterranean axes in monocots.

Jenik (1978) classified the monocot root systems into 5 models, based on their morphology. But the root system of *Calamus* doesnot fall under any of these categories and stands out as a separate model.

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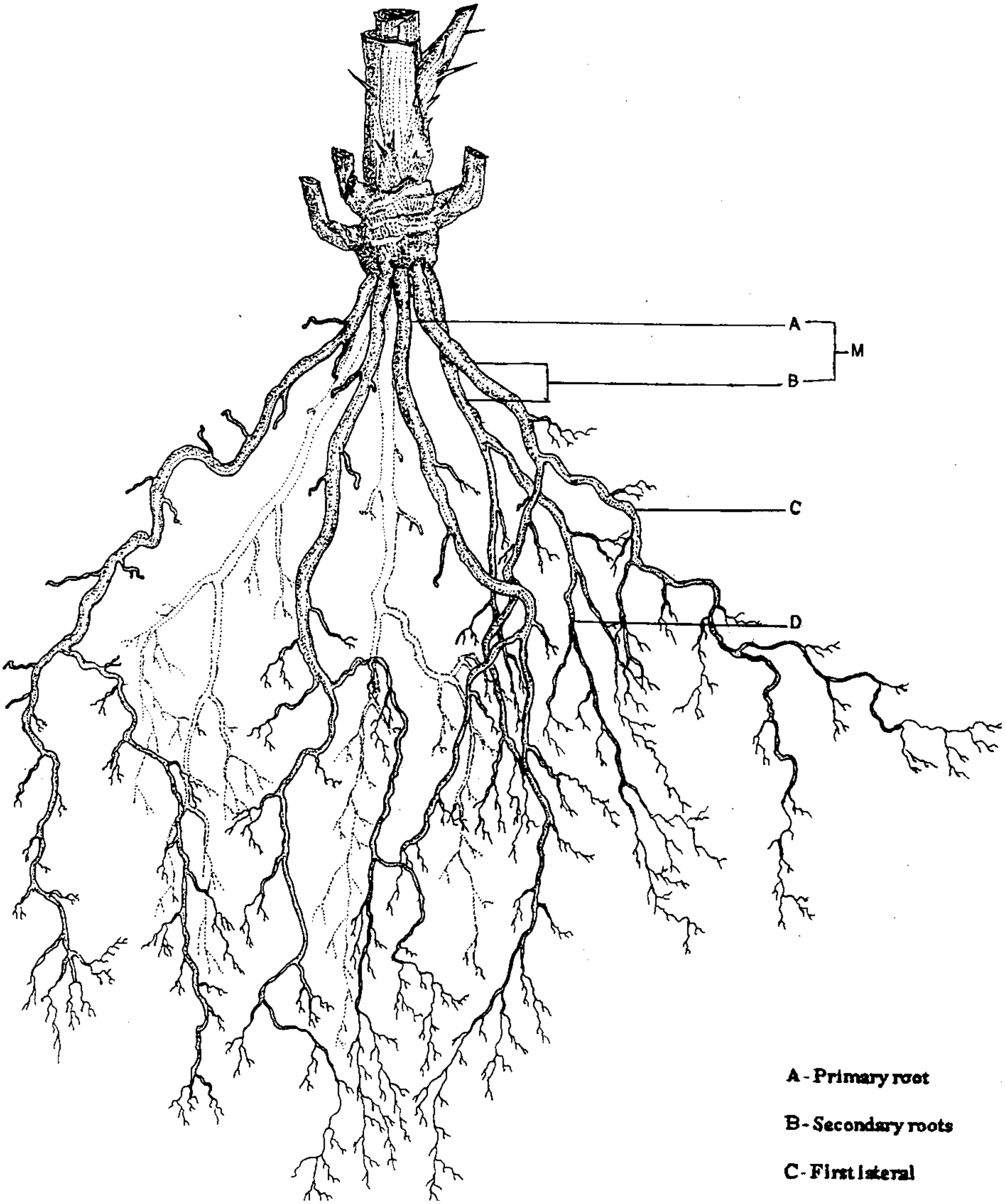
8. Figures



A - Primary root

B - Secondary roots

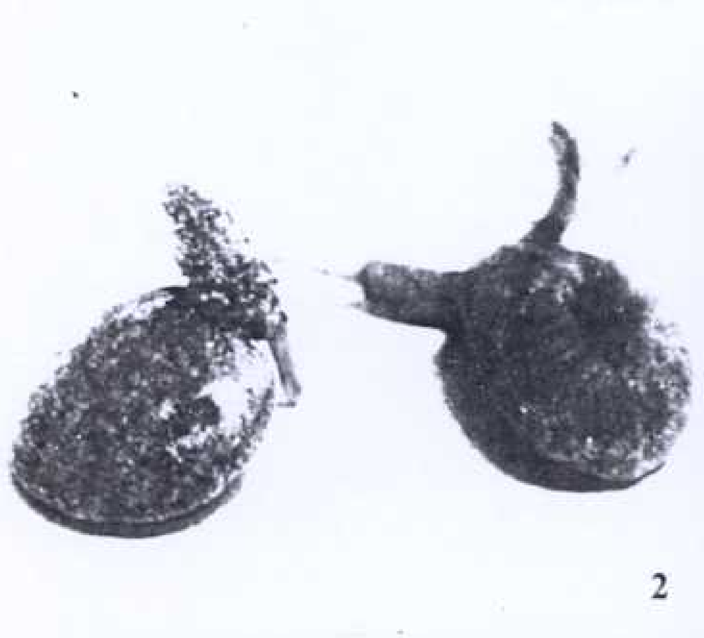
C - First lateral

D - Second lateral

M - Main roots

Fig. 1. General root morphology

Plate 1.	**Fig. 2.**	***C. thwaitesii.* Seed germination.**
	Figs.3-5.	**Root system at 2nd month after germination.**
	Fig. 3	***C. thwaitesii***
	Fig. 4.	***C. pseudotenuis***
	Fig. 5.	***C. rotang***



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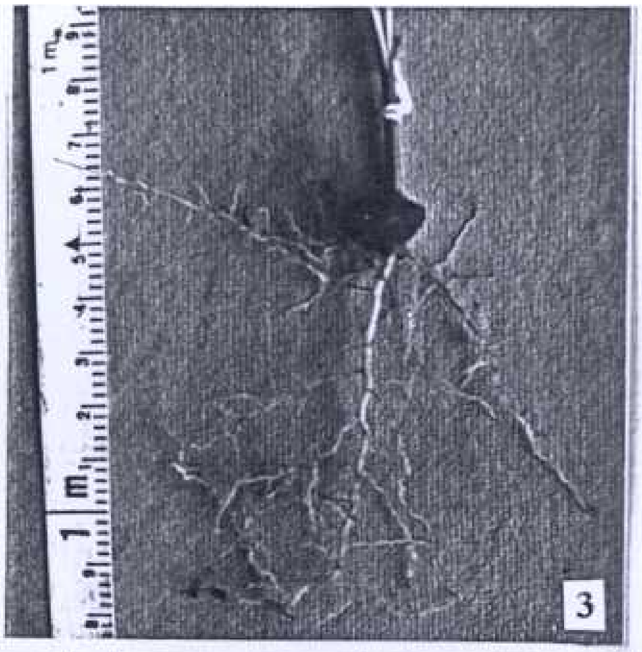

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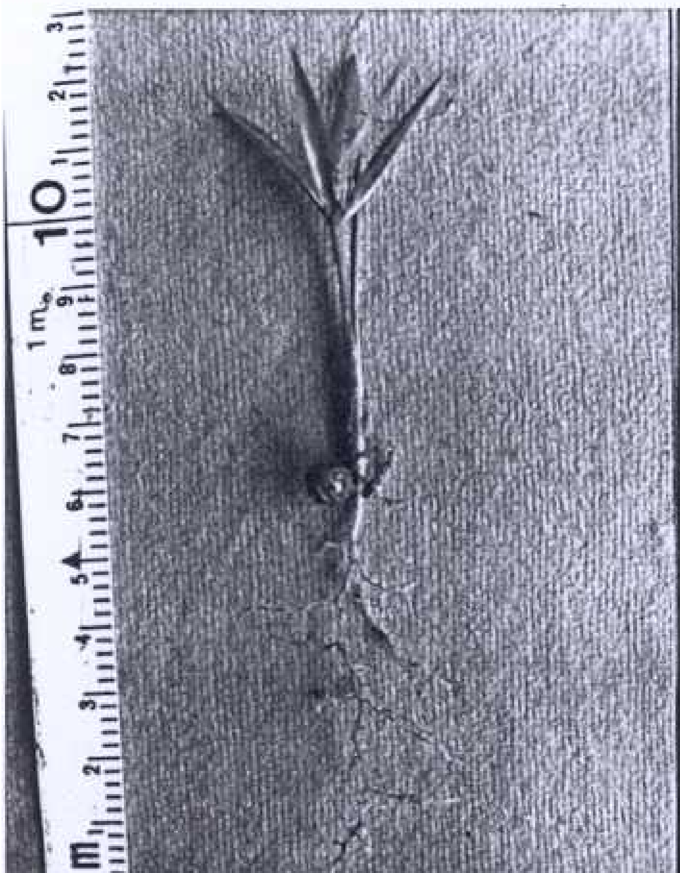

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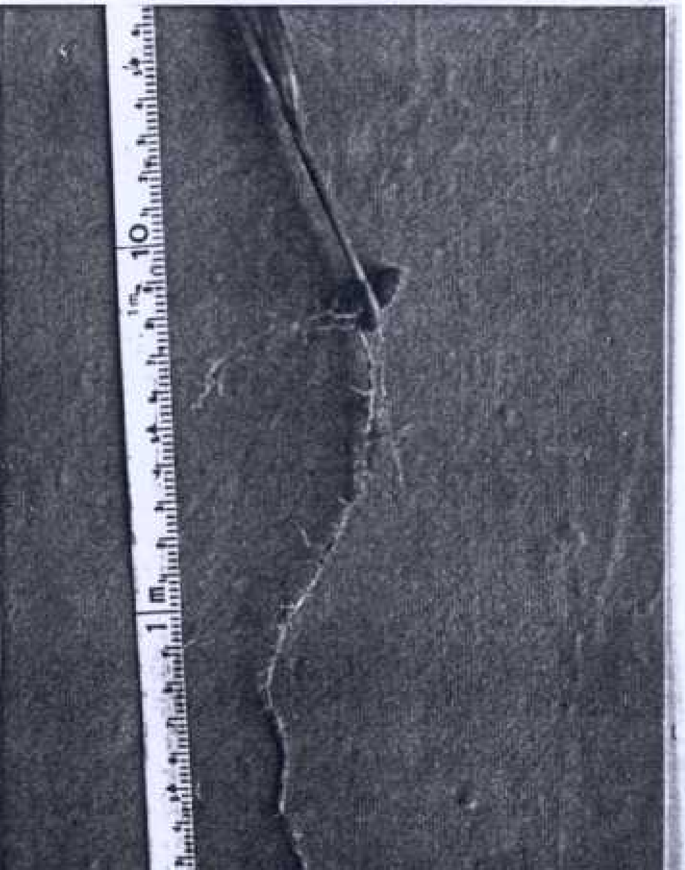

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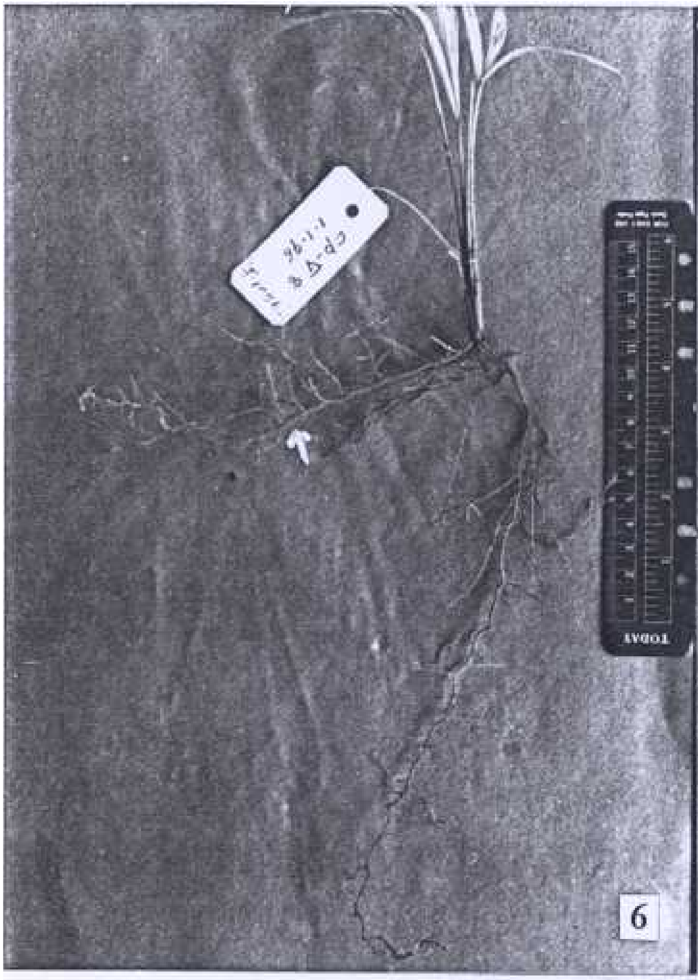
Plate 2. **Figs. 6-8.** **Primary root stops its activity which initiates the origin of additional main roots.**

The arrow mark indicates the primary root.

Fig. 6. ***C. pseudotenuis***
Fig. 7. ***C. rotang***
Fig. 8. ***C. thwaitesii***



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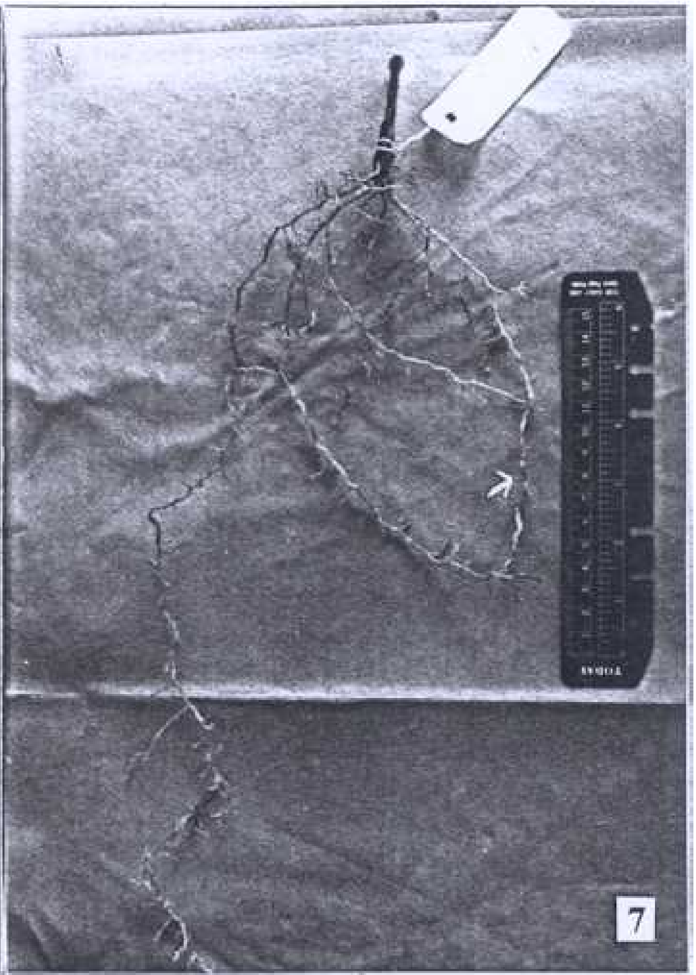

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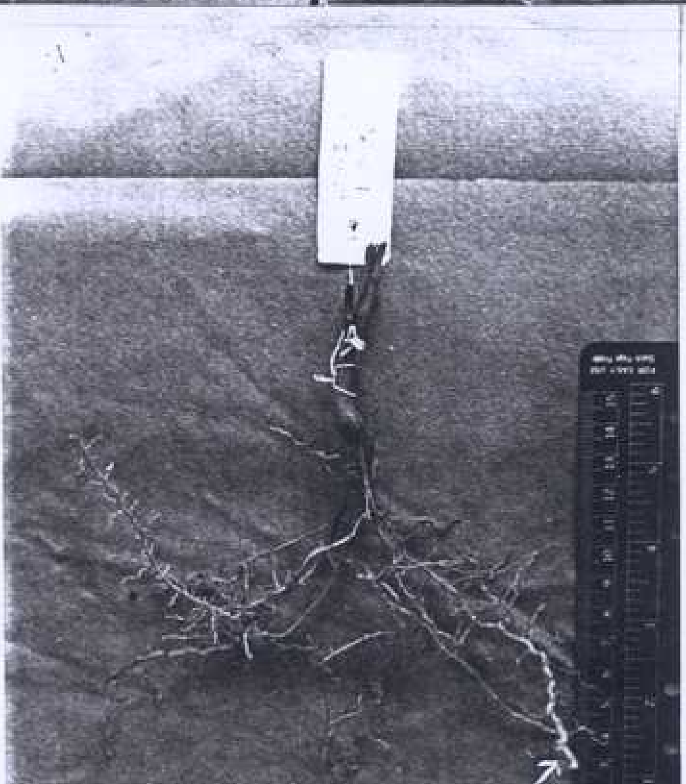

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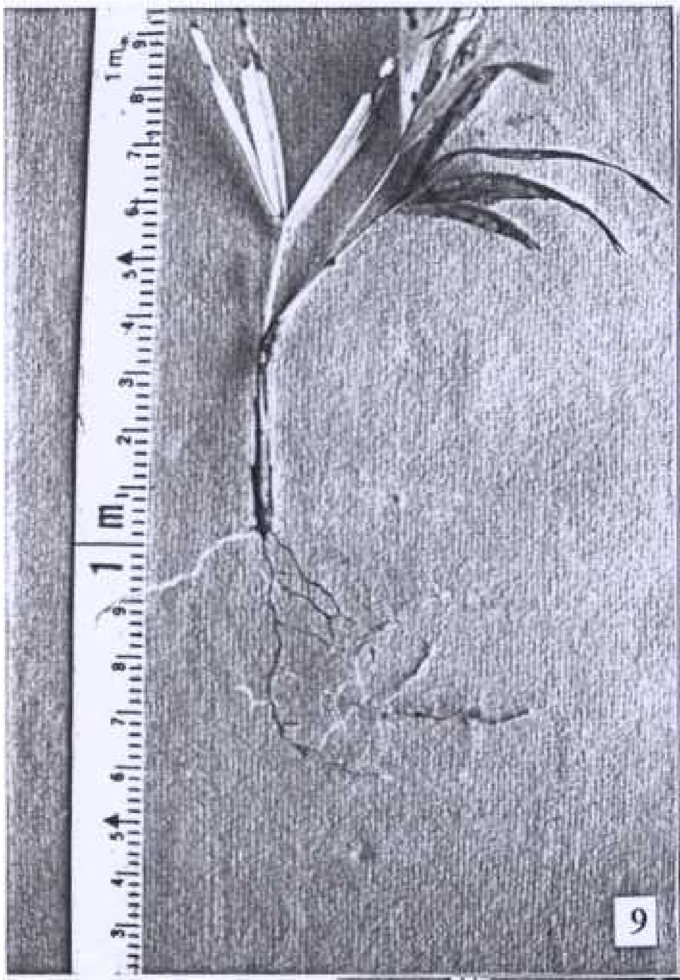
Plate 3.	**Figs. 9-11.**	**Root systems at 19th month after germination.**
	Fig. 9.	***C. pseudotenuis***
	Fig. 10.	***C. rotang***
	Fig. 11.	***C. thwaitesii***



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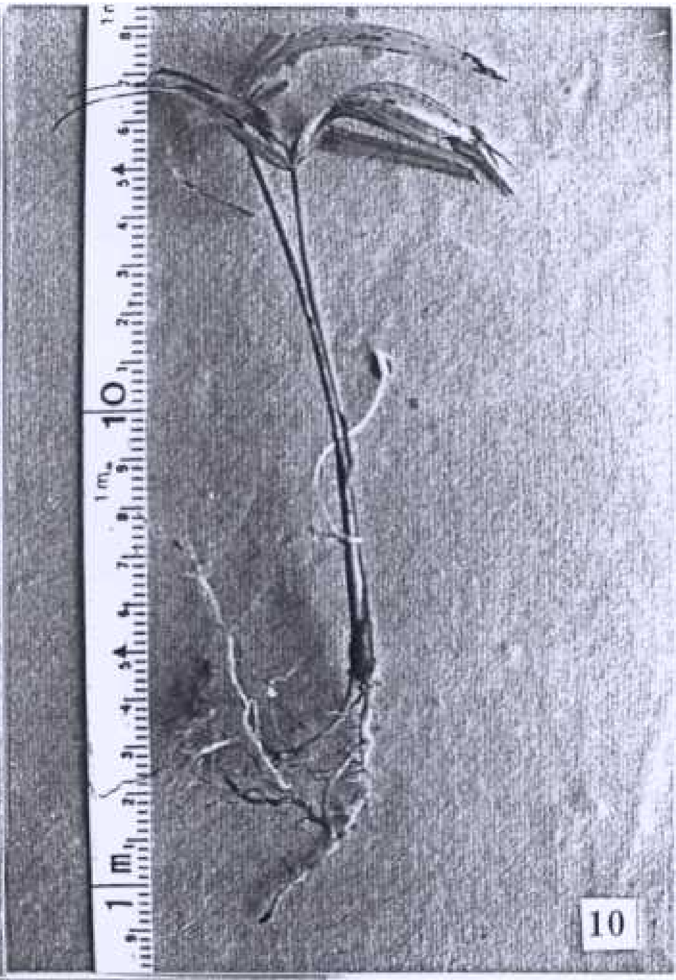

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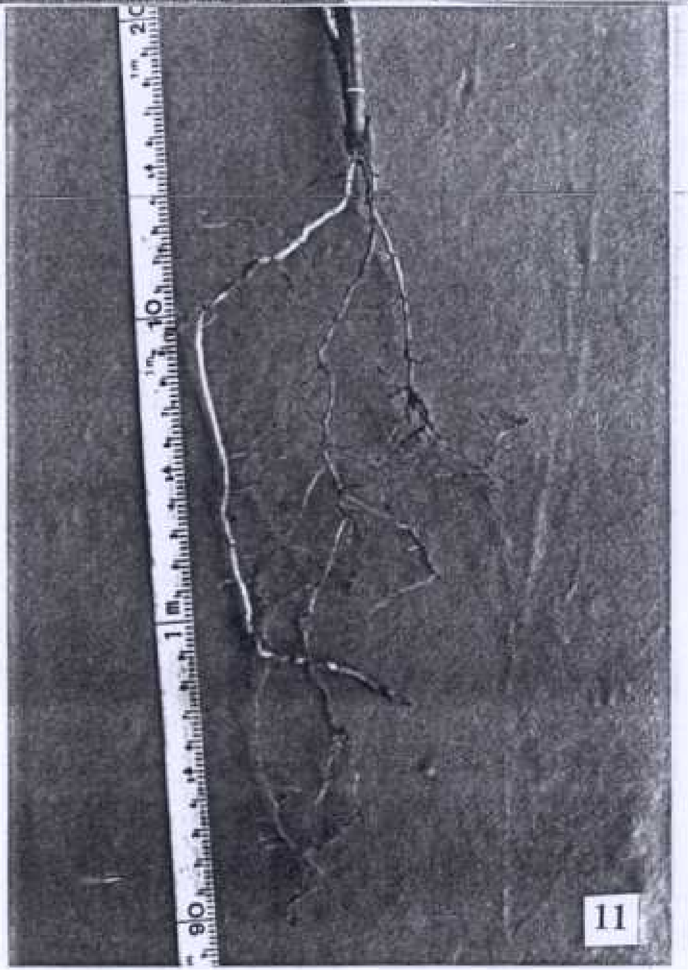
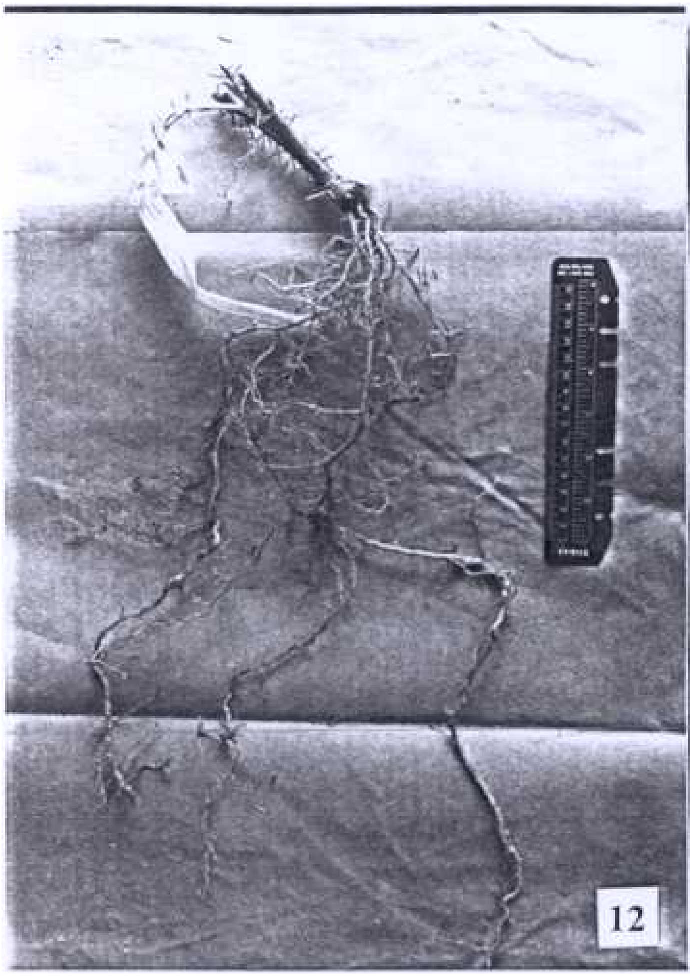


11

Plate 4. **Fig. 12-13. Root system at 26th month after germination**

Fig. 12. ***C. thwaitesii***

Fig. 13. ***C. rotang***



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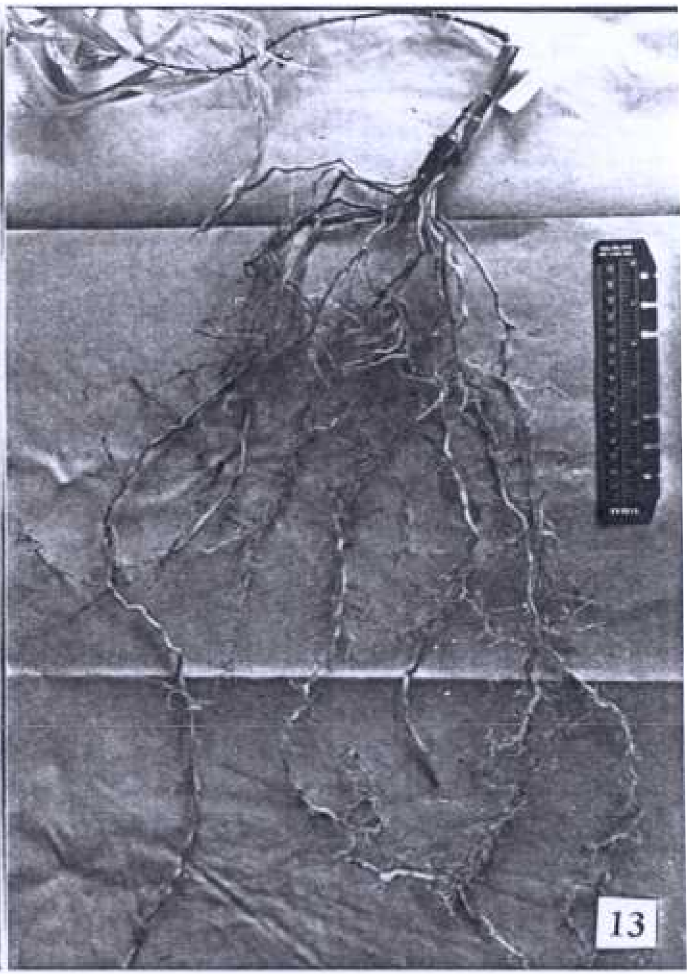

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Fig. 14. *Calamus pseudotenuis* : Relationship between length and diameter of roots

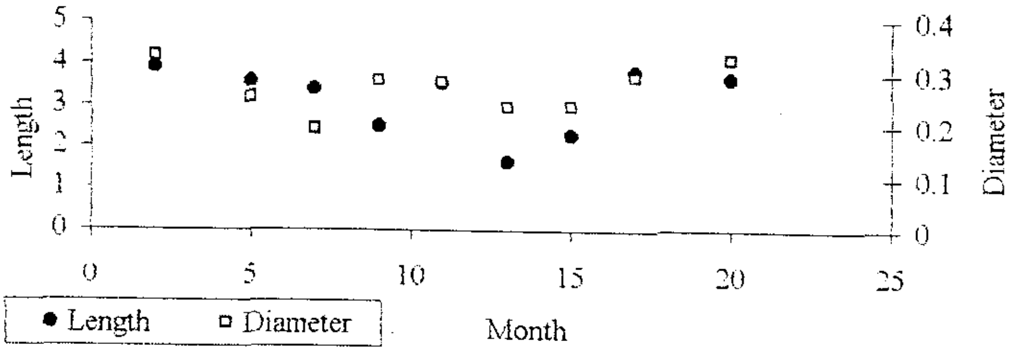


Fig. 15. Comparison of root length between *C. thwaitesii* and *C. rotang*

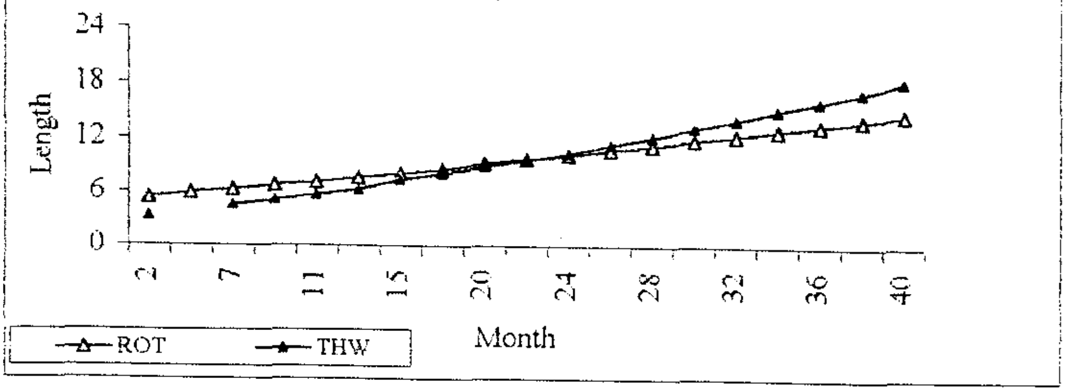
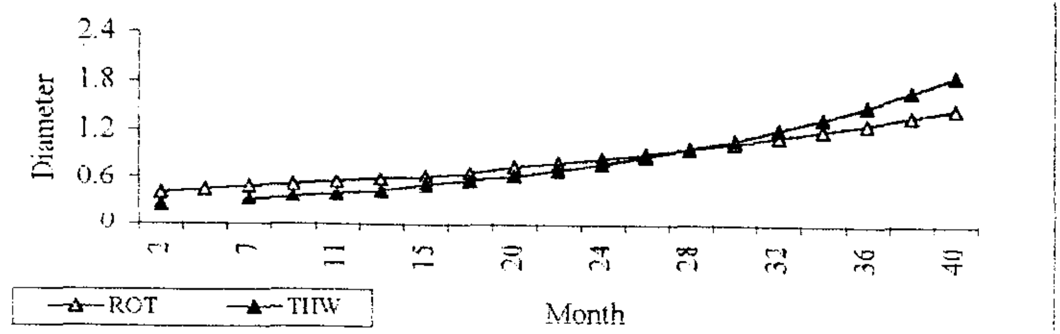


Fig. 16. Comparison of root diameter: between *C. thwaitesii* and *C. rotang*



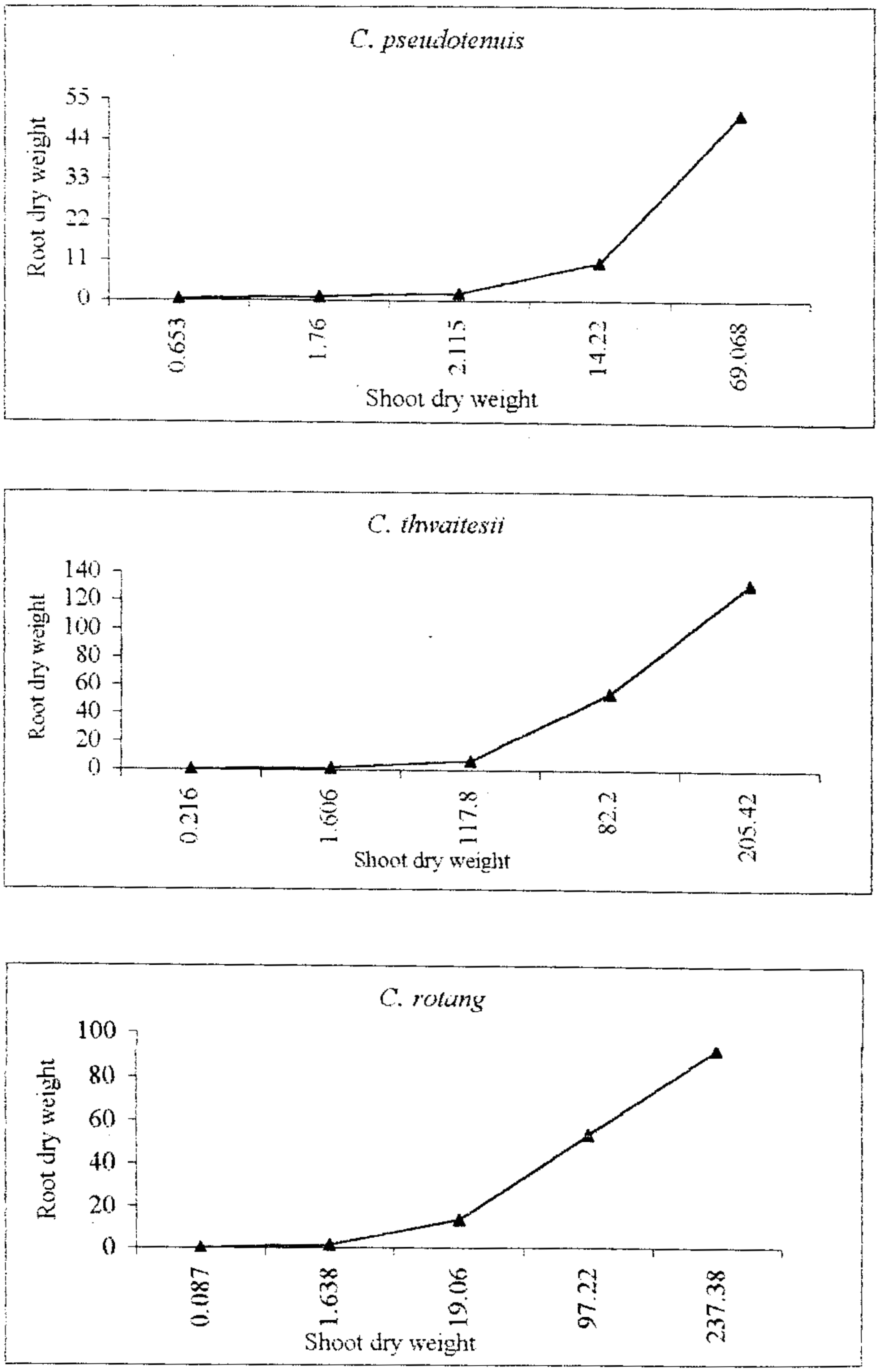
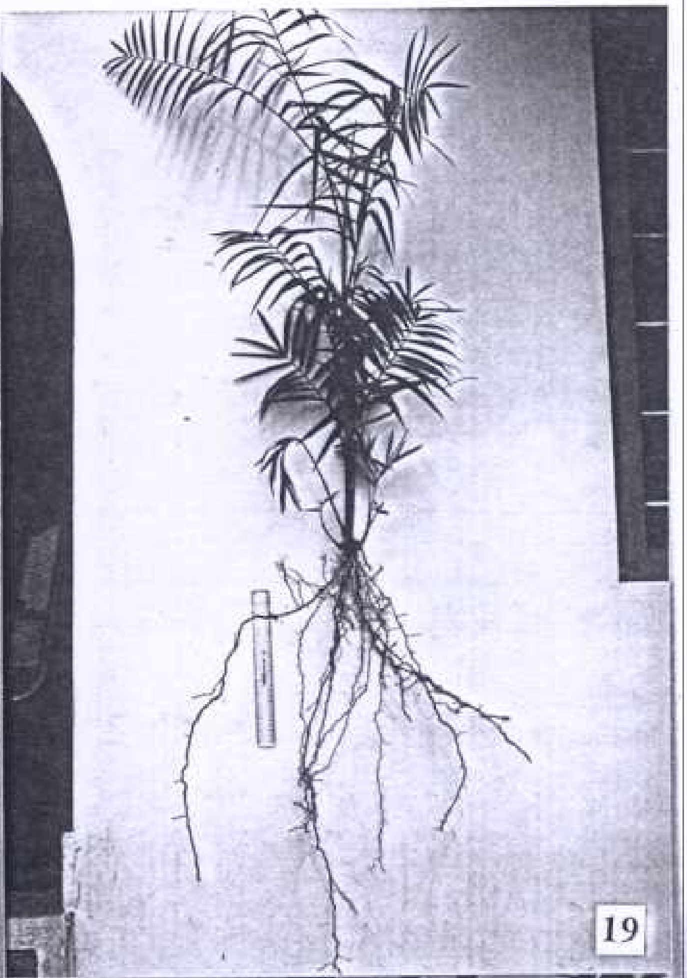


Fig. 17. Root-Shoot Relationship

Plate 5. **Figs. 18-21.** **Rizome development**
Figs 18-19. ***C. thwaitesii***
Figs. 20-21. ***C. rotang***

18



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