KFRI Research Report No. 254 ISSN 0970-8103

MAINTENANCE OF SEED STANDS AND SPECIES TRIAL PLOTS OF RATTANS. PHASE II

(Final report of the project KFRI 289/98 Phase II - Jan. 2001 to Dec. 2002)

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November 2003

PROJECT PROPOSAL

Project No.	KFRI 289/98
Title	Maintenance of seed stands and species trial plots of rattans - Phase II
Investigator	Dr. C. Renuka
Objectives	1. To monitor the growth of different species of rattans in the experimental plots 2. To maintain and manage the seed stands and germplasm plot 3. To study the reproductive biology of flowered species in the experimental plots
Project period	Jan. 2001 – Dec. 2002
Duration	2 years
Funding agency	Kerala Forest Department (Development)

CONTENTS

ABSTRACT

Rattan population in Kerala is getting reduced drastically and hence there is an urgent need for evolving a strategy for scientific management and conservation of this valuable resource. Along with the preservation of existing natural resources, germplasm preservation and cultivation of commercially important species also have to be done. Before starting cultivation in large scale, suitable species for a particular locality should be selected and their performance assessed. In this context, the Kerala Forest Research Institute has initiated germplasm conservation and species trials to evaluate the performance of various species at different altitudes and also seed stands have been established.

Eight rattan species were evaluated for their performance at two different altitudes, 1000 m and 300 m, at Vazhachal and Nelliampathy. With regard to survival and total height, *Calamus baratangensis* was found to be the best species suited for higher elevations and *Daemonorops kurzianus* for lower elevations.

Seed stands for 12 commercially important rattan species were established of which four species have started flowering and fruiting. In the germplasm collection, 30 species of rattans have been established, some of which also have started flowering and fruiting. *Calamus perigrinus*, a species introduced from Thailand, has also started producing fruits regularly.

Rattans are dioecious and flower annually. Age of the plant at first flowering varies according to species. The time of initiation of flowering also varies slightly with locality from year to year. But a correlation between flowering and climatic conditions showed that both male and female plants flowered simultaneously when the rainfall was in the range of 400-500 mm, relative humidity 100%, wind speed up to 0.5 m/s and temperature up to 25 °C. Only *C. hookerianus* showed variation.

The time taken for emergence of inflorescence to fruit maturity was about nine months in *C. hookerianus*, eight months in *C. pseudotenuis*, 11 months in *C. thwaitesii* and six months in *C. rotang*.

Anthesis of flower takes place during night between 1 and 4 AM. All the pollen is shed within 3 to 4 hrs. Male flowers are scented and sterile male flowers produce a droplet of nectar at the base of the flower. Female flowers do not produce nectar, but female flowers are receptive up to 12 to 14 hrs after opening. Pollen viability is lost in about 12 hrs from the time of anthesis.

Even though the species studied have adaptions to both anemophily and entomophily, anemophily is more common.

Embryo development is relatively low. The developing shoot and root apices get shifted through an angle of 90° due to the growth of the cotyledonary lobe.

During germination, a haustorium is developed by the progressive enlargement of the basal part of the embryo. After about one month of the onset of germination, the spongy haustorium completely fills the seed cavity.

The fruits stored in closed plastic bags under room temperature remain viable for two months. Seeds in airtight bags kept at 5 °C maintain viability for 3 months.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the financial support from the Kerala Forest Department for undertaking this work. The whole hearted support and encouragement given by Dr. J. K. Sharma, Director, KFRI and Dr. R. Gnanaharan, Research Coordinator is gratefully acknowledged. The statistical advice was given by Dr. K. Jayaraman, Scientist-in-Charge, Statistics Division, KFRI, whose involvement during the formulation of the experiment and data analysis is much appreciated. Mrs. P. Rugmini, Statistics Division, KFRI did major part of the data analysis. Thanks are also due to Dr. T. S. Nair, Scientist, TBGRI for interpreting the pollen structure, Mr. P. Sreekumar, Sri Chithira Thirunal Institute for Medical Science & Technology, Thiruvananthapuram for taking scanning electron micrograph of floral parts, to Mr. A. G. Varghese for assistance in data processing, to M/s. V. B. Sreekumar, V. V. Rangan, James P. Thomas and K. Dinesan for helping in the field work, and to Dr. R. Gnanaharan, Dr. Muktesh Kumar, and Dr. R. C. Pandalai for editorial scrutiny.

INTRODUCTION

Rattans, the spiny climbing palms with about 600 species under 13 genera, are distributed in tropical and subtropical Asia and equatorial Africa. In India, there are about 61 species of rattans under four genera, *Calamus, Daemonorops, Korthalsia* and *Plectocomia*. These are distributed in the Western Ghats of Peninsular India, sub Himalayan hills and valleys of eastern and northeastern India and the Andaman and Nicobar Islands. One genus and 21 species have so far been reported from the Western Ghats; three genera and 18 species from the Andaman and Nicobar islands and three genera and 17 species and two varieties from North Eastern States (Basu, 1992; Renuka, 1992, 1995, 1999; Renuka *et al.,* 1997; Sunny Thomas *et al.*,1998).

Being an important forest produce next to timber, rattan forms an integral part of rural and tribal populace in many of the tropical countries. It is not only an important chief raw material for industries in various parts of the world, but also holds great social significance as a source of livelihood to the people residing near the forest areas. Although economically important, rattan remained as a neglected natural resource till recent times. With the rampant destruction of forests and habitats, its stock at present, is highly depleted. Presently, there is no sufficient quantity of rattans from natural habitats to meet the demands of the cane industry. Many of the cane industrial units in southern India are known to get their supplies from N.E. India. But the status of forests in N.E. India itself is a matter of concern due to shifting cultivation and heavy logging (Renuka, 1996). In the Andaman and Nicobar islands also, the natural resource is getting depleted at a faster rate due to over-exploitation (Renuka, 1995). If the depletion continues in the present rate, the natural rattan resources will almost be totally decimated in a few years. Therefore, there, is an urgent need to develop a strategy for scientific management to conserve this valuable forest resource.

Rattans are gaining importance as a plantation crop since cultivation of commercially important species for the industrial sector can relieve the pressure on the wild stock. Before adapting the species for large scale plantations outside their natural home, species trials should be conducted to assess the suitability of the species for a particular geo-climatic region. Though rattans occur from almost sea level to 2000 m, most of them show altitudinal preferences. Many of the species are distributed below 1000 m, while some are found only at higher altitudes. Some species are restricted to certain localities.

Majority of the rattan species of the Western Ghats are endangered which necessitates immediate development of conservation strategies. For developing effective conservation strategies detailed knowledge of reproductive biology is essential. When large-scale plantations are grown, use of genetically improved seeds is desirable. In order to produce genetically improved rattans, basic information on floral biology and breeding system is essential.

To start cultivation in the plantation level, a regular seed supply is required for which it will be necessary to set aside some accessible stands of good rattans as seed stands. It has, however, been proved difficult to maintain seed stands in the wild since no rattan seems to be safe from rattan collectors. Extraction of rattan before flowering and the destruction of natural habitat of rattan drastically affect the seed source. Hence, there is a need to raise seed stands in protected areas.

With the alarming rate at which the tropical forests are being destroyed, there is depletion of genetic resources as well. Considering the rate at which tropical forests, the habitat of rattans, is being destroyed, the rattan gene pool required for the selection of species for various purposes is likely to be lost. Hence, effective measures are to be taken to conserve and propagate the endangered as well as other important species.

In this context, the Kerala Forest Research Institute had started germplasm conservation, studies on the *ex-situ* performance of different species of rattans and establishment of seed stands of commercially important rattans under a project funded by IDRC, Canada. When the project period was over, another project was taken up for the maintenance of the established plots with the financial aid from the Kerala Forest Department. The first phase of the project was over in December 2000 (Renuka, 2001). In the second phase reproductive biological studies were given more importance even though the observations on growth parameters were continued. In this report, consolidated result of the growth performance for the past eight years is given. For reproductive biological studies, data collected from the experimental plots from 1998 onwards are included.

REVIEW OF LITERATURE

Species trial, seed stands and germplasm conservation

There are only a few publications available on the *ex situ* studies on rattans. Manokaran (1977, 1982, 1983) reported that survival of three Malaysian species *Calamus scipionum, C. manan* and *C. caesius,* after 5-7 years, is only about 20 per cent. After seven years of growth, no stem was ready for harvest and none had flowered. Renuka and Rugmini (1996) studied the survival and growth performance of eight species of rattans for a period of four years.

Many countries have started genetic conservation of rattans recently. The resource diversity and the conservation activities undertaken in each country have been reviewed (Renuka and George, 2001)

Reproductive biology

Flowering period

Rattans are dioecious and the flowering is annual. Flowering period of rattans varies from place to place. Several researchers have observed that flowering of rattans is induced by fluctuations in temperature and weather (Manokaran, 1989; Raja-Barizan, 1992). Alloysius *et al.* (1994) reported that inflorescences of *C. caesius* emerged between June and September every year. Bogh (1996) investigated the phenology of four species of *Calamus,* viz. *C. longisetus*, *C. perigrinus*, *C. rudentum* and *Calamus* sp. in Southern Thailand. Staminate plants flowered continuously for several months, whereas, pistillate plants had much shorter flowering periods. Some of the species flowered twice in an year (Mohd.-Zaki and Othman, 1998; Banik and Nabi ,1981).

Renuka (2000) reported that most of the W. Ghat species flower during July- August and the fruits mature during March to June.

Flowering age

In plantation, *C. rotang* and *C. hookerianus* started flowering from the 4th year onwards (Renuka, 1994). In a progeny trial of *C. subinermis* in Sabah, some of the plants started flowering in 42 months after seed germination and about 22 months after planting in

the field (Lee and Jong, 1995). In the same species, flowering was reported at the 5th year by Alloysius (1999). Manokaran (1985) observed that *Calamus caesius*, *C. manan*, *C. trachycoleus* and *C. filipendulus* started flowering between 4 and 5 years after planting in the field.

Pollination

At present our knowledge on pollination mechanism in rattans is very limited. Both anemophily and entomophily have been recorded in rattans (Dransfield, 1979, Lee and Jong, 1995, Bogh, 1996, Renuka *et al.* and 1998 Alloysius, 1999;).

Uhl and Dransfield (1987) suggested bees to be the most likely pollinators of many species of *Calamus*, although in some instances they may in fact be pollen thieves. Lee and Jong (1995) observed that, in *Calamus subinermis* and *C. caesius,* anthesis took place during night hours and that wind may contribute to a short distance pollination.

According to Bogh (1996), the exposed stigmas and anthers were easily accessible to any potential insect visitor and even to the wind. The maximum horizontal distance of pollen dispersal by wind in *Calamus subinermis* was 4 km and about 88 per cent of the pollen was dispersed within 3.5 m from the inflorescence (Lee and Jong, 1995). Renuka *et al.* (1998) reported wind pollination in some of the South Indian species of *Calamus.*

The role of sterile male flowers in pollination was suggested as a visual attractant and providing nectar for pollination (Lee and Jong, 1995; Renuka *et al.*,1998).

Fruiting

Manokaran (1985) reported that the supply of *C. manan* fruits varied with the season and there are several months in a year when certain commercial species of rattans bear ripe fruits. Renuka (1995) reported the fruiting phenology of three rattan species from the W. Ghats.

Seed storage and germination

Generalao (1977) reported that viability of rattan seeds was related to moisture content and dry storage methods were not effective. Guangtian and Huangcan (2000) found that the temperature and moisture content were important for seed storage, which also

influenced seed viability. The germination rate remained high even after 6 months when seeds were stored at 15 ^{0}C with moisture of 55 to 65 per cent.

The rattan fruits stored in closed plastic bags maintained high seed viability for one month at room temperature and for 3 months at a temperature between 10 and 14 ^{0}C. The seeds stored in closed bags at room temperature maintained above 50 per cent seed viability for six months (Mori *et al.*, 1980).

Mori *et al.* (1980) suggested complete removal of the sarcotesta as an indispensable pre-treatment for rattan seed germination. They observed that the slow rate of germination may be due to the undeveloped seed structure, especially that of the radicle and not due to seed dormancy; the moisture content of the seeds must be kept between 45 and 55 per cent during the storage period. Agmato (1984) detected embryo dormancy in *C. limuran* and found that Gibberlic Acid at 1000 ppm concentration was successful in breaking the dormancy. A reduction in germination percentage at low moisture content was also reported by Bagaloyos (1987). Biochemical changes during desiccation of *C. rotang* and *C. thwaitesii* have been studied by Girija *et al.* (1998) and their results revealed that hydrolysis of carbohydrates, degradation of proteins and the accumulation of phenolic substances in seeds during desiccation can contribute to the death of the seeds during desiccation.

The germination percentage and the time taken for germination vary widely between and within the species (Generalo, 1977; Manokaran, 1978; Agmato, 1984; Renuka, 1991). The germination varied from 0. 2 to 83-89 per cent and the period from first to final germination varied from 2 weeks to one year. Seeds of *C. andamanicus* take more than one year to germinate (Renuka *et al.*, 1998).

Removal of hilar cover decreased germination time and increased germination percentage (Agmato, 1984). Bagalayos (1987) reported that stratification increased the germination to 80 per cent in *C. ornatus.*

MATERIALS AND METHODS

Species trial

The species trial established in the first phase was continued with eight commercially important species (Table 1) at two different altitudes.

Table 1. Species under trial

Species	Place of collection
Calamus andamanicus (SP5)	Andamans
C. baratangensis (SP1)	Andamans
C. caesius (SP3)	Malaysia
C. gamblei (SP4)	Kerala (Moozhiar)
C. karnatakensis (SP6)	Karnataka
C. pseudotenuis (SP2)	Kerala (Peermedu)
C. rotang (SP8)	Kerala (Quilon)
Daemonorops kurzianus (SP7)	Andamans

The survival percentage and mean height of the main stem after eight years were given in the report of the first phase (Renuka, 2001). In the second phase, total height was considered, *ie*. height of the main stem and height of all suckers produced during this period in order to know the actual extractable length of utilizable cane. The data obtained from each location pertaining to survival percentage and total height over different periods were subjected to statistical analysis. Comparison of means was carried out using Duncan's Multiple Range test (DMRT) wherever needed. The analysis of variance conformed to that of a univariate mixed model analysis. The total height values were subjected to logarithmic transformation and the survival percentage was transformed to angular scale before the analysis.

Seed stands

Seed stands for nine species were established during the first phase. A third plot was established at Vazhachal during June 2002 with four species ie., *C. vattayila, C. andamanicus, C. thwaitesii* and *C. hookerianus.* The measurements from the plots established during the first phase were continued (Renuka, 2001). In the analysis, data from 1999 onwards are included.

Germplasm conservation

Two species were added during the reporting period to the live collection of rattans maintained in the Institute campus. An area of 0.5 ha inside the campus where a moist deciduous vegetation exists is used. Planting materials of different species of rattans procured from India, China, Thailand and Laos have been assembled in the area. Ten plants of each species have been planted in a line at a distance of 2 m with a spacing of 6 m between two lines.

Reproductive biology

Four species of rattan, namely *Calamus thwaitesii, C. hookerianus, C. rotang* and *C. pseudotenuis,* were selected for the study. The study was conducted in flowered plants from the species performance trial plots, seed stands and the germplasm plots. The data collected from 1998 onwards are included in this report. Frequent visits were made to the study sites to monitor the flowering season. Once the flowering started, regular observations were carried out from the period of initiation of inflorescence to the period of fruit maturation. The pollination mechanism of *C. thwaitesii* has been studied under the natural forest conditions (Renuka *et al.*, 1998). During the second phase, pollination studies on this species were repeated in plantations.

For recording the time of floral opening and anthesis, observations were made during night hours. In all the species a large number of inflorescences were examined. During anthesis these inflorescences were observed continuously for 10 to 20 minutes, at an hourly interval. The observations were continued for 48 hours. The sequence of flower opening was studied by marking the individual rachillae.

Pollen viability and stigma receptivity

To study the receptivity of stigma, pollen grains were collected from the male inflorescences undergoing anthesis and kept in a small glass vial. Branches of female inflorescence in which the flowers had started opening, were selected and bagged to avoid pollination from other male flowers. The flowers of two rachillae were pollinated with the collected pollen, bagged, and labelled. After two hours, the process was repeated in another two sets of rachillae. The artificial pollination was continued for eight hours. Then the time gap was increased and it was continued till the stigma turned brown in colour. Percentage of fruit set was registered in all cases.

Pollen viability was tested through in vitro germination of germinating pollen grains in different germination media such as sucrose and Breu Baker medium.

Scanning electron microscopic studies

To study the external morphology of pollen grains and stigma, scanning electron microscopic studies were conducted at Sri Chithira Thirunal Institute for Medical Science & Technology, Thiruvananthapuram. The method suggested by Falk (1980) was followed.

Pollination mechanism

Detailed observations were made on the presence and behaviour of visiting insects. The insects were collected for identification and examination of pollen loads. After scrutiny under a dissection microscope, the captured insects were rinsed for pollen. The resulting suspensions were transferred to micro slides and checked for presence of pollen loads.

A strip of transparent adhesive tape was suspended for approximately 24 hours near the pistillate inflorescences. The strip was observed under microscope for the presence of wind borne pollen deposited on it.

Seed germination

The growth of embryo during germination was studied by trimming the endosperm and scooping the developing embryo. The seed coat and the endosperm were trimmed so as to study the behaviour of the distal end of cotyledon at various stages of seed germination. Microtome sections also were prepared following the procedure of Johansen (1940).

In all the germination experiments, the seeds were sown in plastic trays where the medium consisted of equal amount of top soil and river sand. The seeds were buried just beneath the soil surface and were kept moist by watering twice daily. The trays were kept under shade to reduce the intensity of light. Once the germination started, observations were carried out daily, and the seed was considered as germinated when the conical white structure of the embryo appeared above the soil level.

Seed storage and viability

Fruits as well as seeds were stored in air tight plastic bags at room temperature, at 10 ^{0}C and at 5 ^{0}C and their viability was assessed periodically by withdrawal of samples for germination. To test the viability, tetrazolium test was conducted. The seeds were cut longitudinally through the embryo and were stained in 1% solution of 2, 3, 5 – triphenyl tetrazolium chloride overnight. The live embryo, cotyledons and other tissues stain pink to red indicating that the seeds are viable. This was done on alternate days till the colour of the embryo in the seed remained white indicating the loss of viability.

RESULTS AND DISCUSSION

Species trial

The data collected for eight years have been analysed for survival percentage and growth in total height.

Survival

The analyses of variance on survival percentage for both the locations are presented in Table 2. At Nelliampathy, the effects due to species, and period - species interaction did not turn out to be significant. But variation due to period was significant. The non-significant interaction between species and period indicates that the species do not differ in their survival pattern across time. Mean values of survival percentage of eight species corresponding to different periods are reported in Table 3. At Nelliampathy, *C. gamblei* and *C. karnatakensis* recorded higher survival percentage. At Vazhachal, there was no significant effects due to species (Table 4), but the effects due to period and period - species interaction turned out to be significant. The significant interaction between period and species indicates that the survival pattern of different species differs across time. At the end of the reporting period, at Vazhachal, *D. kurzianus* (SP7) showed higher survival percentage compared to other species (Table 4).

Table 2. Analysis of variance of data on survival percentage of plants at Nelliampathy and Vazhachal (in angular scale)

Source	df	Nelliampathy		Vazhachal	
		MSS	F value	MSS	F value
Species	7	3692.13	1.82(ns)	1231.22	1.99(ns)
Block	1	8576.24	4.23(ns)	5755.79	9.32*
Species x Block	7	2028.65	1.65(ns)	617.65	2.02(ns)
Replication within block x species	24	1227.01	-	305.45	-
Period	6	2107.77	8.52**	10842.09	62.16**
Species x period	42	102.98	0.42(ns)	305.45	1.75*
Block x period within species	48	247.49	0.90(ns)	174.42	1.54*
Residual	144	275.71		113.39	

Df - Degrees of freedom * Significant at P=0.05 (ns) - Nonsignificant
MSS - Mean sum of square ** Significant at P=0.01

Table 3. Mean survival percentage of different species at Nelliampathy at various periods (year)

Period (years after planting)	Survival Percentage							
	SP1#	SP2	SP3	SP4	SP5	SP6	SP7	SP8
2	90.00	70.00	40.00	80.00	75.00	100.00	90.00	100.00
3	90.00	66.25	25.00	80.00	70.00	100.00	80.00	90.00
4	83.00	50.00	15.00	65.00	62.50	100.00	80.00	80.00
5	81.00	42.50	15.00	60.00	55.00	100.00	80.00	80.00
6	71.00	52.50	15.00	60.00	52.00	80.00	40.00	50.00
7	70.00	52.50	15.00	60.00	45.00	80.00	40.00	50.00
8	54.00	52.50	15.00	60.00	40.00	60.00	10.00	50.00

SP1 -- *C.baratangensis* SP2 -- *C. pseudotenuis* SP3 -- *C. caesius*
SP4 -- *C. gamblei* SP5 – *C. andamanicus* SP6 -- *C. karnatakensis*
SP7 -- *Daemonorops kurzianus* SP8 -- *C. rotang*

Even though there was a gradual reduction in the survival rate at both places, in Vazhachal it was very prominent. This can be attributed to the heavy reed growth and disturbance from the elephants.

Table 4. Mean survival percentage of different species at Vazhachal at various periods (year)

Period (years after planting)	Survival Percentage							
	SP1#	SP2	SP3	SP4	SP5	SP6	SP7	SP8
2	95.00	96.25	72.50	97.50	72.50	85.00	80.00	95.00
3	95.00	87.50	70.00	97.50	70.00	85.00	75.00	95.00
4	92.00	78.75	37.50	95.00	60.00	85.00	70.00	85.00
5	86.00	72.50	37.50	95.00	50.00	85.00	70.00	85.00
6	39.00	48.75	27.50	25.00	48.75	25.00	40.00	55.00
7	34.00	28.75	20.00	5.00	26.25	25.00	35.00	25.00
8	10.00	13.75	10.00	0.00	18.75	20.00	35.00	25.00

SP1 -- *C.baratangensis* SP2 -- *C. pseudotenuis* SP3 -- *C. caesius*
SP4 -- *C. gamblei* SP5 – *C. andamanicus* SP6 -- *C. karnatakensis*
SP7 -- *Daemonorops kurzianus* SP8 -- *C. rotang*

Total height

The analyses of variance (ANOVA) on total height, for both the locations, are presented in Table 5. At Nelliampathy, the effects due to species and species - period interaction did not turn out to be significant. But period had significant influence on the total height of plant. The non-significant interaction between species and period indicates that the species do not differ in the growth pattern across time. However, the species *C. baratangensis* (SP1) recorded the maximum total height (Table 6). The mean height values of different species are shown in Table 6. The reduction in total height in some years is due to the damage caused by wild animals.

At Vazhachal, the effect on total height due to species turned out to be significant (Table 5). But the effect due to interaction between species and period did not turn out significant, indicating that the species did not differ in their height growth pattern across time. Mean values of total height of the eight species corresponding to the different periods are presented in Table 7.

In order to evaluate the performance of different species at the end of the trial, pair wise comparison between the species means at the 8^{th} period was carried out. Pair wise comparison between species showed that *C. baratangensis* (SP1) differed significantly from all the other species. At 8^{th} year after planting, *C. baratangensis* (SP1) was found to have higher height value when compared with that of other species in both the locations. This may be due to the small diameter of the cane and to the greater number of suckers produced within this time, many of which had attained commercially utilizable length.

In Vazhachal, the height of most of the species decreased drastically at the 7^{th} year. This was due to the cutting of the extractable length of rattan by the local people as well as the damage caused by elephants.

Performance of species with regard to total height indicated that *C. baratangensis* (SP1) had higher value in total height at Nelliampathy and at Vazhachal. In the case of *Daemonorops kurzianus* (SP7), it performed well at Vazhachal and not at Nelliampathy. This can be attributed to the altitudinal difference in the localities. *D. kurzianus* grows below an altitudinal level of 300 m in the natural forests. *Calamus gamblei*(SP4) occurs naturally above 700 m and hence the better growth in Nelliampathy which is of 1000 m elevation.

Table 5. Analysis of variance of data on total height (cm) of different species at Nelliampathy and Vazhachal

Source	Df	Nelliampathy		Vazhachal	
		MSS	F value	MSS	F value
Species	7	10.461	2.44(ns)	25.119	10.60**
Block	1	35.165	8.20*	10.157	4.29(ns)
Species x block	7	4.287	0.90(ns)	2.369	0.86(ns)
Replication within block x species	24	4.741	-	2.764	-
Period	6	16.249	6.13**	2.283	1.26(ns)
Species x period	42	4.224	1.59(ns)	1.506	0.83(ns)
Block x period within species	48	2.649	0.89(ns)	1.812	0.95(ns)
Residual	144	2.965		1.903	

Df - Degrees of freedom * - Significant at P=0.05 ns - Non significant
MSS - Mean sum of square ** - Significant at P=0.01

ANOVA on survival and total height at Nelliampathy (Table 2 & 5) showed similar results, ie. significant effect due to periods, non-significant effects due to interaction between periods and species and species. No such trend was seen at Vazhachal.

When both survival and total height are considered, *C. baratangensis* is the best species suited for 1000 m elevation. At 300 m, *D. kurzianus* performs better. In the seedling stages, *D. kurzianus* was showing better growth performance at higher elevations also (Renuka and Rugmini, 1996). It showed 80 per cent survival till the 5th year, and then suddenly decreased to 40 per cent in the next year and to 10 per cent in the 8th year. *Calamus caesius* (SP3) was not performing well in both the elevations. Manokaran (1977,1982,1983) reported that survival in *C. scipionum, C. manan and C. caesius* after 5- 7 years was only about 20 per cent. After 7 years, no stem was ready for harvest and neither had any species flowered. In the present experiment, at 1000 m elevation, *C. gamblei* and *C. karnatakensis* recorded 60 per cent survival and at 300 m, *D. kurzianus* showed 35 per cent survival after eight years. Certain species attained a harvestable length at the end of 6 years. Some of the stems were harvested by the local people which is reflected in the total height in the subsequent year. After 6 years, at 1000 m elevation (Nellaimpathy), *C. baratangensis* produced a total of nine stems having 3 m or more in height with a total length of 35.78 m. Discarding 1 m each from the basal and top portion from the nine stems, 17.8 m can be utilized. *Calamus pseudotenuis* produced one stem with more than 3 m, *C. rotang* produced two stems, *C. caesius* produced four

and *C. gamblei* one. At 300 m elevation (Vazhachal), *C. baratangensis* produced 28 stems with more than 3 m height with 45 m of utilizable length of cane. *Calamus caesius* produced six stems with 20.7 m of utilizable cane. *C. gamblei* produced one stem with 9 m, *C. pseudotenuis*, one stem with 1 m and *C. rotang*, 3 stems with 8 m of utilizable cane.

Table 6. Mean total height (cm) of different species at Nelliampathy at various period(year)

Period (years after planting)	Total height (cm)							
	SP1#	SP2	SP3	SP4	SP5	SP6	SP7	SP8
2	206.55	58.23	134.10	126.13	215.06	27.00	48.60	70.80
3	281.30	57.40	100.00	130.00	299.50	42.60	89.30	104.30
4	264.10	83.20	33.60	178.80	281.80	44.70	92.50	120.80
5	306.80	66.00	27.30	208.80	248.70	59.80	107.50	126.20
6	512.05	188.40	43.30	530.75	561.40	126.60	292.70	168.00
7	476.80	156.70	47.00	577.50	570.70	124.25	114.25	142.20
8	3697.00	485.45	527.50	480.00	1222.60	77.65	176.75	166.00

#SP1 – *C baratangensis* SP2 -- *C. pseudotenuis* SP3 -- *C. caesius* SP4 -- *C. gamblei*
SP5 – *C. andamanicus* SP6 -- *C. karnatakensis* SP7 -- *Daemonorops kurzianus* SP8 -- *C. rotang*

Table 7. Mean total height (cm) of different species at Vazhachal at various periods (year)

Period (years after planting)	Total height (cm)							
	SP1#	SP2	SP3	SP4	SP5	SP6	SP7	SP8
2	258.75	87.20	92.60	153.40	265.22	36.95	54.13	60.20
3	354.7	134.77	143.47	207.00	322.80	58.07	67.90	81.20
4	579.30	257.36	150.77	298.10	439.67	71.60	95.00	108.30
5	970.87	323.58	147.99	371.52	581.64	109.28	110.20	149.95
6	7298.29	1976.25	3794.25	33.60	2324.80	172.00	96.30	2780.50
7	2134.50	1795.35	444.90	0.00	2024.70	0.00	548.75	452.00
8*	3328.00^{a}	1028.50^{c}	0.00^{e}	0.00^{e}	1723.30^{b}	85.00^{d}	1575.80^{b}	1087.10^{c}

* Values superscribed by the same letter in the last row do not differ significantly.
# SP1 – *C baratangensis* SP2 -- *C. pseudotenuis* SP3 -- *C. caesius* SP4 -- *C. gamblei*
SP5 – *C. andamanicus* SP6 -- *C. karnatakensis* SP7 -- *Daemonorops kurzianus* SP8 -- *C. rotang*

Seed stands

Out of nine species planted at Kachithodu during the first phase, two species from the Andamans, *C. viminalis* and *Korthalsia laciniosa* did not perform well and perished after three to four years. *K. laciniosa* was replanted during the year 2002. *Calamus delessertianus* and *C. pseudorivalis* were constantly attacked by rodents and only few seedlings are remaining now.

In *C. rotang, C. delessertianus,* and *C. hookerianus* height measurements were taken from year 1999 onwards and in other species from year 2000 (Table 9).

At Kachithodu, *C. thwaitesii* registered very slow growth. It reached only 55 cm while *C. hookerianus* attained a height of 29.4 m in 10 years. *Calamus delessertianus* reached 13.4 m in 8 years. *Calamus travancoricus* and *C. metzianus,* in 6 years, grew 74 cm and 5.8 m respectively. Among in small diameter rattans, *C. travancoricus* is very slow growing. *Calamus rotang* attained a total height of about 23 m in 8 years.

Two species, C. *pseudotenuis* and *C. vattayila,* were planted at Nelliampathy. *Calamus pseudotenuis* is very slow growing. It attained a height of only about 69 cm in 10 years. *C alamus vattayila* has attained a height of about 177 cm within the same period.

Four species, *C. vattayila, C. andamanicus, C. thwaitesii* and *C. hookerianus,* were planted at Vazhachal during 2002. At present seed stands of 12 species exist (Table 8).

Table 8. Species planted in seed stands

Name of species	Place of collection	Place where planted	Year of planting
C. andamanicus	Andaman Islands	Vazhachal	2002
C. delessertianus	Karnataka	Kachithodu	1994
C. hookerianus	Kerala	Kachithodu & Vazhachal	1992 2002
C. metzianus	Kerala	Kachithodu	1996
C. pseudorivalis	Nicobar Islands	Kachithodu	1994
C. rotang	Kerala	Kachithodu	1994
C. thwaitesii	Kerala	Kachithodu & Vazhachal	1992 2002
C. travancoricus	Kerala	Kachithodu	1996
C. baratangensis	Andaman Islands	Kachithodu	1996
Korthalsia laciniosa	Andaman Islands	Kachithodu	1994
C. psedotenuis	Kerala	Nelliampathy	1992
C. vattayila	Kerala	Nelliampathy & Vazhachal	1993 2002

Table 9. Growth characters of different species

Species	Total height (cm)								Total no. of suckers per plant							
	1999		2000		2001		2002		1999		2000		2001		2002	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	S
	Kachithodu								**Vazhachal**							
C.baratangensis					87.92	177.64	95.45	250.59					3.29	2.36	5.00	2
C. delessertianus	117.24	92.42	109.67	88.04	145.63	76.57	133.75	82.70								
C. hookerianus	255.40	148.15	287.67	325.50	290.85	87.05	293.68	105.72	6.20	1.55	6.60	1.65	4.67	1.22	3.64	1
C. metzianus			388.94	120.09	277.50	235.90	580.50	424.36			2.25	0.50	5.40	1.57	5.95	1
C. pseudorivalis					39.74	24.04	83.68	47.48					2.00	1.12	1.57	0
C. rotang	956.33	534.09	960.10	491.95	1910.00	994.34	2312.37	1303.15	5.40	2.10	4.73	1.91	5.00	2.33	5.42	1
C. thwaitesii			44.04	12.12	45.77	29.45	54.75	32.78								
C. travancoricus			77.12	57.33	54.75	57.51	74.37	80.93			1.43	0.53	2.00	0.58	2.00	0

Nelliampathy

Species	Total height (cm)					
	2000		2001		2002	
	Mean	SE	Mean	SE	Mean	SE
C. pseudotenuis	44.94	8.96	58.24	10.62	68.71	13.41
C. vattayila	133.42	82.19	171.00	97.23	177.22	81.78

SE– Standard error

Germplasm conservation

At present, there are 30 species of rattans in the germplasm plot at KFRI at Peechi (Table 10). Four species were introduced from China, two from Malaysia, one from Thailand and one from Laos. Out of these the Malaysian species, *C. caesius* and *C. manan,* perished after an initial growth for two years. Two species collected from the Andamans were destroyed by rodents. The roots of these species were much relished by rodents. *Calamus perigrinus,* introduced from Thailand, started flowering and fruiting. Some of the Indian species also have started flowering.

Table 10. Species planted in the germplasm plot at KFRI

Name	Country of origin	Name	Country of origin
1. *Calamus simplicifolius*	"	16. *C. metzianus*	India
2. *C. tetradactylus*	"	17. *C. nagbettai*	"
3. *C. thysanolepis*	"	18. *C. prasinus*	"
4. *Daemonorops margaritae*	China	19. *C. pseudorivalis*	"
5. *Calamus* sp.	Laos	20. *C. pseudotenuis*	"
6. *C. perigrinus*	Thailand	21. *C. rivalis*	"
7. *C. andamanicus*	India	22. *C. rotang*	"
8. *C. baratangensis*	"	23. *C. tenuis*	"
9. *C. brandisii*	"	24. *C. thwaitesii*	"
10. *C. delessertianus*	"	25. *C. travancoricus*	"
11. *C. dransfieldii*	"	26. *C. vattayila*	"
12. *C. gamblei*	"	27. *C. viminalis*	"
13. *C. hookerianus*	"	28. *Daemonorops kurzianus*	"
14. *C. karnatakensis*	"	29. *D. rarispinosus*	"
15. *C. kingianus*	"	30. *Korthalsia laciniosa*	"

Reproductive biology

Rattans are dioecious and flower annually. In general, male inflorescences are produced first followed by females. Both male and female inflorescences are long and flagellate.

In the species studied 3 to 4 inflorescences with an average length of 5 m, were produced in a single plant at one season . An average of 4 to 5 partial inflorescences were produced in a single inflorescence. Several rachillae were produced on a partial inflorescence and the flowers were arranged on a rachilla (Figs. 1 & 2).

When compared to South East Asian species, rattans of the W. Ghats have longer inflorescence with more number of partial inflorescences and hence more number of flowers. Alloysius (1997) reported that *C. caesius* and *C. subinermis* developed 2 to 3 inflorescences, with an average length of 1.3 m, per plant.

Age of the plant at first flowering

Calamus hookerianus and *Calamus rotang* started flowering after four years. *Calamus pseudotenuis* took six years and *C. thwaitesii* eight years.

Flowering season

The time of initiation of flowering varied slightly with locality and from year to year (Tables 11 and 12). Staminate plants flowered continuously for several months, whereas pistillate plants had shorter flowering periods. Sometimes male inflorescences were produced twice an year and at least one season of flowering was observed to be synchronizing with that of female inflorescence.

Mohd. Zaki and Othman (1998) observed that rain had a predominant influence on flowering. Manokaran (1989) reported that a period of relative dryness and hence higher temperature followed by a period of high rainfall trigger flowering in rattans. A correlation between climatic factors recorded at KFRI and initiation of flowering for three years showed (Table 13) that the climatic factors were almost uniform all the three years when flowering of both sexes occurred simultaneously. The rainfall was around 400-500 mm, humidity 100 percent, wind speed up to 0.5 m/s and temperature up to 25 ^{0}C. Only *C. hookerianus* showed slight variation in that it flowered even when the rain fall increased up to 1300 mm, wind speed up to 5.5 m/s and temperature up to 30 ^{0}C (Figs. 3- 6).

Table 11. Period of initiation of male inflorescence in the study plots

Species	Year	Seed stand, Kachithode	Germplasm plot, KFRI Campus	Species trial plot, Vazhachal
Ch	1998	June-July	May-July November-December	June-July November-December
Ct	,,	-	August	June-July
Cr	,,	October	October	September
Cp	,,	-	January, August	-
Ch	1999	February-March June-July	April-May July	May-June August
Ct	,,	- -	July November-December	June-July -
Cr	,,	September-October	September	October
Cp	,,	-	July - August	-
Ch	2000	May-June November-December	April – July	July-August -
Ct	,,	-	August	May-July
Cr	,,	October - November	September- October	October
Cp	,,	-	February, August	-
Ch	2001	June-July December	April November-December	- May-June
Ct	,,		July	July-August
Cr	,,	September	September	September- October
Cp	,,	-	July	-
Ch	2002	March-April November-December	June-July December	February-March June-July
Ct	,,		June - August	May – June
Cr	,,	September-October	October	September- October
Cp	,,	-	January, July	-

Ch - *C. hookerianus* Ct - *C. thwaitesii* Cr –*C. rotang* Cp - *C. pseudotenuis*

In the year 1998 *C. pseudotenuis* and *C. rotang* flowered even when the wind speed was 3-3.5 ms. Henderson *et al.* (1989) observed a definite bias towards rainy season for flowering of palms in Central Amazon forests.

Table 12. Period of initiation of female inflorescence in the study plots

Species	Year	Seed stand, Kachithode	Germplasm plot, KFRI Campus	Species trial plot, Vazhachal
Ch	1998	July-August	July	June- July
Ct		-	December – January	November-December
Cr		September -October	October	September
Cp		August	July	July- August
Ch	1999	March – June	April- May	May-July
Ct		-	-	July-August
Cr		October	September -October	October
Cp		-	August	-
Ch	2000	June-July	April-May	May-July
Ct		-	July-August	May-July
Cr		October-November	September -October	September -October
Cp		-	August	-
Ch	2001	June-July	April July- August	May-June
Ct		-	May -July	June- August
Cr		September -October	October	October
Cp		-	July	-
Ch	2002	April-May	June-July	June-July
Ct		-	May-June September	April-May
Cr		September	September	September - October
Cp		-	August	-

Ch - *C. hookerianus* Ct - *C. thwaitesii* Cr- *C.rotang* Cp – *C.pseudotenuis*

C. hookerianus , *C. thwaitesii* and *C. pseudotenuis* flowered during June –August and *C. rotang* in September.

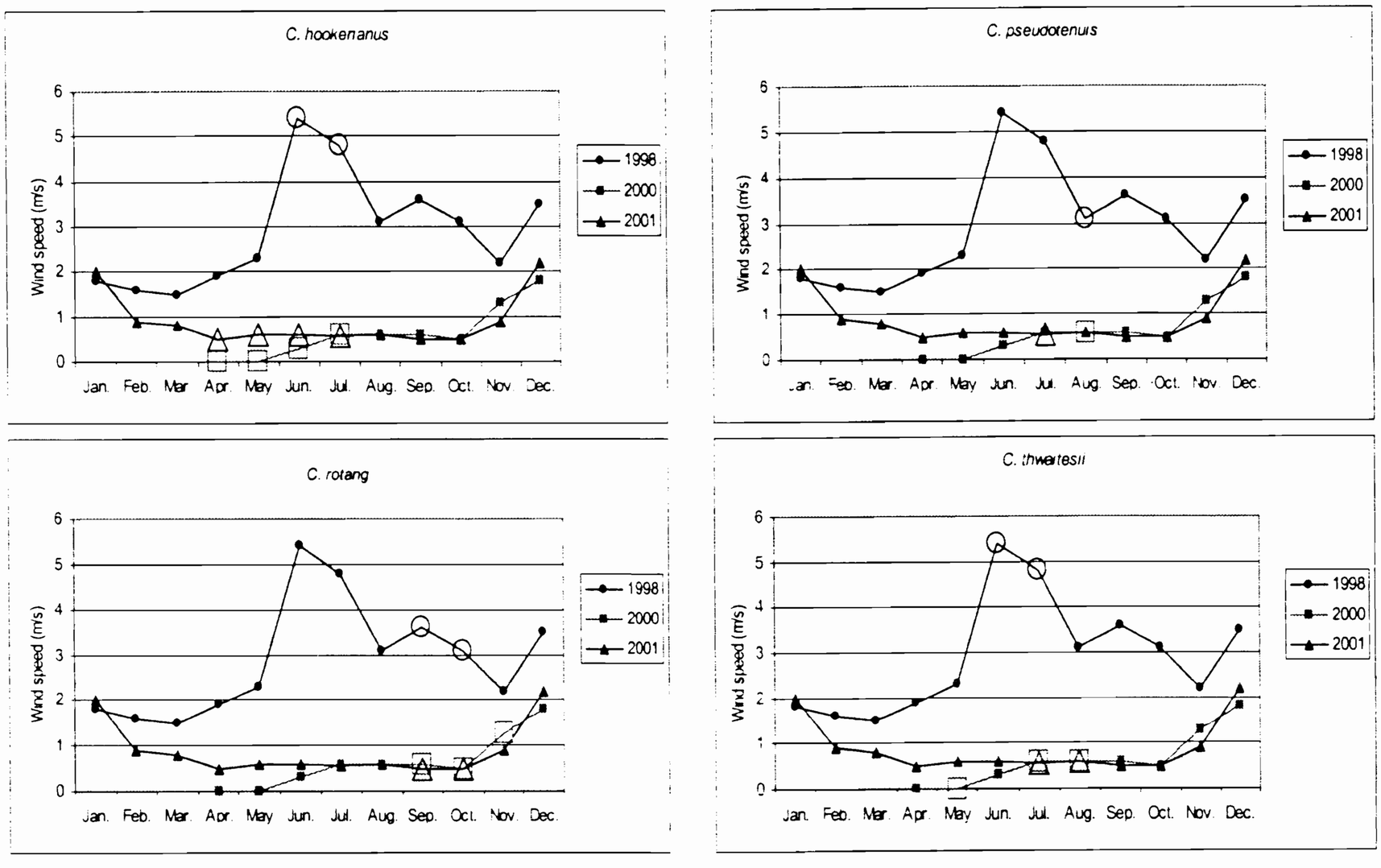


Fig. 3. Correlation between flowering and wind speed

(○, Δ, □ - flowering months)

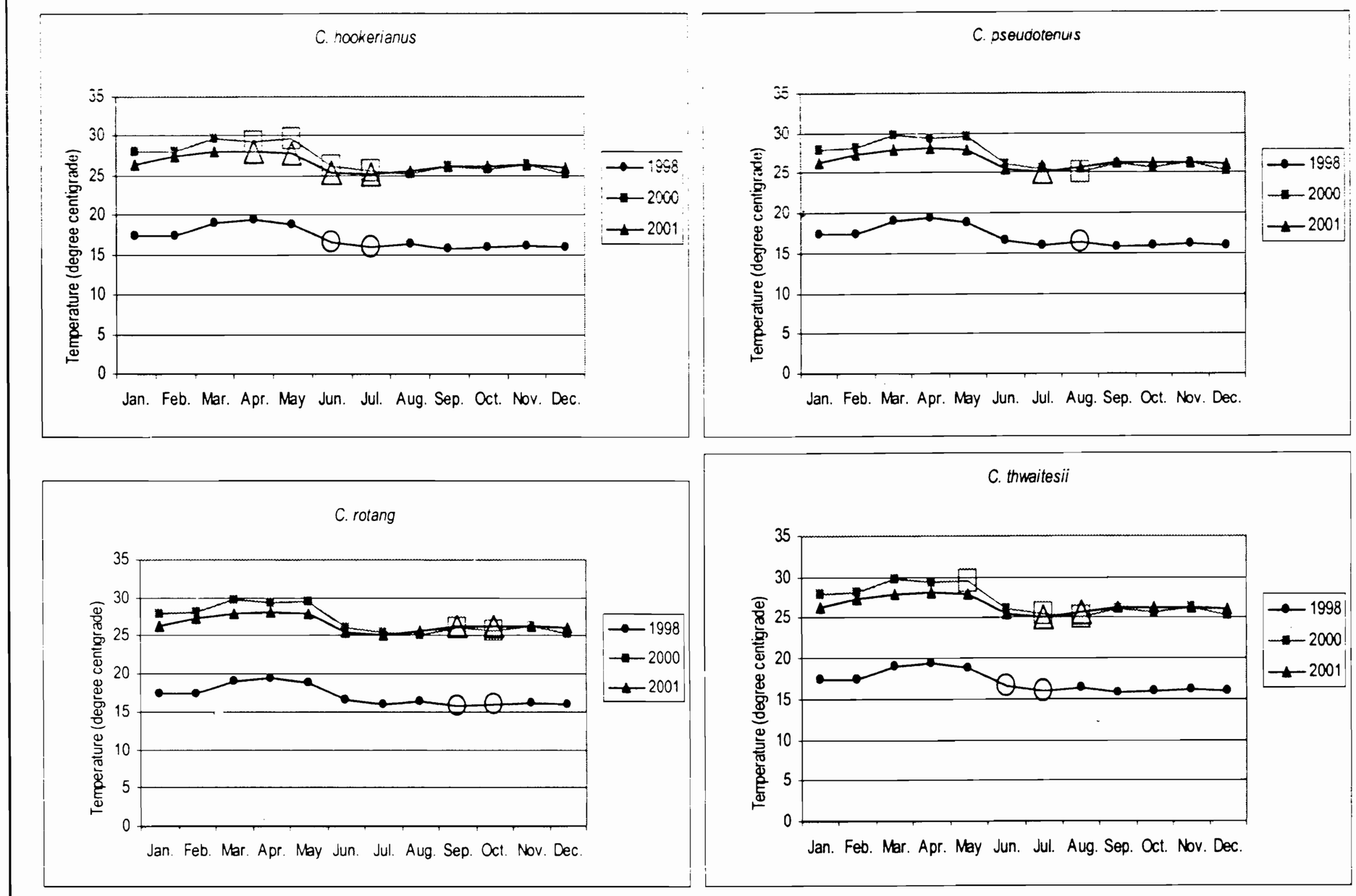
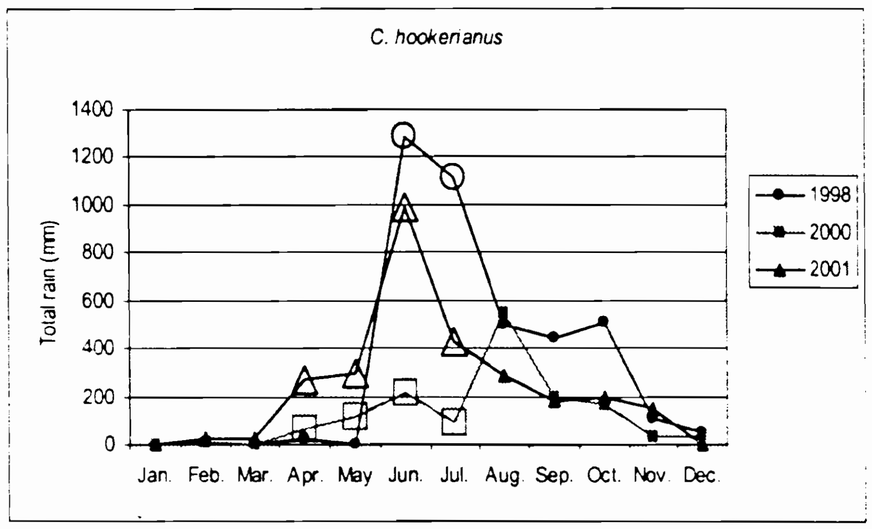
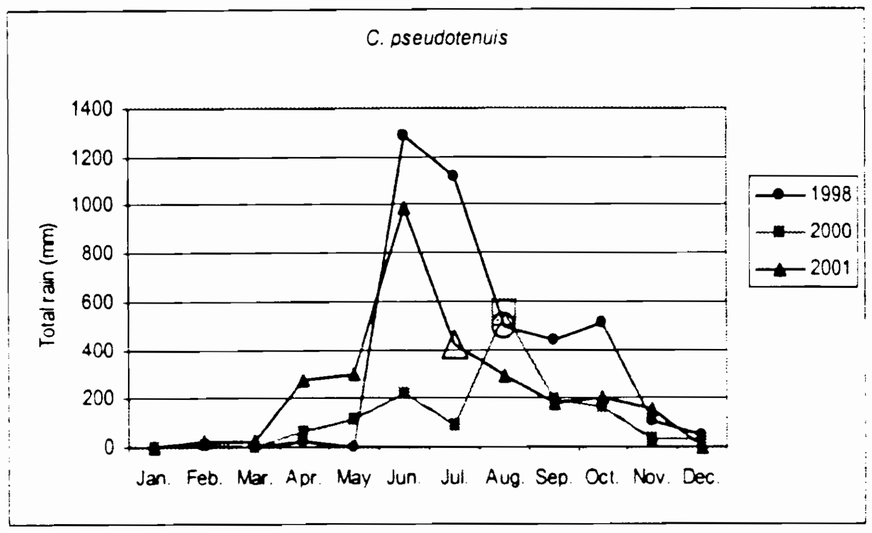
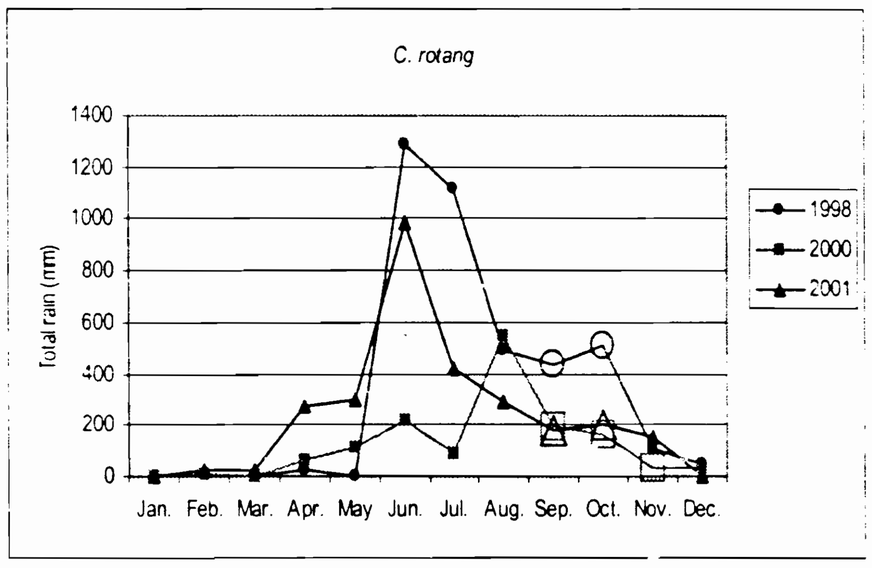


Fig. 4. Correlation between flowering and temperature

(○, Δ, □ - flowering months)







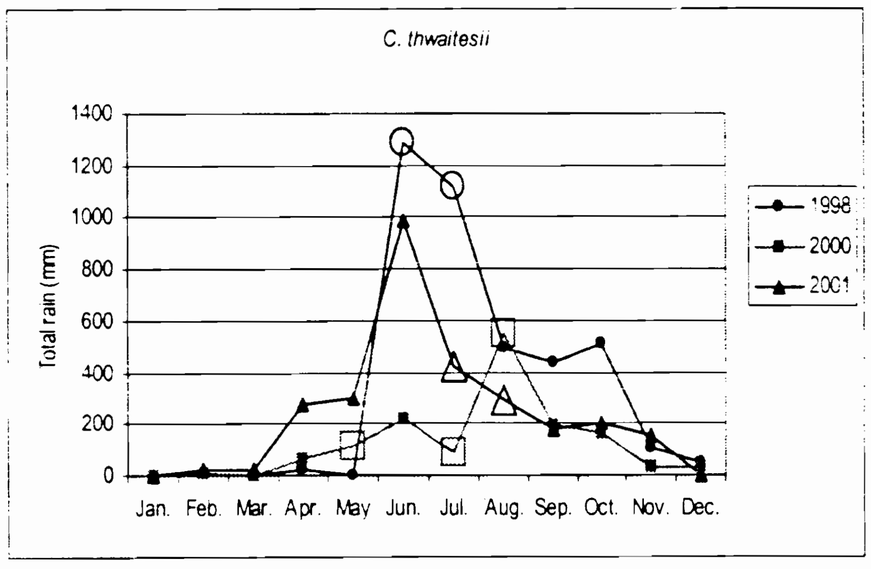
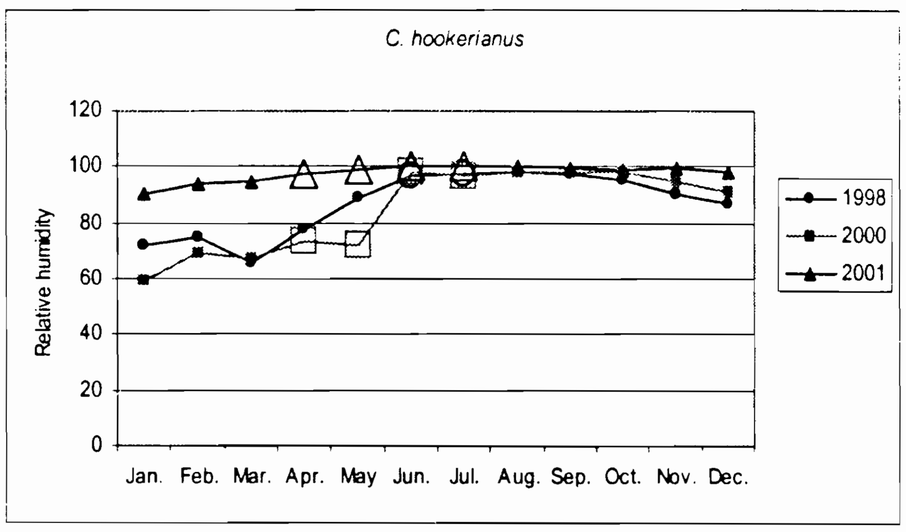
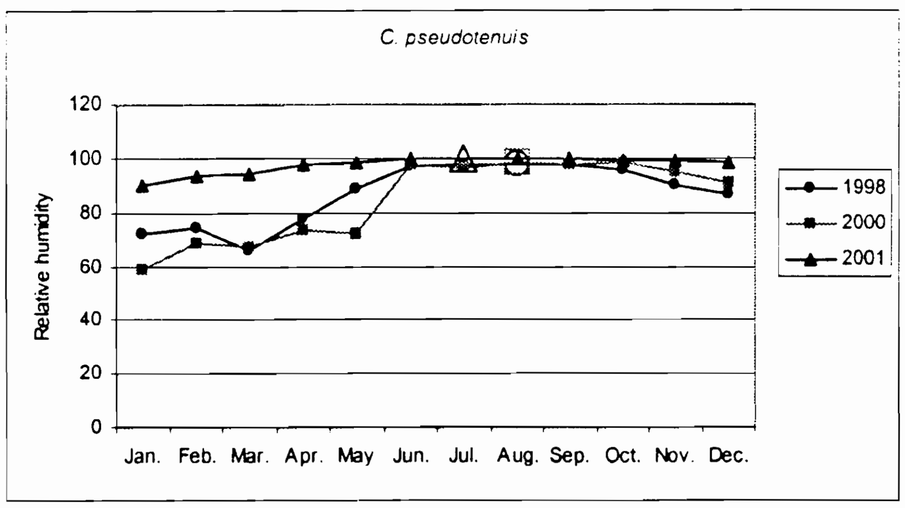
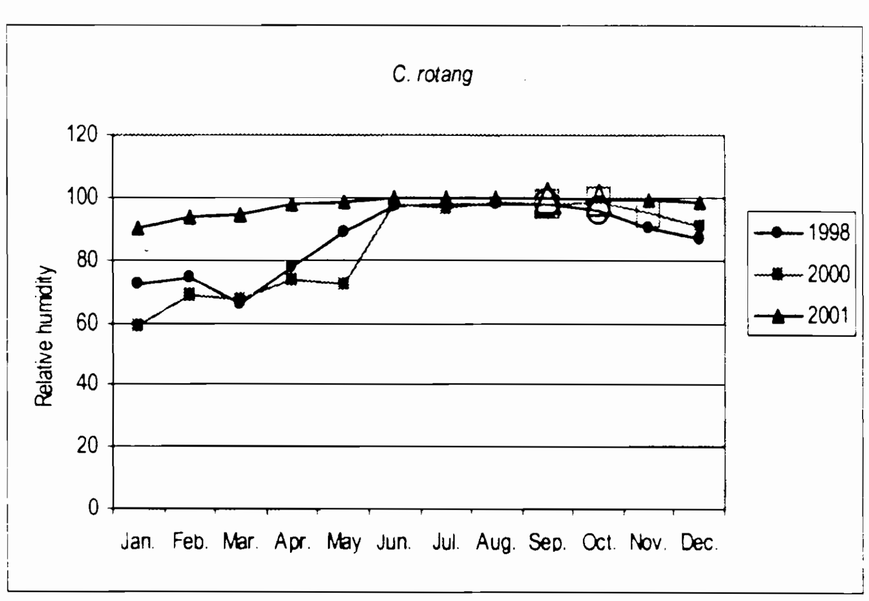


Fig. 5. Correlation between flowering and total rainfall
(○, △,□ - flowering months)







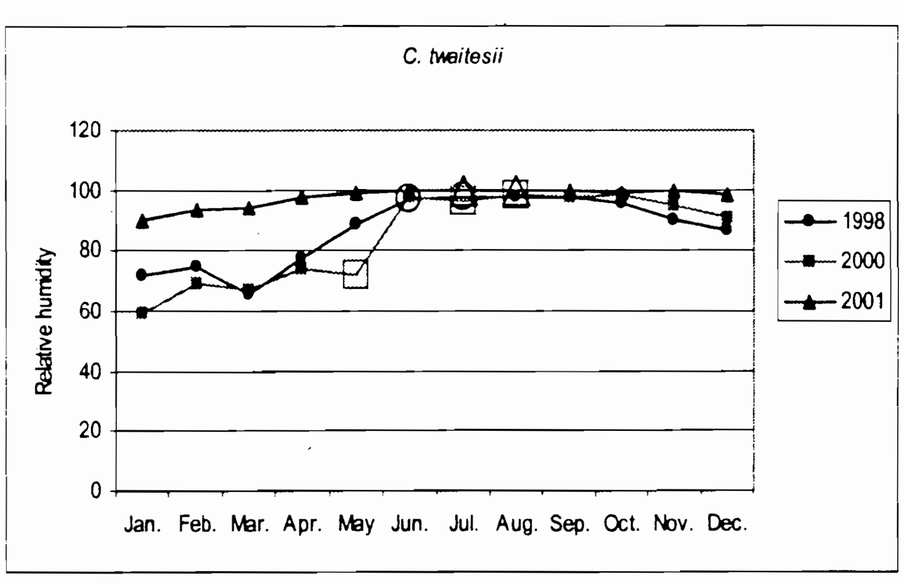


Fig. 6. Correlation between flowering and relative humidity
(○, △,□ - flowering months)

Table 13. Correlation of weather fluctuations and initiation of flowering

Month	*C. hookerianus*			*C. thwaitesii*			*C. pseudotenuis*			*C.rotang*			Wind(m/s)			Temperature(^{0}C)			Humidity(%)			Total rain(mm)		
	1998	2000	2001	1998	2000	2001	1998	2000	2001	1998	2000	2001	1998	2000	2001	1998	2000	2001	1998	2000	2001	1998	2000	2001
Jan.				♀			♂						1.8	NR	2.0	17.5	28.0	26.4	71.8	59.0	90.2	0.0	0.0	0.0
Feb.								♂					1.6	NR	0.9	17.4	28.1	27.4	74.5	68.9	93.6	7.8	4.6	26.1
Mar.													1.5	NR	0.8	19.1	29.7	28.0	65.8	67.3	94.3	0.0	0.0	26.3
Apr.		♂♀	♂♀										1.9	NR	0.5	19.5	29.3	28.1	77.7	73.7	97.5	28.2	67.9	271.4
May		♂♀	♂♀	♂	♂♀	♀							2.3	NR	0.6	18.8	29.6	27.9	88.6	72.0	98.8	3.8	117.2	298.8
Jun.	♂♀	♂♀	♂♀	♂♀	♂	♀							5.4	0.3	0.6	16.6	26.1	25.4	96.8	97.9	99.9	1284.1	214.8	987.1
Jul.	♂♀	♂♀	♂♀	♂♀	♂♀	♂♀	♀		♂♀				4.8	0.6	0 6	16.0	25.5	25.1	97.5	96.5	100.0	1114.4	92.0	423.0
Aug.	♀	♂	♀	♂	♂♀	♂♀	♂♀	♂♀			♂		3.1	0.6	0.6	16.3	25.1	25.6	97.8	98.4	100.0	496.8	550.3	287.4
Sep.										♂♀	♂♀	♂♀	3.6	0.6	0.5	15.8	26.1	26.2	97.5	97.8	99.7	441.0	196.6	180.3
Oct.										♂♀	♂♀	♂♀	3.1	0.5	0.5	16.0	25.7	26.3	95.6	98.2	99.0	511.2	162.3	199.2
Nov.	♂	♂	♂	♀							♂♀		2.2	1.3	0.9	16.1	26.4	26.4	90.1	94.9	99.5	103.0	30.7	149.8
Dec.	♂	♂	♂	♀									3.5	1.8	2.2	15.9	25.2	26.0	86.5	91.0	98.4	50.0	33.9	0.0

♂ - Male ♀ - Female

Development of inflorescence

The development of inflorescence was of the same pattern in all the species. The first indication of flowering was seen as slight inflation of the bracts which ensheath the basal part of the partial inflorescence. The development of the partial inflorescence and the rachillae on it were acropetal. It took more than one month to complete the emergence of all partial inflorescences and rachillae.

In the flowering, four stages of development could be recognized. The first was the emergence stage where inflorescence emerged from leaf sheaths and completed the development of the rachillae. Second was the pre-anthesis stage, when the flowers were developed on the rachillae. Third was the anthesis stage, where the male flowers opened releasing pollen and female flowers were receptive to pollen. The final stage was the post-anthesis stage, where the male inflorescence started to dry out and the fertilized ovary started to develop into fruit.

The period from the first to the second stage was more than one month. Development of fruits could be detected by the naked eye after the third month of emergence of the inflorescences. The size of the fruits increased gradually until the 5^{th} month in the case of *C. rotang* and 8^{th} month for the other three species, when most of the fruits reached their maximum size. The fruits needed some more time to complete the ripening and the colour of the fruits changed from pale-green to straw-yellow. The time taken from emergence of inflorescence to fruit maturity was about nine months in *C. hookerianus,* eight months in *C. pseudotenuis,* 11 months in *C. thwaitesii* and six months in *C. rotang.*

Male inflorescence

In the male inflorescence the flowers were borne on second order of branching in *C. thwaitesii* and third order of branching in all other species (Figs. 7 & 8). The number of male flowers in the species varied from hundreds to thousands depending on the number of rachilla and the length of the inflorescences. The flowers were closely aggregated on the rachillae. Aloysius (1996) reported that in most of the species of *Calamus* and *Daemonorops* the male flowers were borne on branches of the third order.

Anthesis

No sequence of opening was evident as anthesis progressed (Figs. 9-11). In *C. thwaitesii* anthesis in male flowers commenced even before the flowers began to

spread their petals. The anthesis of the individual flowers began around 1 AM and most of the flowers opened by 4 AM (Figs.12-13). In the other three species the opening of the flowers did not take much time and all the flowers opened around 4 AM. Here anthesis immediately followed the opening and all the pollen was shed within 3-4 hrs. Large amount of pollen was available. When the flowers opened, it exuded a droplet of nectar at the base. Before opening, the inflorescence emitted a strong, sweet scent smell. This smell was strong throughout the night and diminished gradually by day time. Following anthesis when most of the pollen had been shed, the flowers shrivelled and fell off. The longevity of the flowers was about 12 to 18 hrs. Anthesis of the whole inflorescence lasted for 12 to 15 days.

Reports on other species of rattans also show that in all the species the flowers open during night time. In *C. subinermis* male flower took about 20 minutes to open and most of the flowers opened between 6 and 8 PM (Alloysius, 1996). Following anthesis, the flowers shrivelled and fell off between midnight and 6 AM (Lee and Jong, 1995). Observations made by Bogh (1996) on four *Calamus* species in Thailand revealed that anthesis of male flowers occurred between 10 PM and 6.30 AM and most of the anthers were empty and the male flowers dropped off by sunset around 6.30 PM. In all cases reported, during the opening of staminate flowers, nectar was produced and a strong fragrance emitted.

Ultrastructure of pollen grains

Pollen morphology was similar in all the species studied.

Pollen grains were prolate, spheroidal or spherical; equatorial and polar outline elliptic, notched at both sides and dicolpate. Sculpturing was microreticulate (Figs.14-15). The pollen is somewhat oval with pointed polar ends and with a prominent stalk like structure which appeared as electron dense. Pollen wall was semitectate and collumellate with well developed foot layer. Dicolpate nature of pollen of *Calamus* has also been reported by Zavada (1983) and Thanikaimoni (1970).

The dorsal side of the pollen grain showed a perforated pattern indicating the furrowed tectum. Each perforation has an average pore size of 0.5 to 0.7 µ. The rich distribution of perforation on the pollen surface and stalked nature are adaptations to biotic means of pollination.

The pollen grains of *C. hookerianus* and *C.pseudotenuis* measured about 40 µm x 43 µm and that of *C. thwaitesii*, measured 44.5 µm x 43.5 µm. Sculpturing was

microreticulate in all species studied. The size of the pollen grains was reported in some other rattan species (Lee and Jong, 1995) and a comparison shows that the pollen grains of the four species studied are larger than many of the South East Asian species. Lee and Jong (1995) reported the pollen grains of *C. subinermis* and *C. caesius* to be round or elliptic and of 15-25 microns. Bogh (1996) reported the diameter of the pollen grains of *C. manan* as 70-100 microns. He has also studied the pollen grains of *C. peregrinus*, *C. rudentum* and *C. longisetus* and the diameter of the grains was found to be 32-33 µm; 26—29 µm and 27 µm respectively. There is a wide range in the size of pollen in the Palmae, with the equatorial diameter ranging from 20 µ to 75 µ (Sowunmi, 1968). In the present study the pollen grains are comparatively larger than that of *C. peregrinus*, *C. rudentum, C. longisetus, C. subinermis* and *C. caesius* but smaller than that of *C. manan*.

Female inflorescence

In the female inflorescences, the flowers were borne on second order branching and the female flowers were subtended at their base with a sterile male flower (Fig. 16).

Anthesis

Anthesis in the female flowers mostly occurred at 4 AM and senescence and abscission between 6 and 8 PM. Anthesis in the female flowers resulted in the emergence of receptive stigma which were bright, hyaline and adaxially covered with a liquid film (Figs. 17). The loss of the receptivity was characterized by the disappearance of fragrance and stigmatic liquid and by the colour change of the stigmas from white to brown and later to reddish black (Figs. 18). Pistillate flowers did not produce nectar. The longevity of flowers was similar in all the species studied and anthesis lasted for 12 to 15 days in an inflorescence.

Sterile male flower

The behavior of the sterile male flowers on the female inflorescence during anthesis was the same as that of the fertile males, except that no pollen was produced by the staminodes which bore empty anthers. Like male flowers, these flowers also produced nectar. There was no particular time for the opening of the sterile male flowers. It was observed that in different parts of the same inflorescence few flowers opened before the anthesis of pistillate flowers and in certain other parts they opened after the stigma of pistillate flowers turned black in colour. Similar observations are recorded by Dransfield (1984) and Lee and Jong (1995) in *C. subinermis* and *C. caesius.*

In Monocotyledons, the common position of the nectariferous tissue is in the ovary (septal nectaries). This may develop between stipes with opening below the stigmatic lobes opening by the pores on the surface of the gynoecium. But in Calamoideae septal glands are absent (Renuka, 1981: Renuka and Manilal, 1986). Thus the absence of nectar glands in the female flower is compensated by the sterile male flower.

Ovary and ovule

The ovary comprised of three carpels in all the species. Placentation of the ovules was axile. During the course of development, two ovules degenerated and only a single ovule developed into seed (Fig.19). The ovules were anatropous and were curved downwards by approximately 180° (Fig. 20).

Ultrastructure of style and stigma

The stigmatic surface contained a lot of lobes which appeared as tubular frills with a groove in the centre (Figs. 21 - 22). The lobed structures on the ridges of stigma indicates insect pollination. The style was solid and was composed of parenchymatous cells.

Method of pollination

In all the species studied, the male inflorescences during anthesis were predominantly visited by a species of *Drosophila* (Dyptera), honey bees, wasps (Hymenoptera) and ants. Later in the day, hymenopterans became rarer, whereas a few flies were present until sunset. Worker ants (Hymenoptera) were seen crawling during the morning hours in the male and female inflorescences. In the female inflorescence, mainly wasps and Drosophila were observed, but none of the these were abundant.

The body of the insect visitors sampled from the pistillate inflorescences did not show any pollen grains. Pollen collected with transparent adhesive tape from near the female inflorescences showed the presence of pollen grains of *Calamus* species. The pollen grains were powdery and produced in large quantity in all species. Even though the structure of pollen and stigma suggest the possibility of insect pollination, other evidences show that the pollination is also by wind. Event hough the inflorescences are visited by *Drosophila* species, honey bees and ants, it seems that they are attracted by the sweet scent and the nectar produced by the male flowers.

In all the species studied, the morphology of the flower presented several features of the wind pollinated plants, viz. the production of large quantity of powdery, non-sticky, yellowish-white pollen grains, a distinct exposure of anthers to the air, designed for scattering of pollen to the wind, the three tongue-like slightly curved stigma, well exposed at the time of fertilization and lack of showy, bright coloured floral parts. At the same time, the exine sculpturing and ornamentation of pollen grains and the lobed structures on the ridges of stigma show an affinity towards biotic pollination.

Even though the *Calamus* species studied have adaptations to both animophily and entomophily, it seemed anemophily worked better. Wind pollination was reported in *C. subinermis* and *C. caesius* also (Lee and Jong, 1995).

Pollen germination and viability

Pollen germination studied from the time of anthesis up to 18 hrs after floral opening with an interval of 2 hrs showed that maxium germination occurred at 8^{th} hr after anthesis in the case of *C. hookerianus* and *C. pseudotenuis,* 6^{th} hr in *C. rotang* and at 2^{nd} hr in *C. thwaitesii* (Fig. 23). Pollen viability was lost after about 12 hrs from the time of anthesis.

Mature embryo

Embryo development was similar in all the species studied. The stem tip was formed exactly at the terminal pole of the embryo (Fig. 24). During further development, the shoot apex came to lie deep within the cotyledonary lobes due to the over growth of the cotyledon and the terminally placed shoot apex slowly became shifted to one side of the embryo, (Fig. 25) turning through an angle of 90^0 .

Embryo development was relatively slow. In a 3 to 4 month old fruit, the embryo was still at the globular stage. Embryo development and endosperm development seemed to go hand in hand.

Lying opposite to the plumule was the radicle, directed towards the suspensorial region (Fig. 26). The developing root apex, also got shifted through an angle of 90^0 and in a mature embryo, was in line with shoot apex but on opposite side.

The bulk of the embryonic tissue was made up of the cotyledon, part of which extended laterally over and enveloped the plumule. The cotyledonary portion acted as a sucker. Except at the top, the embryo was flanked on all sides by the endosperm .

Formation of haustorium

During the germination of *Calamus* seed, a haustorium was developed by the progressive enlargement of the basal part of the embryo. At the initial phase of growth, the haustorium was a spongy, slightly ridged, pear-shaped structure having rough serrations over the surface (Fig. 28). The outer surface was marked by ramifying fissures. As germination proceeded, the enlarged haustorium was found to displace the endosperm almost entirely. The endosperm during this period was progressively disintegrated from the centre to make room for the haustorium (Fig. 29). After about one month of the onset of germination the spongy haustorium completely filled the seed cavity (Fig. 30).

When moisture reached the embryo it activated the growth of the cotyledon which in turn began to enlarge and digest the endosperm. The onset of enlargement in the haustorium was followed by growth in the lower part of the cotyledonary primordium as a result of which, a portion of the cotyledonary sheath, protruded out as a conical structure pushing out the pore cover.

During this period, the other part of the cotyledon enlarged, digested the endosperm and occupied the entire space within the seed, formerly filled by the endosperm. The endosperm was consumed completely by the time the first leaf was expanded (Fig. 30).

Fruit and seed

The shape and size of the fruit differ with species (Figs. 31 – 34). Fruits of *Calamus* consisted of a scaly pericarp and the seed was covered by a fleshy layer of sarcotesta. The scales were arranged in vertical rows (Figs. 35 & 36). The fruit of *C. hookerianus* measured 1 cm x 0.8 cm and was sub-globose with 18 rows of reflexed scales and that of *C. thwaitesii* measured 2 cm x 1.3 cm and was ovoid with scales in 12 vertical rows. Fruits of *C. pseudotenuis* were subovoid and measured 1.5 cm x 0.8 cm and the scales were arranged in 18 rows. In *C. rotang* fruits were ovoid with scales arranged in 21 rows and the fruits measured 1 cm x 1.2 cm.

The seeds were dorsi-ventrally differentiated and a well developed median groove was present on the ventral side which was filled with tannin cells (Figs. 37 & 38). The small, cylindrical embryo was positioned basally on the dorsal side of the seed, just below the "hylar plug" (Fig. 29). The micropylar region of the seed was covered by hylar plug. The cell of this plug was rich in tannin globules.

Storage of fruits and seeds

The fruits stored in the closed plastic bags under room temperature were found to be viable for 2 months. Seeds in air tight plastic bags kept in the refrigerator at 5 ^{0}C, maintained viability for 3 months in all species.

Reduction of the moisture content level of the seeds adversely affected their viability. All species showed 80-95 per cent germination in the fresh condition. The reduction of moisture content to 10 per cent resulted in the death of seeds. The tetrazolium test with seeds showed that viability was adversely affected by the decrease in moisture content and there was a gradual change in the colour of the embryo from deep red to pearl white through an intermediate red colour (Fig. 39). The seeds of *C. hookerianus* lost viability on the 12th day of collection and that of *C. thwaitesii* on the 10th day. *Calamus pseudotenuis* became non viable on 8th day and *C. rotang* on 13th day after collection. A correlation between moisture content and viability indicates that the seeds are recalcitrant.

Seed germination

The mode of seed germination was similar in all species. The germination of seeds was of adjacent ligular type. The first sign of germination was the development of a conical structure formed by a part of the cotyledon which came out through the thin tissue covering the pore (Fig. 40). This button-like structure carried the radicle and shoot apex from inside the seed. Root emerged first from this tissue through one side of the protrusion after 3-5 days, and later an upright cylindrical outgrowth or ligule was also formed from the tissue. The first eophyll developed after 40 – 50 days (Fig. 40 & 41).

CONCLUSIONS

Eight rattan species were evaluated for their performance at two different altitudes, 1000 m and 300 m, at Vazhachal and Nelliampathy. With regard to survival and total height, *Calamus baratangensis* was found to be the best species suited for higher elevations and *Daemonorops kurzianus* for lower elevations.

Seed stands for 12 commercially important rattan species were established. Nine species were planted at Kacchithodu, two at Nelliampathy and four species at Vazhachal. Of these, four species have started flowering and fruiting. In the germplasm collection, 30 species of rattans have been established, some of which also have started flowering and fruiting. *Calamus perigrinus*, a species introduced from Thailand, has also started producing fruits regularly.

Rattans are dioecious and flower annually. Age of the plant at first flowering varies according to species. The time of initiation of flowering also varies slightly with locality form year to year. But a correlation between flowering and climatic conditions showed that both male and female plants flowered simultaneously when the rainfall was in the range of 400-500 mm, relative humidity 100 per cent, wind speed up to 0.5 m/s and temperature up to 25 °C. Only *C. hookerianus* showed variation.

The time taken for emergence of inflorescence to fruit maturity was about nine months in *C. hookerianus*, eight months in *C. pseudotenuis*, 11 months in *C. thwaitesii* and six months in *C. rotang*.

Anthesis of flower takes place during night between 1 and 4 AM. All the pollen is shed within 3 to 4 hrs. Male flowers are scented and produce a droplet of nectar at the base of the flower. Female flowers do not produce nectar, but sterile male flowers produce nectar. Female flowers are receptive up to 12 to 14 hrs after opening. Pollen viability is lost in about 12 hrs from the time of anthesis.

Even though the species studied have adaptions to both anemophily and entomophily, anemophily is more common.

Embryo development is relatively low. The developing shoot and root apices get shifted through an angle of 90° due to the growth of the cotyledonary lobe.

During germination a haustorium is developed by the progressive enlargement of the basal part of the embryo. After about one month of the onset of germination the spongy haustorium completely fills the seed cavity.

The fruits stored in closed plastic bags under room temperature remains viable for two months. Seeds in airtight bags kept at 5 ^{o}C maintains viability for 3 months.

REFERENCES CITED

Agmato, A. 1984. Rapid germination method for Palasan, *Calamus merrillii* Becc. seed. Technical paper. 10th Annual FORI Anniversary Research Symposium, College, Laguna, pp 15-19.

Alloysius, D. 1994. Flowering and fruiting pattern of *Calamus caesius*. PISP Report, No.1/94. pp 1-7.

Alloysius, D. 1996. Rattan reproductive biology. Quantitative measurement of female inflorescence and variation in male inflorescence of *Calamus subinermis*. PISP Report, pp 1-10.

Alloysius, D. 1997. Reproductive biology of rattans. *In* : A.N. Rao, V.R. Rao (eds.) Rattan : Taxonomy, Ecology, Silviculture, Conservation, Genetic Improvement and Biotechnology. Proceedings of Training courses cum workshops, 14-26 April 1996, Sarawak, Sabah. IPGRI-APO, Serdang, Malaysia. pp 137-145.

Alloysius, D. 1999. Reproductive Biology of *Calamus manan* Miq. Abstract of thesis presented to the Senate of University Putra, Malasia in fulfilment of the requirements for the degree of master of science. Malaysia. pp 12-13.

Bagaloyos, A.P. 1987. Rattan seed collection and storage. Rattan Information Centre. Occasional paper, No. 5, Kuala Lumpur, Malaysia. pp 7-12.

Banik, R.L. and M.N. Nabi. 1981. An observation on the flowering time and seed germination in bara bet *Calamus viminalis* var. *fasciculatus* (Griff.) Becc. In: R.L. Banik and M.N. Nabi (eds.). Proceedings of the 4th and 5th Bangladesh Science Conference, Rajshastri, Bangladesh, 2-5 March, 1980. pp 52-56.

Basu, S.K. 1992. Rattans (Canes) in India - A monographic revision. Rattan Informaton Centre, Kepong, Kuala Lumpur. 141 p.

Bogh, A. 1996. The reproductive phenology and pollination biology of four *Calamus* (*Arecaceae*) species in Thailand. Principes, 40(1) : 5-15.

Darus, H. A. and A.G. Rasip, 1989. Flowering and fruiting in *Calamus manan* Miq. RIC Bull. 8 (1/4): 2.

Dransfield, J. 1979. A manual of the rattans of the Malay Peninsula. Forest Department, Ministry of Primary Industries, Malay. For. Rec., 29: 270 p.

Dransfield, J. 1984. The rattans of Sabah. Sabah Forest Records No.13. Forest Department, Sandakan.

Falk, R.H. 1980. Scanning electron microscopy (SEM) INC., AMF O'Hare, Chicago, IL-60666, U.S.A. pp 79-87.

Generalao, M.L. 1977. Effect of pre-treatment media on the germination of Palasan (*Calamus maximus* Becc.) and Limuran (*C. ornatus* Blume) seeds at Pagbilao. Quezon, Sylvatrop Philipp. For. Res. J., 2: 215 – 218.

Girija, T., P.S. Srinivasan, M. Marzalina, K.C. Khoo, N. Jayanthi and B. Krishnapillay, 1998. Metabolic changes associated with desiccation in *Calamus* L. seeds. In: B. Krishnapillay (ed.). "Recalcitrant seeds". Proceedings of the IUFRO - Seed Symposium, Kuala Lumpur, Malaysia, 12-15 October, 1998. pp 25-28.

Guangtian, Y. and X. Huangcan, 2000. Suitable storage conditions for seeds of *Daemonorops margaritae* Becc. *In*: H.C. CXu, A.N Rao, B.S. Zeng and G.T. Yini (eds.). Research on Rattans in China. IPGRI. pp 35– 38.

Henderson, A., A. Scariot and M.P. Whitaker, 1989. The Ecology of the Palmae in an Amazon Rainforest. Projecto dinamica biologica de fragmentos florestais, BDFF. pp 1-12.

Johansen, D.A. 1940. Plant Microtechnique. McGraw Hill Co., New York. pp 23-110.

Lee, Y.F. and K. Jong, 1995. Longevity of *Calamus subinermis* H.A Wendl. and *Calamus caesius* Bl. flowers. Sandakania, No. 6: 1-14.

Manokaran, N. 1982. Survival and growth of Rotan sega *(Calamus caecius*) seedlings at $5^{1}/_{3}$ years after planting. Malay. For. 45(2): 193-202.

Manokaran, N. 1983. Survival and growth of Rotan semambu (*Calamus scipionum* Lour.) seedling at 7 years after planting. Malay. For. 46(1): 81-85.

Manokaran, N. 1977. Survival and growth of the economically important rattan *Calamus manan*, in Ulu Langat, Malay. For. 40(4): 192-196.

Manokaran, N. 1978. Germination of fresh seeds of Malaysian rattans. Malay. For. 41(4): 319-324.

Manokaran, N. 1985. Biological and ecological considerations pertinent to the silviculture of rattan. *In*: K.M. Wong and N. Manokaran (eds.) Proceedings of the Rattan Seminar, Kuala Lumpur. October 2 – 4, 1984. The Rattan Information Centre, FRIM, Kepong. pp 95 – 105.

Manokaran, N. 1989. Flowering and fruiting patterns in *Calamus caesius* Bl. *In*: A.N. Rao (ed.). Recent Research on Rattans, Proceedings of the International Rattan Seminar. Nov. 12– 14, 1987. Chiangmai, Thailand. Kasetsart University, Thailand and IDRC Canada. pp 122 – 129.

Mohd. Zaki, H.A. and J. Othman. 1998. Phenological observations on *Calamus palustris* Griff., *C. scipionum* Mart. and *Cocos nucifera* L. in Peninsular Malaysia. *In*: R. Bacilieri and S. Appanah (eds.). Rattan cultivation: Achievements, problems and prospects. An international consultation of experts for the project Conservation, genetic improvement and silviculture of rattans in South East Asia, Kuala Lumpur, Malaysia. 12-14 May 1998: pp 61-71.

Mori, T.H., A.R. Zollfatah bin, and C.H. Tan. 1980. Germination and storage of rotan manan (*Calamus manan* Miq.) seeds. Malay. For. 43(1): 44-55.

Raja-Barizan, R. S. 1992. Phenology of rattans. *In*: Wan Razalli Wan Mohd. (ed.). A guide to the cultivation of rattan. Malay. For. Rec. No. 35, FRIM, Kepong, Kuala Lumpur. pp 39– 46.

Renuka, C. 1981. Morphological studies in the family Palmae. Ph.D thesis submitted to the University of Calicut, Kerala, India. 240p. (Unpublished).

Renuka, C. 1992. Rattans of the Western Ghats- A taxonomic Manual. Kerala Forest Research Institute, Peechi. India . 61p.

Renuka, C. 1994. Genetic diversity and conservation of rattans. *In*: V. Ramanatha Rao and A.N Rao (eds.). Bamboo and Rattan Genetic Resources and Use. Proceedings of the first Rattan Biodiversity, Genetic Resousrces and conservation working Group. November 7–9, 1994. Singapore. IPGRI, Rome & INBAR. pp 39 – 41.

Renuka, C. 1995. Reproductive biology of rattans. *In*: J.T. Williams, I.V.R. Rao and A.N. Rao (eds.). Genetic enhancement of Bamboo and Rattan. INBAR, Technical Report No. 7, New Delhi. pp 135-141.

Renuka, C. 1995 *A manual of the rattans of Andaman and Nicobar Islands*. KFRI, Kerala. 72 p.

Renuka, C. 1996 Rattans of North Eastern India- A cause for great concern, *Arunachal Forest News* 14(2), 8-11.

Renuka, C. 1999. Indian rattan distribution An update. Indian For. 125(6) : 591-598.

Renuka, C. 2000. Field identification key for rattans of Kerala. Kerala Forest Research Institute. Peechi. 34p.

Renuka, C. and K.F. George 2001. Genetic conservation of rattans – A state of the art review (with an annotated bibliography) KFRI consultancy report No.1 (Part 2) 92p.

Renuka, C. and K.S. Manilal. 1986.Anatomy of the rattan flowers. RIC Bull. 5,(2): 1-3,8.

Renuka, C., E.P. Indira and E.M. Muralidharan. 1998. Genetic diversity and conservation of certain species of rattan in Andaman and Nicobar Islands and Southern India. KFRI Research Report, No.157. 25p.

Renuka, C. and P. Rugmini, 1996. Studies on the *ex-situ* performance of different species of rattans, Indian For. 122 (3), 235-240.

Renuka, C., N. Sasidharan and P.V. Anto. 1997. A new species of *Calamus* (Aecaceae) from Silent Valley, Kerala, India. Rheedea, 7(2): 69-71.

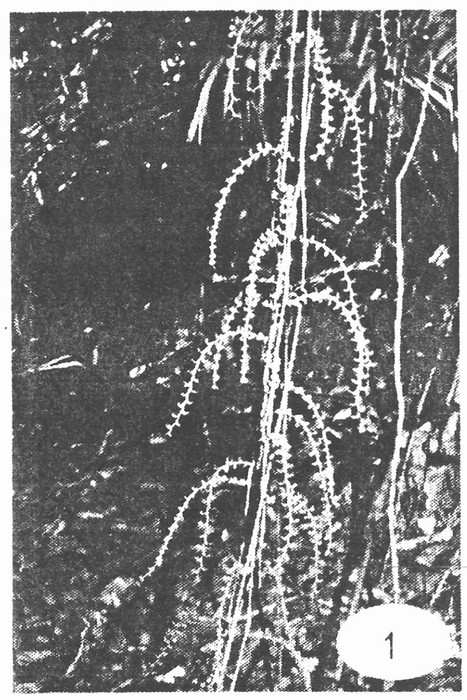
Sowunmi, M.A. 1968. Pollen morphology in the Palmae, with special reference to trends in aperture development. Rev. Palynol., 7: 45-53.

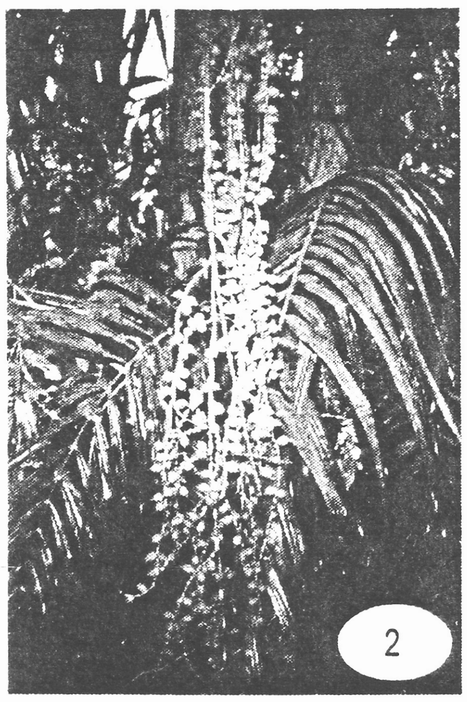
Sunny Thomas, K. Haridasan and S.K. Borthakur. 1998. Floristic study on rattans and its relevance in forestry of Arunachal Pradesh. Arunachal Forest News. 16(1&2): 19-24.

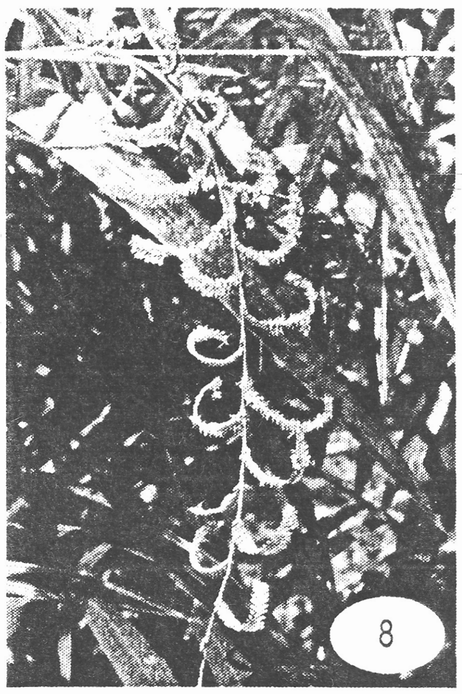
Thanikaimoni, G. 1970. Pollen morphology, classification and phylogeny of palmae. Adansonia, Ser. 2, 10(3): 347-365.

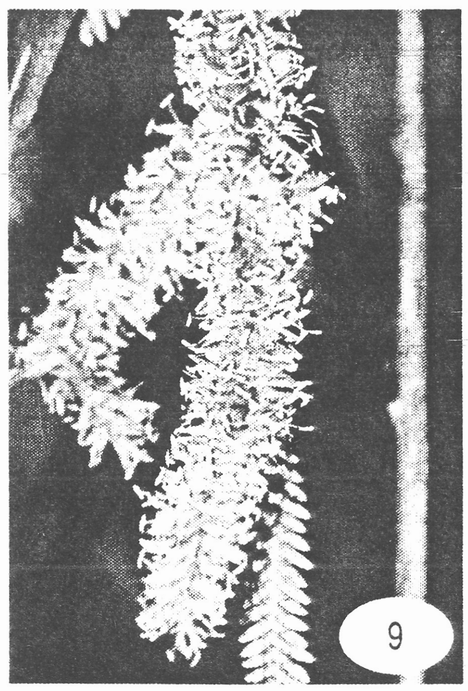
Uhl, N.W. and J. Dransfield. 1987. Genera Palmarum, The L.H. Bailey hortorium and the International palm society, Allen Press, Lawrence, Kansas. 610p.

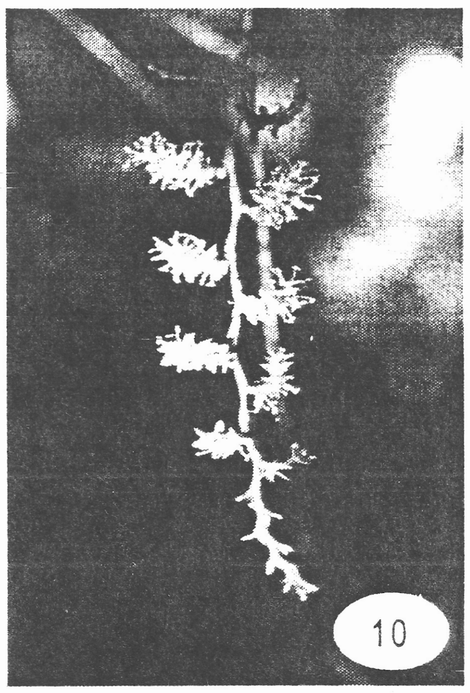
Zavada, M.S. 1983. Comparitive morphology of monocot pollen and evolutionary trends of apertures and wall structures Bot. Rev., 49(4): 331-379.

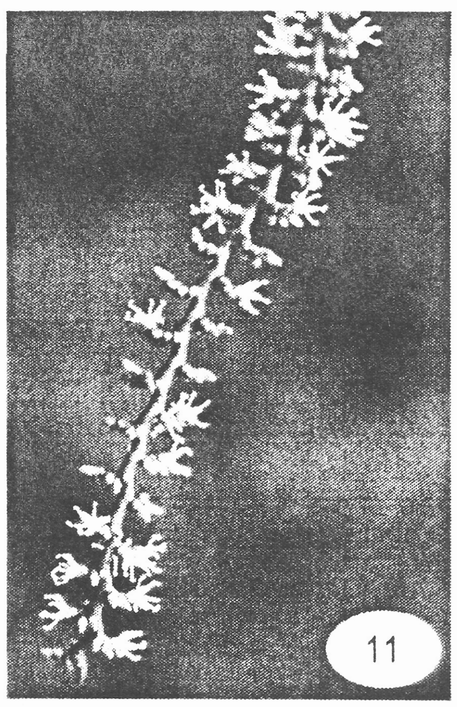


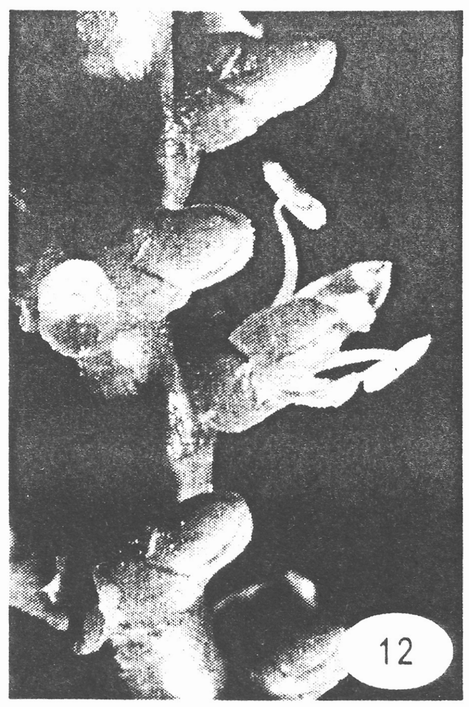












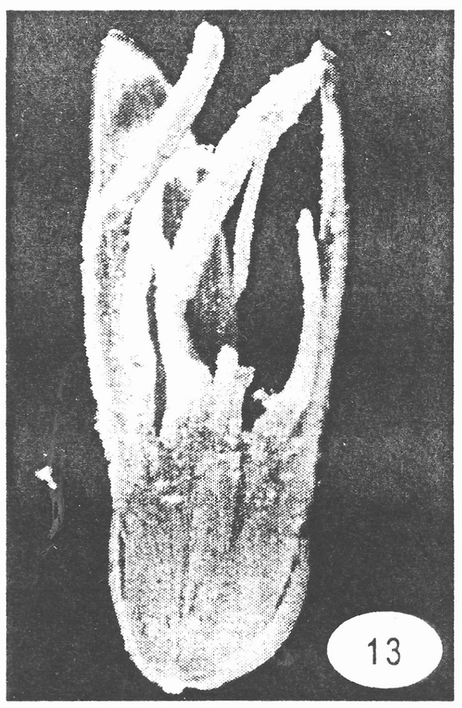
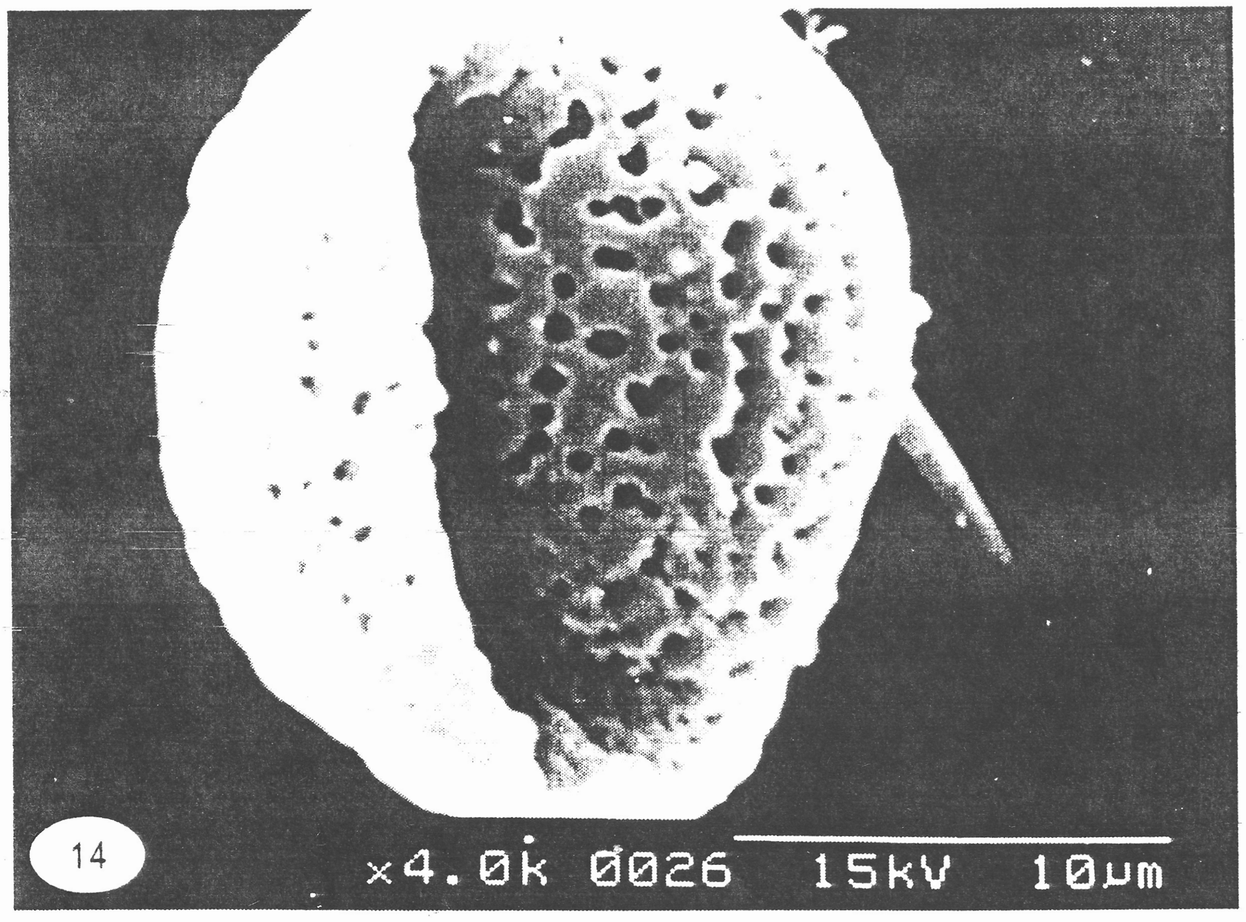


Fig. 1. *C. hookerianus* - Inflorescence
Fig. 2. *C. thwaitesii* - Inflorescence
Fig. 7. *C. psuedotenuis* – A partial inflorescence showing the 3rd order of branching
Fig. 8. *C. thwaitesii* – A partial inflorescence showing the 2nd order of branching
Fig. 9. *C. thwaitesii* – Male flower opened
Fig. 10. *C. rotang* – Male flowers
Fig. 11. *C. hookerianus* – Irregular opening of male flowers
Fig. 12. *C. hookerianus* - Male flower during anthesis
Fig. 13. *C. thwaitesii* - L.S of a male flower



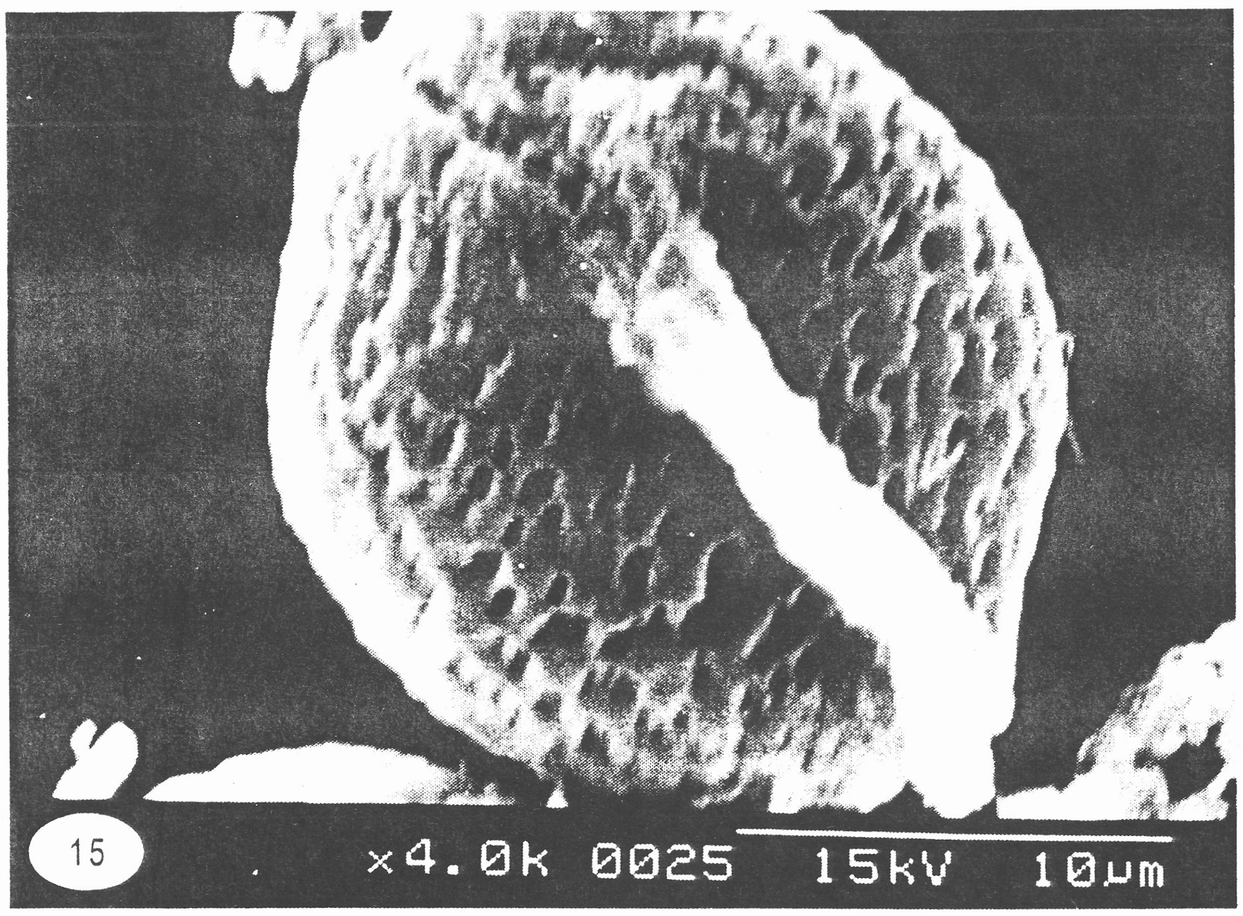
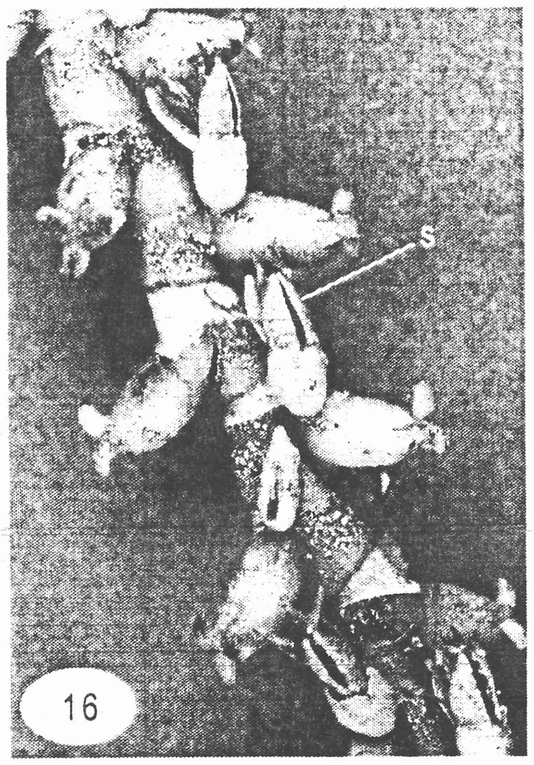
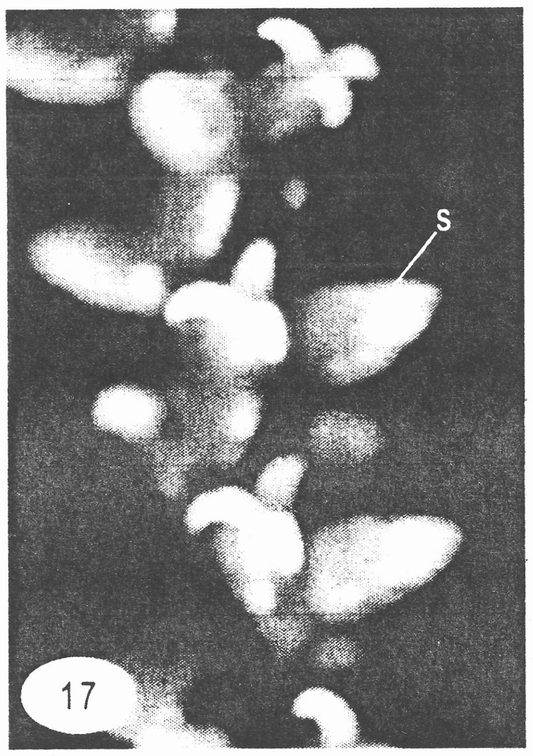
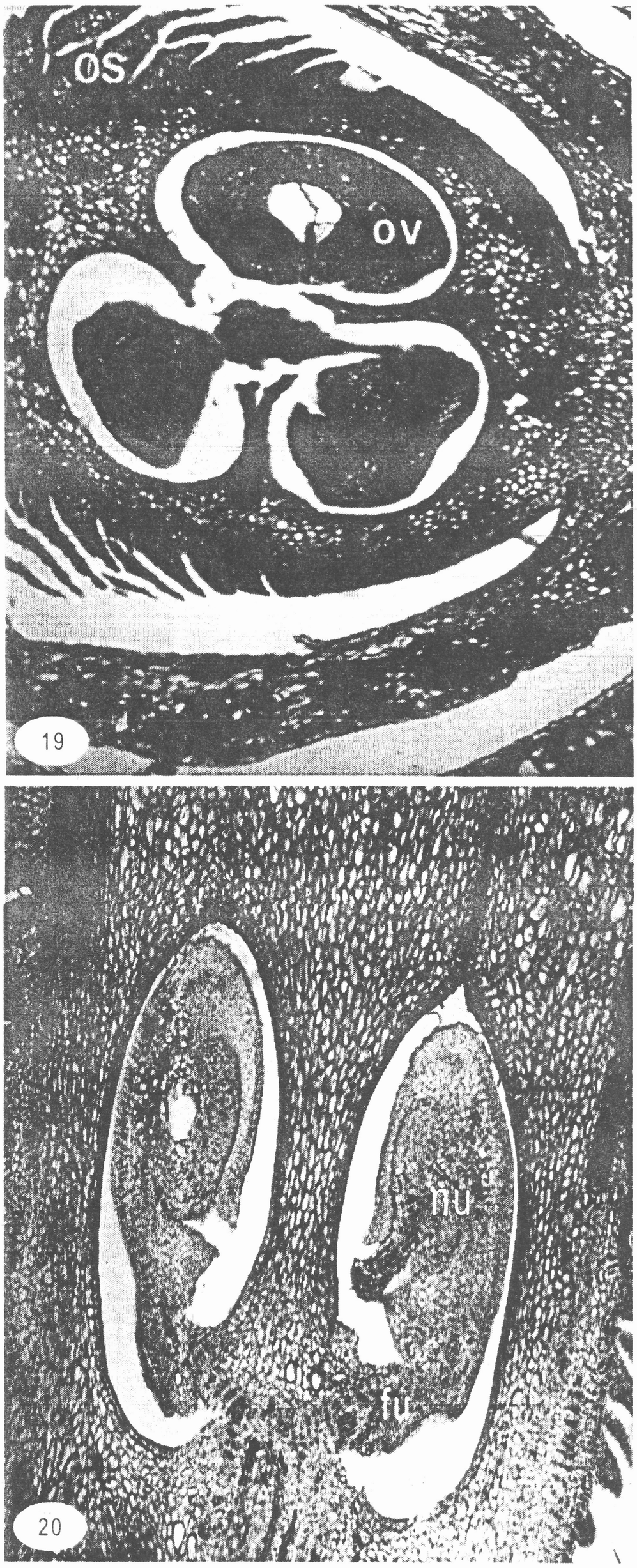
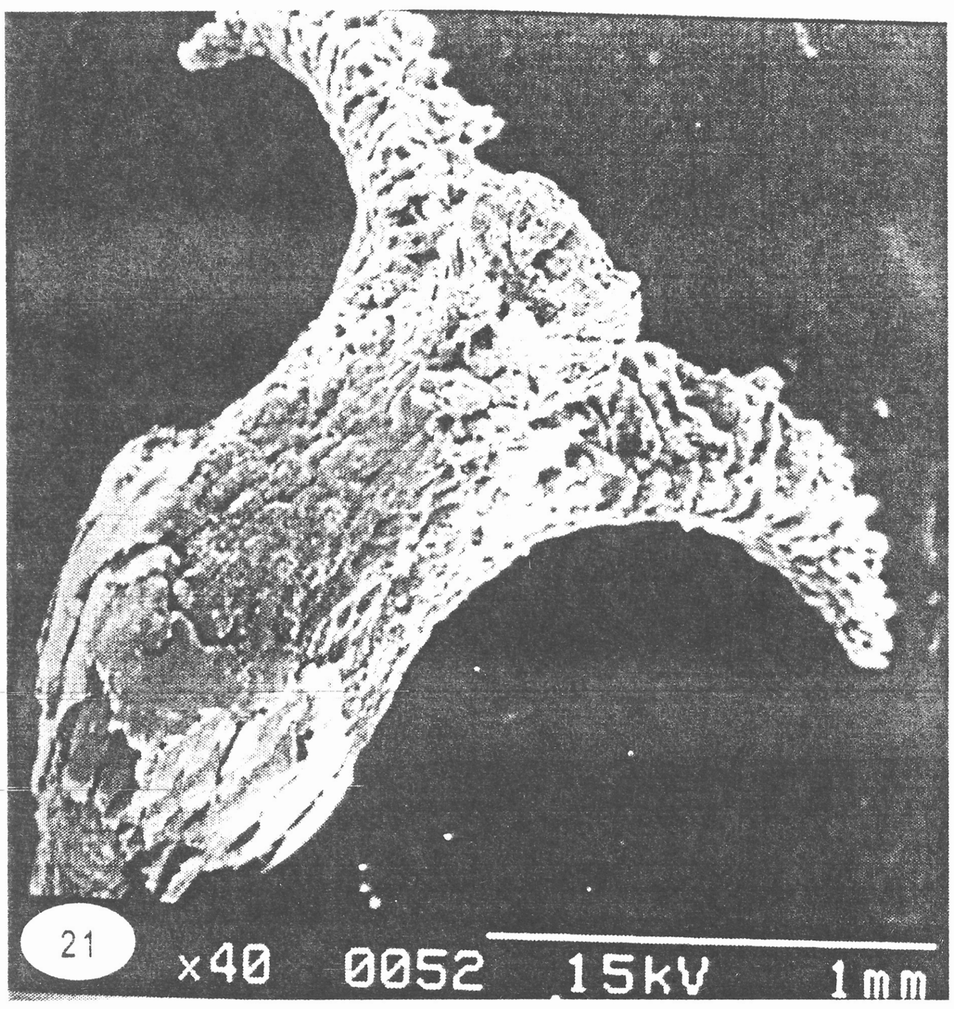


Fig. 14. *C. hookerianus* - Pollen grain, lateral view
Scanning electron micrograph
Fig. 15. *C. hookerianus* - Pollen grain, dorsal view
Scanning electron micrograph
Fig. 16. *C. thwaitesii* - A portion of female inflorescence showing female flower and sterile male flower
Fig. 17. *C. thwaitesii* - Female flower during anthesis
Fig. 18. *C. thwaitesii* - Female flower after anthesis
s - sterile male flower









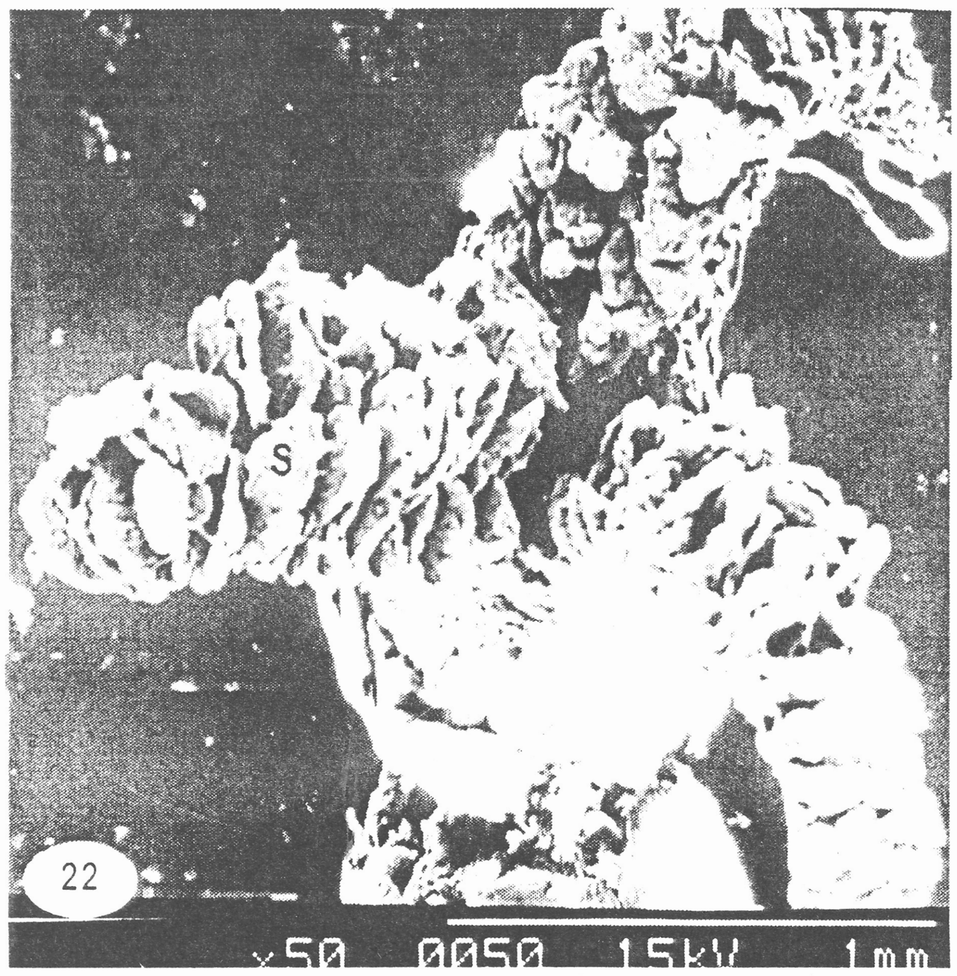
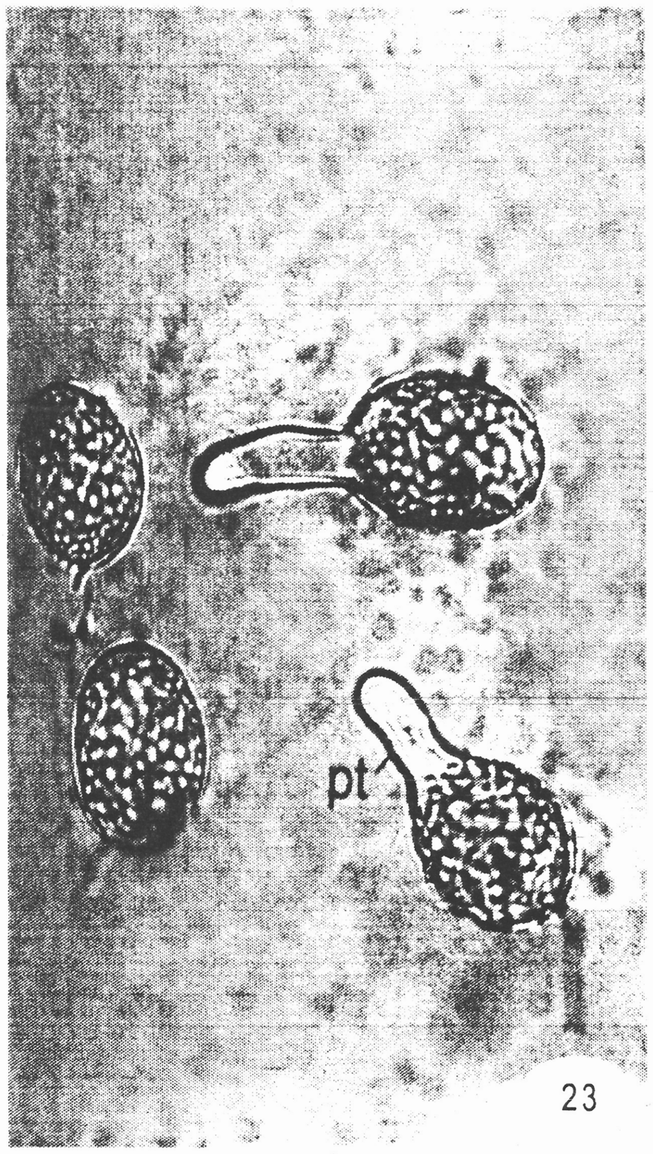


Fig. 19. *C. hookerianus* - T.S. of the ovary showing one developing and two degenerating ovules
Fig. 20. *C. thwaitesii* - L.S. of the ovary
Fig. 21. *C. hookerianus* - Scanning electron micrograph of pistil
Fig. 22. *C. hookerianus* - Scanning electron micrograph of stigma
ov - developing ovule os - ovular scales
fu - funicle nu - nucellus



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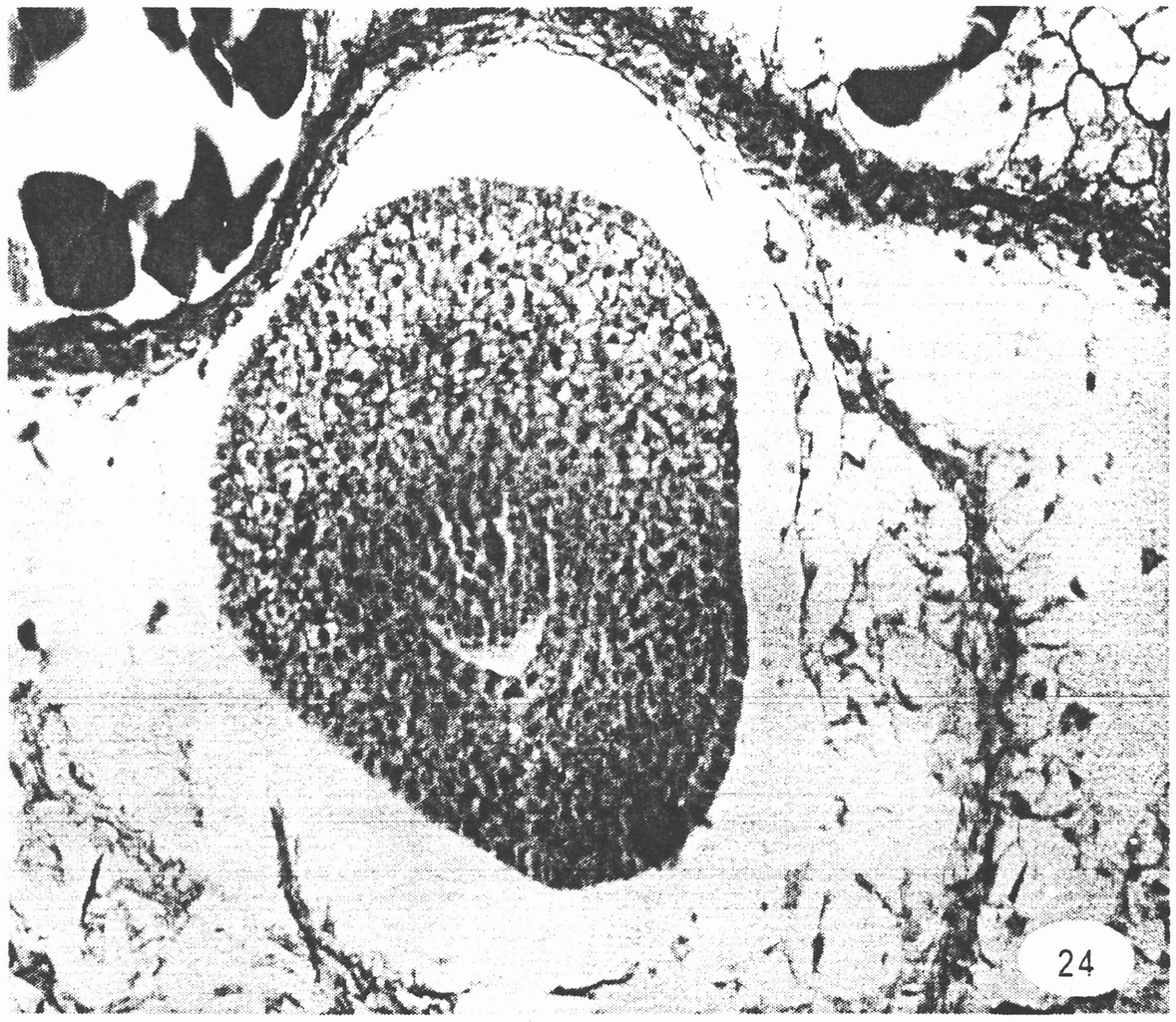

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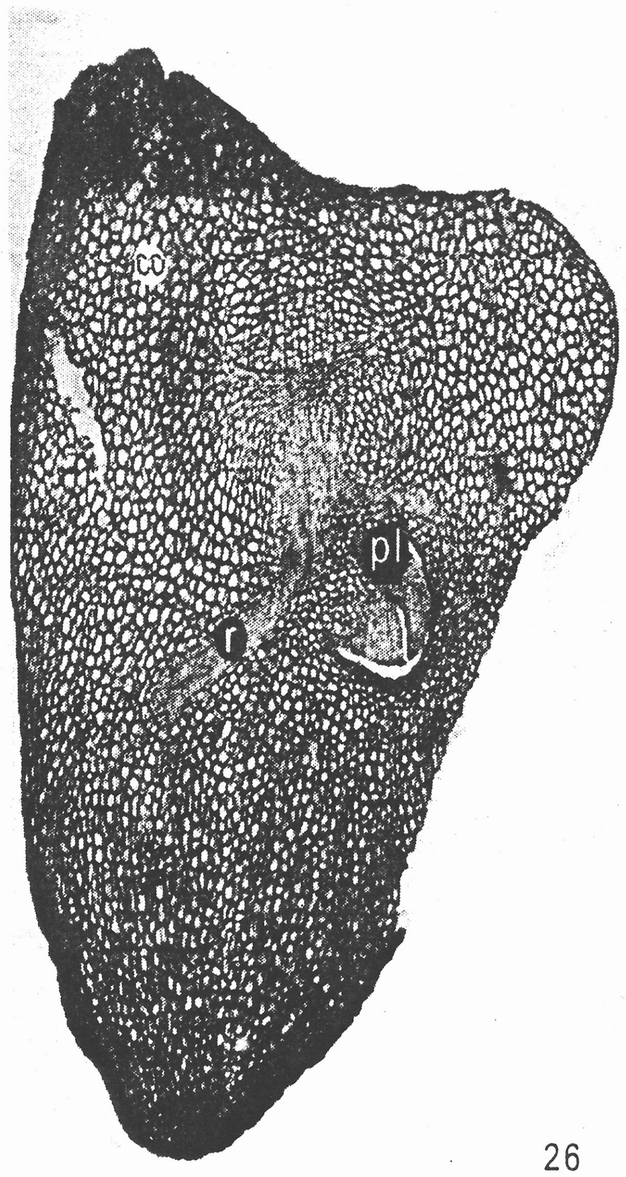

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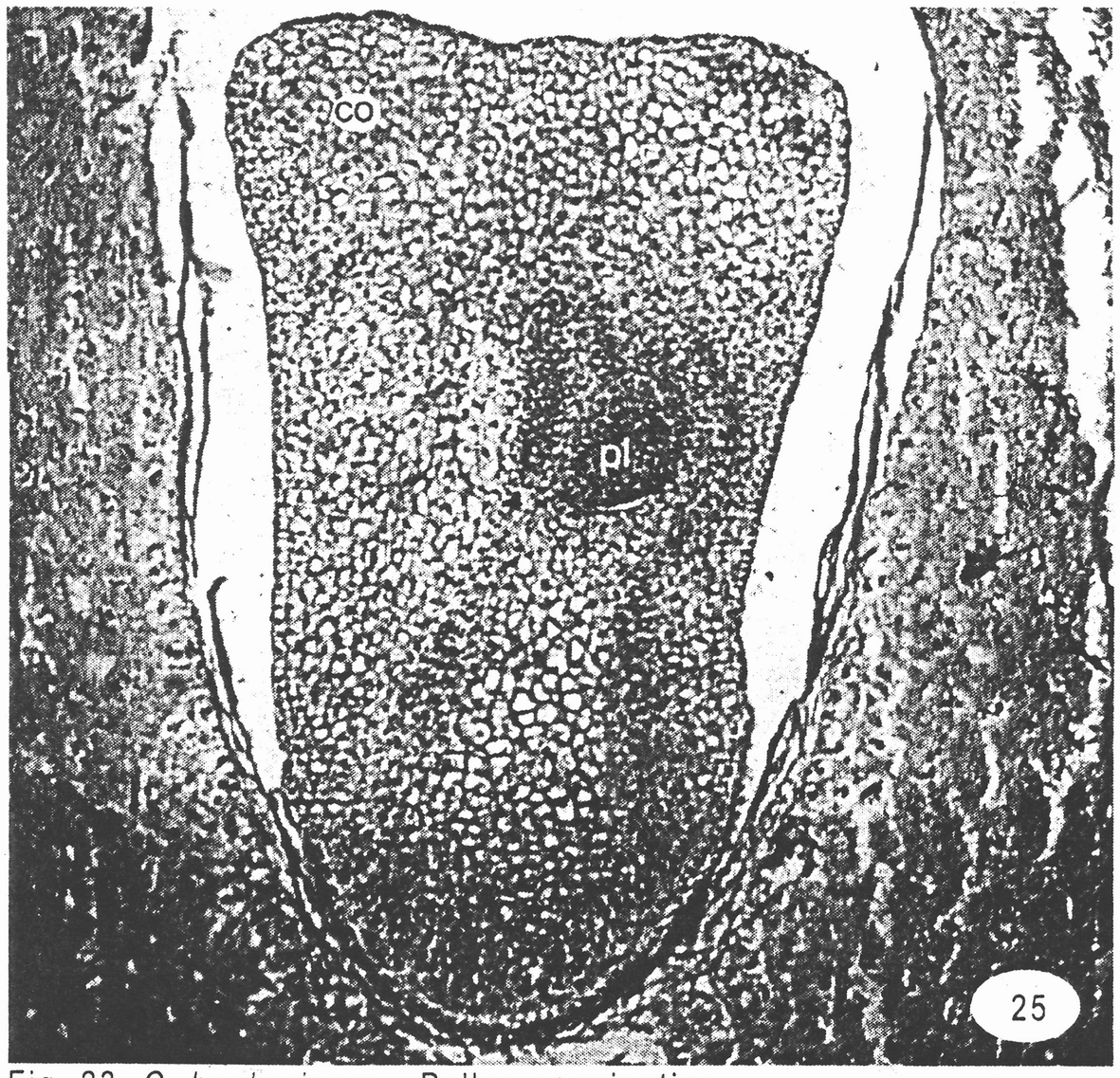
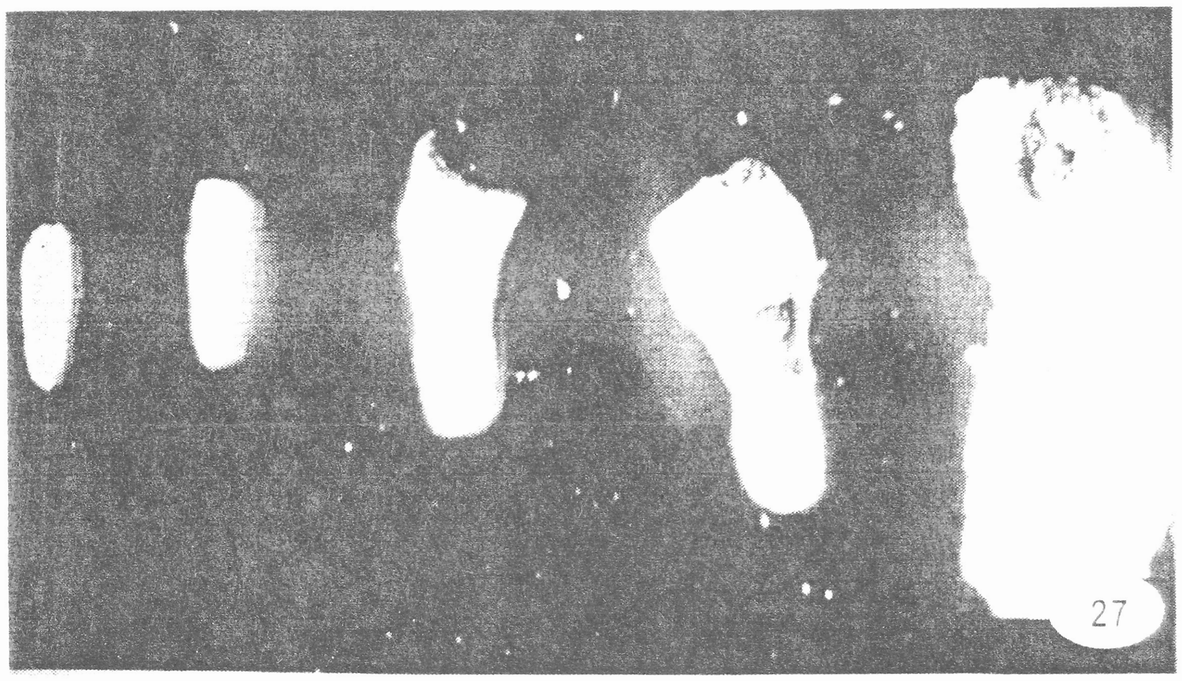
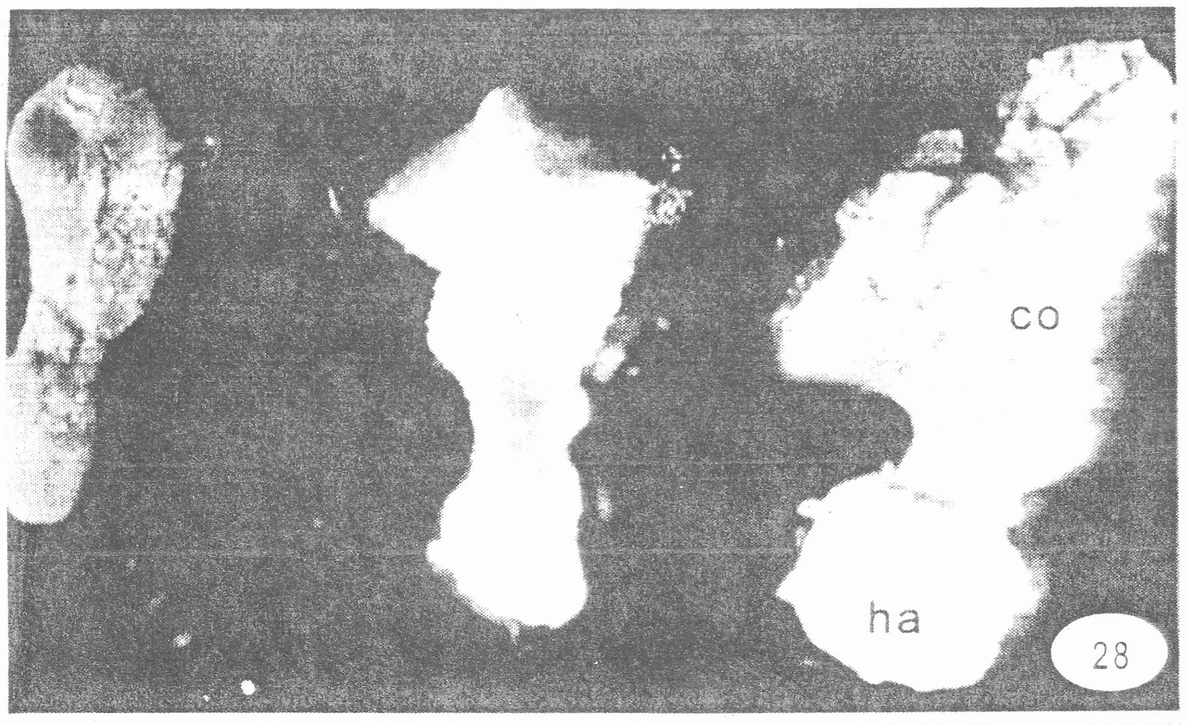
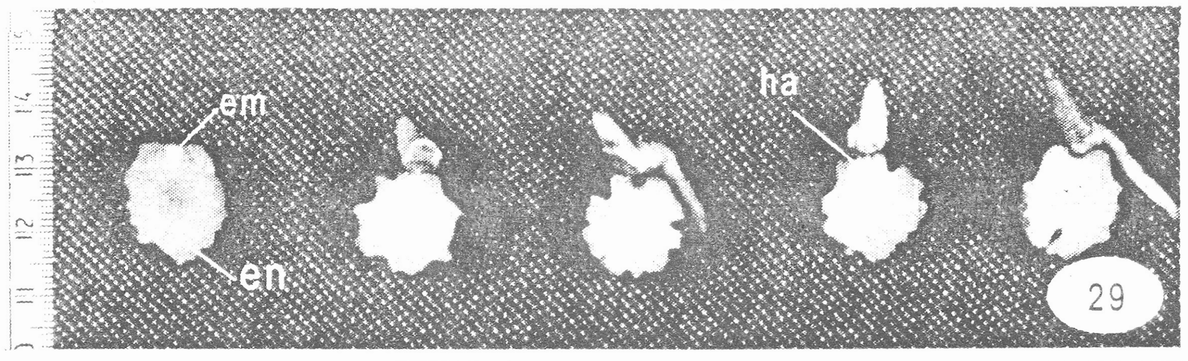


25

Fig. 23. *C. hookerianus* - Pollen germination.
Fig. 24. *C. hookerianus* - Embryo showing differentiation of plumule.
Fig. 25. *C. hookerianus* - Embryo showing plumule shifted to the side.
Fig. 26. *C. thwaitesii* - Embryo showing development of radicle
co - cotyledon pt – pollen tube pl - plumule r- radicle







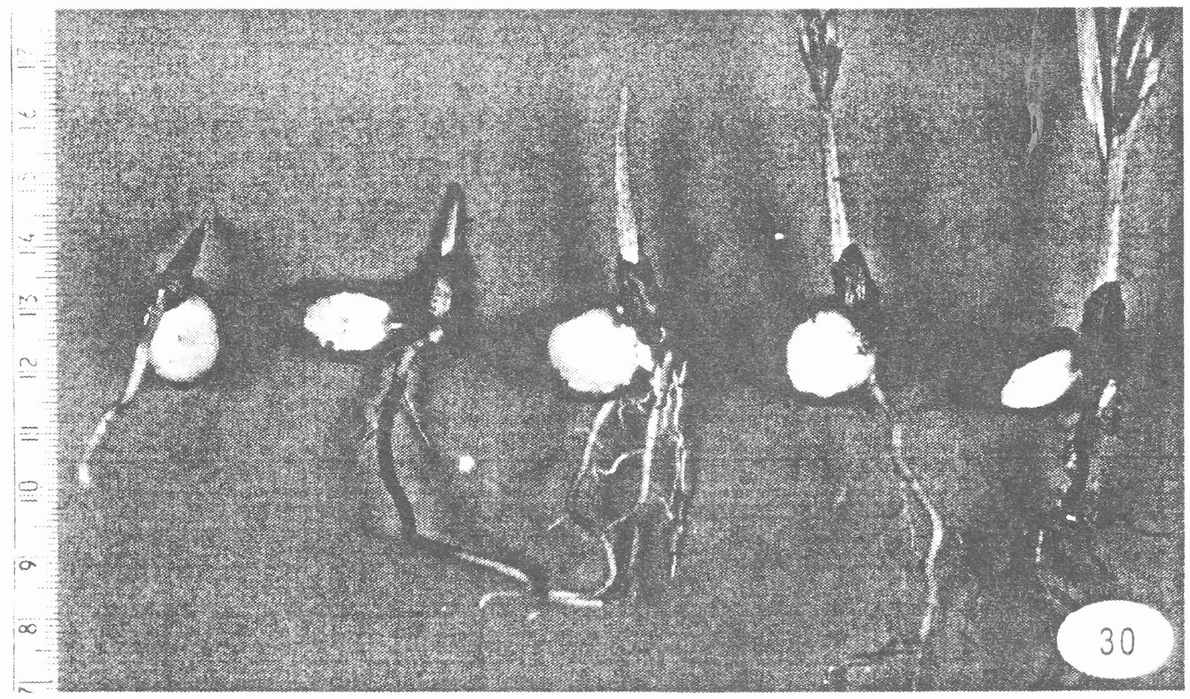
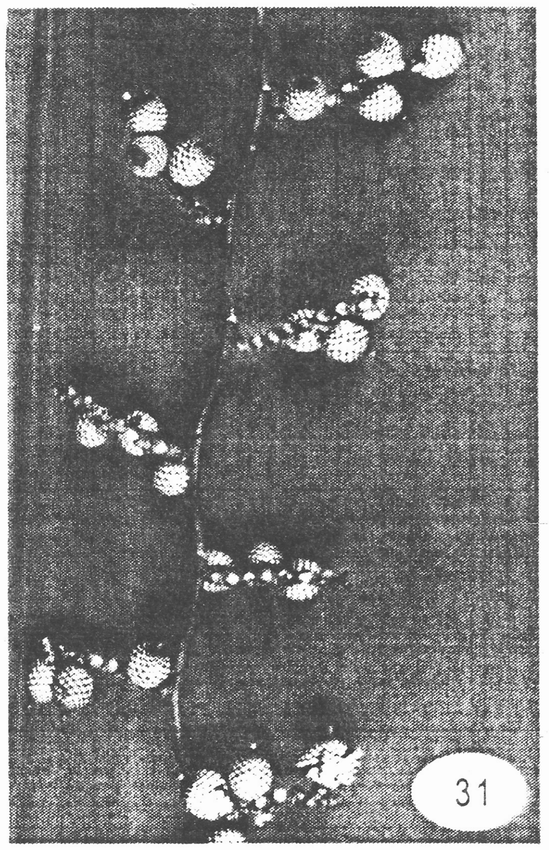
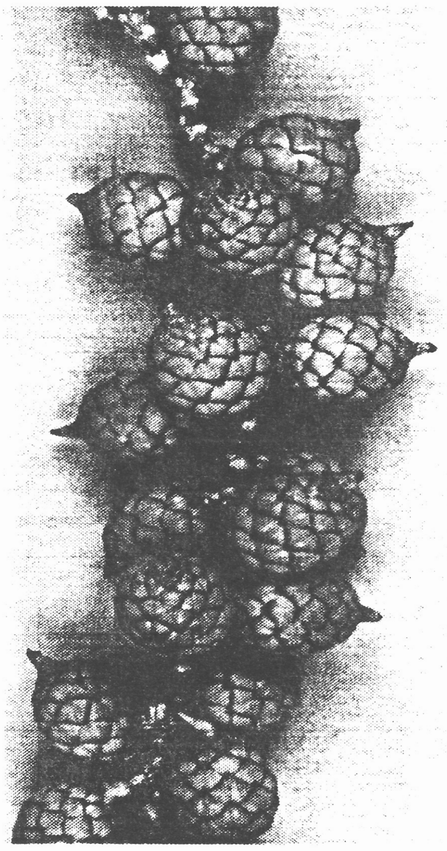
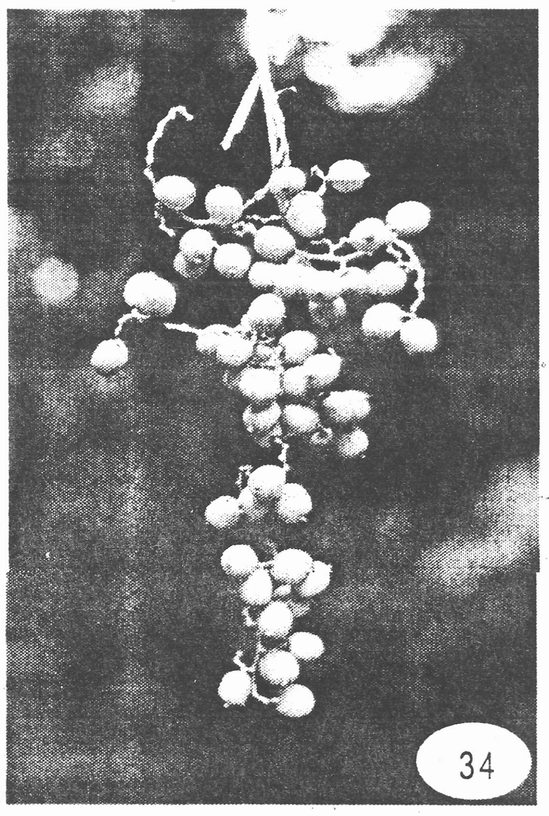
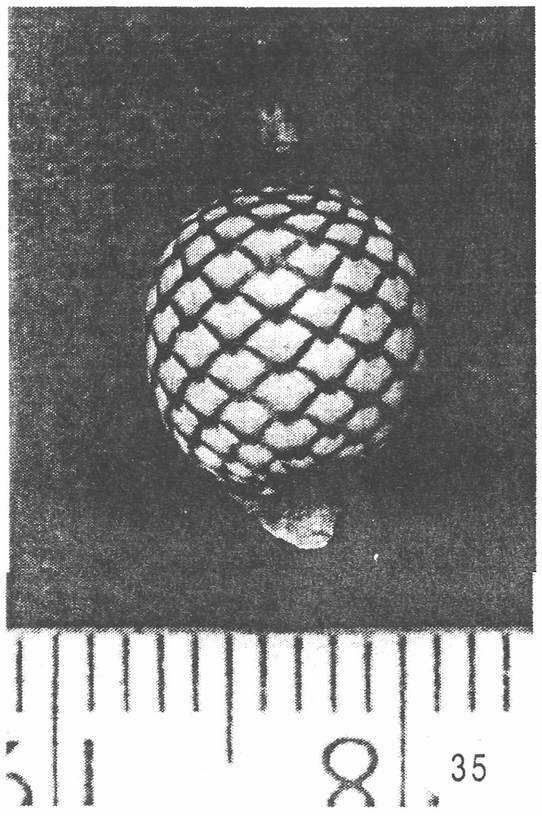


Fig. 27 & 28. *C. hookerianus* - Embryo showing development of haustorium
Fig. 29. *C. hookerianus* - Development of embryo and haustorium
Fig. 30. *C. thwaitesii* - The haustorium completely digest the endosperm by the time the first eophyll comes out
em-embryo en-endosperm ha-haustorium co-cotyledon









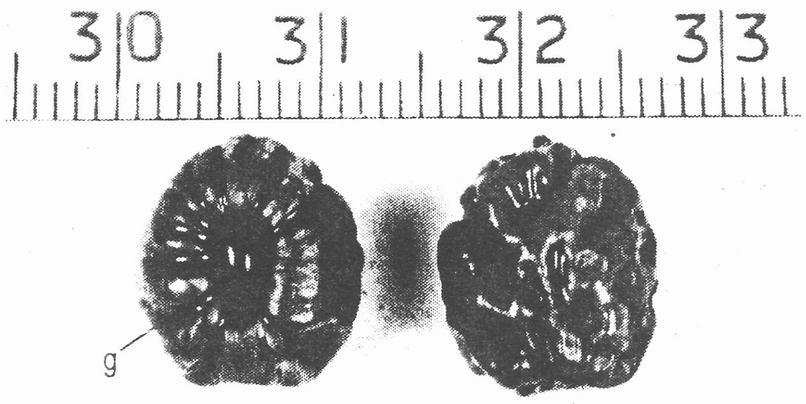


Fig. 31. *C. hookerianus* - Fruits
Fig. 32. *C. thwaitesii* - Fruits
Fig. 33. *C. pseudotenuis* - Fruits
Fig. 34. *C. rotang* - Fruits
Fig. 35. *C. pseudotenuis* - Single fruit enlarged
Fig. 36. *C. thwaitesii* - Single fruit enlarged
Fig. 37. *C. hookerianus* - Seed dorsal and ventral views
Fig. 38. *C. thwaitesii* - Seed dorsal and ventral views
v – ventral side d – dorsal side g - groove

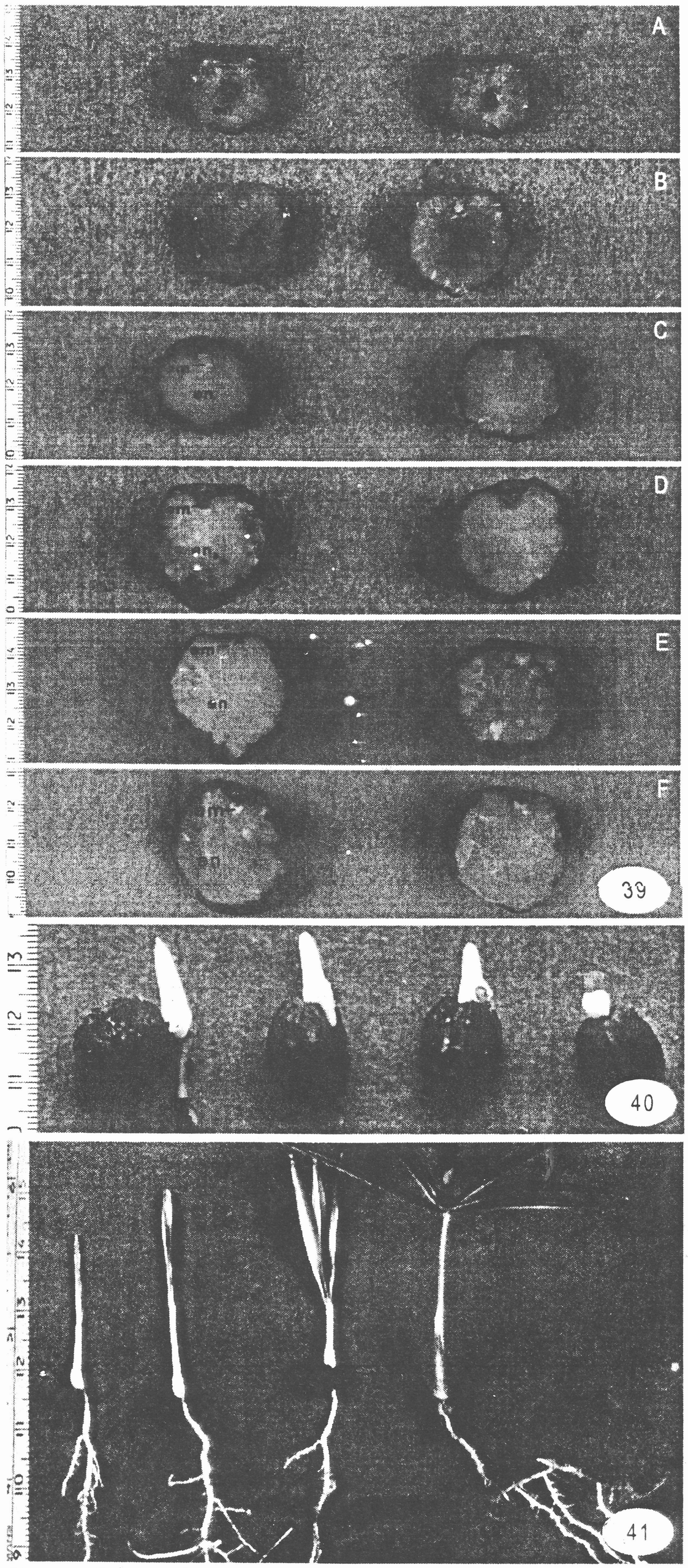


Fig. 39. Result of tetrazolium test
A-C -*C. hookerianus* D-F -*C. thwaitesii*

Fig. 40 & 41. *C. hookerianus* - Different stages in germination
em - embryo en - endosperm