"EFFECT OF PRE-SOWING TREATMENTS ON GERMINATION AND GROWTH OF SEEDLINGS OF *CALAMUS SPP.*"

By,

JISHA, E. D.

THESIS

Submitted in partial fulfillment of the requirement for the degree

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Faculty of Agriculture
Kerala Agricultural University

Department of Forest Management and Utilization
COLLEGE OF FORESTRY
KERALA AGRICULTURAL UNIVERSITY
VELLANIKKARA, THRISSUR - 680 656
KERALA, INDIA

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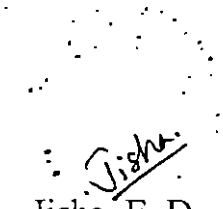
Declaration

I hereby declare that this thesis entitled **"Effect of Pre-Sowing Treatments on Germination and Growth of Seedlings of *Calamus Spp.*"** is a bonafide record of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society to me.



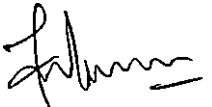
Vellanikkara
Date:

Jisha, E. D.
2007-17-101

Dr. K. Vidyasagaran
Associate Professor and Head
Dept. of Forest Management and Utilisation,
College of Forestry,
Kerala Agricultural University
Trichur
Kerala - 680656

CERTIFICATE

Certified that this thesis, entitled **"Effect of Pre-Sowing Treatments on Germination and Growth of Seedlings of *Calamus Spp.*"** is a record of research work done independently by Ms. **Jisha, E. D. (2007-17-101)** under my guidance and supervision and it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.



Dr. K. Vidyasagaran
Chairman
Advisory Committee

CERTIFICATE

We, the undersigned members of advisory Committee of Ms. **Jisha, E. D.** a candidate for the degree of **Master of Science in Forestry,** agree that this thesis entitled **"Effect of Pre-Sowing Treatments on Germination and Growth of Seedlings of *Calamus Spp.*"** may be submitted by Ms. **Jisha, E. D.** in partial fulfillment of the requirement for the degree.

Dr. K. Vidyasagaran
Associate Professor and Head
Dept. of Forest Management and Utilisation,
College of Forestry,
Kerala Agricultural University,
Trichur, Kerala
(Chairman)

Dr. P.K. Ashokan,
Professor & Head,
Dept. of Tree Physiology
and Breeding,
College of Forestry,
Vellanikkara
(Member)

Mr. S. Gopakumar
Assistant Professor (S. S)
Dept. of Forest Management
and Utilisation
College of Forestry
Vellanikkara
(Member)

Dr. T. K. Kunhamu
Associate Professor
Dept. of Silviculture and Agroforestry
College of Forestry, Vellanikkara
(Member)

Sd/-
Dr. Ramakrishna Hegde
Associate Professor
College of Forestry,
Ponnampet
External Examiner

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Jisha, E. D.

Dedicated to My Teacher
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Introduction

1. INTRODUCTION

Rattans are climbing palms belonging to the family *Arecaceae* (*Palmae*). Wood of rattans is strong, with medium density, yet much lighter than other hardwoods and extremely pliable. Because of these desirable characters, it is extensively used in the manufacture of a wide range of furniture and handicrafts items for low, medium and high end markets. It is a major non-wood forest product after timber in South East Asia. The rattan industry has become a labour intensive and rural (or forest) based with increasing prospects for earning foreign exchange. About half a million people are directly employed in harvesting and processing rattans in South East Asia. The Indian cane furniture industries produced materials worth Rs 50 million with the value of exports standing at Rs 5 million during early 20th century (Cibele *et. al.*, 2009). In India, Assam, Arunachal Pradesh, Andaman and Nicobar Islands, Karnataka and Kerala are the main suppliers of unprocessed rattans. In recent years, uncontrolled harvesting and deforestation have lead to resource exhaustion of the desired species in many rattan-producing countries in Asia. An analysis of distribution of rattans in the three different major areas of India (Peninsular, Northeastern and the Andaman and Nicobar Islands) showed that much change has taken place over the last 20 years.

Although rattans are still found in the natural forests in Kerala, they are restricted to less accessible areas. One of the major reasons for the depletion of resources appears to be the indiscriminate extraction of rattans due to heavy demand for raw material. Even immature rattans are extracted before they could bear flowers or fruits, which drastically affect the production of seeds. On the other hand, this is partially due to the non-adherence to the prescribed cutting cycles, and also due to inadequate information available on silviculture aspects of species for purposes of developing sound management practices. Another factor which has substantially affected the status of the cane resource is the large scale conversion of natural forests

into plantations and agricultural purposes, thus destroying the original habitat of canes. As a result of such continuous and steady pressures on the natural habitat of rattans, the broad genetic base of rattan is being reduced rapidly.

The severe depletion in the rattan resources resulted in an urgent need for effective conservation and propagation measures to be taken. The available resources in Kerala are scarce to meet the demands of the cane industry creating a wide gap between demand and supply. But this can be reduced by augmenting the existing resources by large scale cultivation of canes in the State. The increasing global demand for rattans necessitated the research on the propagation aspects of rattans species.

Due to dormancy condition which prevents the easy germination of rattan seeds, farmers and foresters are facing a major problem in the propagation of rattan species. Other members of the *Arecaceae* family also suffer from the same dilemma due to presence of seed dormancy. But this situation can be altered by seed treatments, subjecting the seeds to favorable condition of moisture and temperature. So a study of the pre-sowing treatments holds major scope in the propagation of rattan seedlings which usually could not germinate well under ordinary conditions due to dormancy.

With this background information, the present study was carried out with the following objectives.

1. To study the effect of pre-sowing treatments on germination of seeds of *Calamus spp.*
2. To understand the growth pattern of seedlings

Review of literature

2. REVIEW OF LITERATURE

The literature pertaining to *Calamus* and other important palm (*Arecaceae*) trees relevant to the present study are reviewed here under.

2.1. Palms and climbing palms

The palms are a globally important family of socio-economic plants. The *Arecaceae* family includes palm trees of economical importance both as a source of agricultural produce and as ornamental components in landscaping projects. *Arecaceae* comprises 198 genera and approximately 2,650 species throughout the world (Domingues, 1995). Palms are distributed mainly close to the equator line within the limits of 44°N and 44°18'S (Henderson *et al.*, 1995).

Rattans are climbing palms belonging to the family *Arecaceae* (*Palmae*). "Rattan" is an English word which has been derived from the Malayan word "rotan" which is the collective name of a big group of palms called Lepidocaryoid and which means 'scaly fruited' in Greek. The word "rattan" emanated from Malay word "raut" which means to pare, smoothen or whittle which a rattan collector does i. e., twists the newly dragged down cane around any convenient rough-basket or tree trunk to rub off the prickly leaf sheaths (Shiva, 1992). According to New Webster's Dictionary of the English Language "rattan" is the commercial name for the long trailing stems of several Asiatic palms used for making furniture, wicker work and walking sticks. In Chambers Twentieth Century Dictionary, "rattan" means a climbing palm with a very long thin stem. It is therefore a collective term commonly used for the spiny climbing palms with about 600 species and 13 genera although exceptionally some are not climbing plants (Dransfield, 1981). In many parts of the world including India, they are popularly known as "canes" although canes often

include watery stems of larger grasses such as sugar cane and bamboo. Therefore, often bamboos and canes are not treated separately in the trade in spite of marked difference in performance and behaviour. Hereafter, the term "rattan" is adopted in view of its wider usage and acceptance in the international trade (Bhat, 1993).

2.1.1. Habit

The diversity in habit of the rattans depends on the branching behaviour (Renuka, 1992a). In most species, branching is confined to the basal suckering. Aerial branching is a consistent phenomenon in the genus Korthalsia. *C. lacciferus*, a species of the Western Ghats, show a particular kind of aerial branching. The basal flagella always get modified into new shoots. Subaerial shoot development is reported formerly in *C. gamblei, C. merrlilii* and *C. erectus* (Renuka and Nambiar, 1985; Fernando, 1987; Alam and Basu, 1988).

Basal branching or suckering is a very common feature among rattans which results in clump formation. Some species like *C. prasinus, C. vattayila* and *C. dransfieldii* are solitary while others are clump forming. For a given species the character of solitary versus suckering is usually constant and often of value in field identification (Renuka, 1992a). There are cluster forming species as *C. thwaitesii* and *C. gamblei* and solitary species like *C. dransfieldii* and *C. vattayila*. Suckering species are preferable in the sense that one single plant produces many aerial stems. Manokaran (1981) reports a few plants of *C. manan* and *C. tumidus*, both solitary species, found suckered. Hence, there is a tendency to shift from solitary nature to clump forming nature. This is a character which needs detailed investigation. From a commercial view point the character of solitary nature is not favoured, since no regeneration takes place from the cut stump and unless cutting occurs after the plant has fruited, there will be no chance for regeneration from seed also (Renuka, 1992a).

Lengths of internodes greatly within species, among stems from the same clumps, or even on the same rattan stem. Surface characteristics such as colour, gloss and texture vary considerably among different species of rattan. This is the reason why some rattans are more commercially acceptable than others (Shiva, 1992). The type of clumping, whether open or close, is of some silvicultural importance, as competition between aerial stem may decrease the potential yield. In most of the clump forming species, the clumps become very dense and many of the lateral shoots do not develop because of competition, *eg. C. thwaitesii* and *C. hookerianus*. *C. stoloniferus*, a rattan from Karnataka region, develops long stolons, the clump thus becoming very open. There is not much competition between aerial stems. The great advantage of this growth form difference make *C. stoloniferus* an ideal silvicultural subject (Renuka, 1992b). There are large diameter canes such as *C. dransfieldii* and *C. thwaitesii*, medium diameter canes like *C. gamblei, C. hookerianus* and *C. pseudotenuis* and small diameter canes as *C. travancoricus* and *C. rotang* (Indira, 1992).

Another character which needs observation is the stem height attaining on maturity. Rattans produce single or clustering stems with diameters ranging from 3 mm to 20 cm and extending to a length of from a few meters to 200 m as in *C. caesius* (Shiva, 1992). The stem height was found to be the highest in *C. thwaitesii* and the shortest in *C. travancoricus*. Among many species studied when these canes are ready for harvesting (Bhat and Renuka, 1986) strength properties also differ much. Of the fifteen species tested from South India, *C. metzianus* and *C. laccíferus* were found relatively light, weak and breakable. Why these two rattans are different from all other commercial species, posing the problem of rejection in rattan trade is the concern of many furniture manufacturers and rattan technologists (Bhat and Thulasidas, 1992).

Normally, rattans mature in about 10 to 15 years. In general flowering is annual *C. pseudotenuis* flower twice in a year. In most of the species flowering starts between October and January and fruits mature between April and June. In *C. pseudotenuis*, the first flowering starts from October and continues till February and the fruits mature during April-June. The second flowering occurs in July and the mature fruits during October-November (Renuka, 1992a).

Rattans are prolific seeders. A single stem can produce clusters of fruits reaching even upto a thousand individuals. The fruits are beautiful and edible. They range from round to oblong and are characterised by the presence of scales on the outer covering arranged in neat vertical and diagonal rows. The scales are brown and have high lustre. A gelatinous pulp, either sweet or sour, surrounds the seed. The fruits appear in cluster, an individual fruit ranging in size from 0.3 to 1.5 cm in diameter and from 0.5 to 2 cm in length depending on the species. A fruit usually has one seed, rarely two or three seeds (Shiva, 1992).

2.1.2. Distribution

There are 13 genera and about 600 rattan species in the world (Uhl and Dransfield, 1987). They belong to several genera, the largest being *Calamus* with 375 species distributed from West Africa to Taiwan, Australia to Fiji with the greatest number concentrated in the Dipterocarp rain forests of Malaysian archipelago. *Daemonorops*, another genus of Rattan with about 85 species extends from Assam through Malaysia to the Philippines (Purseglove, 1983).

Basu (1985) reported that there are about 44 cane species belonging to 4 genera viz., *Calamus, Daemonorops, Plectocomia* and *Korthalsia*, and these account for half of the total *Arecaceae* in India. But few more species were identified and added to the list making it about 60 species of rattans distributed in Peninsular India, forests of

north eastern states and Andaman and Nicobar Islands. Depending on the species they are distributed in the evergreen, semi-evergreen and moist deciduous forests. Out of the total 51 established taxa of indigenous rattans, 29 taxa are endemic and a large number of these endemic taxa are considered as threatened (Basu, 1986). North Eastern region is the centre of genetic diversity for *Calamus* species with about 25 species.

Calamus is the only genus occurs in Southern India. Western Ghats of Peninsular India, with its tropical evergreen rain forests, form one of the ideal habitats of rattans. They are also seen in the Nilgiris and in the Ghat forests of Andhra Pradesh. Rattan is almost universally present all along the stretch of the Western Ghats in the evergreen and semi-evergreen forests spreading over about 500 Km^2. More species occur towards the southern part of Western Ghats. Fischer (1931) reported 11 species of *Calamus* from South India during a survey in Western Ghats, out of 25 species of *Calamus* were located which are rare and endangered (Renuka, 1991). From Andhra Pradesh, two species are reported. But throughout South India due to over exploitation, mature canes are very scarce and are restricted to very remote areas (Renuka, 1992b). A few species are common to Kerala and Tamil Nadu, Kerala and Karnataka or in all the three states. *C. dransfieldii, C. metzianus, C. travancoricus* and *C. vattayila* are seen in Kerala, Karnataka and Tamil Nadu but are restricted to certain areas only (Renuka, 1992b).

Within South India, Karnataka has perhaps the richest assemblage of rattans. Most of the species are concentrated in Kodagu District. Twelve species were collected from this region alone (Renuka, 1992b). *C. nagabettai* was reported by Fernandez and Dey (1970) from Karnataka state. *C. prasinus, C. stoloniferus, C. lacciferus, C. lakshmanae, C. karnatakensis* and *C. nagabettai* are endemic to Karnataka.

From Kerala, nine species of Calamus (*C. brandisii, C. gamblei, C. hookerianus, C. huegelianus* Mart., *C. pseudotenuis, C. rheedii* Griff., *C. rotang* Linn., *C. thwaitesii* and *C. travancoricus* Bedd.) have been reported earlier. An extensive field survey carried out by Renuka (1987) has added few more species to the list. Of these, *C. metzianus* Schlecht. is a new record, while *C. dransfieldii* Renuka and *C. vattayila* Renuka are new species. On the other hand, *C. rheedii, C. huegelianus* and *C. brandisii*, reported earlier in Kerala, could not be relocated. In another survey done in forests of Kerala ten species of Calamus were located and rattan resources and their availability in Kerala forest are discussed (Renuka, 1987). Presently 15 species of rattans belonging to the genus Calamus are reported in Kerala (Renuka, Personal communication; Anto *et al.*, 2001). In Kerala, the forests at Kollam, Pathanamthitta, Palakkad, Malappuram and Wynad Districts are comparatively rich in rattan population. Kanyakumari and Madurai Districts of Tamil Nadu also contain considerable population of rattans (Renuka, 1992b).

Generally rattans are distributed in the evergreen and semievergreen forests. Certain species are seen in the moist deciduous forests as well. Rattans occur from almost sea level to 2000 m above mean sea level. With the exception of *C. rotang*, a cane of the plains, all others are montane (Renuka, 1992a). Most of the species showing altitudinal preference are distributed below 1000 msl while *C. brandisii, C. gamblei, C. lacciferus* and *C. pseudotenuis* are seen above 700 msl and they reach up to 2000 msl.

Of the species reported, *C. thwaitesii* has a wider range of distribution. It is seen throughout the Western Ghats below 900 m. *C. dransfieldii, C. travancoricus* and *C. vattayila*, though seen throughout the Western Ghats, are restricted to certain areas and the number of individuals is very less in a particular area when compared to other species. While *C. gamblei* and *C. pseudotenuis* are found frequently at higher altitudes in Kerala, it is less frequent in other states of South India (Renuka, 1992b).

Some species like *C. dransfteldii* and *C. metzianus* are seen in the moist deciduous forests also. *C. rotang* is a species of marshy area near coastal regions while *C. lacciferus* is seen always near the water courses. *C. travancoricus, C. rotang, C. dransfieldii* and *C. nambariensis* have become extremely rare in their original localities.

A phytosociological study carried out in the tropical wet evergreen forest of Vazhachal forest division indicated that that four Calamus species are endemic to Western Ghats (Abhilash, 2004). They are *C. thwaitesii, C. hookerianus, C. vattayila*, and *C. travancoricus*. The investigation on various forest ecosystems *viz.,* wet evergreen forest, semi evergreen forest and moist deciduous forest of vazhachal Forest division revealed that the occurrence of all these four important Calamus species in Vazhachal (Rony, 2005).

It has been reported that canes are found to grow in position where the canopy is relatively open, suggesting that adequate light is an important requirement for rapid growth (Manokaran, 1980; Mori, 1980; Nainggolan, 1985). Canes are found to prefer moist sites.

2.2. Propagation

Propagation of canes can be of two types' *viz.,* seed propagation and vegetative propagation. Not many studies are available about the pre-sowing treatments and growth attributes especially on Indian rattans.

2.2.1. Seed propagation

In most of the sexually reproducing species, especially the palms, Bino *et al.* (1998) reported that the seed is the primary spreading material and success in

controlling their quality is the basis for greater productivity. Germination of seeds for many species is slow and erratic and germination percentage can be very low (Broschat, 1998). Most palm seeds germinate best if they were picked when fully ripe, have the fleshy mesocarps removed, are planted promptly in a well-drained medium, and are maintained at temperatures of 30–35°C. Palm seed loses its viability within three to six weeks due to dehydration, but can be stored for 8 months or longer if the seed is cleaned, air-dried, dusted with a seed protecting fungicide, sealed in a plastic container, and stored at 18^0C to 23^0C (Broschat, 1998).

2.2.1.1. Seed Maturity

The maturation of the seed is regarded as the result of all changes morphological, physical and physiological characteristics, such as increasing the size and changes in the degree of humidity and in dry matter accumulation which is a process that begins with fertilization and extends onto the physiological maturity (Marcos, 2005). Ramanayake (1999) found 72 per cent germination in Indian rattans when ripe cane seeds sown in soil.

Palm seed should be collected when the fruit is completely ripe (showing full colour), or as soon as it falls from the tree (Meerow, 1991). A few exceptions have been noted from some previous studies. Seed from green fruits of queen palm (*Syagrus romanzoffiana*) germinate better than seed from half-ripe or ripe seed (Broschat and Donselman, 1987), perhaps due to inhibitors in the fruit. Seed of royal palm (*Roystonea regia*) from ripe fruits, germinated more slowly than seed from half-ripe or green fruits, but fewer of the unripe seed ultimately germinated (Broschat and Donselman, 1987).

When checking the periods of ripening fruits, eight species of Palm trees in tropical climate conditions in Hawaii. Chapin (1999) showed that these periods are

not correlated with the mature fruit for sizes (diameter). *Phoenix roebelenii* seeds collected from three different locations, harvested at different times, were studied by Matthes and Castro (1987) and they reported that depending on location, the germination started at different moments *viz.,*. 47, 60 and 120 days after sowing. This diversity of results was ascribed to the high degree of heterozygosis shown by different plants of this species. This is thought to frequently occur between different individuals of the *Phoenix* species (Matthes and Castro, 1987).

Emerson *et al.* (2007) studied germination of seeds collected on different days after anthesis (DAA) in *Phoenix roebelenii.* The highest values were obtained to 180 DAA (99 percent germination), 145 and 187 DAA (97%), 117 and 166 DAA (96%), 138, 110 and 152 (95%). These data are similar to those submitted by Ndon-Remison (1983) in which the seed of *Elaeis guineensis* reached physiological maturity between 105 and 110 days, while only from 150 DAA the exocarp and mesocarp of fruit were mature nutritionally optimized.

2.2.1.2. Seed Viability

Viability of seeds can vary among trees of the same species, and even from year to year from the same tree. Age of the seed and/or the storage methods used can directly influence the ultimate germination percentage. Seeds of some palms generally remain viable for only 2-3 weeks (e. g., Latania spp.), while others may retain viability for over a year (*Dypsis lutescens*) if stored properly (Broschat and Donselman, 1986).

Generally, cane seeds are known to be viable only for short periods of about 1-2 months (Badhwar *et al.,* 1961; Gulati and Sharma, 1983). It is better to sow the seeds fresh soon after extraction. However, a longer period of storage is sometimes necessary due to the large quantity of fruits being harvested. Fruits can be stored if,

closed plastic bags for one month at room temperature, and for three months at temperatures between 10^0 C and 14^0 C (Mori, 1980). The moisture content of seeds must be kept between 45 to 55 per cent during the storage period. A moisture content of more than 60 per cent will induce seed germination during storage and less than 40 per cent will decrease the seed viability (Mori *et al.*, 1980).

Negreiros and Perez (2004) found that seeds of (*E. edulis*) newly collected had 37 per cent moisture content. Seeds of four *Ravenea* (Arecaceae) species were screened for desiccation tolerance (Rakotondranony et al., 2006). Seeds of all species were intolerant of dehydration to 5 per cent moisture content. For *Ravenea rivularis*, the mid-point for desiccation-induced viability loss was 22 per cent moisture content (70 per cent RH at 20°C). Results suggested the need to consider alternative storage methods, such as embryo cryopreservation, for ex-situ conservation of genus Ravenea.

Earlier attempts to introduce Malayan canes such as *C. caesius, C. scipionum* and *C. ornatus* to India through seeds were not successful since the seeds lost viability even during air transport (Badhwar et al., 1961). The fully ripened seeds germinate within two weeks (Renuka, 1992c). Stored seeds of cane lost viability within 2 weeks due to dehydration of embryos (Ramanayake, 1999). Seeds are viable only for a very short period. The seeds should be kept moist.

2.2.1.3. Seed Storage

With few exceptions, it is best to plant palm seeds shortly after cleaning. If this is not possible, the best general storage procedure is to dust cleaned and air-dried seed with thiram (Thylate or captan), seal the seed in plastic bags, and store at 65° to 75° F. There is some evidence that maintaining this covering of fungicide when the seeds are sown may negatively influence germination (Meerow, 1994). Seeds of most

tropical palms will lose viability if stored at temperatures below 60° F. Broschat and Donselman (1986, 1987, 1988) found that cleaned seed of Areca (*Dypsis lutescens*) could be stored at 73° F for over one year without significant loss of viability, royal palm (*Roystonea regia*) for nine months, queen palm (*Syagrus romanzoffiana*) for four months, and pygmy date (*Phoenix robelenii*) for eight months. In the case of royal palm, up to nine months of storage actually increased germination relative to sowing fresh seed immediately.

Seeds of more tropical species (eg. *Dypsis lutescens*,) may be killed after storage for 24 hours at 40°F (Broschat and Donselman, 1986). Seeds of pindo palm (*Butia capitata*) require a period of dry storage for optimum germination (Carpenter, 1988a). The duration of the period increases with decreased temperature: 90 days at 77° F, 120 days at 59° F, and 150 days at 41° F. Generally, palms from seasonal climates (versus uniformly tropical) may have greater tolerance for low temperature storage. Seeds of the native silver palm (*Coccothrinax argentata*) and thatch palm (*Thrinax morrisil*) have withstood -4°F and 15°F respectively for one week without loss of viability (Carpenter, 1988b; Carpenter and Gilman, 1988).

Cane seeds stored in closed bags at room temperature maintain above 50 per cent viability for six months (Darus and Aminah, 1985). Seeds treated with fungicides (0.1 - 1.0 per cent Benlate) prior to storage maintained a high germination percentage after four or five months (Darus and Aminah, 1985). It may be rather difficult to provide suitable storage conditions for maintaining proper moisture content.

Seeds of the four cane species (*C. merrilii, C.ornatus* var. *philippinensis*, *C. filispadix* and *Daemonorops mollis*) can be stored as long as moisture content level is not below 26 per cent (Bagaloyos, 1988). Results showed that seeds of *C. merrilii* with an initial germination rate of 78 per cent and a moisture content of 34 per cent

stored for a long time. Results showed that in all the treatments germination was either nil or negligible after three months. For *C. ornatus* var. *philippinensis*, seeds with moisture content below 51.3 per cent cannot be stored. Seeds below this moisture content desiccated. The same is true for *C. filispadix*; seeds having moisture content below 26 per cent cannot be stored. Likewise, *Daemonorops mollis* seeds cannot be stored if the moisture content is below 26 per cent. Seeds with 26 per cent moisture content, when stored under various treatment conditions and temperature regimes, lost their viability after three months. Mori *et al.* (1980) have shown that *C. manan* fruits stored in closed plastic bags could still maintain a high germination rate of 81 per cent after one month under room temperature of 21°C -28°C.

2.2.1.4. Pre-sowing treatments

Due to the often slow and uneven germination of palm seeds, there has been a great deal of interest in any pre plant treatments that might speed germination or result in more even rates of germination. A fairly universal recommendation has been to soak palm seed in water for seven days. It is advisable to change the water daily. Such a pre-treatment is useful only after dormancy requirements (if any) have been met, though few palm species have been tested for indications of seed dormancy. The seed must be planted immediately after the treatment, as storage following water imbibitions may induce a secondary dormancy (Meerow, 1991).

The occurrence of mysterious numbness, which inhibits the germination of seeds even on favourable conditions (Popinigis, 1985; Oak and Nakagawa, 1988), has been regarded as a major cause of variation in the germination in Palm (Mullet *et al.*, 1981; Villalobos *et al.*, 1992). According to Odetola (1987), there is no mysterious numbness in relation to the embryo, which develops continuously after maturing fruit; however, several species of the family areca have mysterious physical numbness in varying degrees, demanding pre treatment in water or growth regulatory

chemicals, chemical or mechanical stratification or even degrees of exposure to brightness. Some researchers have the opinion that the slow rate of germination in rattan may due to slow development of embryo and not due to any inherent dormancy. (Manokaran, 1978; Mori *et al.*, 1980).

According to some authors Nagao and Sakai (1979), Nagao *et al.* (1980), Frazão and Pinheiro (1981) and Frazão *et al.* (1981), seed probably possessed sufficient gibberellic acid indigenous levels for germination, and supplementation can be supplied exogenously deterrent effect may have caused. The increase in germination percentage values due to gibberellins has also been reported in several works with different species (Duarte, 1982). According to Metivier *et al.* (1986), gibberellins can decrease the average speed of germination. Palm seed treated with growth regulators like BAP and GA_3 did not show any effect on germination percentage and emergency speed index of species.

Scarification of palm seed involves thinning the bony endocarp that may impede imbibition of water. It may be accomplished mechanically, by abrading the surface of the seed until the endosperm becomes visible, or by soaking the seed in dilute to concentrated sulphuric acid (H_2S0_4) for 10 to 30 minutes. Scarification has increased the rate of germination of a number of palm species with hard, water-impermeable seed coats (Holmquist *et al.*, 1967; Nagao *et al.*, 1980; Odetola, 1987). The danger in mechanical or acid scarification is the possible damage to the embryo during this process. The practice should be reserved for seeds with hard and impermeable seed coats. Species that have slow or uneven germination without scarification should have seed scarified on a trial basis before the entire lot of seed is treated (Merrow, 1991).

Kitze (1958), working with palm seeds of *Copernicia* obtained good results, performing the mechanical scarification seeds. The use of sulphuric acid also

provided good results, but lower when compared with the use of mechanical scarification. Seeds of 15 species of the genus *Copernicia* germinated entirely in water. Not all species respond positively to a water soak treatment (Doughty *et al.*, 1986; Odetola, 1987; Carpenter, 1987; and Broschat and Donselman, 1987, 1988) and experiments documented in the literature have tried varying the duration of the pre-soak period on seeds of the same species. However, unlike some of the other pre-treatments, a water soak poses little danger to the seed.

Pre-sowing treatment by soaking, mechanical or acid scarification had no significant promotory effect on either rate or totality of germination of mature *Phoenix reclinata* seeds, while use of water transiently at 100° C was highly deleterious. However, germination of partially dehydrated seeds was initiated sooner if they had been soaked or scarified (Patricia *et al.*, 2004). But, Berjak *et al.* (2004) observed the effect of deteriorating effect of heat treatment at 100° C in the germination of seeds *Phoenix reclinata* and pre-scarification did not provide engineering and spicy effect on the germination.

Flach (1997) noted that germination in sago palm, *Metroxylon sagu* can be speeded up if the seed husk is removed and the covering over the embryo (operculum) is loosened. Care should be taken not to damage the embryo. Removal of flesh, accelerates the germination of seeds of some species such as *Euterpe oleracea* (Broschat, 1994; Meerow, 1991; Lorenzi *et al.*, 2004; Bovi and Buchanan 1976a; Bovi and Buchanan, 1976b; Maeda, 1987. Elias *et al.* (2006), searching the same species, found the germinal pore depth in the substrate provided emergency increase and decrease the percentage of dormant seed.

Figliolia *et al.*, (1987), comparing the germination of seeds of *Euterpe edulis* by removing fruit flesh, after soaking in water for 24 h and mechanically, concluded that scarification of seeds, faster and uniform the germination than those of control.

Viana (2003), studying the effect of four temperatures (30^0 C, 20 to 25^0 C, 25 to 30^0 C and 25 to 35^0 C) with or without mechanical scarification in germination of seeds of *Livistona rotundifolia*, noted that the best results were obtained with treated seeds under temperature of 25 to 35^0 C. Already, Pivetta *et al.* (2005) have checked that treated seeds of *Syagrus schizophylla* showed greater germination percentage and faster germination compared to untreated seeds.

Bovi and Buchanan (1976a), studied effect of treatments which include immersion in water and hot water (±80° C) and sulphuric acid (75 per cent) treatments for 5 or 10 minutes on of seeds of *Euterpe oleracea* and concluded that both the use of sulphuric acid and the hot water were not satisfactory. Frazão and Pinheiro (1982) also concluded that the use of mechanical scarification stimulates and standardizes the germination of seeds Palm of the genus *Orbignya* . Ferreira and Gentle (2006), studying the germination of *Astrocaryum aculeatum* confirmed the removal of the core material without causing damage to the viability of seed germination resulted in 58 per cent, regardless of various periods imbibition analyzed.

Bovi and Buchanan (1976b) studied the effect of mechanical scarification (scraping with needle growing pore region seeds) and chemistry (sulphuric acid by 5 or 10 minutes) in the germination of seeds of *Euterpe edulis*, concluding that there was no difference between scarified seed and non-scarified seeds and sulphuric acid treated for more than 5 minutes was harmful. Nagao *et al.* (1980) managed to accelerate the germination of seeds of *Archontophoenix alexandrae* through mechanical scarification of seed coat, followed by a soaking in aqueous solution of gibberellic acid to 1000 mg/L for 72 hrs; however, the ultimate per cent of germination has been reduced due to damage caused by treatment.

Frazao and Pinheiro (1981) and Frazao *et al.* (1981) noticed increase in

germination of Palm with GA_3 application. A number of investigators have reported a hastening affect on germination by soaking seed in 10 to 2000 ppm concentration of GA_3 for 1 to 3 days (Doughty *et al.*, 1986; Nagao and Sakai, 1979; Nagao *et al.*, 1980; Odetola, 1987). Odetola (1987) reported 10-25 ppm GA_3 worked well for a wide variety of species. Excessive elongation of Areca palm (*Dypsis lutescens*) seeds was caused by pre soaking seed in GA_3. Treatment with growth regulator causes excessive elongation of the seedling, in some cases even preventing the seedling from supporting itself (Broschat and Donselman, 1987, 1988). Consequently, it is not advisable to use a GA_3 pre-soak despite any positive effects on germination rate (Meerow, 1991).

Concerning seed dormancy breaking, germination percentages and rates were determined for 13 treatments by Kouakou (2009). The best treatments were pre-soaking unscarified seeds for four days in 1.01 g/L and 0.10 g/L KNO_3, with 79 per cent and 68 per cent of germination, respectively and in 3.46×10^{-3} g/L GA_3 for 68 per cent of germination. These methods are suggested to improve germination of *Laccosperma secundiflorum* seeds. Successful and recommended methods for *Eremospatha macrocarpa* are pre-soaking scarified seeds in 3.46 × 10–3 g/Land 3.46×10^{-4} g/L GA_3, 96 and 94 per cent of germination, respectively. Dormancy, probably a combination of mechanical and chemical dormancy, is present in the two species

Patterson *et al.*, (2008) evaluated the effectiveness of different pre-sowing treatments to accelerate and standardize the germination of seeds of *Rhapis excelsa* (lady palm). The use of mechanical scarification presented a tendency to increase the percentage of emergence, but not statistically differed treatment with sulphuric acid for one, two, and four minutes and control. Soaking seeds in water heated about 100° C, for one, two and four minutes has not occurred germination. Results indicated that exposure of seed at temperatures close to 100° C may have killed the embryo.

Removal of sarcotesta in canes is necessary as a pre treatment in order to shorten the germination period but, if the sarcotesta is a physical obstacle to gas exchange or if it contains inhibitory factors is not clear (Goel, 1992). Removal of the hilar cover gave the best germination results for *C. merrillii*, germination time was drastically shortened from the usual range of 90 - 120 days to only two days as a result of the removal (Bagaloyos, 1988). Likewise, the reduction was from 240 - 365 days to only 8-14 days for *C. ornatus* var. *philippinensis*. Siddiqi *et al.* (1996) studied the germination and seedling growth of *C. tenuis* at the Bangladesh Forest Research Institute, Chittagong. Germination was 70 per cent for the whole fruit (seed + sarcotesta + scale), 10 per cent for seeds with pulp (seed + sarcotesta), and 86.66 per cent for cleaned (seeds without sarcotesta and scale) seeds.

Mature seeds of *C. tenuis* and *C. rotang* were used to study the germination frequency in nursery soil by Singh *et al.* (1999) at Assam Agricultural University. There was no germination from the intact seeds or from the seeds after removal of outer scaly pericarp. The germination percentage increased (45 and 65 per cent for *C. tenuis* and *C. rotang* respectively) and corresponding days for germination were 32 and 35 respectively, when the outer scaly pericarp, fleshy sarcotesta and hilum were removed mechanically by rubbing with sand and ash. Removal of the micropyle gave 100 per cent germination for both species and reduced the time to germination to 11-12 days in vivo. All the plants raised were successfully established in the soil.

Swapon and Baruah (1994) found out a technique for enhancing germination frequency of rattan seeds. Seeds of *C. tenuis* were treated after collection in Assam, by removing the scale or the scale and the fleshy pericarp, and then sown in moist sand under shade. Germination was very poor with no pre-treatment (only 7 per cent after 53 days), and not improved by scale removal (8 per cent), but increased to 90 per cent after removal of both scale and mesocarp.

Aminuddin and Zollpatah (1990) carried out some tests under nursery conditions for *C. manan* and *C. tumidus*, but under laboratory conditions only for *C. manan*. Seeds were sown on forest soil in germination boxes, and covered with a thin layer of sawdust. In the laboratory, cumulative germination of *C. manan* was 76 per cent over 3-7 weeks, in the nursery it was 74 per cent over 4-11 weeks. Figures for *C. tumidus* in the nursery were 43 per cent and 6-31 weeks. A method is presented for raising seedlings of *C. viminalis* var. *fasciculatus*, with details of their performance after planting out in Bangladesh (Siddiqi *et al.*, 1998). The germination per cent of *C. viminalis* sown in nursery beds was 24.37. This figure is lower than that reported for other rattan species in Bangladesh. Sunlight was necessary for the germination of *C. viminalis*, since seeds sown in the shade did not germinate at all. The optimum time for seedling pricking from the seedbed to the polybag was 90 days after germination; 100 per cent survival could be obtained for this operation.

C. thwaitesii fruits are collected when fully ripe, the outer scaly cover and the fleshy layer can be easily separated by pressing them between the fingers (Parameswarappa and Lakshmana, 1992). Before planting the seeds, the scaly and fleshy layers should be removed by rubbing and washing in water. The seeds should be sown as early as possible after collection as the seeds cannot withstand drying out. Germination rate of 90 per cent is obtained. Mori *et al.* (1980) found that complete sarcotesta removal of *C. manan* seeds resulted in germination rates of 90-100 per cent. Bagaloyos (1988) has reported that removal of the hilar cover gave the best germination rates of 78 per cent and 87 per cent respectively for *C. merrilli* and *C. ornutus* var. *philippinensis*. Though the hilar cover removal techniques gave very encouraging results, it cannot be practised on a commercial scale for large quantities of seeds since it is a very tedious and risky process.

Sumantakul (1989) has reported a low germination rate of 16 per cent for *C. latifolius* when the pericarp and sarcotesta were removed completely. Sowing the

whole fruit as well as fruit with only the pericarp removed surprisingly gave 54.5 and 32.0 per cent germination rates respectively. The unusual low germination rate for clean removal of pericarp and sarcotesta probably confirmed the reservation expressed by Darus and Aminah (1985) that the embryos can be damaged during the cleaning process. Sumantakul (1989) also found that for *C. latifolius*, seed seasoning at 40° C for 24-48 hours gave a significantly higher germination rate of about 70 per cent than in controls. Soaking seeds in water did not improve germination. The pre-treatment with heat at 40° C appears promising for large scale application. Tan (1994), summarized pre-sowing treatments for canes in his study. In a variation in the method in fruit processing, fruits are depulped after being soaked in water for about 24-48 hours. The pericarp and sarcotesta are removed by rubbing the pre-soaked fruits with hand. Seeds are cleaned by repeated washing in water. To prevent any moisture loss before sowing, the seeds are kept mixed with moist sawdust. The processed seeds should be sown immediately wherever possible. Should there be any delay in sowing, the processed seeds should be spread out on gunny sacks laid flat, and kept moist and cool as is done for fruits before processing begins.

2.2.1.5. Seed Sowing

Palm seed germination media must be well-drained, yet have some moisture-holding capacity. A pattern of alternate extremes of dryness and wetness is detrimental to palm seeds during germination. Particle size in the medium should not be excessively large nor prone to separation with repeated irrigation. A 1:1 mixture by volume of peat moss and perlite has been successfully used under a wide range of nursery conditions. The mix in a germination medium should be adjusted depending on the conditions to which the seed will be exposed. For example, seed germinated in full sun will require a medium with higher water holding capacity than seed germinated under shade, all other conditions being equal (Meerow, 1991).

Yocum (1961), found that, generally, the vermiculite as a substrate suitable for seed germination of palms. In fact, the vermiculite substrate is widely used by researchers to conduct experiments with seed germination of palms in general. For the dwarf-palm, virtually no difference between the substrates. However, it is considered the IVG and evaluated the characteristics of the seedlings; the vermiculite was the substrate where they obtained the worst results. The use of vermiculite produced seedlings with higher root length and low occurrence of secondary and tertiary roots, when compared with those of other substrates. The use of vermiculite as a substrate for the IVG seed testing and evaluation of seedlings of dwarf-palm is not advised and sphagnum is the best substrate for most characteristics assessed in *P. roebelenii* seedlings (Emerson *et al.*, 2003). Marcus and Banks (1999), recommended the use of sphagnum as a substrate for seed germination difficult palms showing, while these species to germinate easily be sown in a substrate composed of sphagnum only, or mixed with the same amount of vermiculite, perlite, sand, sawdust, rocks or volcanic ash with a maximum of 9 mm in diameter.

Cibele *et al.*, (2009) studied the substrate moisture level effect on seedling emergence and vigour of peach palm (*Euterpe edulis*). The wetting of vermiculite with water in quantities from 60 to 90 ml/100 g of substrate (from 0.6 to 0.9 x the weight of water or 77.6 to 86.7 per cent of the retention capacity of the substrate in water, respectively) had shown higher emergence percentage of seedlings. The wetting with 90 ml water/100 g of vermiculite resulted in the higher speed of emergency and vigour of seedlings (length, diameter and mass). But, working with seeds of *Orbignya pharelata*, Frazao and Pinheiro cited by Melo (2001) noted that the use vermiculite, at a temperature of 30° C, resulted in half of germination when compared with washed sand.

The initial planting density depends on the ultimate use of the germinated seedlings as well as how quickly the nursery operator anticipates transplanting the

seedlings. It is best to sow the seed with some space between adjacent seeds. Large seeds, especially those of difficult to transplant species such as *Bismarckia*, are often sown one per container (Meerow, 1991).

For canes, raised seed beds are prepared using sand and saw dust. The bed consists of a layer of sand, about 10 cm in thickness, and over it a layer of saw dust, about 3 cm in thickness, and is supported on the sides by wooden planks. The bed is 1 m wide and of any convenient length. Shelters with suitable plastic sheets are provided over the seed beds to minimise the effects of direct sunlight and heavy rain. Seed beds are given fungicidal treatment twice a month (Renuka and Rao, 1997).

2.2.1.6. Germination

Despite the importance of the palm family, *Arecaceae* little has been systematically documented about the seed behaviour of the many species. According to Uhl and Dransfield (1987), the types of germination of palm seeds are: adjacent-ligular, remote-ligular, or remote-tubular. Some common palms with adjacent germination include areca (*Dypsis lutescens*), King Alexander palm (*Archontophoenix alexandrae*) and coconut (*Cocos nucifera*). The seeds of Mediterranean fan palms (*Chamaerops humilis*), Chinese fan palms (*Livistona chinensis*), date palms (*Phoenix* spp.) and Mexican fan palms (*Washingtonia robusta*) have remote germination (Meerow, 1991).

Emerson *et al.* (2006) investigated the morphology, anatomy and germination behaviour of *Phoenix roebelenii* seeds. Germination started between 27 and 58 days after sowing. The plumule is composed of a sheath which dresses up the first complete juvenile leaf (first eophylum). Starting on the 42nd day after sowing, the sheath gradually opens up thus allowing the ousting of the first eophylum. The first leaves of *P. roebelenii* are simple and lanceolate.

As rattan seeds germinate, the first sign is the emergence of a spear like protuberance from which the seedling leaves expands later. Seedlings are generally ready for transplanting when the first seedling leaves are fully expanded (Renuka *et al.*, 2002). The spear like protuberance is called "prophyl" (Renuka, personal communication).

The rate at which palm seed germinates, the uniformity of germination, and the percentage of total germination can vary tremendously from species to species, from seed lots collected from different plants of the same species, and even from seed lots collected in different years from the same plant. Seed of Mexican fan palm (*Washingtonia robusta*) may begin to germinate in less than two weeks, seed of areca palm (*Dypsis lutescens*) in 3-4 weeks, while seed of parlor palm (*Chamaedorea elegans*) may not begin to germinate for several months and then continue sporadically for over a year (Meerow,1991). When planting palm seed of species with which one has no previous experience, or for which no germination information can be found, one should remain patient as long as the seed appears in good condition.

Viable seeds of peach palm (*Eateries edulis*) started germination on average to 170 days after sowing (Oak, 1994). Germination percentage varied with the period of germination in peach palm (Martins-Corder *et al.*, 2006). The magnitude of variation was from 0 to 4 per cent (60 days), 0 to 15 per cent (90 days), 3 to 25 per cent (120 days) and 14 -56 per cent (150 days). There was variability in germination between progenies of *E. edulis* has been observed (Martins-Corder *et al.*, 2006). Similar work carried out with Palm trees also noted variations between genotypes for the germination percentage (Cunha and Garden, 1995).

2.2.1.7. Germination Conditions

Many factors can affect the germination of seeds, Palm as species, substrate temperature, humidity and aeration substrate and the storage period. The rapid and uniform germination of seeds, followed by prompt emergency are highly desirable characteristics for seedlings formation (Koebernick, 1971).

Alternating periods of extreme wet and dry during this time period will usually have deleterious effects on total germination percentages. If the germination medium does not receive some type of automatic irrigation, it may be necessary to cover the containers with clear plastic to retain adequate soil moisture. Over watering can be equally deleterious. At no time should standing water be visible on the surface of the germinating medium (Meerow, 1991).

Virtually all palms require high temperatures for the most rapid and uniform germination of their seed. 70 to 100^0 F is the accepted range, and 85-95^0 F probably yields the best results. Seed of paurotis palm (*Acoelorraphe wrightil*) has been reported to germinate best at 92-102^0 F, with only 11 per cent germination whin temperature was below 86^0 F (Carpenter, 1988b). Thatch palm (*Thrinax morrisii*) and silver palm (*Cocothrinax argentata*) germinated best at 91-97^0 F, with few seeds germinating below 77^0 F (Carpenter, 1988a; Carpenter and Gilman, 1988).

Seed of pindo palm (*Butia capitata*) germinated best with 2-3 weeks at 102^0 F, followed by 86^0 F for the duration of the germination period (Carpenter, 1988b). Some research has suggested that fluctuating temperatures at 12 hour intervals may increase total germination for certain species (Carpenter, 1987, 1989), but this is not practical for most growers. Since palm seeds require high germination temperatures, it is best to sow seed during the warmer months of the year (Meerow, 1991).

According to Lorenzi *et al.*, (1996) for germination of several species of palm are considered favourable temperatures between 24^0 C and 28^0 C with relative humidity of approximately 70 per cent. Already, Broschat (1994) noted that many palm seeds germinate better in the range of 30^0 C to 35^0 C. Carpenter (1988) studied the limits of temperature for germination of seeds of four species of palms: *Acoelorraphe wrightii, Coccothrinax argentata, Sabal Eton* and *Thrinax morrisii.* Germination was best at 35^0 C, with temperatures from 5-10^0 C above or below 35^0 C, often delayed and reduced germination and become irregular and uniformity.

Sento (1972) described and illustrated and the course of seed germination of *Pheonix dactilifera* and found that 90 per cent of seeds germinate at temperatures between 25^0 C and 35^0 C and the substrates used (sand/vermiculite and sand/soil) are also appropriate. Loomis (1958) reported that the period of germination for seeds of *P. roebelenii* is approximately 39 days and recognizes three factors harmful to the seeds of palms: excessive drying, which causes the shrinkage of the embryo and reduces the viability; fungi formed on the surface, which can penetrate the embryo, impairing the viability and the age of seed.

Sento (1972) they studied species of the genus *Phoenix*, noting that 90 per cent of seeds of *Pheonix dactilifera* germinated between 25 and 35^0 C, and the substrates used (sand/vermiculite and sand/soil) are also appropriate. Studies done by Emerson *et al.* (2003) proved highly significant effect of temperature on seed germination of *P. roebelenii*, whose best results were obtained with temperatures of 25^0 C and 30^0 C. The temperatures of 20^0 C and 35^0 C provided low percentage of germination of seeds of *P. roebelenii*, however, were higher than the temperature of 40^0 C where it obtained the lowest percentage of germination between the temperatures studied. Emerson *et al.* (2003) studied the speed of germination of *Phoenix roebelenii* seeds in different substrates and in different temperatures. In temperatures of 20^0 C and 40^0 C, there was no significant effect of substrates. Furthermore, effects were observed on

substrates at temperatures of 25, 30 and 35^0 C in the IVG seeds of *P. roebelenii*. The highest GSI was obtained at a temperature of 30^0 C, using sphagnum (0.87) or sand (0.83), followed by sawdust not differ from the sand (0.74), while the vermiculite (0.70) had the lowest GSI and not statistically different from the sawdust.

The average period-related information required for the germination of seeds of *Rhapis excelsa* are very divergent, ranging from 50 to 130 days (McKamey, 1989; Lorenzi *et al.*, 2004). Aguiar *et al.* (2005), studying the effect of light, temperature and substrate in germination of *R. excelsa*, noted that the temperature of 25^0 C, the percentage increased sand substrate and the germination rate index of the species, regardless of the presence or absence of light.

Many palms germinate in the understory of a forest canopy in their native habitats, even if they eventually grow up into full sun (for example royal palm). Seedlings of these species can be germinated in full sun but their leaves may bleach to some extent under those conditions. Many growers feel that, despite the bleaching, root growth and overall seedling development are enhanced in full sun. Under shade, seedlings will generally have a deeper green colour. Some species grow best in the shade (*Licuala* species). Seed of the latter group should be germinated under shade. Seedlings of such species, if exposed to full sun, usually bleach severely, burn and may even die. Species native to open habitats show no ill effects when germinated in full sun. It is generally necessary to adjust seed planting depth according to the light levels to which the seed will be exposed (Meerow, 1991). Palm seedlings do not require supplementary fertilization for the first two months after germination. The endosperm within the seed provides all the nutrition that the seedling needs during this period. Supplemental fertilization during the first two months not only wastes fertilizer but can injure the young seedling (Meerow, 1991).

2.2.1.8. Maintenance of rattan seedlings

Maintenance is essentially of watering, fertilizer application, and weeding and disease control. As is the general practice in the nursery for all species of potted seedlings, rattan seedlings are watered twice a day. This is done once in the morning and once in the late afternoon. If it rains earlier, watering is waived for that day. To ensure healthy growth foliar fertilization is carried out four times a year. Bayfolan (11 %, N, 8 % P_2O_5, 6 % K_2O and trace elements) is sprayed, at the rate of 2-3 ml/L water per 100 seedlings. Weeds have not been found to be a serious problem for the potted seedlings, and weeding is only done whenever necessary during the first 6 months (Darus and Aminah, 1985). Seedlings are kept in the nursery until they are transplanted to the field. They should not be completely exposed due to scorching of their leaves by sun's rays (Manokaran, 1980, 1981).

Alternating periods of extreme wet and dry during this time period will usually have deleterious effects on total germination percentages. If the germination medium does not receive some type of automatic irrigation, it may be necessary to cover the containers with clear plastic to retain adequate soil moisture. Over watering can be equally deleterious. At no time should standing water be visible on the surface of the germinating medium (Meerow, 1991).

Artificial regeneration of canes is done in West Bengal with the following cultural practices. Seeds are collected from natural forest from December to March. Seeds are sown at the rate of 2 Kg per bed to get 1000 seedlings. The beds should be shaded and frequently watered. Only two years or older seedlings can be transplanted with success. Seedlings of lesser age do not survive. Some plantations were raised in open areas in the past with seedlings of age less than a year and that is why could not succeed (Sultan, 1992).

Norani *et al.* (1985) noted that leaf diseases are the most common for various species of rattan seedlings in the nursery, and that when severe, seedling mortality could occur. Several fungal pathogens were identified by them as having caused shot holes, brown rings or brown spots. Fungicidal application is recommended whenever disease symptoms appear. Termites and other insects are found to be attacking rattan seedlings (Maziah *et al.*, 1994).

A serious outbreak of leaf blight of *C. trachycoleus*, caused primarily by *Colletotrichum gloesporoides*, devastated almost 30 per cent of the growing stock in the Kepong nursery in early 1983. The disease, to which *C. manan* and *C. caesius* seedlings were found to be resistant, was controlled by spraying Bayleton (0.02 %) over the entire nursery stock at ten day intervals. All diseased seedlings were also burnt. Norani *et al.*, (1985) have recommended the introduction of strict nursery hygiene such as the culling of weak plants, planting out in the field of old stock, spacing of seedlings to avoid crowding, and avoidance of excessive watering. In general, rattan seedlings may be kept in the nursery for up to 8-12 months by which time they may have reached a height of 30-40 cm. They should then be transplanted to the field.

2.2.1.9. Transplanting the Seedlings

Palm seedlings may be transplanted either immediately after germination or after 1-4 leaves have formed. The objective is to lessen the degree of root disturbance to the seedlings; thus it is best to transplant before roots begin to circle the container or roots of adjacent seedlings become entangled. Transplant in the warmer months of the year, when root growth will be rapid. Delay transplanting until at least one leaf has appeared. Seedlings will usually have one long root at the time of first transplanting. Two strategies are then possible for subsequent transplanting of the seedlings. They can be shifted successively to slightly larger containers as they grow

(frequent small shifts), or they can be transplanted to larger containers than their size might seem to warrant (fewer and larger shifts). Ideally, newly transplanted seedlings should be placed under light shade (30-50 per cent) for several weeks, or until new growth is apparent. If this is not possible, irrigation frequency must be carefully monitored so that the transplants are not water stressed during establishment (Meerow, 1991).

The size of the polybag for rattan seedlings will vary depending on the species. In general, a size of 16 cm x 12 cm is sufficient for raising the seedlings up to 9 months, an optimum field planting age. Tan (1994) suggests a size of 15 cm x 23 cm. It is better to use black polythene bags. Potting mixture consists of forest topsoil and sand in the ratio of 3:1 (Renuka, 1991) or soil, sand and farm manure in the ratio of 5:3:1. According to Goel (1992) when the cane seedling develops at least two leaves, they are old enough to transplant with a ball of earth in polybag and kept under shade. After one year polybag seedlings are transplanted in the field.

2.2.2. Vegetative Propagation of Palms

Despite the overwhelming reliance on seed propagation for palms, there are several methods of clonal (vegetative) propagation that can be used for a few species. Due to the uncertainty of viable seeds being available in large quantities, seeds are unlikely to be a dependable source of propagation material. Also, extraction of canes before flowering occurs further complicates the situation. Vegetative propagation using suckers, rhizome and stem cuttings appear to be a viable alternative to circumvent this problem (Renuka and Seethalakshmi, 1988).

Clustering palms, that is those that produce new erect shoots from a common base or system of rhizomes, can be propagated by division as a means of increasing stock (Meerow, 1991). Species that produce new shoots at some distance from the

parent stems (*Rhapis species*), are the most easily divided. Many *Chamaedorea* species, Areca and other *Dypsis* species, and Paurotis palm (*Acelorraphe wrightil*) are amenable to this type of propagation. Stock in containers is generally easiest to divide. For best results in the field or landscape, it is advisable to separate divisions from the parent plant with a sharp spade in the spring, but leave the divisions in place until new growth is evident. At that time the divisions can be carefully lifted, with as much of the root ball as can be managed. Newly separated divisions are best potted and kept shaded and well-watered until established (at least 1 year), after which they can situated in the ground.

A number of *Chamaedorea* (Arecaceae) species produce conspicuous short aerial roots at the stem nodes (leaf scars). These species can be air layered by applying a swath of moist sphagnum peat moss around one to several nodes and wrapping the area in aluminium foil (Meerow, 1991). The aerial roots will grow into the moss. When sufficient root growth has occurred, the stem can be cut from the parent plant and potted. Newly cut layers should be kept shaded and well-irrigated until established in their containers (Meerow, 1991).

Several date palm species, most notably the commercial date palm, *Phoenix dactylifera*, produce offsets or suckers at the base of the trunk. These can be cut from the parent plant and either planted in containers or planted directly in the ground. If no roots are present when the suckers are cut, the leaves should be reduced in number and/or size (Meerow, 1991). Suckers can also be used after treating them with growth regulating substances like NAA (1-naphthaleneacetic acid) and IBA (indole-3-butyric acid) for better rooting.

A study was conducted by Kouakou *et al.*, (2009) to examine regeneration using offsets combined with several physical and chemical treatments of seeds of *Laccosperma secundiflorum* and *Eremospatha macrocarpa*. Offsets categorized into

small, medium and large diameters, were planted in three conditions: shaded and open nursery, and greenhouse. We tested sucker from *E. macrocarpa*, and sucker and rhizome from *L. secundiflorum*. For both species, high viability percentage (ranging from 55 per cent to 100 per cent) were observed for small and medium suckers planted in shaded nursery and greenhouse, against less than 49 per cent for sucker planted in open nursery. The mean seedling emergence times were estimated to 84, 77 and 75 days after planting (DAP) for small, medium and large sucker of *L. secundiflorum*, respectively under open nursery condition, and 76, 75, 95 DAP for small, medium and large suckers of the same species, respectively in shaded condition. Greenhouse has a significant positive effect on *E. macrocarpa* seedlings emergence time. For this species, the mean seedling emergence times were estimated to 43 DAP for small sucker and 76, 93 DAP for medium and large suckers. No seedling was obtained from rhizome planted in all the growing conditions tested.

Methods of propagation of rattans by seeds and by vegetative means by rhizomes, suckers, stem cuttings, layering and tissue culture, was reviewed by Aziah and Manokaran (1985) and Manokaran and Wong (1983) has reported vegetative propagation of *Daemonorops jenkinsiana* using rhizomwln India, a few attempts have been made to raise plantations of rattans by various methods. Planting trials with about eight indigenous species were carried out in Bengal during 1957-1958 (Ghosh, 1961). Different methods of planting, using seedlings, rhizomes and offsets with and without shade, and with propagules exposed and also covered with soil, were tried to evolve suitable planting techniques. Maximum percentage of establishment after three years for seedlings/wildings and rhizomes/offsets indicated that rhizomes/offsets were better for more of the species.

Planting of rooted suckers during the monsoon was found promising. Successful propagation with suckers of *C. caesius* (Badhwar *et al.*, 1961) and *C. tenuis* (Gulati and Sharma, 1983) has also been reported. The percentage of

establishment with transplanted propagules can be enhanced by inducing profuse rooting by treatment with growth regulating substances (GRS). A preliminary trial with suckers of *C. hookerianus* at Kerala Forest Research Institute showed better root formation with a treatment of indole butyric acid (IBA, 100 ppm) Further work on the effect of various GRY method of treatment and dosage is necessary to make any recommendation on this aspect (Renuka and Seethalakshmi, 1988). Suckers extracted during July-September after a treatment with NAA at 2000 ppm have shown good rooting (Seethalakshmi, 1993). (Shoot) cuttings of *C. diepenhorstii*, did not root in a mist box, but the use of suckers separated in May-August gave good results (Yimsawat *et al.*, 1995).

Layering may be another promising method for propagation of canes. There are a few instances of layering occurring under natural conditions in *C. javensis, C. heteroideus* and *C. reinwardtii* (Dransfield, 1977). In these species short aerial stems in the forest undergrowth flop over and produce roots. Vegetative reproduction from aerial parts of *C. gamblei* and *C. hookerianus* has also been observed in Kerala (Renuka and Nambiar, 1985). In *C. gamblei*, the axillary buds develop into new shoots. After developing 2-3 leaves, roots are produced and if they happen to come in contact with the soil, they develop into new plants. Likewise many of the distal axillary buds, which would have normally developed into flagella, are also transformed into new shoots. Root development from distal nodes, which are in contact with the soil, has also been observed in *C. hookerianus*. These observations indicate that canes have a potential for vegetative propagation using cuttings. However, proper treatments may be necessary for shoot and root induction.

The earliest reports of tissue culture studies on Indian rattans were those by Padmanabhan and Krishnan (1989), Padmanabhan and Sudhersan (1989), Padmanabhan and Illangovan (1989, 1994). Research on in vitro culture of rattans is currently being carried out in India at the Kerala Forest Research Institute (KFRI),

Peechi and Tropical Botanical Gardens and Research Institute, Palode. At KFRI, work was initiated in 1992 and micro-propagation protocols have been developed for seven species of Calamus of Western Ghats and the Andaman and Nicobar Islands, using immature or mature embryos or shoot tips of (1-2 year old) seedlings for initiating the culture (Muralidhran, 1994; Valsala and Muralidhran, 1998, 1999). Regeneration of plantlets in some of the species has been achieved through organogenesis in callus cultures as well as from in vitro leaf segments. Somatic embryogenesis and plantlet formation were also achieved from callus cultures (Valsala and Muralidharan, 1998).

2.3. Growth

Nursery growth studies are important because they are the indicators of the performance of the species in the main field. Martins-Corder *et al.*, (2006) studied growth of peach palm (*Euterpe edulis*). The progenies of peach palm showed significant differences with respect to the height of seedlings characteristics, diameter and number of leaves. The overall average height of seedlings was 92 cm and collar diameter was 0.73 cm to 0.62 cm and it produced an average of 1.45 leaves per seedling within 210 days after germination. Collar diameter seedling is a characteristic appropriate to indicate the differentiation between genotypes (Nodari and Fantini, 2000).

The number of leaves may be a good indicative of the force of seedlings, reflecting in performance under natural conditions, because more vigorous smaller seedlings are more suited for establishment. Seedlings of peach palm with higher number of sheets were favoured growth, as photosynthesis exceeds respiration (Venturi and Paulilo, 1998).

A survival of 98 per cent was observed in wildings (commonly used as planting stock in India) of *C. manan* and *C. tumidus* when they were transferred from the field to the polybags at an average height of 8.5 cm. One year old wildings were significantly lower in height in the nursery than one year old polybag-raised seedlings. Survival of field planted seedlings at Hinguli, Chittagong, was 77.5 per cent after one year. Average height increment of the seedlings was 25.5 cm with usually 4-5 leaves within one year followed by planting under 15 year old teak plantation with 70 per cent canopy closure (Aminuddin and Zollpatah, 1990).

Among the different substrates for seedlings of *Pheonix roebelenii*, the best substrate was found to be sphagnum as it was having a shoot length of 9.98 cm, which was significantly different from the others (Emerson *et al.*, 2003). The sawdust (6.97 cm) and sand (7.27 cm) did not differ. The vermiculite (5.74 cm) showed the lowest length of shoot, which did not differ from sawdust. Similarly, results were obtained with shoot dry matter of the seedlings studied, and all the substrates differed significantly giving 0.74 g in sphagnum, 0.55 g in sawdust, 0.49 g in sand and 0.30 g in vermiculite. For the length of the root, it was found that the best treatments were obtained with the use of sand (7.59 cm) and vermiculite (7.14 cm), followed by sphagnum (6.22 cm) not differ from vermiculite. The worst treatment was the sawdust (2.59 cm). Moreover, the higher the root dry weight was found in sphagnum (0.29 g) or sawdust (0.25 g), followed by sand (0.17 g), which did not differ from sawdust. The vermiculite (0.15 g) showed the lowest value and not different from the sand.

Petterson *et al.*, (2008) studied the effect of fertilisation and substrate application on lady palm. Data were collected at 140, 170, 200, 230, 260, and 290 days after transplanting (DAT) for plant heights, stem diameter at substrate level, number of leaves, shoots, and canopy, roots fresh and dry matter samples were harvest at 290 days. Foliar fertilization resulted in significantly greater plant height in

a 140, 120, 200, and 230 DAT and plant diameter on the 140, 260, and 290 DAT. There was interaction among factors for number of leaves with fertilization based on P_2O_5 and K_2O when leaf fertilizer was added that resulted in a greater number of leaves.

Sapindus emerginatus produced a root length of 14.9 cm and shoot length of 28.4 cm in 3 months the dry weight produced was 2.17 g (Suresha, *et al.*, 2007). In *Terminalia chebula* reported shoot length of 33.17 cm and root length of 40.66 cm in 3 months. It produced an average of 24 leaves per seedling and a collar diameter of 5.57 cm at the age of three months. The biomass production by it was 1.53 g in shoot and by its shoot 0.82 g in root which gave a total dry weight of 2.35 g in 3 months (Hossain *et al.*, 2005).

Though growth data for rattans are scanty some reports available. Manokaran and Wong (1983) reported that *C. caesius* seedlings at near optimum condition (canopy thinned, poorly drained substrate) can grow as much as 5-6 m per year during 1^{st} to 5^{th} year from planting. Parameswarappa and Lakshmana (1992) reported that cane plants have grown 36 cm per year in the first 3 years. The average growth over a period of 16 years is 90 cm per year.

Growth of *C. diepenhorstii* was better in open (light) conditions than in natural forest (Yimsawat *et al.*, 1995). *C. zollingeri*, seedlings produced from more than 96 per cent of seeds and 61 per cent of vegetative cuttings were raised to transplanting size (25 cm with 2-3 leaves) over 20 months (Siebert, 2000). *C. zollingeri* seedlings produced from cuttings were transplanted into each of three coffee or cacao farms and one primary forest site and exhibited an overall survival rate of 96 per cent, 12.7 cm of height growth and the production of 0.8 new leaves per plant after eight months. Rattan cultivation in coffee and cacao agroforests represents a potential means of intensifying and diversifying perennial cash crop farming systems.

Royal palms (*Roystonea regia*), coconut palms (*Cocos nucifera*), queen palms (*Syagrus romanzoffiana*) and pygmy date palms (*P. roebelenii*) were grown in a rhizotron to determine the patterns of root and shoot growth over a two year period (Broschat, 1998). Roots and shoots of all four species of palms grew throughout the year, but both root and shoot growth rates were positively correlated with air and soil temperature for all but the pygmy date palms. Growth of primary roots in all four species was finite for these juvenile palms and lasted for only five weeks in royal palms, but seven weeks in the other three species. Elongation of secondary roots lasted for only nine weeks for coconut palms and less than half of that time for the other three species. Primary root growth rate varied from 16 mm for coconut and pygmy date palms to 31 mm· for royal palms, while secondary root growth rates were close to 10 mm in first week for all species. About 25 per cent of the total number of primary roots in these palms grew in contact with the rhizotron window, allowing the prediction of the total root number and length from the sample of roots visible in the rhizotron.

Tavares *et al.*, (2007) studies the effect of GA_3 on growth of lady palm. Plantlets of *Rhapis excelsa* approximately one year old were sprayed every 21 days (4 applications) with GA_3 solution at concentrations of 0; 75; 150; 225 and 300 mg/L. The results showed that GA_3 was efficient in promoting the growth of the species and was statistically significant for petioles, leaf length and plant height. Petiole dry and fresh mass did not show any significant difference between treatments for stem diameter, with root dry and fresh mass having a higher value for the control than for the 225 and 300 mg/L treatments. Due to the higher height and leaf architecture changes observed, GA_3 can be used as a tool to stimulate Lady Palm growth, adding commercial value to the plantlets.

Growth of two priority species of rattan (*C. latifolius* Roxb. and *C. tenuis* Roxb.) has been studies in a highly economical medium for in vitro zygotic embryo

germination (Meitram and Sharma, 2006). Seedling growth of embryo explants in three different media, namely, Murashige and Skoog medium (MS), woody plant medium (WPM) and Y3 medium supplemented with plant growth regulators (PGRs) was investigated. Embryo explants inoculated onto WPM supplemented with various concentrations of plant growth regulators produced increased seedling growth compared to the other two media used.

Materials and Methods

3. MATERIALS AND METHODS

The present investigations were carried out at the tree nursery of College of Forestry, Kerala Agricultural University, Vellanikkara, Thrissur, Kerala, during the period 2007 to 2009. The details about the experiment site, materials used and methodology adopted are furnished below:

3.1 Location

The experimental site has an elevation of 40.3 m above sea level and located at 10° 13'N latitude and 76° 13' E longitude.

3.2 Climate

The study area experiences a warm humid climate, having mean annual rainfall of 2890 mm, most of which is received during the south west monsoon (June to August). The mean maximum temperature recorded at Vellanikkara varied from 20.9° C in June to 35.1° C in March. The mean minimum temperature varied from 20.9° C in July to 25.3° C in April.

3.3. Materials

Calamus is an important genus of canes. So here in this study four *Calamus* species were selected for studying the effect of pre-sowing treatments on germination and growth vigor of seedlings. Distribution and morphology of species were studied prior to the identification of seed sources and standardizing collection methods (Renuka, 1992a).

3.3.1. *Calamus thwaitesii* Becc. & Hook. f. in Hook.f.,

Local name: Pannichural, Vandichural, Thatiyanchural.

It is a robust, clustering and high climbing cane (Plate 1). It is distributed in evergreen, semi-evergreen and moist deciduous forests, between 75 to 900 msl. Seen throughout the Western Ghats. This is the thickest cane available along the Western Ghats. It is one of the best quality canes used in furniture industry. Stems are 20 m or more in length, with sheath to 6 cm in diameter, without sheaths to 3.5 cm, internodes are 45 cm long, sometimes with brown spots. Sheath is yellow, densely armed with spines, smaller spines scattered in between. Knee absent. Leaves are 3 m long, ecirrate. It flowers from November to January and fruiting is during February to May. Fruits are 2 x 1.3 cm, ovoid, scales in 12 vertical rows, with median grooves, yellow with deep brown margins.

3.3.2. *Calamus metzianus* Schlecht.

Local name: Odiyanchural.

It is distributed in moist deciduous forests up to 50 msl. it is a clustering cane, climbing high into the canopy (Plate 2). Stem reaches up to 15 m long, with sheaths to 2 cm in diameter, without sheaths to 1 cm, internodes to 39 cm long. Sheath pale green, densely armed with spines, spines to 2 cm long, triangular, yellowish, with numerous small spines in between; knee is conspicuous. This cane is not economically important as it is not used for any purpose because of its easily breakable nature. It flowers from November to January and fruiting is observed in May to June. Fruits are ovoid, scales in 17 rows, grooved in the middle, light yellow with white border and apex.

Plate 1. Generalized view of *Calamus thwaitesii*

Plate 2. Generalized view of *Calamus metzianus*

3.3.3. *Calamus hookerianus* Becc.

Local name: Velichural, Kakkachural, Vanthal, Kallan.

C. hookerianus (Plate 3) is a clustering, moderate sized cane, climbing high into the canopy. It is extensively used in furniture industry and basket making. It is distributed in evergreen forests up to 1000 msl. Stems to 15 m long, with sheaths to 2 cm in diameter, without sheaths to 1 cm, internodes to 39 cm long. Sheath pale green, densely armed with spines. Knee is conspicuous. It flowers in January to June and fruiting starts from July and lasts up to December. Fruits are 1 cm x 0.8 cm, subglobose, scales in 18 rows, yellowish brown with a dark brown border.

3.3.4. *Calamus travancoricus* Bedd. ex. Becc. & Hook. f. in Hook. f.,

Local name: Arichural.

It is clustering, very slender climbing cane (Plate 4). It is distributed in evergreen forests from 200 to 500 m. It is a very good small diameter cane; used in handicrafts and furniture industry. Stems gain a length of 20 m or more, with sheath up to 6 cm in diameter, and without sheaths about 3.5 cm, intermodal length 45 cm, sometimes with brown spots. Sheath yellow, densely armed with smaller spines scattered in between. Leaves grow up to 3 m long and ecirrate. Flowering time starts in October and ends in November. Fruit setting is from May to June. Fruit length 1 cm across, globose, scales in 24 rows, straw yellow with a dark brown border.

Plate 3. Generalized view of *Calamus hookerianus*

Plate 4. Generalized view of *Calamus travancoricus*

3.4 Methods

3.4.1. Collection of seed

Seeds of *Calamus thwaitesii* and *C. metzianus* were collected from KFRI subcentre at Palappilly, in Thrissur district of Kerala. Seeds of *C. hookerianus* and *C. travancoricus* were collected from natural forests of Vazhachal in Thrissur district (Plate 5). Seeds were collected from the mother plant. As the viability of the seeds is very short, seeds were sown in 3-4 days after collection. The seeds were removed from the seed bunch manually by picking individuals seeds and cleaned properly.

3.4.2. Seed treatments

Uniform sized seeds were selected and following specific treatments were applied species wise, which include,

T1. Complete removal of outer pericarp manually: The pericarp of each seeds was removed manually (Plate 6).

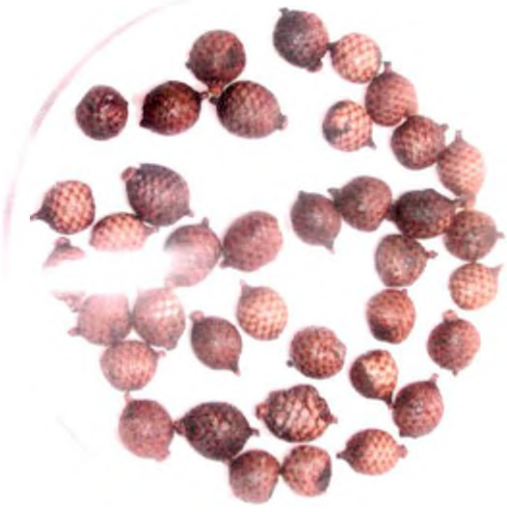
T2. Complete removal of outer pericarp and sarcotesta manually: The outer pericarp and sarcotesta of each seed were removed manually (Plate 7).

T3. Scarification with sand and ash to remove the pericarp and sarcotesta completely: Seeds were rubbed with sand and ash to remove pericarp and sarcotesta.

T4. Fermentation of the seed after removing pericarp: The seeds were soaked in water for 46 hours after removing pericarp.

Calamus thwaitesii

Calamus metzianus



Calamus hookerianus

Calamus travancoricus

Plate 5. Fruits of *Calamus spp.* (seed + sarcotesta+ pericarp)

Calamus thwaitesii

Calamus metzianus

Calamus hookerianus

Calamus travancoricus

Plate 6. Fruits of *Calamus spp*. after removal of pericarp

Calamus thwaitesii

Calamus metzianus

Calamus hookerianus

Calamus travancoricus

Plate 7. Seeds of *Calamus spp.* after removal of sarcotesta and pericarp

T5. Sulphuric acid treatment for 3-5 minutes without removing sarcotesta: Seeds were soaked in sulphuric acid for 3-5 minutes after removing pericarp followed by soaking in cold water for 24 hours.

T6. Sulphuric acid treatment for 3-5 minutes after removing sarcotesta: Seeds were soaked in sulphuric acid for 3-5 minutes after removing pericarp and sarcotesta followed by soaking in cold water for 24 hours.

T7. Hot water treatment (50^0C) after removing sarcotesta for two minutes followed by soaking in water for 12 hours: The seeds were soaked in hot water for 2 minutes and soaked in water for 12 hours after removing sarcotesta.

T8. Cold water treatment after removing sarcotesta for 24 hours: The seeds were soaked in cold water for 24 hours after removing sarcotesta.

T9. Treatment with GA_3 (100 ppm): The seeds were soaked in 100 ppm GA_3 solution for 24 hours after removing the sarcotesta and pericarp.

T10. Control: Untreated seeds were sown as such, without removing the pericarp and sarcotesta.

3.4.3. Seed sowing

Pre-treated seeds were sown in polybag and arranged in completely randomized design (CRD) with 3 replications with 20 seeds in each replication. The total number of seeds sown for each species was 600 (20x3x10). The potting media used was a mixture of sand, soil, cow dung (1:1:1 ratio). Each seed was placed in the polybag filled with the media and uniformly covered with 2 cm layer of sawdust.

3.4.5. After care

Seedlings were kept under shade during the study period. Watering was done twice a day before germination and once a day after germination. Weeding was done as and when required.

3.5. Observations and Calculations

Observation on seed germination and growth of seedling were taken. Growth and biomass observations were taken after the completion of germination for six months.

3.5.1. Observations on germination

Number of seeds germinated was monitored everyday till the end of germination. Emergence of the shoot above the sawdust level was considered as germination. Based on the germination counts, the following parameters were recorded.

1. **No. of seeds germinated on each day**

No. of seeds germinated on each day were recorded

2. **The germination percentage**

Germination percentage was found out using the formula

$$\text{Germination percentage} = \frac{\text{Total seeds germinated}}{\text{Total seeds sown for germination}} \times 100$$

3. **Days required for half of the germination.**

The days required for half of the germination was recorded.

4. **Days required to start germination**

The day on which germination started for each replication of the 10 treatments were recorded.

5. **Days required to end germination**

The day on which the germination came to an end was recorded from for each replication.

6. **Mean daily germination**

Mean daily germination was found out using the following formula

$$\text{Mean daily germination} = \frac{\text{Germination per cent}}{\text{Total number of days}}$$

7. **Peak value of germination**

Peak value is the maximum mean daily germination reached at any time during the period of germination test.

8. **Germination value**

Germination value aims to combine an expression of total germination at the end of the test period with an expression of germination energy or speed of germination. It was estimated according to the method prescribed by Czabator (1962).

Germination value (GV) = PV X MDG

Where,

PV = Peak value of germination

MDG = Final mean value of germination

3.5.2. Growth observations

After germination seedlings of uniform size were selected from each species and their growth parameters and biomass estimation were taken. Shoot observations were taken in every 15 days intervals for six months. Root observations were taken at monthly intervals using destructive sampling methods.

1. Length of prophyl

Prophyl emerges first from which the first leaf emerges. The length of primary prophyl is measured using scale and expressed in centimeter.

2. Height of the seedling

The seedlings remain in the rosette stage in the first few months. The height of the seedling increases only after attaining enough basal diameter. Here height of the seedling was measured from the collar region to the tip of the longest leaf and expressed in centimeter.

3. Number of leaves per seedling

The total number of leaves was counted on the selected seedlings from each replication and expressed as average number of leaves per seedling. The observation was taken at an interval of 15 days.

4. Collar diameter:

The collar diameter was measured slightly above the soil surface at the bulged portion of the seedling at an interval of 15 days using a digital caliper and expressed in millimeters.

5. Root length

Root length was measured monthly by destructive sampling method using a meter scale and expressed in centimeter.

6. Root spread

Root spread was observed as the spread of secondary roots from the primary roots from left to right. Observations on root spread was measured monthly by destructive sampling method using a meter scale and expressed in centimeter.

7. Shoot-root length ratio

Shoot-root length ratio was worked out for each month using the formula

$$\text{Shoot-root length ratio} = \frac{\text{Shoot length (cm)}}{\text{Root length (cm)}}$$

3.5.3. Biomass observations

Biomass observations were taken monthly for six months after germination. Seedlings were selected randomly from each species for taking biomass observations by destructive sampling method. This was replicated three times. The following parameters were estimated (all weights expressed in grams).

1. Fresh weight of roots

Roots were removed carefully from the soil, washed thoroughly, weighed in an electronic balance and weights were expressed in gram.

2. Dry weight of roots

The dry weight was found out after oven-drying the roots at 60^0 C to 80^0 C and expressed in gram.

3. Fresh weight of shoot

Observations on shoot weight was measured monthly by destructive sampling method using a electronic balance and expressed in gram.

4. Dry weight of shoots

The dry weight was found out after oven-drying the shoots at 60^0 C to 80^0 C and expressed in gram.

5. Fresh weight of the seedling

Total fresh weight of the seedling was found out by adding the fresh weight of shoot and fresh weight of root.

6. Dry weight of the seedling

Total dry weight was found out by adding the dry weight of shoot and dry weight of root.

7. Percentage of dry root weight

Percentage of dry root weight to dry weight of seedling was calculated using the following formula. It was then subjected to arc sine transformation before statistical analysis.

$$\text{Percentage of dry root weight} = \frac{\text{Root dry weight (g)}}{\text{Seedling dry weight (g)}} \times 100$$

8. Percentage of dry shoot weight

Percentage of dry shoot weight to dry weight of seedling was calculated using the following formula. The value was corrected using arc sine correction before statistical analysis.

$$\text{Percentage of dry shoot weight} = \frac{\text{Shoot dry weight (g)}}{\text{Seedling dry weight (g)}} \times 100$$

9. Shoot-root dry weight ratio

Shoot- root dry weight ratio was worked out for each month using the formula

$$\text{Shoot root dry weight ratio} = \frac{\text{Shoot dry weight (g)}}{\text{Root dry weight (g)}}$$

3.5. Statistical analysis

The field data were tabulated and subjected to analysis of variance using MSTAT-C statistical package and treatment means were compared following DMRT. For all the percentage data, transformations were used depending on the nature of the data. Here in the present study two transformations were used viz. Square root and Arc sine.

Results

4. RESULTS

The present series of investigations were carried out in College of Forestry, Kerala Agricultural University, Vellanikkara, Thrissur with the objective to know the effect of different pre-sowing treatment on seed germination and growth rate of different *Calamus spp*. The results obtained are furnished below.

4.1 Effect of pre-sowing treatments on germination

Different types of pre-sowing treatments were given to the four species included in this study and the results are given below.

4.1.1 Effect of pre- sowing treatment on germination of *C. thwaitesii* seeds

The effect of pre-sowing treatment on germination of *C. thwaitesii* differed significantly. The results are furnished in Table 1. Comparing all the parameters treatments, scarification with sand and ash (T3), hot water treatment (T7) and treatment with GA_3 (T9) gave good germination per cent within a short time span.

In case of germination percentage, a varied result was evident from the Table 1 and Figure 1. Significant difference was observed among the treatment for germination percentage. A significantly higher germination per cent was obtained from scarification with sand and ash (T3), T7 (Hot water treatment), T8 (cold water treatment after removing sarcotesta) and T9 (Treatment with GA_3). T10 (Control) gave a lower germination per cent of 53.82.

The value of the mean daily germination (MDG) varied significantly and presented in Table 1. Variation was also observed in the mean daily germination between the treatments from 0.006 to 0.020. Significantly higher (0.020) mean daily germination was recorded in T9 (Treatment with GA_3) while, the minimum (0.006) was recorded by T10 (Control).

Table 1. Effect of pre-sowing treatments on germination of seeds of *Calamus thwaitesii*

Treatments	Germination % ***	Mean Daily Germination	Peak Value of germination	Germination Value	Days required for 50% of the Germination	Days to start Germination	Days to end Germination
T1	69.21^{BC} (86.67)	0.011^{B}	0.012^{BC}	0.00013^{B}	49.33^{B}	35.67^{BC}	77.33^{C}
T2	67.38^{B} (85.00)	0.014^{CD}	0.015^{D}	0.00022^{C}	39.33^{A}	31.00^{AB}	60.00^{B}
T3	79.52^{CD} (95.00)	0.016^{D}	0.016^{DE}	0.00026^{CD}	39.33^{A}	29.67^{A}	60.67^{B}
T4	71.92^{BC} (90.00)	0.010^{B}	0.010^{B}	0.00011^{B}	64.33^{C}	39.33^{CD}	77.33^{C}
T5	68.64^{BC} (86.67)	0.016^{D}	0.018^{E}	0.00028^{D}	36.67^{A}	28.00^{A}	55.67^{AB}
T6	71.92^{BC} (90.00)	0.011^{B}	0.012^{BC}	0.00014^{B}	57.33^{BC}	43.00^{D}	80.00^{C}
T7	73.37^{BCD} (91.67)	0.016^{D}	0.017^{DE}	0.00027^{CD}	40.67^{A}	32.00^{AB}	57.67^{B}
T8	75.21^{BCD} (93.33)	0.012^{BC}	0.012^{C}	0.00015^{B}	57.33^{BC}	38.33^{CD}	77.00^{C}
T9	83.82^{D} (96.67)	0.020^{E}	0.020^{F}	0.00041^{E}	34.33^{A}	28.00^{A}	48.67^{A}
T10	53.82^{A} (65.00)	0.006^{A}	0.006^{A}	0.00004^{A}	86.67^{D}	68.00^{E}	110.33^{D}
F test	5.16**	23.27**	53.93**	31.13**	37.04**	44.82**	51.26**
SEm ±	15.76	0	0	0	11.98	7.97	11.17

The values having similar alphabets do not differ significantly Significance at 1% level - **
Mean germination percentage is given in parenthesis -***

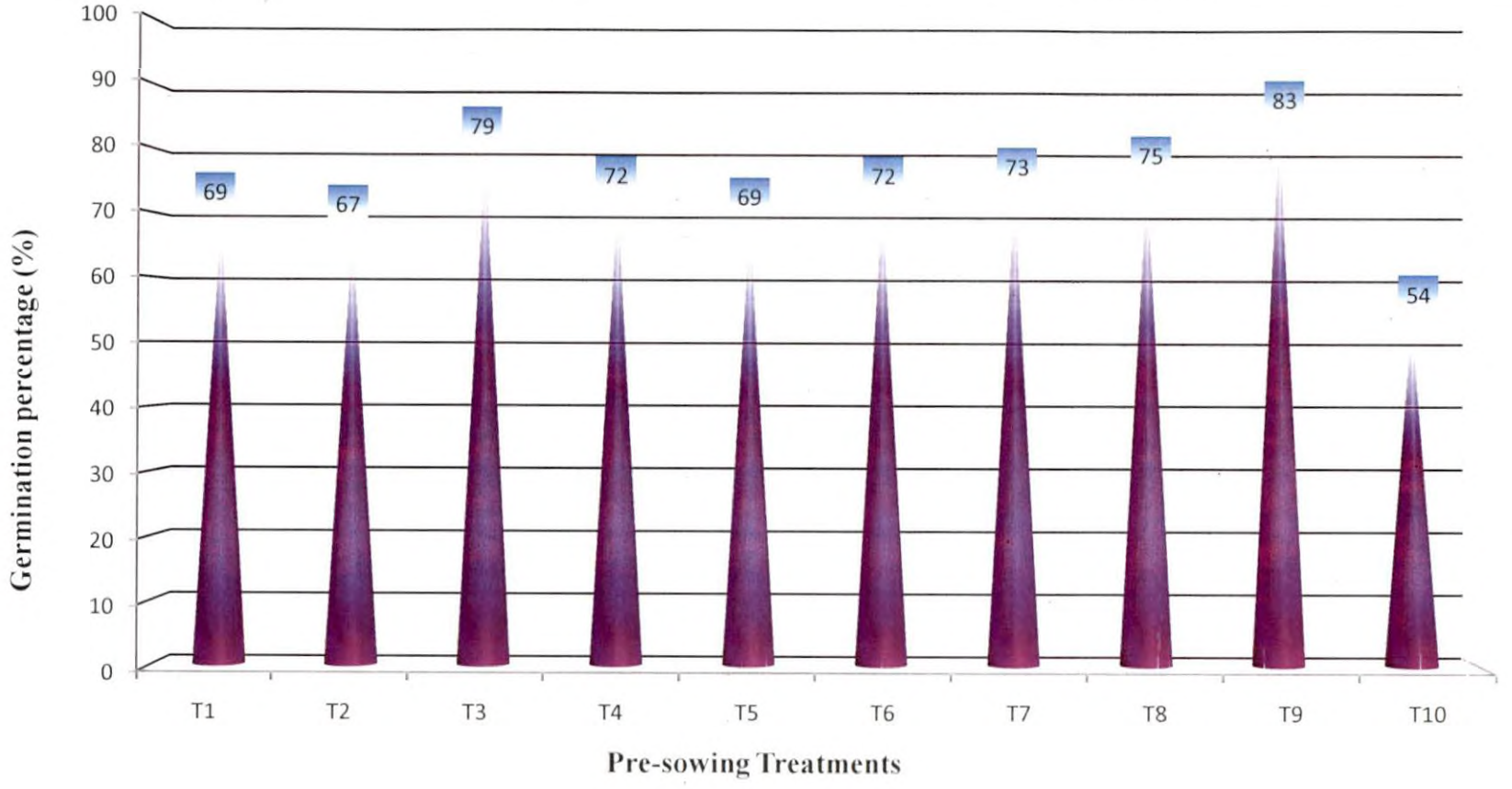


Fig. 1. Effect of pre-sowing treatments on germination percent of seeds of *Calamus thwaitesii*

The data pertaining to the peak value of germination (PVG) was furnished in Table 1. In most of the treatments, peak value of germination was same as mean daily germination. The data range was also same as the highest being 0.020 in T9 (Treatment with GA_3) and lowest being 0.006 on T10 (Control).

Variation in the germination value (GV) was significant among the ten different treatments (Table 1). The germination value varied as high as 0.0041 to as low as 0.00004. Treatment with GA_3 (T9) recorded the highest value (75.23) and Control (T10) showed the lowest. Treatments T1 (Complete removal of outer pericarp manually), Fermentation of the seed after removing pericarp (T3), T6 (H_2SO_4 treatment after removing sarcotesta), and T8 (cold water treatment after removing sarcotesta) showed significantly higher values above T10 (Control) but did not differ from each other. All the other treatments were significantly higher but below the T9 (Treatment with GA_3).

The days on which germination started, came to an end and the days required for half of the germination are depicted in the Table 1. The days required for the commencement of germination was minimum in Treatment with GA_3 (T9) without significant difference. But in T9 (Treatment with GA_3) and T5 (H_2SO_4 treatment without removing sarcotesta) the germination came to an end faster than any other treatment. The day taken for half of the germination was less in case of treatments like T2, T3, T5, T7 and T9. Control took maximum days for half of the germination (86.67).

4.1.2 Effect of pre-sowing treatment on germination of *C. metzianus* seeds

The effect of pre-sowing treatment on germination of *C. metzianus* differed significantly. The results are furnished in Table 2. Treatment with GA_3 (T9) followed by complete removal of outer pericarp and sarcotesta manually (T2) good germination per cent with good speed of germination.

C. metzianus showed a relatively high germination percentage (89.96%). The results are depicted in Table 2 and Figure 2. Treatments differed in germination percentage values, but the difference was nonsignificant. Lowest germination per cent was recorded in treatments viz., T3 (64.2 %), T4 (68.04 %) and T5 (68.04 %) and these were followed by control (T10) and H_2SO_4 treatment after removing sarcotesta (T6) gave a lower germination per cent (81.11).

The value of the mean daily germination (MDG) varied significantly and presented in Table 2. T1 (Complete removal of outer pericarp manually), T2 (Complete removal of outer pericarp and sarcotesta manually), T6 (H_2SO_4 treatment after removing sarcotesta), T7 (Hot water treatment) T8 (cold water treatment after removing sarcotesta), and T9 (Treatment with GA_3) showed a good mean daily germination. Mean daily germination was ranged from 2.04 to 3.39.

The data pertaining to the peak value of germination (PVG) is furnished in Table 2. Peak value of germination value was same as mean daily germination in all the treatments. Control (T10), Scarification with sand and ash (T3), Fermentation of the seed after removing pericarp (T4) and H_2SO_4 treatment without removing sarcotesta (T5) gave a lower peak value of germination, which did not differ significantly. Germination value also showed the same fluctuations as mean daily germination and peak value of germination decides the GV. It had a range of 4.20 (T10) to 11.56 (T9).

Table 2. Effect of pre-sowing treatments on germination of seeds of *Calamus metzianus*

Treatments	Germination % ***	Mean Daily Germination	Peak Value of germination	Germination Value	Days required for 50% of the Germination	Days to start Germination	Days to end Germination
T1	89.96^{A} (100.00)	2.29^{AB}	2.29^{AB}	6.66^{A}	29.33^{BC}	25.67^{B}	32.00^{AB}
T2	89.96^{A} (100.00)	2.97^{AB}	2.97^{AB}	8.84^{AB}	30.33^{BC}	26.33^{B}	33.67^{BC}
T3	64.20^{A} (73.33)	2.17^{A}	2.17^{A}	5.18^{A}	30.33^{BC}	26.33^{B}	33.33^{BC}
T4	68.04^{A} (80.00)	2.15^{A}	2.15^{A}	4.88^{A}	34.00^{D}	29.33^{B}	37.33^{D}
T5	68.04^{A} (80.00)	2.21^{A}	2.21^{A}	5.06^{A}	31.67^{CD}	29.00^{B}	36.00^{CD}
T6	81.11^{A} (93.33)	2.72^{AB}	2.72^{AB}	7.45^{AB}	31.33^{BCD}	28.00^{B}	34.33^{BC}
T7	89.96^{A} (100.00)	2.86^{AB}	2.86^{AB}	8.22^{AB}	28.67^{B}	26.33^{B}	35.00^{CD}
T8	89.96^{A} (100.00)	2.89^{AB}	2.89^{AB}	8.35^{AB}	29.00^{BC}	26.00^{B}	34.67^{BCD}
T9	89.96^{A} (100.00)	3.39^{B}	3.39^{B}	11.56^{B}	23.00^{A}	20.00^{A}	29.67^{A}
T10	81.11^{A} (93.33)	2.04^{A}	2.04^{A}	4.20^{A}	42.00^{E}	40.00^{C}	45.67^{E}
F test	1.77NS	1.68*	1.68*	2.48*	28.84**	10.74**	22.26**
SEm ±	35.73	1.57	1.57	6.50	4.00	6.86	4.027

The values having similar alphabets do not differ significantly
Significance at 5% level - * Significance at 1% level - ** Non significant – NS
Mean germination percentage is given in parenthesis -***

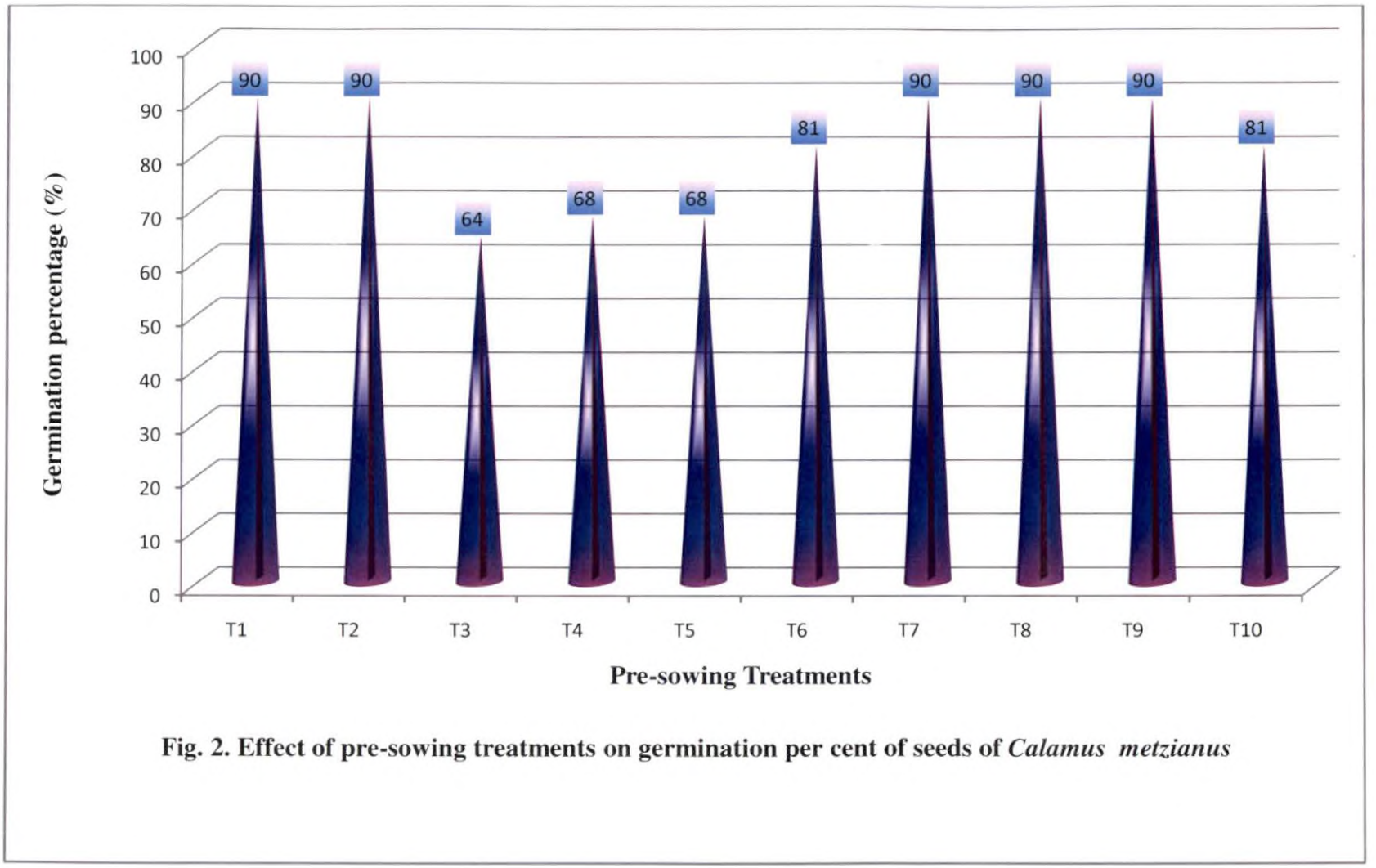


Fig. 2. Effect of pre-sowing treatments on germination per cent of seeds of *Calamus metzianus*

Germination was a faster in *C. metzianus*. In all the treatments germination started within 20th to 28th days except Control. The period of germination was 6-10 days only. Even though germination started late in T10 (40th day), the germination was completed within six days (46th day). Days required for half of the germination was lowest in T9 whereas, it was highest in T10.

4.1.3. Effect of pre-sowing treatment on germination of *C. hookerianus* seeds

The effect of pre-sowing treatment on germination of *C. hookerianus* differed significantly. The results are furnished in Table 3 and Figure 3. The best treatments were identified considering germination per cent and germination value and they are Hot water treatment (T7), followed by Cold water treatment (T8) and Scarification with sand and ash (T3).

Although germination percentage was low in the case of *C. hookerianus*, pre-sowing treatments showed a significant effect in increasing the germination percentage. Seeds without any treatment gave zero per cent germination. Treatment involving fermentation of seed after removing pericarp resulted in poor germination of seeds. All the other treatments were found promising with increasing the germination. The maximum germination (27.74%) was obtained from T7 (Hot water treatment).

The value of the mean daily germination varied significantly and is presented in Table 3. Control got zero value because no germination was recorded from T10 (Control). Scarification with sand and ash (T3), T6 (H_2SO_4 treatment after removing sarcotesta), T7 (Hot water treatment) and T8 (cold water treatment after removing sarcotesta) showed a good mean daily germination. It was evident from the Table 3 that the data pertaining to the peak value of germination was same as mean daily germination in all the treatments, just like *C. metzianus and C. travancoricus*. Peak value of germination (0.41) was recorded in T7 (Hot water treatment). Germination values recorded lowest values which did not statistically

Table 3. Effect of pre-sowing treatments on germination of seeds of *Calamus hookerianus*

Treatments	Germination % ***	Mean Daily Germination	Peak Value of germination	Germination Value	Days required for 50% of the germination	Days to start germination	Days to end germination
T1	13.84^{BC} (8.89)	0.13^{ABC}	0.13^{ABC}	0.03^{A}	43.67^{BC}	40.00^{BC}	45.00^{BC}
T2	19.26^{C} (11.11)	0.18^{ABC}	0.18^{ABC}	0.03^{A}	60.67^{C}	52.33^{C}	60.67^{C}
T3	24.84^{C} (17.78)	0.25^{CD}	0.25^{CD}	0.06^{A}	67.00^{C}	51.67^{C}	71.33^{C}
T4	4.99^{AB} (2.22)	0.04^{AB}	0.04^{AB}	0.01^{A}	17.33^{AB}	17.33^{AB}	17.33^{AB}
T5	19.26^{C}(11.11)	0.19^{ABC}	0.19^{ABC}	0.04^{A}	58.00^{C}	52.67^{C}	58.00^{C}
T6	21.41^{BC} (13.33)	0.22^{BCD}	0.22^{BCD}	0.05^{A}	59.33^{C}	52.67^{C}	59.33^{C}
T7	27.74^{C} (22.22)	0.41^{D}	0.41^{D}	0.20^{B}	52.33^{BC}	49.33^{BC}	54.00^{C}
T8	20.97^{C} (13.33)	0.26^{CD}	0.26^{CD}	0.08^{A}	51.00^{BC}	50.00^{BC}	51.67^{BC}
T9	14.27^{BC} (8.89)	0.15^{ABC}	0.15^{ABC}	0.04^{A}	39.00^{BC}	34.33^{BC}	39.00^{BC}
T10	0.00^{A} (0.00)	0.00^{A}	0.00^{A}	0.00^{A}	0.00^{A}	0.00^{A}	0.00^{A}
F test	4.275**	3.726**	3.726**	2.359**	3.70**	3.22**	3.85**
SEm ±	18.68	0.27	0.27	0.10	49.16	45.05	49.59

The values having similar alphabets do not differ significantly Significance at 1% level - **

Mean germination percentage is given in parenthesis -***

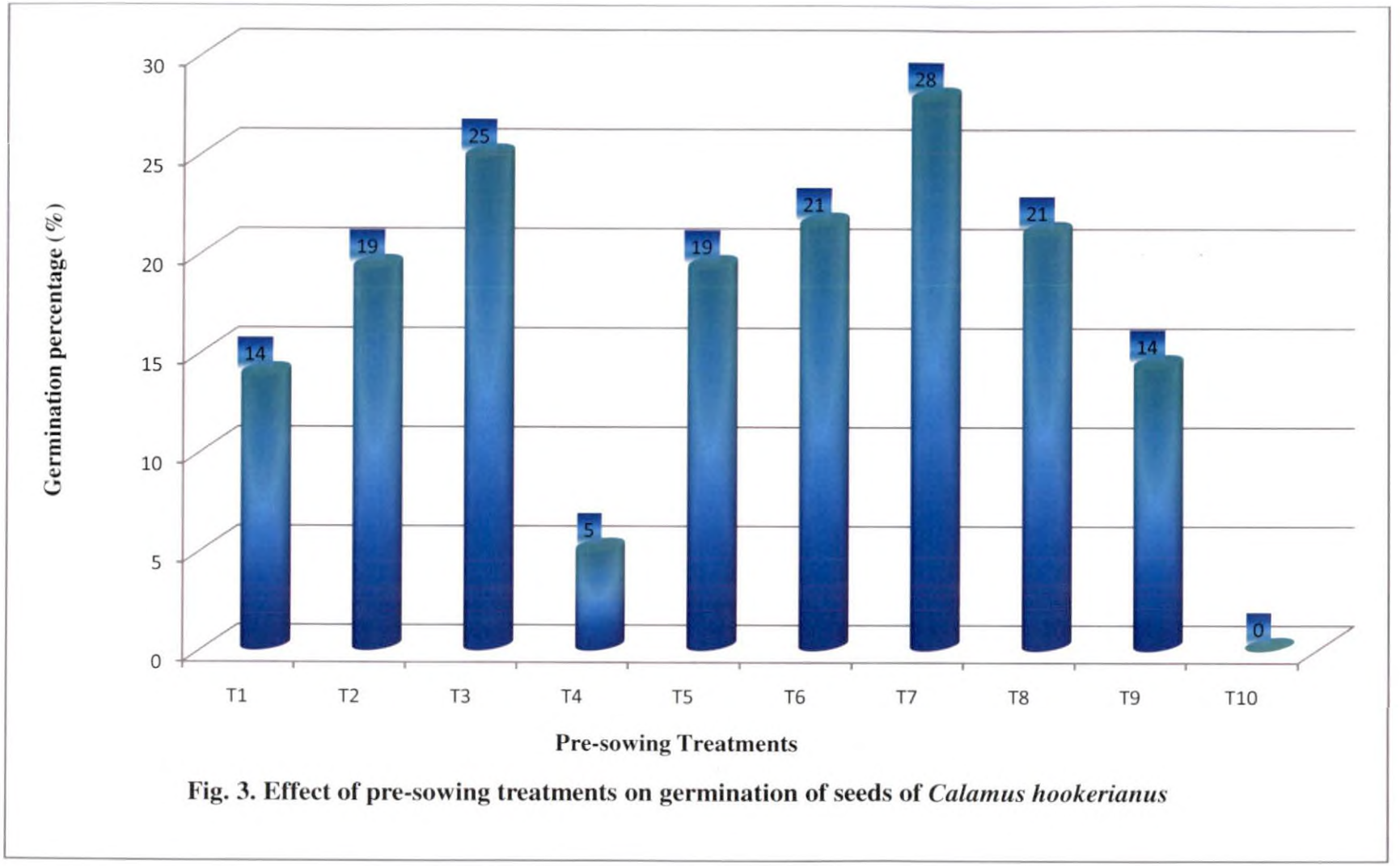


Fig. 3. Effect of pre-sowing treatments on germination of seeds of *Calamus hookerianus*

differ from zero in all the treatments except T7. T7 (Hot water treatment) has the highest value of 0.20.

Fermentation of the seed after removing pericarp has given low germination percentage, though the seeds germinated early than that of the other treatments. Days required for half of the germination was lowest in T4 and T10. All the other treatments had no significant difference in effects.

4.1.4. Effect of pre-sowing treatment on germination of *C. travancoricus* seeds

Germination of *C. travancoricus* seeds was very poor with all the treatments. The results are depicted in the Table 4. The best treatments which gave faster and maximum germination percentage were T2 (complete removal of outer pericarp and sarcotesta)and T5 (Sulphuric acid treatment without removing sarcotesta).

Germination per cent given by different treatments is furnished in the Table 4 and Figure 4. The germination percentage varied from 0.00 per cent to 17.11 per cent. No germination was obtained from control (T10) and cold water treatment after removing sarcotesta (T8), in complete removal of outer pericarp manually (T1) and Treatment with GA_3 (T9). The other treatments did not vary significantly, but T1 and T9 were almost equal to zero per cent germination.

The value of the mean daily germination (MDG) was very poor. It is presented in Table 4. Control (T10) and cold water treatment after removing sarcotesta (T8) are having zero values as there was no germination for those treatments. T1 (Complete removal of outer pericarp manually), T2 (Complete removal of outer pericarp and sarcotesta manually) and T9 (Treatment with GA_3) also recorded lower mean daily germination which significantly do not differ from zero value.

Table 4. Effect of pre-sowing treatments on germination of seeds of *Calamus travancoricus*

Treatments	Germination % ***	Mean Daily Germination	Peak Value of germination	Germination Value	Days required for 50% of the germination	Days to start germination	Days to end germination
T1	4.99^{AB} (2.22)	0.023^{AB}	0.023^{AB}	0.0016^{AB}	32.33^{AB}	32.33^{AB}	32.33^{AB}
T2	9.97^{BC} (4.44)	0.039^{ABC}	0.039^{ABC}	0.0023^{AB}	76.00^{BC}	76.00^{BC}	76.00^{BC}
T3	17.11^{C} (8.89)	0.074^{BC}	0.074^{BC}	0.0060^{AB}	119.67^{C}	118.33^{C}	119.67^{C}
T4	14.96^{C} (6.67)	0.062^{BC}	0.062^{BC}	0.0039^{AB}	107.67^{C}	107.67^{C}	107.67^{C}
T5	17.11^{C} (8.89)	0.078^{C}	0.078^{C}	0.0065^{B}	112.33^{C}	110.00^{C}	112.33^{C}
T6	17.11^{C} (8.89)	0.073^{BC}	0.073^{BC}	0.0059^{AB}	120.33^{C}	111.00^{C}	120.33^{C}
T7	17.11^{C} (8.89)	0.073^{BC}	0.073^{BC}	0.0059^{AB}	120.67^{C}	118.67^{C}	120.67^{C}
T8	0.00^{A} (0.00)	0.000^{A}	0.000^{A}	0.0000^{A}	0.00^{A}	0.00^{A}	0.00^{A}
T9	4.99^{AB} (2.22)	0.023^{AB}	0.023^{AB}	0.0016^{AB}	32.33^{AB}	32.33^{AB}	32.33^{AB}
T10	0.00^{A} (0.00)	0.00^{A}	0.00^{A}	0.00^{A}	0.00^{A}	0.00^{A}	0.00^{A}
F test	5.68**	3.92**	3.92**	1.91*	7.10**	6.67**	7.10**
SEm ±	13.64	0.07	0.07	0.80	85.62	85.75	85.62

The values having similar alphabets do not differ significantly Significance at 5% level - * Significance at 1% level - **
Mean germination percentage is given in parenthesis -***

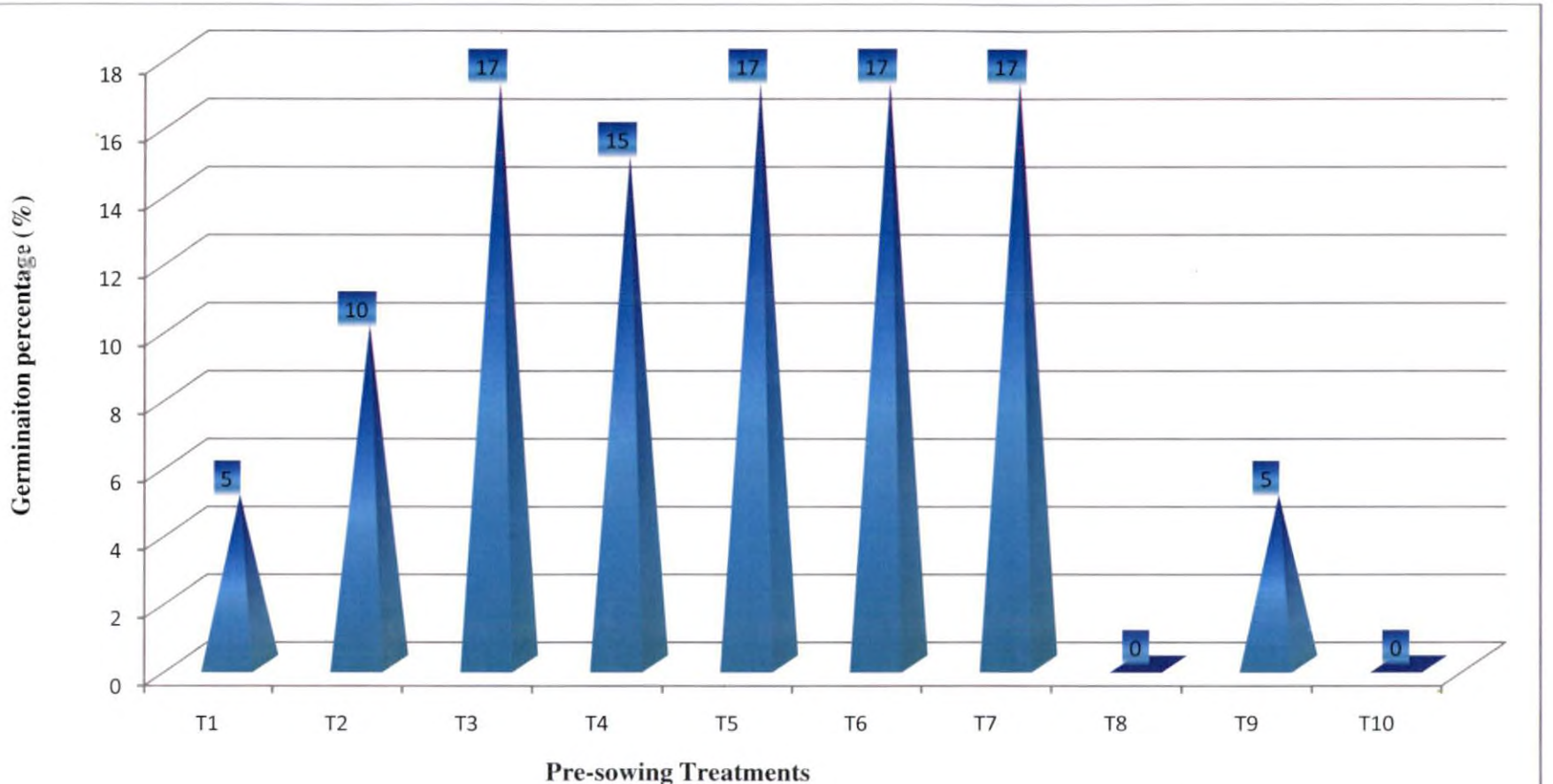


Fig. 4. Effect of pre-sowing treatments on germination percent of seeds of *Calamus travancoricus*

It was evident from the Table 4, that the data pertaining to the peak value of germination was same as mean daily germination in all the treatments, just like *C. metzianus* and *C. hookerianus*. The peak value of germination ranges from 0.0 - 0.078.

Germination value was lower, which did not differ significantly in all the treatments except T5 (H_2SO_4 treatment without removing sarcotesta). T5 has the highest value of 0.0065.

Germination was noticed early in T1 (Complete removal of outer pericarp manually) and T9 (Treatment with GA_3) followed by T2 (Complete removal of outer pericarp and sarcotesta manually). But they do not differ significantly. The day of starting and ending day of germination was same in some treatments as the germination was very poor. The days taken for half of the germination were minimum (32.33) in T1, and T9.

4.1.5. Comparison of effect of pre-sowing treatment on the *Calamus spp.*

The effect of pre-sowing treatment on the four species of *Calamus* is compared (Table 5). Treatment with GA_3 and cold water gave a relatively higher germination percent in all the species except *C. travancoricus*. Hot water treatment and scarification with sand and ash were found promising in all the species. From Table 5, it is evident that the seeds sown without any treatment gave poor germination in all the species.

4.2. Growth observations

Detailed investigation on growth attributes of four species of *Calamus* were done to know their performance in the nursery for the six months after germination. There were no casualties during the period of study. For field planting the optimum stage and size of the seedlings should be standardized.

Table 5. Comparison of effect of pre-sowing treatments on germination per cent of various *Calamus spp.*

Treatments	Germination percentage of *Calamus spp.* ***			
	C. thwaitesii	*C. metzianus*	*C. hookerianus*	*C. travancoricus*
T1	69.21^{BC} (86.67)	89.96^{A} (100.00)	13.84^{BC} (8.89)	4.99^{AB} (2.22)
T2	67.38^{B} (85.00)	89.96^{A} (100.00)	19.26^{C} (11.11)	9.97^{BC} (4.44)
T3	79.52^{CD} (95.00)	64.20^{A} (73.33)	24.84^{C} (17.78)	17.11^{C} (8.89)
T4	71.92^{BC} (90.00)	68.04^{A} (80.00)	4.99^{AB} (2.22)	14.96^{C} (6.67)
T5	68.64^{BC} (86.67)	68.04^{A} (80.00)	19.26^{C}(11.11)	17.11^{C} (8.89)
T6	71.92^{BC} (90.00)	81.11^{A} (93.33)	21.41^{BC} (13.33)	17.11^{C} (8.89)
T7	73.37^{BCD}(91.67)	89.96^{A} (100.00)	27.74^{C} (22.22)	17.11^{C} (8.89)
T8	75.21^{BCD} (93.33)	89.96^{A} (100.00)	20.97^{C} (13.33)	0.00^{A} (0.00)
T9	83.82^{D} (96.67)	89.96^{A} (100.00)	14.27^{BC} (8.89)	4.99^{AB} (2.22)
T10	53.82^{A} (65.00)	81.11^{A} (93.33)	0.00^{A} (0.00)	0.00^{A} (0.00)
F test	5.16*	1.77NS	4.275**	5.68**
SEm ±	15.76	35.73	18.68	85.62

The values having similar alphabets do not differ significantly

Significance at 5% level - * Significance at 1% level - ** Non significant – NS

Mean germination percentage is given in parenthesis -***

The growth parameters showed an increasing trend with the increasing age. But the variation was not significant between adjacent fortnights or months.

4.2.1. Length of primary prophyl

Prophyl is the first part emerges as a shoot prophyl, which is light green in colour and stands like a protection to the leaf at collar region even after the emergence of leaf. The prophyl length for all the four species is shown in Table 6.

C. thwaitesii showed much higher prophyl length (5.77 cm) (Plate 8) whereas *C. travancoricus* indicated relatively a much lower length (1.52 cm). *C. metzianus* (3.56 cm) and *C. hookerianus* (3.40 cm) do not differ significantly with respect to prophyl length (Table 6).

4.2.2. Length of first leaf

The total length of first leaf was equal to the height of seedlings of *Calamus spp.* in the initial months. Height of seedlings was calculated from the collar to the tip of leaf and expressed in centimeters. The second leaves were produced later; however the length was less than the first leaf.

It was noticed from Table 6, that *C. thwaitesii* had a height of 30.54 cm for the first six months. *C. metzianus* and *C. hookerianus* were showing slight difference in height (Plate 9 and Plate 10), but they vary significantly. *C. travancoricus* had the smallest seedling compared to the other species.

4.2. 3. Number of leaves per seedlings

Each species took a different period to produce leaves (Table 6). The first leaf emerged from the prophyl within one week after germination from all the species. The second leaf was produced at different months which varied with

Plate 8. Seedlings of *Calamus thwaitesii*

Table 6. Seedling morphology of different *Calamus spp.* in the nursery

Seedling Morphology	*Calamus spp.*				F value	SEm_±
	C. thwaitesii	*C. metzianus*	*C. hookerianus*	*C. travancoricus*		
Length of Prophyl (cm)	5.77^{C}	3.56^{B}	3.40^{B}	1.52^{A}	304.06**	0.26
Length of first leaf (cm)	30.02^{D}	16.42^{B}	17.28^{C}	14.17^{A}	153.55**	0.74
No. of leaflets per leaf	2	5-6	4 - 6	8-9	-	-
Width of one Leaflet (cm)	2.60^{B}	0.37^{A}	0.43^{A}	0.32^{A}	56.82 **	0.41
Leaf Area per leaf (cm^2)	51.89^{B}	9.47^{A}	13.99^{A}	9.95^{A}	227.77**	3.84

The values having similar alphabets do not differ significantly Significance at 1% level - **

Plate 9. Seedlings of *Calamus metzianus*

Plate 10. Seedlings of *Calamus hookerianus*

species to species. The second leaf was slightly smaller in appearance. All the leaves were palmately compound, with varied number of leaflets. The leaflets width and number of leaflets belonging to each leaf are shown in Table 6.

In the first ten fortnights, the seedlings of *C. thwaitesii* were having one leaf with two leaflets. The leaflets were long and wide compared to the other species. After 10^{th} fortnight, second leaf arrived, which was also having two leaflets, as it was slightly smaller than the first leaf in appearance.

C. metzianus seedling produced fan shaped leaves which were having five to six leaflets. It had a leaf area of 9.47 cm^2. Each leaflets recorded a thickness of 0.37 cm.

In *C. hookerianus* the second leaf appeared after 8^{th} fortnight. The first and second leaves were having 4-6 leaflets, and in most of the cases first leaf was showing five leaflets and second leaf was with four leaflets. Leaflets were arranged in the form of a half circle. The third leaf was produced at the end of sixth month. No leaves were fully emerged into leaflets then.

From fourth month onwards *C. travancoricus* seedlings were having 2 leaves. Each leaf had eight to nine leaflets which were arranged in almost a circle. The leaflets were very less in length and width (0.32 cm) which made a total leaf area of 9.95 cm^2 which was relatively higher that of *C. metzianus*. This was because *C. travancoricus* had more number (8-9) of leaflets (Plate 11).

4.2.4. Collar diameter

Collar diameters of the four species are depicted in Table 7 and Figure 5. Even though the collar diameter of the seedlings was found to increase in every fortnight significantly in all the four rattan species, for the first five fortnights and the last five fortnights in all the species, except *C. hookerianus*.

Plate 11. Seedlings of *Calamus travancoricus*

Table 7. Collar diameter of seedlings of different *Calamus spp.* in the first twelve fortnights after germination

Fortnights	Collar Diameter (cm)			
	C. thwaitesii	*C. metzianus*	*C. hookerianus*	*C. travancoricus*
1	1.91^{A}	1.00^{A}	1.25^{A}	0.74^{A}
2	2.23^{B}	1.12^{B}	1.84^{B}	1.02^{B}
3	2.41^{C}	1.26^{C}	2.03^{BC}	1.17^{C}
4	2.58^{D}	1.34^{D}	2.17^{CD}	1.32^{D}
5	2.69^{E}	1.41^{E}	2.20^{CDE}	1.49^{E}
6	2.71^{E}	1.48^{F}	2.26^{DE}	1.59^{F}
`7	2.91^{F}	1.53^{F}	2.41^{E}	1.69^{G}
8	2.94^{F}	1.62^{G}	2.66^{F}	1.83^{H}
9	3.09^{G}	1.66^{G}	2.91^{G}	2.01^{I}
10	3.28^{H}	1.82^{H}	2.92^{G}	2.12^{J}
11	3.53^{I}	1.95^{I}	3.13^{G}	2.25^{K}
12	4.12^{J}	2.13^{J}	3.49^{H}	2.57^{L}
F value	352.10**	381.74**	74.87**	740.03**
SEm ±	0.18	0.17	0.35	0.10

The values having similar alphabets do not differ significantly

Significance at 5% level -* Significance at 1% level -**

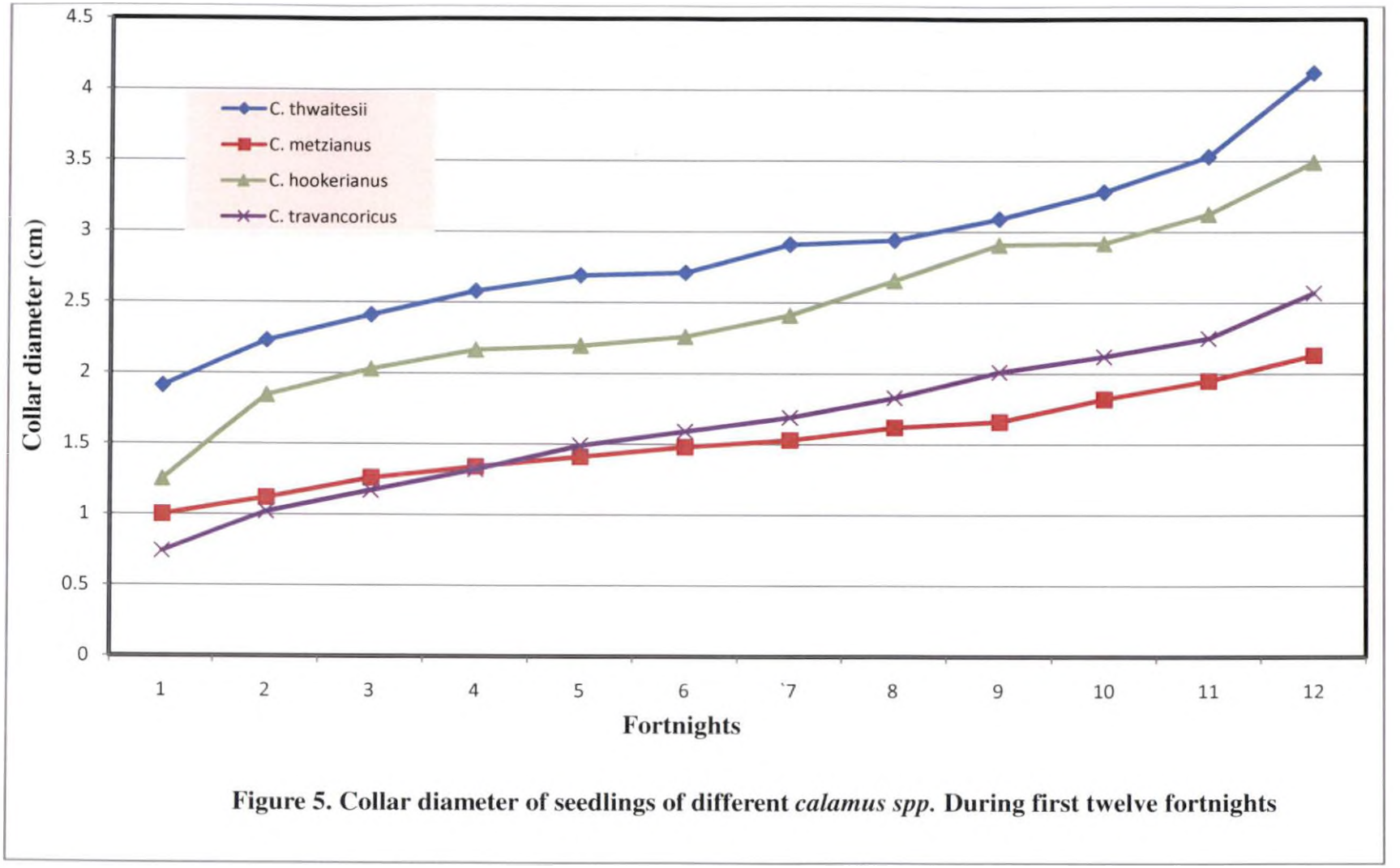


Figure 5. Collar diameter of seedlings of different *calamus spp.* During first twelve fortnights

C. thwaitesii showed the maximum diameter growth as it increased its collar diameter from the first fortnight (1.91 cm) to 12th fortnight (4.12 cm). During the period of six months, the collar diameter was almost doubled. In the 12th fortnight it showed a drastic increase from 3.53 cm to 4.12 cm. This may be due to the emergence of new leaves (Table 7).

C. hookerianus recorded a collar diameter of 1.25 cm during the first fortnight and it has increased in the next fortnight to 1.84 cm. But later it showed a gradual increase upto ninth fortnight. During the ninth month, it showed a rapid increase in collar girth. *C. metzianus* was showing a steady increase in collar diameter. But it showed a much slower growth rate than that of the other species (Figure 5). *C. travancoricus* was showing a steady increase in collar diameter. It had much higher growth rate when compared to *C. metzianus*.

4.2.5. Root length

Studies on the root parameters of various *Calamus* species indicated that, all the species produced one long and thick root on which secondary roots aroused. Branching was observed in few seedlings, but both branches were almost equal in size. From Table 8, it was evident that the root length was constantly increasing during every month. *C. thwaitesii* had shown increase in root length within six months. During every month, root growth was significantly higher than that the previous month. Initial growth was concentrated on the roots as the shoot started producing second leaf only after five months (Figure 6).

C. metzianus also showed relatively higher increase in the root length. It was 10.50 cm during the first month, which later increased more than double (22.42 cm) within next five months. Even though it showed significant root growth during most of the months, except in second and third month, the growth was slow and it was not significant.

Table 8. Root parameters of seedlings of different *Calamus* spp. during first six months after germination

Species	Root parameters	Months						F value	SEm ±
		1	2	3	4	5	6		
C. thwaitesii	Root Length (cm)	13.42^{A}	17.00^{B}	18.92^{C}	20.75^{D}	23.50^{E}	28.42^{F}	117.79**	1.66
	Root Spread(cm)	3.88^{A}	5.65^{B}	6.45^{B}	7.75^{C}	8.13^{C}	11.25^{D}	246.50**	0.3
	Shoot:Root Length	2.29^{E}	1.8^{D}	1.62^{C}	1.47^{C}	1.3^{B}	1.08^{A}	62.27**	0.17
C. metzianus	Root Length(cm)	10.50^{A}	14.17^{B}	16.08^{C}	16.81^{C}	19.83^{D}	22.42^{E}	191.80**	1.04
	Root Spread(cm)	0.41^{A}	1.54^{B}	2.89^{C}	3.41^{C}	4.50^{D}	5.92^{E}	120.50**	0.54
	Shoot:Root Length	1.56^{E}	1.15^{D}	1.01^{C}	0.97^{C}	0.82^{B}	0.73^{A}	382.81**	0.09
C. hookerianus	Root Length(cm)	8.33^{A}	10.96^{B}	13.31^{C}	14.77^{D}	15.64^{E}	16.17^{F}	671.21**	0.40
	Root Spread(cm)	0.77^{A}	2.14^{B}	2.89^{C}	3.20^{D}	4.27^{E}	6.08^{F}	1073.71**	0.18
	Shoot:Root Length	2.2^{E}	1.67^{D}	1.38^{C}	1.24^{B}	1.17^{A}	1.13^{A}	503.06**	0.26
C. travancoricus	Root Length(cm)	11.11^{A}	11.83^{B}	12.42^{C}	13.03^{D}	13.75^{E}	14.61^{F}	68.29**	1
	Root Spread(cm)	0.50^{A}	1.00^{B}	1.25^{C}	1.50^{D}	1.70^{E}	2.00^{F}	1174.80**	0.219
	Shoot:Root Length	1.03^{F}	0.97^{E}	0.92^{D}	0.88^{C}	0.83^{B}	0.78^{A}	74.04**	0.95

The values having similar alphabets do not differ significantly Significance at 5% level - * Significance at 1% level -**

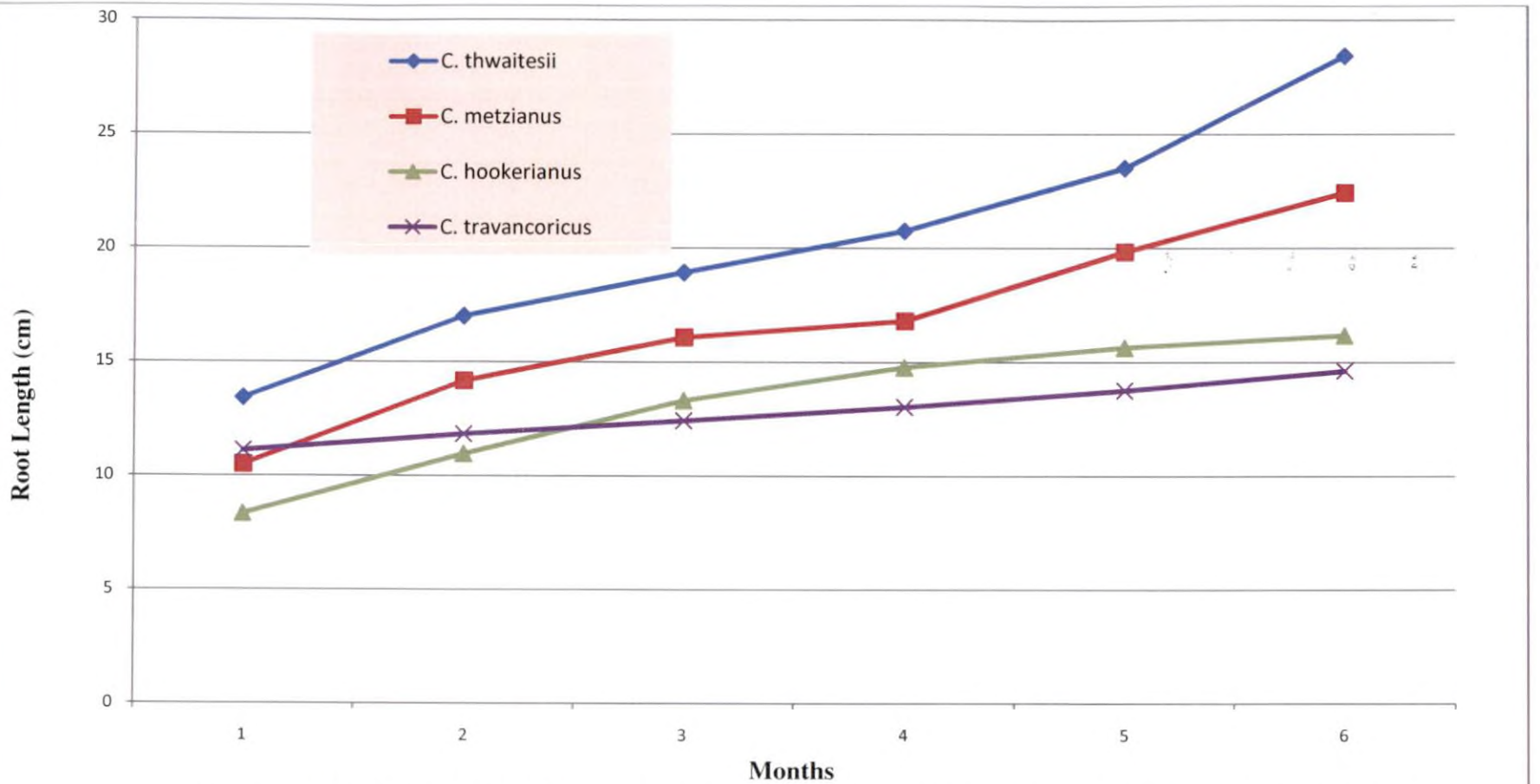


Figure 6. Root length of seedlings of different *Calamus spp*. during first six months after germiantion

C. hookerianus put forth a short root in the first month. Later it showed a steady growth rate which slightly reduced in the sixth month. This may be due to the allocation of photosynthate to the production of third leaf. It is found that *C. hookerianus* had a root growth rate which was almost similar to the growth rate of *C. thwaitesii* and *C. metzianus*. Comparative evaluation of growth of all *Calamus spp.* revealed that *C. travancoricus* was exhibiting slow growth in root (Figure 6). The roots were not showing much growth during the last five months, even though it had a relatively good root growth during the initial months. This may be because of low rate of photosynthesis in small leaves which as it possessed in the initial months.

4.2.6. Root spread

In all the species, secondary roots were produced from the primary roots and spread to the lateral sides. The secondary roots were not too long and they were very thin also. *C. thwaitesii* showed a sharp increase in root spread. It had a root spread of 3.88 cm in the first month, which was highest among the four species studied (Table 8). The root spread did not vary significantly between advancing months. The same trend was followed by *C. metzianus* whereas *C. hookerianus* and *C. travancoricus* showed significant increase in root spread between various months studied. However at the end of the study period, *C. metzianus* and *C. hookerianus* showed almost similar root spread in the first six months (Figure 7).

4.2.7. Shoot : Root length

Estimations on shoot-root length ratio of various *Calamus spp.* indicated a decreasing trend with advancing months (Table 8). It was because, the shoot length was constant in the initial months, but root length was increasing. *C. thwaitesii* and *C. hookerianus* were having shoot length almost double than the

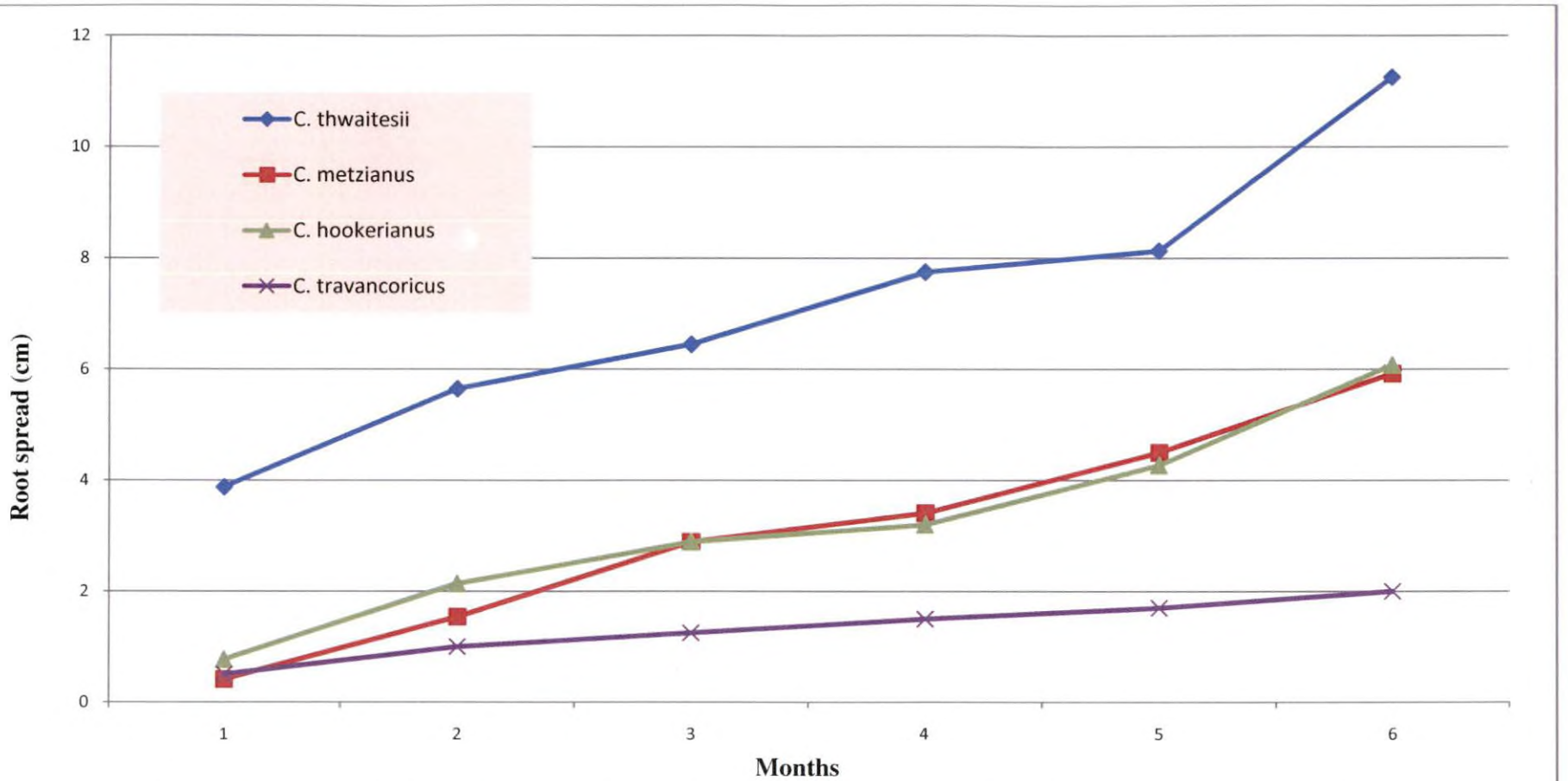


Fig. 7. Root spread of seedlings of different Calamus spp. during the first six months after germinaiton

root length. But within six months it reduced and reached almost equal. The shoot-root ratio of *C. metzianus* was 1.56 in the first month. Later the root length crossed shoot length and ratio became reduced to 0.73. In *C. travancoricus* the shoot and root length was reported to be almost equal (ratio 1.03) in the first month and then reduced to 0.78 at the end of six months.

4.3. Biomass observations

Biomass observations were carried out monthly by destructive sampling method. The fresh weight and dry weights were found out separately for roots and shoots.

4.3.1. Seedling biomass in *C. thwaitesii*

Biomass observations of seedlings of *C. thwaitesii* are shown in tables 9 and 10. Its biomass compared to other species can be seen from the figures 8, 9 and 10.

Fresh weight of *C. thwaitesii* showed an increasing trend (Table 9). In the first few months, *C. thwaitesii* showed almost steady and slow increase in root fresh weight. But from the Figure 8, it was noted that in the 5^{th} and the 6^{th} month, it showed a drastic increase in the case of fresh weight of roots. Likewise, the shoot weight also showed a sudden increase as in the case of fresh root weight and seedling fresh weight.

The fresh root weight variation started from 0.26 g in the first months to 1.40 g in the sixth month. Almost six times increase was noticed. Shoot weight started from 1.13 g in the first month which reached 3.66 g in the sixth month as recorded 3 times increase. So the accumulation of fresh weight was maximum in *C. thwaitesii*, but it produced a maximum initial shoot weight soon after germination.

Table 9. Seedling biomass of *Calamus thwaitesii* during the first six months after germination

Months	Root weight (g)		Shoot weight (g)		Seedling weight (g)	
	Fresh	Dry	Fresh	Dry	Fresh	Dry
1	0.26^{A}	0.06^{A}	1.13^{A}	0.36^{A}	1.39^{A}	0.43^{A}
2	0.27^{AB}	0.07^{A}	1.23^{AB}	0.41^{AB}	1.50^{AB}	0.47^{AB}
3	0.29^{AB}	0.08^{B}	1.28^{AB}	0.42^{B}	1.57^{BC}	0.50^{B}
4	0.33^{B}	0.09^{B}	1.38^{B}	0.48^{C}	1.72^{C}	0.57^{C}
5	0.81^{C}	0.21^{C}	2.15^{C}	0.68^{D}	2.96^{D}	0.90^{D}
6	1.40^{D}	0.36^{D}	3.66^{D}	1.22^{E}	5.05^{E}	1.58^{E}
F Value	528.5**	693.93**	398.99**	458.23**	798.19**	652.006**
SEm ±	.07	.02	.17	.05	.12	.02

The values having similar alphabets do not differ significantly

Significance at 1% level - *

Table 10. Percentage contribution of biomass components to total biomass of *Calamus thwaitesii* seedling during the first six months after germination

Months	Percentage of dry weight to total weight ***		Shoot-root ratio
	Root	Shoot	
1	23.12^{AB} (15.41)	66.85^{BC} (84.54)	5.49^{BC}
2	22.17^{A} (14.23)	67.79^{C} (85.71)	6.02^{D}
3	23.99^{B} (16.53)	65.97^{B} (83.41)	5.05^{B}
4	23.03^{AB} (15.30)	66.94^{BC}(84.65)	5.55^{C}
5	29.21^{C} (23.81)	60.76^{A} (76.13)	3.20^{A}
6	28.51^{C} (22.78)	61.45^{A} (77.15)	3.39^{A}
F value	78.47**	78.47**	62.04**
SEm ±	1.09	1.09	0.25

The values having similar alphabets do not differ significantly
Significance at 1% level - **
Mean germination percentage is given in parenthesis -***

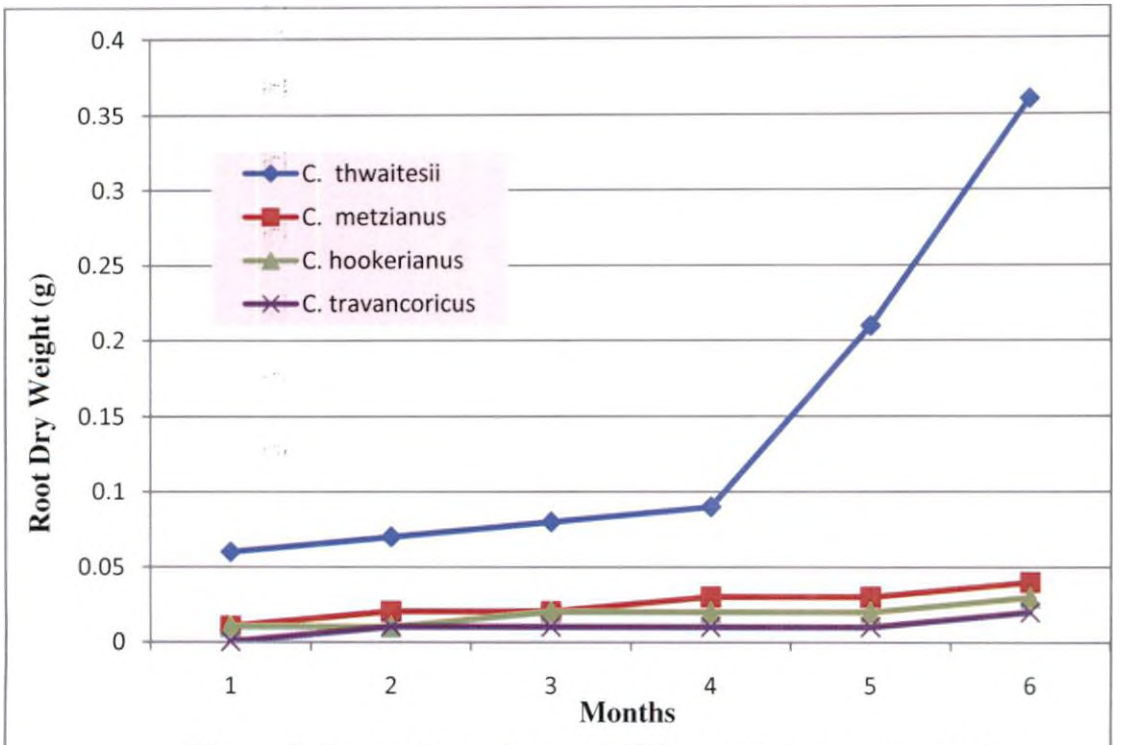


Figure 8. Dry weight of root of different *Calamus spp*. during the first six months

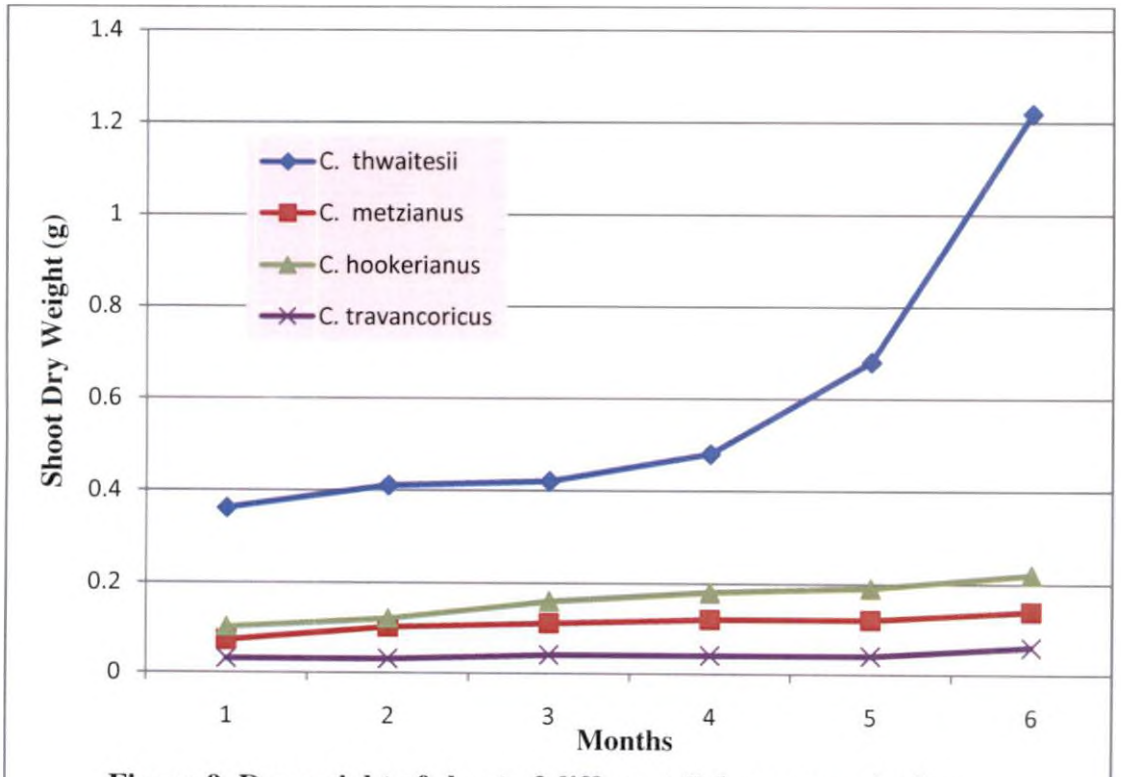


Figure 9. Dry weight of shoot of different *Calamus spp.* during the first six months

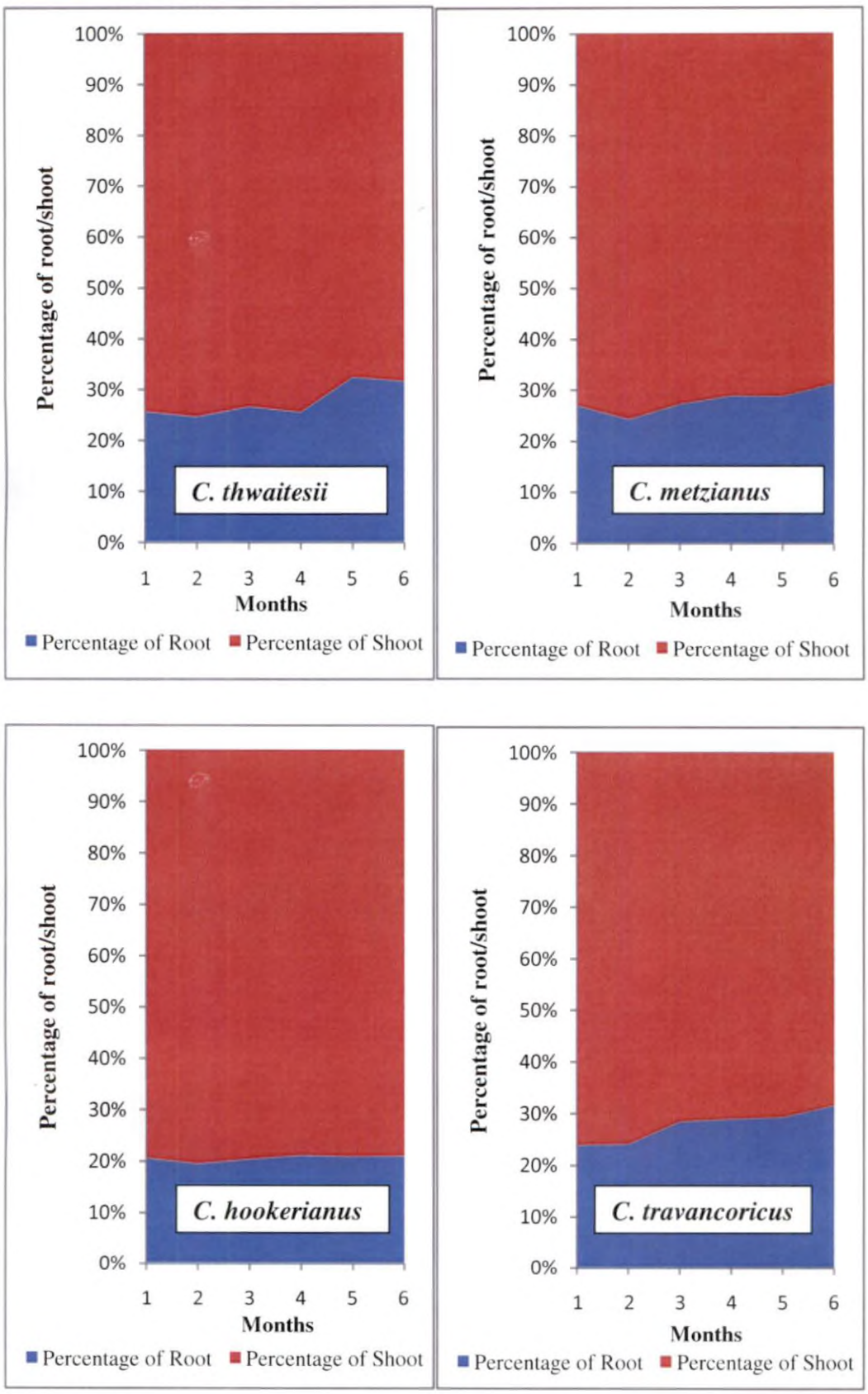


Figure 10. Dry weight percentage of root and shoot to Total dry weight of the four *Calamus spp.* during the first six months

The dry weight of root was very less in the first month (0.06 g), which did not vary significantly in the second month (0.07). It had a six times increase in next five months (0.36 g). In the initial stages, the root growth in terms of dry weight was very slow. It showed an increase of 0.09 g within four months. During the last 2 months it showed a four times increase in dry weight.

C. thwaitesii had high initial shoot dry weight (0.36 g). It showed a steady increase in the first four month and had a rapid increase during the last 2 months. At the end of the sixth month (1.22 g), shoot dry weight was almost double (0.68 g).

Total dry weight of seedling also followed the same trend as indicated by shoot and root. It is noticed that the growth rate was steady and slow till fourth month later it started increasing its dry weight. The increase in total dry weight was lesser than that of initial months (1.58 g).

A perusal of data furnished in Table 10 indicated the percentage of root and shoot dry weight to the total dry weight of the seedling of *C. thwaitesii*. Dry weight percentage of root was showing an increasing trend. The data ranged from 23.12 per cent in the first month to 28.51 per cent to the sixth month. The shoot weight percentage to the total seedling weight showed a decreasing trend in which in the initial stages, it was 66.85 per cent but decreased to 61.45 per cent at the end of the study period.

The shoot-root ratio also showed decreasing trend as growth rate of root was more than the rate of shoot growth. Shoot-root ratio was 5.49 in the first month which reduced to 3.39 during the sixth month. However the highest ratio was shown in the second month (6.02). All the species except *C. thwaitesii* showed an increasing trend in the dry weight percentage. In *C. thwaitesii,* there was an increasing trend in the initial stage up to fifth month but decreased during sixth month.

4.3.2. Seedling biomass of *C. metzianus*

Seedling biomass of *C. metzianus* is furnished in tables 11 and 12. A comparison of biomass with other species is depicted in figures 8, 9 and 10.

Table 11 indicates that both shoot and root exhibited slow and steady growth. Dry weight of root, shoot and seedling vary slightly in magnitude, but, the variation was significant.

Fresh weight of root started from 0.07 g in the first months to 0.18 g in the sixth month. It showed an increase of more than double when compared to first month. In case of shoot weight it started from 0.22 g in the first month and later it reached 0.45 g in the sixth month. It was also doubled within six months. So the growth rate of root and shoot was almost similar in the first six years. The fresh weight and dry weight of seedling also increased significantly during the first six months. The initial weight of seedling was 0.29 g and it reached 0.63 g in six months.

In the initial stages, the root and shoot in terms of dry weight was very slow. It only got an increase of 0.04 g in six months (Table 11). The dry weight of shoot was 0.07 g in the first month significantly increased to 0.14 g in six month. The seedling weight was only 0.09 g in the first month, and reached 0.19 g in the sixth month.

Proportion of dry weight of root and shoot of *C. metzianus* is given in the Table 12. The percentage of dry weight of root and shoot to total dry weight was exhibiting an increasing trend except in the first month. But the root growth was more and it showed an increase in six months and shoot growth was in decreasing fashion.

The root weight percentage to the total seedling weight showed an increasing behaviour. In the initial stages it was 24.33 per cent which increased to

Table 11. Seedling biomass of *Calamus metzianus* during the first six months after germination

Months	Root weight (g)		Shoot weight (g)		Seedling weight (g)	
	Fresh	Dry	Fresh	Dry	Fresh	Dry
1	0.07^{A}	0.01^{A}	0.22^{A}	0.07^{A}	0.29^{A}	0.09^{A}
2	0.08^{B}	0.02^{B}	0.34^{B}	0.10^{B}	0.41^{B}	0.12^{B}
3	0.11^{C}	0.02^{C}	0.36^{C}	0.11^{C}	0.47^{C}	0.13^{C}
4	0.13^{D}	0.03^{D}	0.38^{D}	0.12^{D}	0.51^{D}	0.14^{D}
5	0.14^{E}	0.03^{D}	0.40^{E}	0.12^{E}	0.54^{E}	0.15^{E}
6	0.18^{F}	0.04^{E}	0.45^{F}	0.14^{F}	0.63^{F}	0.19^{F}
F Value	2084.01**	969.59**	1031.44**	1006.25**	1383.36**	1100.72**
SEm ±	0	0	0	0	0	0

The values having similar alphabets do not differ significantly. Significance at 1% level - **

Table 12. Percentage contribution of biomass components to total biomass of *Calamus metzianus* seedling during the first six months after germination

Months	Percentage of dry weight to total weight ***		Shoot-root ratio
	Root	Shoot	
1	24.33^{B} (16.97)	65.64^{D} (82.98)	4.89^{D}
2	21.92^{A} (13.93)	68.04^{E} (86.05)	6.17^{E}
3	24.64^{C} (17.38)	65.32^{C} (82.56)	4.75^{C}
4	26.07^{D} (19.31)	63.90^{B} (80.65)	4.18^{B}
5	26.02^{D} (19.24)	63.95^{B} (80.71)	4.19^{B}
6	28.25^{E} (22.40)	61.72^{A} (77.55)	3.46^{A}
F value	610.59**	610.59**	725.71**
SEm ±	0.06	0.06	0.12

The values having similar alphabets do not differ significantly
Significance at 1% level - **
Mean germination percentage is given in parenthesis -***

28.25 per cent. The data regarding shoot weight percentage showed a decreasing trend from 65.64 per cent in the first month to 61.72 per cent to the sixth month.

The ratio of shoot to root showed a zigzag pattern. Shoot-root ratio was 4.89 in the first month which reduced to 3.46 at the end of six months. The ratio was highest in the second month as indicated by *C. thwaitesii*.

4.3.3. Seedling biomass of *C. hookerianus*

Seeding biomass observations of *C. hookerianus* is shown in tables 13 and 14. Its biomass compared to other species can be seen from the figures 8, 9 and 10.

Fresh weight of *C. thwaitesii* showed an increasing trend. It was depicted in Table 13. In the first few months, *C. hookerianus* showed almost steady and slow increase in fresh weight of root, shoot and seedling. In the first month, fresh weight was 0.04 g, 0.30 g and 0.33 g for root, shoot and seedling respectively. Within six months it produced a fresh weight of 0.12 g, 0.61 g and 0.73 g for root, shoot and seedling respectively. From the figures 8, and 9, it was clear that the growth rate of root and shoot was very low in *C. hookerianus* when compared to *C. thwaitesii*.

The dry weight of root was very less in the first month (0.01 g). It had a three times increase in fifth months (0.03 g). The biomass accumulation in roots was very less in *C. hookerianus* in the initial months. Shoot of *C. hookerianus* had a dry weight of 0.10 g which was ten times more than that of dry weight of root. It also got doubled within next five months (0.22 g). The biomass accumulation was 0.11 g in the first month and increased to 0.25 g in the sixth month. A comparative increase in biomass is illustrated in the figures 8 and 9.

Table 13. Seedling biomass of *Calamus hookerianus* during the first six months after germination

Months	Root weight (g)		Shoot weight (g)		Seedling weight (g)	
	Fresh	Dry	Fresh	Dry	Fresh	Dry
1	0.04^{A}	0.01^{A}	0.30^{A}	0.10^{A}	0.33^{A}	0.11^{A}
2	0.06^{B}	0.01^{A}	0.38^{B}	0.12^{A}	0.45^{B}	0.13^{A}
3	0.08^{C}	0.02^{B}	0.39^{B}	0.16^{B}	0.47^{B}	0.18^{B}
4	0.08^{C}	0.02^{BC}	0.48^{C}	0.18^{B}	0.56^{C}	0.20^{B}
5	0.09^{D}	0.02^{C}	0.55^{D}	0.19^{BC}	0.65^{D}	0.21^{BC}
6	0.12^{E}	0.03^{D}	0.61^{E}	0.22^{C}	0.73^{E}	0.25^{C}
F Value	95.35**	23.02**	141.01**	11.93**	140.42**	12.97**
SEm ±	0	0	0.03	0.04	0.04	0.05

The values having similar alphabets do not differ significantly Significance at 1% level - **

Table 14. Percentage contribution of biomass components to total biomass of *Calamus hookerianus* seedling during the first six months after germination

Months	Percentage of dry weight to total weight ***		Shoot-root ratio
	Root	Shoot	
1	18.50^{AB} (10.06)	71.47^{AB} (89.90)	8.93^{AB}
2	17.52^{A} (9.06)	72.44^{D} (90.89)	10.19^{B}
3	18.32^{AB} (9.87)	71.64^{AB} (90.07)	9.12^{AB}
4	18.97^{B} (10.56)	70.99^{A} (89.38)	8.46^{A}
5	18.80^{AB} (10.38)	71.16^{AB} (89.57)	8.62^{A}
6	18.89^{B} (10.48)	71.08^{A} (89.48)	8.55^{A}
F value	1.789^{NS}	1.789^{NS}	1.96^{NS}
SEm ±	0.26	0.26	0.26

The values having similar alphabets do not differ significantly
Non Significant : NS
Mean germination percentage is given in parenthesis -***

The data furnished in Table 14 revealed the percentage of root and shoot dry weight to the total dry weight of the seedling of *C. hookerianus*. Dry weight percentage of root was showing an increasing trend as it increased from 18.50 per cent in the first month to 18.89 per cent to the sixth month. The contribution of root to total dry weight was less in *C. hookerianus* than that of other species.

In the initial stages, shoot weight was 71.47 per cent which decreased to 71.08 per cent in the next five months. The percentage of shoot weight to total dry weight was more than those recorded by other species. Shoot-root ratio was higher in the first month (8.93), which reduced to 8.55 in the sixth month. However the largest value for shoot-root ratio was recorded in the second month (10.19).

4.3.4. Seedling biomass of *C. travancoricus*

Biomass observations of *C. travancoricus* were shown in tables 15 and 16. A comparison of biomass with other species is depicted in the figures 8, 9 and 10.

Fresh weight and dry weight of *C. travancoricus* was depicted in Table 15. The fresh weight of root ranged from 0.02 to 0.07 during the six months. The fresh shoot weight variation started from 0.10 g in the first month to 0.19 g in the sixth month. In case of seedling weight, it started from 0.12 g in the first month and reached 0.26 g in the sixth month.

The root and shoot growth in terms of dry weight was found very slow in *C. travancoricus*. In the first month dry weight of root was very low and tends to zero. It exhibited an increase of 0.02 g in six months (Table 16). The dry weight of shoot was 0.03 g in the first month significantly increased to 0.06 g in six month. The seedling weight was only 0.04 g in the first month, and 0.08 g in the

Table 15. Seedling biomass of *Calamus travancoricus* during the first six months after germination

Months	Root weight (g)		Shoot weight (g)		Seedling weight (g)	
	Fresh	Dry	Fresh	Dry	Fresh	Dry
1	0.02^{A}	0.00^{A}	0.10^{A}	0.03^{A}	0.12^{A}	0.04^{A}
2	0.02^{B}	0.01^{A}	0.10^{A}	0.03^{AB}	0.12^{A}	0.04^{A}
3	0.03^{C}	0.01^{B}	0.11^{A}	0.04^{B}	0.14^{B}	0.04^{B}
4	0.04^{D}	0.01^{C}	0.12^{B}	0.04^{C}	0.16^{C}	0.05^{C}
5	0.04^{E}	0.01^{C}	0.13^{B}	0.04^{C}	0.17^{C}	0.05^{C}
6	0.07^{F}	0.02^{D}	0.19^{C}	0.06^{D}	0.26^{D}	0.08^{D}
F Value	9655.19**	226.51**	97.73**	164.24**	234.11**	203.47**
SEm ±	0	0	0	0	0	0

The values having similar alphabets do not differ significantly

Significance at 1% level - **

Table 16. Percentage contribution of biomass components to total biomass of *Calamus travancoricus* seedling during the first six months after germination

Months	Percentage of dry weight to total weight ***		Shoot-root ratio
	Root	Shoot	
1	21.52^{A} (13.45)	68.44^{D} (86.49)	6.42^{D}
2	21.71^{A} (13.68)	68.25^{D} (89.26)	6.31^{D}
3	25.63^{B} (18.71)	64.33^{C} (81.23)	4.34^{C}
4	26.13^{BC} (19.39)	63.84^{BC} (80.56)	4.16^{BC}
5	26.46^{C} (19.85)	63.51^{B} (80.10)	4.04^{B}
6	28.51^{D} (22.78)	61.45^{A} (77.15)	3.39^{A}
F value	167.238**	167.238**	212.43**
SEm ±	0	0	0.30

The values having similar alphabets do not differ significantly
Significance at 1% level - **
Mean germination percentage is given in parenthesis -***

sixth month. This indicated a very low growth rate as compared to all the other species.

Percentage of root to total dry weight was showing a steady increase in the case of *C. travancoricus*. It started from 21.52 per cent in the first month to 28.51 per cent. Likewise, the percentage of shoot was 68.44 per cent in the first month and 61.45 per cent in the sixth month. It was showing a steady pattern as in the case of other *Calamus spp.* studied.

Discussion

5. DISCUSSION

Rattan resource is getting depleted considerably due to over exploitation and reduction in habitats. Planting in natural habitat without disturbing the existing vegetation is a simple way to increase the rattan resource. The large scale cultivation warrants detailed knowledge of propagation methods and their growth attributes.

The present investigation was carried out at College of Forestry, Vellanikkara to study the effect of pre-sowing treatments on germination and growth of seedlings of selected rattan species of Kerala. The salient results are discussed hereunder.

5.1. Effect of pre-sowing treatment on germination

Rattan produce seeds in bulk, but their germination per cent are very low in most of the species if sown as such. According to Odetola (1987), several species of the family *Arecaceae* have mysterious physical numbness in varying degrees, demanding pre-sowing treatment in water or growth regulatory chemicals, chemical or mechanical stratification or even degrees of exposure to brightness. The present study therefore investigates, the effects of pre-sowing treatments on four *Calamus* species. This is discussed in comparison with various works reported elsewhere.

Pre-sowing treatments increased germination percentage in all the *Calamus spp.* except for *C. metzianus* (Fig.2), in which relatively high germination per cent was observed in un-treated seeds also. *C. thwaitesii* also exhibited better germination per cent in untreated seeds. This indicates the scope of *C. thwaitesii* and *C. metzianus* in its fast establishment and perpetuation. Different physiological, anatomical or morphological factors can be drawn as the reason for poor germination results in *C. hookerianus* and *C. travancoricus*. Different pre-sowing treatments also gave poor results in *C. hookerianus* and *C. travancoricus* with regard to the *C. metzianus* and *C.*

thwaitesii (Table 5). According to Specht and Schaefer (1990) in their study on *Terminalia brownii* and *T. spinosa*, it was found that *T. brownii* showed difficulty in germination since the fruit had a hard endocarp. Results of their study indicated strongly that the fruits must have a moisture content of 10-12 per cent to produce best germination. Freshly harvested fruits have an initial moisture content of 32 per cent, thus drying recommendations are given for better germination results. Seedling establishment studies revealed removal of fungal contamination from the seed coats will markedly improve seed germination and seedling establishment in the nursery.

In general, seeds without seed treatments gave low germination. The effect of pre-sowing treatments on germination varied with species to species. In the present study *C. thwaitesii* and *C. metzianus* also gave better results with control along with other pre treatments (tables 1 and 2). In contradiction, germination results were nil with respect to *C. hookerianus* and *C. travancoricus.* Works done in terminalias also highlights that untreated fruits did not germinate and most of the treatments tested resulted in only occasional germination. Studies by Barylnikova (1971) also indicates that in all cases, treatment improved germination, but in some species like *Gleditsia caspica* and *Cercis griffithii*, the dry (untreated) seeds germinated well.

Physiological maturity of seeds significantly determines the germination of seeds and establishment of seedlings. This is accounted by maximum fruit weight and peak germinability. Relative size, health and adapatability of seeds to the given environment also plays a crucial role in the germination of seeds. A fruit at maturity level also produces seedlings characterized by maximum size, dry matter production and vigour index. (Ramakrishnan, *et al.*, 1990). In the study of seed management in *Casuarina equisetifolia,* Rai (1990), has recommended to select heavy cones by size grading and thereafter using dense seeds isolated by density grading.

Treatment with GA_3 (T9) was successful in both *C. thwaitesii* and *C. metzianus*. The positive effect of GA_3 was established in the studies of Upreti and Dhar (1997). It was found that soaking in 500 ppm GA_3 solution for 12 hours significantly enhanced seed germination percentage to 91.73 per cent. The use of growth regulators as gibberellins (Bevilaqua *et al.*, 1993) and cytokinins (Cunha and Casali, 1989) during the germination can improve performance of various species, mainly under adverse conditions. Frazao and Pinheiro (1981) and Frazao *et al.* (1981), noticed increase in germination of palm with GA_3 application.

A number of investigators have reported a hastening affect on germination by soaking seed in 10-2000 ppm concentration of GA_3 for 1-3 days (Nagao and Sakai, 1979; Nagao *et al.*, 1980; Doughty *et al.*, 1986;). Odetola (1987) reported 10-25 ppm GA_3 worked well for a wide variety of species. Apart from treatment with GA_3, a significantly higher germination percentage was also obtained from, T3 (Scarification with sand and ash) T8 (cold water treatment after removing sarcotesta) and T7 (Hot water treatment after removing sarcotesta) in *C. thwaitesii* (Table 1 and Figure 1).

An overall better performance was exhibited by *C. metzianus* towards all the subjected pre-sowing treatments (Table 2 and Figure 2) and showed relatively high germination percentage (90%). Different treatments found to have influenced the germination percent, but they do not differ significantly from each other (Table 2). This indicates that *C. metzianus* germinates well without any pre-sowing treatments. This may be because of the better physiological and morphological make-up of the seeds. Better adaptability of the seeds to the nursery conditions may also have played a significant role for their successful germination results.

The removal of sarcotesta and pericarp (T2) gave an increase in germination percentage in *C. hookerianus* and *C. travancoricus* (Table 3 and 4). Swapon and Baruah (1994) also got 90 per cent germination after removal of scale and mesocarp,

8 per cent after removing only scale and 7 per cent germination without any treatment in *C. tenuis*. In general all the pre sowing treatments are found to be useful in the germination of *C. hookerianus* and *C. travancoricus*, were the present study reveals the difficulty in germination of untreated seeds. *C. thwaitesii* comparatively showed a low germination percentage with removal of pericarp and sarcotesta with respect to other treatments. According to the study conducted by Msanga and Maghembe (1989), seeds whose seed coat was completely removed germinated poorly (5-16 per cent), as a result of rapid water uptake which caused damage to internal seed structures.

Sumantakul (1989) has reported a low germination rate of 16 per cent for *C. latifolius* when the pericarp and sarcotesta were removed completely. Sowing the whole fruit as well as fruit with pericarp removed, surprisingly gave 54.5 and 32.0 per cent germination rates respectively. The unusual low germination rate for clean removal of pericarp and sarcotesta probably confirmed the reservation expressed by Darus and Aminah (1985) that the embryos can be damaged during the cleaning process.

Hot water treatment after removing sarcotesta and pericarp (T7) gave higher germination value in *C. hookerianus* (Table 3 and Figure 3). Emerson *et al.* (2003) got a higher germination speed index (GSI), when the *Phoenix roebelenii* was germinated at a temperature of 30^0C. In case of *C. travancoricus*, germination value was lower, which do not statistically differ from zero in all the treatments except T5 (H_2SO_4 treatment without removing sarcotesta). Kitze (1958) also got promising results for germination in palm seeds of *Copernicia* while using sulphuric acid, but lower when compared to the value obtained with mechanical scarification. Bovi and Buchanan (1976a), studied effect of treatments which include immersion in cold water, hot water (± 80° C) and sulphuric acid (75 per cent) for 5 or 10 minutes on

seeds of *Euterpe oleracea* and concluded that both the use of sulphuric acid and the hot water were not found satisfactory.

Flach (1997) noted that germination in sago palm *Metroxylon sagu* can be speeded up by removing the seed husk and by loosening the covering over the embryo (operculum). Removal of flesh, accelerates the germination of seeds in many palm species. (Bovi and Buchanan 1976a; Bovi and Buchanan, 1976b; Maeda, 1987; Meerow, 1991; Broschat, 1994; Lorenzi *et al.*, 2004). Ferreira and Gentle (2006), studied the emergence of the seeds of *Astrocaryum aculeatum* and observed that the treatments considerably increased the emergence in germination. Elias *et al.* (2006), researching in the same species, found the germinal pore depth in the substrate could decrease the percentage of dormancy in seeds.

In the present study it was observed from Table 1 that, the initiation of germination and its ceasing came to an end more rapidly than any other treatment for *C. thwaitesii,* with respect to T9 (Treatment with GA_3) and T5 (H_2SO_4 treatment without removing sarcotesta). Germination within short time span will be helpful in generating seedlings of uniform growth pattern. Figliolia *et al.* (1987), while comparing the germination of seeds of *Euterpa edulis* fruit found that scarification of seeds gave faster and uniform germination than the control.

In general the treatments in which the pericarp and sarcotesta were removed gave earlier germination in all the species. The seeds sown without any pre-treatments showed very slow germination. According to Goel (1992), removal of sarcotesta in canes is necessary as a pre-sowing treatment, in order to shorten the germination period. Removal of the hilar cover gave the best germination results for *C. merrillii*, where its germination time was drastically shortened from the usual range of 90 - 120 days to only two days (Bagaloyos, 1988). Likewise, the reduction was from 240 - 365 days to only 8-14 days for *C. ornatus* var. *philippinensis*.

Germination was a faster process in *C. metzianus* (Table 2). In all the treatments germination started early, within 20th to 28th days except for T10 (Control). This observation supports the necessity of pre sowing treatment in *C. metzianus,* when the requirement is for faster production of seedlings. The period of germination was 6-10 days only. Even though germination started late in T10 (Control) (40th day), the germination finished within 6 days (46th day). This ensured a more uniformity with respect to the morphology of the seedlings. Cumulative germination of *C. manan* was 74 per cent over 4-11 weeks, and 43 per cent over 6-31 weeks for *C. tumidus* (Aminuddin and Zollpatah, 1990).

In comparison to *C. thwaitesii* and *C. metzianus*, *C. hookerianus* and *C. travancoricus* showed slower germination rate. In *C. hoookerianus,* germination was early in T1 (Complete removal of outer pericarp manually) and T9 (Treatment with GA_3) followed by T2 (Complete removal of outer pericarp and sarcotesta manually). Even though the germination percentage of T4 (Fermentation of the seed after removing pericarp) was very less in *C. travancoricus,* it germinated earlier than that of other treatments. Days required for half of the germination was lowest in case of T4 and T10. All the other treatments were non-significant to each other (Table 3 and 4).

Viable seeds of peach palm (*Euterpe edulis*) started germinating on an average of 170 days after sowing (Oak, 1994). Germination percentage varied with respect to the period of germination in peach palm (Martins-Cordor *et al.,* 2006). The magnitude of variation was from 0-4 per cent (60 days), 0-15 per cent (90 days), 3-25 per cent (120 days) and 14-56 per cent (150 days) respectively. In the present study, the values obtained from the germination percentage were similar to those cited for the peach palm. As per different studies, the germination rate was found to be 44 per cent in 160 days (Negreiros and Perez, 2004); 73 per cent in 100 days (Nodari, 1998). Variation in germination was observed among the progenies of *E. edulis* (Martins-

Cordor *et al.,* 2006). Similar work carried out with Palm trees also noted variations between genotypes for the germination percentage (Cunha and Garden, 1995).

Mature seeds of *C. tenuis* and *C. rotang* were used to study the germination frequency in nursery soil by Singh *et al.* (1999) at Assam Agricultural University. There was no germination from the intact seeds or from the seeds after removal of outer scaly pericarp. The germination percentage increased (45 and 65 per cent for *C. tenuis* and *C. rotang*, respectively) and corresponding days for germination were 32 and 35 per cent respectively, when the outer scaly pericarp, fleshy sarcotesta and hilum were removed mechanically by rubbing with sand and ash. Removal of the micropyle gave 100 per cent germination for both species and reduced the time for germination to 11-12 days *in vivo*.

5.1. Growth of *Calamus* seedlings

Different growth parameters like height of seedlings, length of prophyl, number of leaves, collar diameter, root length and spread, were investigated in the present study.

C. thwaitesii showed much higher prophyl length of 5.77 cm and *C. travancoricus* showed lowest length (1.52 cm). *C. metzianus* (3.56 cm) and *C. hookerianus* (3.40 cm) did not differ significantly in prophyl length (Table 6). The first stage of development during rattan seed germination is the emergence of a spear like protuberance called prophyl from which the seedling leaves expands later (Renuka *et al.,* 2002). The length of prophyl may have relation to the size of leaf which emerges from it. This was true with *C. thwaitesii* as it produced the larger leaves corresponding to its lengthy prophyl.

Secondary leaf production varied with species. Different species took different periods to produce second leaf. *C. thwaitesii* produced leaves at later stages than that of other species. It may be because, of the larger leaf area. This in turn creates larger photosynthetic area and helps in biomass accumulation as it is already known that biomass productivity is influenced by leaf area index. The similar result is reported by Alamgir and Hossain (2005) in *Albizia saman.* The number of leaflets per leaf was maximum in case of *C. travancoricus* (Table 6). Only two leaflets, but with larger leaf area was produced in *C. thwaitesii.*

The number of leaves produced may be a good indicative of the vigour of the seedlings. This in turn reflects in the establishment and survival of seedlings. Studies by Venturi and Paulilo (1998) suggest that seedlings of peach palm with higher number of sheaths favored growth, as photosynthesis exceeds respiration in the presence of sheath. But the number of leaves in the seedlings of palms is less compared to other species. At the age of three months *Terminalia chebula* produced an average of 24 leaves per seedling (Hossain *et al.,* 2005).

Even though the leaflets produced per leaf was least in case of *C. thwaitesii*, its leaf area was significantly high from other species in the present study (Table 6). Leaf length and breadth taken were also the highest in *C. thwaitesii* as shown in the Table 6. Morphologically greater growth and development will be exhibited by *C. thwaitesii* when compared with similar aged other seedlings of different species in the study. Leaf area was the less in case of C. *travancoricus* that exhibited maximum number of leaflets.

The collar diameter of the seedlings was found to be increasing with every fortnight, but they did not vary significantly between all the adjacent fortnights (Table 7 and Figure 5). *C. thwaitesii* increased considerably in collar diameter from the first fortnight (1.91 cm) to 12^{th} fortnight (4.12 cm). In the final fortnight, it

showed a rapid increase from 3.53 cm to 4.12 cm. This may be because of the emergence of new leaf and thereby producing greater photosynthetic area. *C. metzianus* was showing a steady increase in collar diameter. But it showed a much slower growth rate than the other species. This may be because of its genetically smaller size and slow growth pattern.

C. hookerianus showed a collar diameter of 1.25 cm in the first fortnight and it had a rapid increase in the next fortnight to 1.84 cm (Table 7 and Figure 5). But later, it showed only gradual increase up to ninth fortnight. *C. travancoricus* also exhibited a steady increase in collar diameter. The increment in girth was relatively higher than that of *C. metzianus* (Figure 5). From the Figure 5, it is clear that collar diameter was maximum in case of *C. thwaitesii,* followed by *C. hookerianus*, *C. travancoricus* and *C. metzianus*. This result was in correspondence with the leaf area exhibited by the experimented *Calamus* species. Martins-Cordor *et al.* (2006) studied growth of peach palm (*Euterpe edulis*) and reported that the progenies showed significant differences with respect to the height of seedling, diameter and number of leaves. The average height of seedlings was 92.00 cm and collar diameter was 0.73 cm.

As *Calamus* species remains in the rosette stage they do not have true shoot in the initial stages. Many palms have displayed true shoots in the initial stages. *Phoenix roebelenii* had a shoot length of 9.98 cm and root of length (7.59 cm), in the nursery stage (Emerson *et al.*, 2003). *Terminalia chebula* produced a shoot length of 14.67 cm (Hossain *et al.*, 2005) whereas *Sapindus emerginatus* produced 28. 4 cm (Suresha, *et al.*, 2007) long shoot within 3 months.

C. thwaitesii exhibited an increase in root length within six months. In every month, root growth was significantly greater than that in the previous month (Table 8). During the early stages the growth is mostly concentrated on the roots but later shoot elongation initiate after the emergence of the second leaf. *C. metzianus*

followed *C. thwaitesii* in case of increase in the root length. It was 10.50 cm in first month which increased to more than double to 22.42 cm at the end of the sixth month. *C. metzianus* gave better results for root length even when its leaf area and collar diameter was lowest. This can be interpreted as the need for water and other minerals required for *C. metzianus* may be comparatively higher.

C. hookerianus showed a short root in the first month. Later it underwent a steady growth rate upto the end of the sixth month. This may be due to the corresponding allocation of photosynthate to the production of the third leaf. *C. hookerianus* exhibited almost similar trend in root growth rate as displayed by *C. thwaitesii* and *C. metzianus* (Table 8). *C. travancoricus* exhibited a slow growth in the roots (Figure 6). This was evident from the data given for root growth in the last five months. But in the first month *C. travancoricus* could exhibit a faster root growth, even better than *C. hookerianus*. This may be because of less photosynthetates production due to small leaves which it possessed in the initial months (Fig. 6). Broschat (1998) revealed that root and shoot of seedlings (upto two year old) of Royal palm, coconut palms, queen palms and pygmy date palms grew throughout the year, and both root and shoot growth were positively correlated with air and soil temperature for all except for the pygmy date palms. Primary root growth rate varied from 16 mm for coconut and pygmy date palms to 31 mm for royal palms, while secondary root growth rates were close to 10 mm in first week for all species. This supports the fact that great variability exists in root growth within and between the species.

5.3. Biomass production of seedlings

Biomass parameters like shoot and root weight of the seedlings were analyzed. It indicated that the dry weight of root was very less in the first month (0.06 g) in *C.*

thwaitesii (Table 9). The increase was six times higher at the end of fifth month (0.36 g). In the initial stages, the root growth in terms of dry weight was very slow.

In *C. thwaitesii*, dry weight percentage of root was showing an increasing trend (Table 10). The data ranged from 23.12 per cent in the first month to 28.51 per cent in the sixth month. An increase in root biomass may be because of the existing favourable conditions in the nursery. Ravindra (2007), in his work has shown that *Mucuna pruriens* seedlings grown under 75 per cent shade produced highest root biomass, followed by those growing in 50 per cent and 25 per cent. The nursery condition in which the present study was conducted had considerable shade. This may have influenced in the production of good shoot growth.

Shoot of *C. thwaitesii* had relatively high initial dry weight (0.36 g). It showed a steady increase in the first four months and had a drastic increase in the last two months (Table 9). Seedling weight also followed the same trend as indicated by the shoot and root upto the end of the study period. The growth rate was steady upto fifth month and later it started increasing shoot growth in case of *C. thwaitesii*. Sreelekha (2004) in her studies have revealed that seedlings grown in potting media containing soil, sand and cowdung could record higher values with regard to shoot fresh and dry weight. Specific anatomic and physiological reasons may also have contributed towards higher shoot production. Studies (Girijapushpam, 2004) have shown that generally larger sized vessels are characteristics of fast growing species. Due to fast growing nature of this species biomass accumulation was fast within a given time period.

The dry weight percentage of shoot to the total seedling weight of *C. thwaitesii* showed a decreasing behaviour (Table 10). Shoot-root ratio also had a decreasing trend from first month to the sixth month. Root growth and spread has been significantly higher in *C. thwaitesii* in comparison to the shoot portion. Root length,

root spread and leaf area for *C. thwaitesii* was notably higher when compared to other species (figures 6 and 7).

In the initial stages, the root and shoot growth in terms of dry weight was very slow in *C. metzianus* (Table 11). The seedling dry weight became 0.19 in the sixth month from 0.09 in the initial month. The percentage of dry weight of root and shoot to total dry weight did not follow a steady pattern (Table 12). The shoot-root ratio showed a declining trend in *C. metzianus*. It varied from 4.89 in the first month to 3.46 in the sixth month. *C. metzianus* produced more root biomass in comparison to the shoot with respect to other *Calamus* species. This may be due to the fact that *C. metzianus* displayed comparatively smaller leaf area and good root growth. Biomass accumulation, when compared to initial month was more towards the root region during the later months (Vidyasagaran, 2005).

The dry weight accumulation was relatively very slow in *C. hookerianus* in the initial months. Dry root weight varied from 0.01 to 0.03 within six months. However, the shoot growth of *C. hookerianus* indicated a different trend in which the growth was ten times higher than that of dry weight of root (Table 13). Dry shoot weight reached to 0.22 from 0.10 at the end of sixth month. Shade under the nursery condition may have favoured the shoot growth in *C. hookerianus*. The root and shoot biomass production in *Terminalia arjuna* was found to be comparatively higher under 75 per cent shade and lowest under 0 per cent shade (Prasad, 2002).

Percentage of dry root weight and dry shoot weight to the total weight did not vary much within six months of growth of seedling in *C. hookerianus* (Table. 14). Unlike other species of *Calamus* in the present study, *C. hookerianus* did not show any notable difference in the shoot-root ratio. This may be attributed towards the fact that *C. hookerianus* exhibited a better leaf area correspondingly to root length and root spread.

The slow growth of root as well as shoot in terms of dry weight was reported in *C. travancoricus*. Dry root weight was recorded as 0.02 at the end of sixth month (Table 15). Dry shoot weight varied from 0.03 to 0.06 within these six months. Correspondingly percentage of dry root weight and dry shoot weight exhibited a slow accumulation in biomass (Table 16). Even though the growth rate of the seedling was slow in *C. travancoricus*, its shoot-root ratio showed a decreasing trend from 6.42 in the initial month to 3.39 in the sixth month. The accumulation of biomass to the shoot region was high in *C. travancoricus* also. Genetic factors and poor adaptability to external factors can be regarded as reasons for the slow growth in *C. travancoricus*.

In general, the biomass accumulation in the seedlings of *Calamus spp.* is more than four times in the shoots than that of the roots. At later stages the root dry weight increases and the ratio between shoot and root decreases. Palms produce a lower biomass in the initial stages as in *Phoenix roebelenii* which produced a shoot dry matter of 0.74 g in the nursery stage (Emerson *et al.*, (2003). In the initial stages, seedlings of other trees reported to be producing more biomass than palms. The dry weight produced by *Terminalia chebula* its shoot was 2.17 g where in the root was 0.82 g which gave a total dry weight of 1.55 g in 3 months (Suresha, *et al.*, 2007). Similarly *Sapindus emerginatus* it accumulated a dry weight of 2.17 g within the period of three months (Hossain *et al.*, 2005).

Seedling dry weight was highest for *C. thwaitesii* followed by *C. hookerianus*, *C. metzianus* and *C. travancoricus*. The same trend was followed in characters like length of prophyl, leaf area per leaf, collar diameter, root length and root spread. It is evident that dry matter production was influenced due to morphological characters. The lower dry weight accumulation in *C. travancoricus* may be due to delayed germination, intern growth and dry weight have influenced the biomass accumulation. Similar results were shown in dry weight of other *Calamus* species. But, this reason cannot be attributed for *C. metzianus* as its germination process

initiated within few days of sowing. Genetic and environmental factors might have played a major role in low biomass accumulation in *C. metzianus*.

Summary

6. SUMMARY

The present study on the "Effect of pre-sowing treatments on germination and growth of seedlings of *Calamus spp.*" was carried out in the tree nursery, College of Forestry, Vellanikkara, during 2007 – 2009.

The programme envisaged the evaluation of different pre-treatments for better germination by studying variation in germination percent, germination energy of four *Calamus spp.* and their growth and biomass in the nursery stage for six months. The salient findings of the experiments with different *Calamus spp.* are summarized here under:

1. Germination

1. Most of the treatments gave better performance than the control in all the *Calamus spp.* under study.

2. The species showed variations in their performance to the different pre-sowing treatments.

3. Comparing all the treatments, *Calamus thwaitesii* gave maximum germination value when scarified with sand, ash and treated with hot water along with application of GA_3 after removal of sarcotesta and pericarp.

4. A significantly higher germination percent was obtained from scarification with sand and ash, hot water, cold water (after removal of sarcotesta) and GA3 when compared to the control in *C. thwaitesii.*

5. *Calamus metzianus* gave the maximum germination percent with good germination speed when treated with GA_3 followed by the treatment involving the removal of outer pericarp and sarcotesta.

6. *C. metzianus* gave different germination percentage values under different treatments but they do not differ significantly. Seedlings under

control and H_2SO_4 treatment after removing sarcotesta gave a lower germination percentage.

7. Germination value also showed the similar fluctuations for the different treatments.

8. In *Calamus hookerianus,* the best treatments were identified as hot water treatment followed by cold water (after removal of sarcotesta) and scarification with ash and sand treatment, considering germination percentage and germination value.

9. Germination values recorded lowest, and did not statistically differ from each other in all the treatments except when *C. hookerianus* was treated with hot water.

10. *Calamus travancoricus* gave the maximum germination percentage with better speed when its pericarp and outer sarcotesta were removed and treated with sulphuric acid after removal of sarcotesta.

11. The highest germination percentage of 17.11 was recorded in *C. travancoricus* whereas minimum was under control and cold water treatment after removal of sarcotesta. The other treatments did not vary significantly.

12. In *C. travancoricus*, the germination value did not significantly vary in the treatments except when treated with H_2SO_4 without removing the sarcotesta.

2. Growth

1. *C. thwaitesii* showed much higher prophyl length (5.77 cm) whereas relatively lower length in *C. travancoricus* (1.52 cm).

2. *C. metzianus* and *C. hookerianus* did not differ significantly in the prophyl length.

3. In the initial rosette stage of seedling growth, it was found that the total length of first leaf equaled the height of seedlings. The length of the second leaf was found to be less than the first leaf.

4. The maximum height was recorded for the seedlings of *C.thwaitesii*. whereas *C. travancoricus* had the least seedling height during the first six months.

5. *C. metzianus* and *C. hookerianus* varied significantly in the height growth.

6. The first leaf emerged from the prophyl within one week after germination in all the species. The time taken to produce the second leaf was different for each *Calamus spp.*

7. The collar diameter of the seedlings was found to show significant increase with every fortnight's period, in all the *Calamus spp.* under study.

8. Seedlings possessed one long and thick root on which secondary roots aroused. Branching is observed in few seedlings, but both branches were almost equals in size.

9. Root length and root spread is constantly increasing in every month. *C. thwaitesii* had maximum increase in root length and root spread during the six month period.

10. Shoot-root length ratio showed a decreasing trend because; the shoot length did not show corresponding increase as shown by root.

3. Biomass

1. All the *Calamus spp.* showed an increasing trend in the biomass production in terms of fresh and dry weight.

2. Biomass accumulation was maximum in *C. thwaitesii*, as it produced a maximum initial shoot weight soon after germination. Compared to other

species *Calamus thwaitesii* possessed more photosynthetic area which might have caused the rapid increase in biomass

3. The root and shoot in terms of dry weight was very slow in *C. metzianus, C. hookerianus* and *C. travancoricus* in the initial stages

4. During the study period of six months, the contribution of shoot weight to the total biomass of seedling was more than that of root weight, in all the species.

5. The shoot root ratio was more than four times in the first month in all the species.

6. The shoot growth was less compared to root growth, so the shoot-root ratio decreased during the study period but never equaled unity.

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APPENDICES

Appendix 1. Meteorological data of the location of the study during the study periods

Year	2007					2008					2009				
Month	MMT (^{0}c)		R.H (%)	MMRF (mm)	Rainy days	MMT (^{0}c)		R.H (%)	MMRF (mm)	Rainy days	MMT (^{0}c)		R.H (%)	MMRF (mm)	Rainy days
	Max	Min				Max	Min				Max	Min			
Jan	-	-	-	-	-	32.3	21.7	59	0.0	0	32.8	20.9	54	0.0	0
Feb	-	-	-	-	-	33.6	22.9	61	29.7	3	35.1	22.1	57	0.0	0
Mar	-	-	-	-	-	33.2	23.4	64	205.3	7	35.1	24.4	70	29.0	3
April	-	-	-	-	-	33.2	24.9	75	65.6	3	34.5	25.3	74	16.5	2
May	-	-	-	-	-	33.0	24.7	73	11.5	2	33.0	24.8	77	179.5	10
June	-	-	-	-	-	29.9	23.5	85	636.7	25	30.0	23.7	84	565.0	19
July	-	-	-	-	-	29.3	23.2	84	416.3	22	-	-	-	-	-
Aug	-	-	-	-	-	29.8	23.6	82	321.9	12	-	-	-	-	-
Sept	-	-	-	-	-	30.6	23.2	810	314.2	14	-	-	-	-	-
Octo	30.5	22.5	79.0	383.8	14	31.7	23.4	76	380.8	12	-	-	-	-	-
Nov	31.7	24.6	67.0	24.8	3	32.2	23.1	70	21.7	2	-	-	-	-	-
Dec	31.6	22.7	56.0	8.7	1	31.6	22.5	60	2.6	0	-	-	-	-	-

MMT – Mean monthly temperature
R. H. – Relative Humidity
MMRF – Mean monthly rain fall

"EFFECT OF PRE-SOWING TREATMENTS ON GERMINATION AND GROWTH OF SEEDLINGS OF *CALAMUS SPP.*"

By,

JISHA, E. D.

ABSTRACT OF THE THESIS

Submitted in partial fulfillment of the requirement for the degree

Master of Science in Forestry

Faculty of Agriculture
Kerala Agricultural University

Department of Forest Management and Utilization
COLLEGE OF FORESTRY
KERALA AGRICULTURAL UNIVERSITY
VELLANIKKARA, THRISSUR - 680 656
KERALA, INDIA

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ABSTRACT

The present study entitled "Effect of pre-sowing treatments on germination and growth of seedlings of *Calamus spp.*" was carried out on four Calamus species namely, *Calamus thwaitesii, C. metzianus, C. hookerianus,* and *C. travancoricus* in the tree nursery of College of Forestry, Vellanikkara, during 2007 – 2009.

In the first phase, seeds of four Calamus *spp.* were subjected to 10 different pre-treatment methods. Most of the treatments gave better performance than the control in all the *Calamus spp.* under study. Treatment with GA_3 and cold water gave a relatively higher germination percentage in all the species except *C. travancoricus*. Hot water treatment and scarification with sand and ash were found promising in all the species. Seeds sown without any treatment returned poor germination in all the species.

In the second phase, the growth and biomass production of the four species were studied for the first six months in the nursery. The first leaf emerged from the prophyl within one week after germination in all the species. In the initial rosette stage of seedling growth, it was found that the total length of first leaf equalled the height of seedlings. The collar diameter of the seedlings was found to show significant increase with every fortnight's period, in all the *Calamus spp.* under study. Shoot-root length ratio showed decreasing trend because, the shoot length is constant in the initial months, but root length was increasing. In case of biomass production, all the *Calamus spp.* showed an increasing trend in the biomass production in terms of fresh and dry weight. During the study period of six months, the contribution of shoot weight to the total biomass of seedling was more than that of root weight, in all the species. *C. thwaitesii* was superior in growth attributes and biomass among the four species studied.