БОТАНИЧЕСКИЙ ЖУРНАЛ, 2023, том 108, № 2, с. 163–170

СООБЩЕНИЯ

STUDIES ON THE EMBRYOLOGY OF *CALAMUS PRASINUS* (ARECACEAE) – AN ENDEMIC PLANT FROM THE WESTERN GHATS OF KARNATAKA

© 2023 г. H. N. Krishna-Kumar[1,*]

[1] Department of Studies in Biotechnology Pooja Bhagavat Memorial Mahajana Education Centre PG wing of SBRR Mahajana First Grade College (Autonomous) Affiliated to University of Mysore K.R.S. Road Metagalli, Mysore-570 016, Karnataka, India

**e-mail: hnkrishnakumars@gmail.com*

Received July 8., 2022
Revised December 23., 2022
Accepted January 17., 2023

The genus *Calamus* in the family Arecaceae is embryologically not well studied. The present work on the embryology of *Calamus prasinus* is the first investigation. A transverse section of young male staminate flower shows 6 tetrasporangiate anthers. The anther wall comprises an epidermis, an endothecium, a middle layer and a tapetum. The tapetum is of secretory type and its cells are 2–3 nucleated. The successive meiotic division in the pollen mother cells resulting in the formation of isobilateral and tetrahedral microspore tetrads. Occasionally, T-shaped and linear tetrads have been observed. The pollen grains are shed at 2-celled condition. The ovary is superior, tricarpellary, syncarpous and contains 3 ovules on an axile placenta. The ovule is anatropous, bitegmic and crassinucellate. The archesporial cell divides periclinally to form a primary parietal cell and a sporogenous cell. The sporogenous cell differentiates transformsin to megaspore mother cell, which undergoes meiotic division and subsequent cytokinesis forming a linear tetrad. The chalazal functional megaspore undergoes three successive mitotic divisions without cytokinesis that results in the formation of an 8-nucleate embryo sac. The embryo sac contains two synergids, one an egg cell at the micropylar end, three antipodal cells at the chalazal end and a central cell with two polar nuclei. The development of female gametophyte conforms to the *Polygonum* type.

Keywords: Calamus prasinus rattans, anther wall, pollen grains, ovule, female gametophyte.

DOI: 10.31857/S0006813623020072, **EDN:** EXIXET

The genus *Calamus* L. belongs to the family Arecaceae Bercht. & J. Presl. The family Arecaceae comprises about 212 genera and 3000 species (Takhtajan, 1987). The members of the Arecaceae commonly called Palms are particularly abundant in the Indomalayan region and South America. *Calamus* is a paleotropical genus with about 370 species distributed worldwide (Uhl, Dransfield, 1987). They are mainly found in the tropical rain forests and constitute an integral part of the tropical forest ecosystem. In India, the genus *Calamus* (commonly called cane or rattan) is represented by about 31 species of which 8 species are endemic (Ahmedullah, Nayar, 1986). Indian rattans are distributed in tropical wet evergreen forests and semi-evergreen to moist deciduous forests from almost sea level to 1500 meter altitude with rainfall ranging from 1500–3000 millimeter. There are 14 species of rattans recorded in Karnataka (Hajra et al., 1996; Krishna Kumar, Ramaswamy, 2004), of which about 5 are endemic (Renuka, 1992). Evergreen and moist deciduous forests of Western Ghats form the largest natural home of rattans in Karnataka. Rattans are perennials, generally clustered, high climbing spiny palms. The slender rattan palms with a scandent habit grow through the canopy of some of the tallest trees of tropical forests and reach a length of hundreds of meters (Bailey, 1946). They are dioecious, flowering is annual and pleonanthic. *Calamus* is economically very important. Rattans are extensively used for making furniture, fancy articles etc. Rattan products play an important role in the economic activity of many countries. In South East Asia, it is estimated that over 5 million peoples are involved in rattan industry. The annual global revenue exceeds US $ 6.7 billion (Lakshmana, 1993). Rattans are also used in Ayurvedic system of medicine for curing various diseases like Cough, Edema, Herpes, Diabetes, Rabies etc (Lakshmana, 1993). Over exploitation and deforestation for the past few decades has led to a drastic depletion of rattan resources in India. *Calamus rheedi* Griff. formerly reported in the forests of Western Ghats could not be found now. The Red data book has already warned about *Calamus nagbettai* R.R. Fernandez & Dey. A few species like *Calamus dransfieldii* Renuka, *C. karnatakensis* Renuka & Lakshmana, *C. lakshmanae* Renuka, *C. prasinus* Lakshmana & Renuka,

C. stolonifer Renuka, *C. travancoricus* Bedd. ex Hook. f., *C. vattayila* Renuka have decreased in their abundance in the forests of Western Ghats (Lakshmana, 1993). Despite this, it is surprising that, canes have not attracted any studies on their reproductive biology. This may be because of their spiny character, inaccessibility and the difficulties in collecting flowers and fruits in forests at great heights.

Calamus prasinus Lakshmana & Renuka is a solitary high climbing palm growing up to 30 meters height. It is endemic to the forests of Western Ghats of Karnataka. Stem is covered over by sheath with densely armed long spines. Leaves grow up to 2.5 m long and have curved spines. Inflorescence is long, pendulous and spiny. Flowering period is generally from November to December and the fruiting period is from May to June. Fruits are globose with hard seeds.

The embryological studies of the family Arecaceae have been reviewed by Schnarf (1931), Davis (1966) and Johri et al., (1992). However, the embryology of thousands of species of palms has remained uninvestigated. This is especially so with reference to the rattans, they are embryologically understudied (Krishna Kumar, Ramaswamy, 2003). Furthermore, active research of the reproductive biology of these interesting climbers is needed to save some of them from extinction. The present study proposes to fill a gap in our knowledge on the reproduction of *Calamus prasinus* and compare the development of its reproductive structures with other investigated species of Arecaceae.

MATERIALS AND METHODS

The staminate and pistillate flowers of *Calamus prasinus* Lakshmana & Renuka at different stages of development for the present study were collected from evergreen forests of Sampaje (Kodagu district) and Kollamogaru (Dakshina Kannada district), Karnataka State, India. Frequent field trips were undertaken to the same locality to collect the floral materials. The collected materials were fixed in FAA (Formalin: Acetic acid: 70% Alcohol). After fixation (24–48 hrs), the fixed materials were washed in running tap water and preserved in 70% ethanol. The male and female flowers at different stages of development were dehydrated using ethanol and xylol. After dehydration, paraffin infiltration and embedding of the floral materials were made. Transverse and longitudinal sections were taken at 8–14μm thickness using a microtome. The paraffin ribbons containing sections were affixed on to the slides using egg albumen as adhesive. The micropreparations were processed following the customary method of Alcohol-Xylene series. The sections were stained with Heidenhein's iron alum and Haemetoxylin, counterstained with erythrosine and mounted using DPX mountant. The slides were observed under microscope, stages were identified and micrographs were made.

Plant names and surnames of taxon authors are given in accordance with the standards adopted in the International Plant Names Index (IPNI) database (https://www.ipni.org/).

RESULTS

Development of male reproductive structures

The staminate flowers of the *Calamus prasinus* are small and pale yellow in colour. A transverse section of young flower shows 6 stamens located in one whorl and a pistillode at the centre (Fig. 1a). Each anther has 4 microsporangia (Fig. 1a). The archesporial cell is differentiated at the early stages of development. The archesporium in the anther primordium consists of one layer of hypodermal cells in each corner, which divides periclinally to form the primary parietal and sporogenous cells. Further the primary parietal cells divide anticlinally and periclinally to form 3 layers underneath the epidermis. The anther wall comprises an epidermis, an endothecium, one middle layer and a tapetum (Fig. 1b). Tapetum is of the secretory type which nourishes the developing pollen mother cells. The tapetal cells are initially uninucleate but become 2–3 nucleate later (Fig. 1c). They start disorganizing along with middle layer during meiosis–I in the pollen mother cells. The sporogenous cells divide to form a sporogenous tissue (Fig. 1b, c). In the young microsporangium, the epidermal layer is very prominent with conspicuous nucleus. The cells of the epidermis of the mature anther don't contain the nuclei (Fig. 1d). During the course of development of the anther the cells of the endothecium elongate radially and it is one of the prominent layers in the mature anther. The endothecium develops fibrous thickenings on cell walls. The same fibrous thickenings develop in the cells of the connective (Fig. 1d). Several epidermal cells at the border of the neighboring microsporangia have thin walls and form a stomium involved in the dehiscence of the anther (Fig. 1d). When the septum becomes disorganized, the two anther loculi coalesce and release the pollen grains.

The pollen mother cells undergo meiotic divisions and subsequent cytokinesis resulting in the formation of isobilateral and tetrahedral microspore tetrads. Occasionally, T-shaped and linear tetrads have been noticed (Fig. 2a, b). The microspogenesis in the pollen mother cells is of the successive type. Microspores released from the tetrads have a centrally located nucleus (Fig. 2c). Then, the nucleus of microspore migrates to the periphery before it divides to form a small lenticular generative cell and large vegetative cell. Pollen grains at the time of shedding are 2-celled (Fig. 2d).

Development of female reproductive structures

The ovary is superior, tricarpellary, syncarpous and has 3 ovules on an axile placenta (Fig. 3a) of which only one ovule is functional, other two degenerates at the

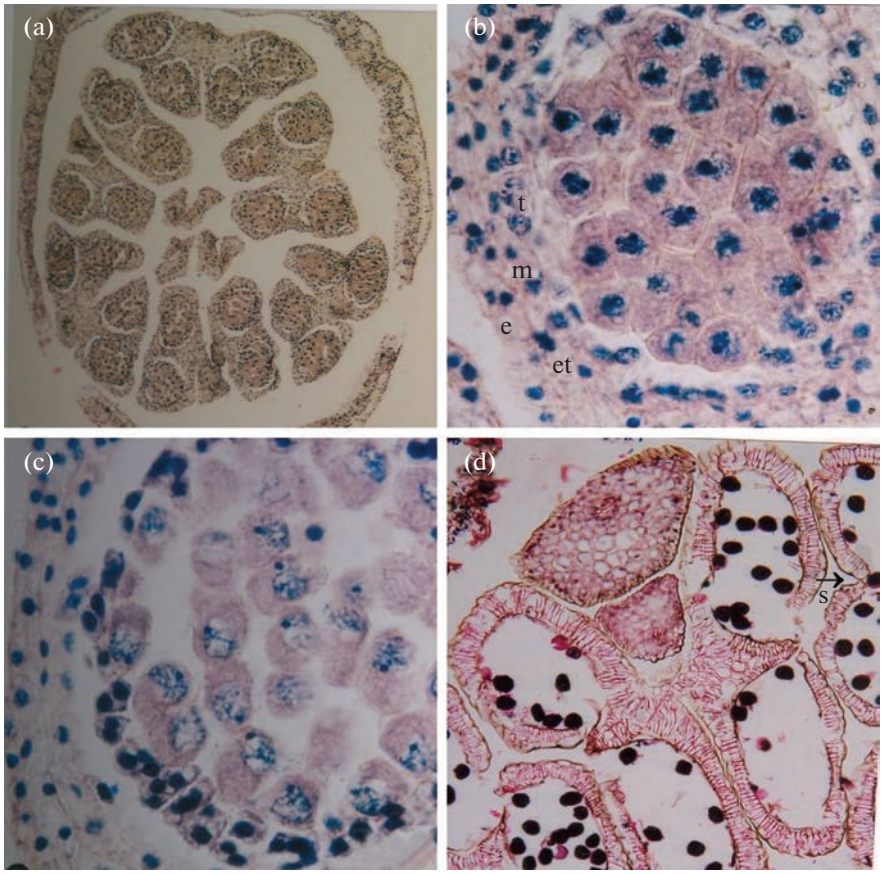

Fig. 1. Anther development in *Calamus prasinus* a – transverse section (hereinafter T.S.) of a male flower showing sections of young anthers. ×50.b – T.S. of young microsporangium showing sporogenous tissue. ×400. (e – epidermis; et – endothecium; m – middle layer; t – tapetum) c – T.S. part of microsporangium to show pollen mother cells. ×400. d – section of an anther at the time of dehiscence (S – stomium) ×200.

2-nucleate stage of embryo sac development. The ovule is anatropous, bitegmic and crassinucellate (Fig. 3b). The funiculus of the ovule is massive and cylindrical. The stylar canals as well as the locular extensions are lined by radially elongated glandular cells, which show starch grains and these cells function as the transmitting tissue. In each ovule, one vascular bundle from the funiculus enters the chalaza and branches into the outer integument. The ovular primordium takes its origin early in the development of the ovary. The initials for both the integuments become demarcated simultaneously. The outer integument is thicker than the inner integument. The micropyle is straight, formed by both integuments (Fig. 3b). The terminal part of the young ovules which develops in to the nucellus is relatively very small when compared to the funicular part. The nucellus in the ovular primordium is scanty and one- layered. Gradually it becomes 2–3 layered by the time the megaspore mother cell is differentiated.

One of the hypodermal cells in the ovular primordium enlarges with prominent nucleus and dense cytoplasm and functions as archesporial cell. The archesporial cell divides periclinally to form a primary parietal cell and a sporogenous cell and the latter differentiates as the megaspore mother cell (Fig. 3c). During its development it acquires an elongated and tapering form (Fig. 3d). The primary parietal cell by periclinal and anticlinal division forms 2–3 layered parietal tissue above the megaspore mother cell. The megaspore mother cell consecutively undergoes two meiotic divisions and subsequent caryokinesis resulting in a linear tetrad of megaspores. The three megaspores present at the micropylar side degenerate at the later stages of its development. The chalazal megaspore becomes functional (Fig. 4). The functional megaspore undergoes three successive mitotic divisions without cytokinesis that results in the formation of an 8-nucleate embryo sac (Fig. 5a, b). The embryo sac contains seven cells which include two synergids, one egg cell at the micropylar end, three antipodal cells at chalazal end and a central cell with two polar nuclei (Fig. 5c). Later, the polar nuclei fuse to form a secondary nucleus (Fig. 5d). The antipodals are small and ephemeral. They degenerate after the fusion of polar

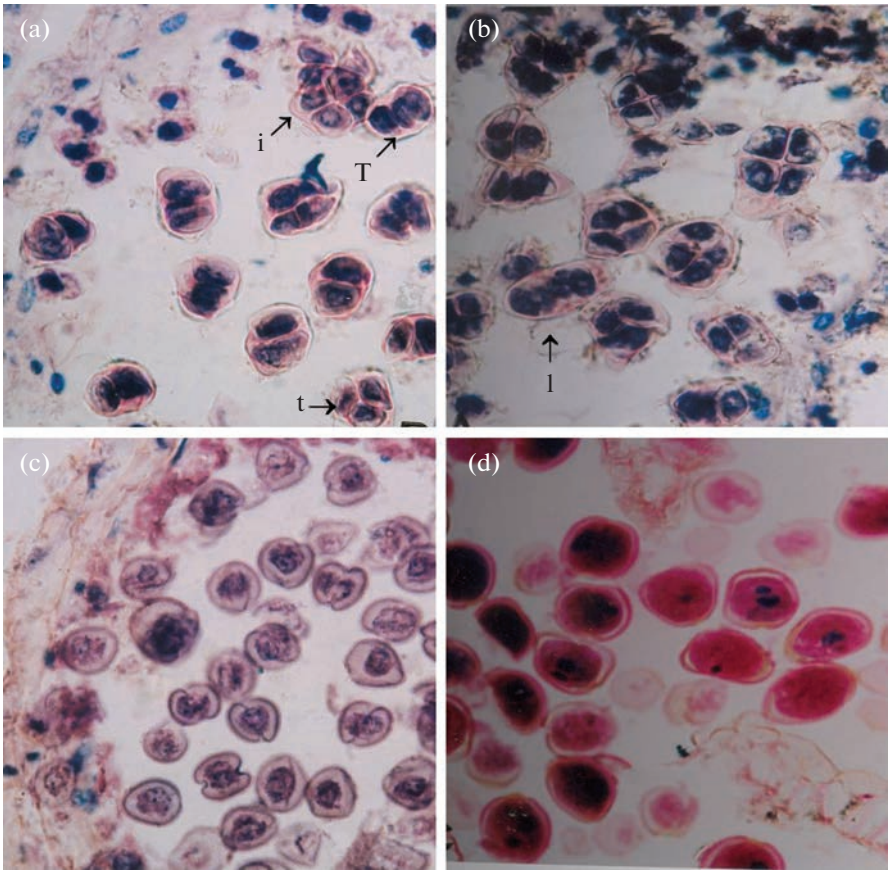

Fig. 2. Microspore tetrads and pollen grain development in *Calamus prasinus*a, b – T.S. part of microsporangium to show tetrads. ×400. (i – isobilateral tetrad; T – T-shaped tetrad; t – tetrahedral tetrad; l – linear tetrad)c – T.S. of a microsporangium at the microspore stage. ×400.d – T.S. part of microsporangium to show pollen grains at the time of shedding. ×400.

nuclei. The development of female gametophyte conforms to the *Polygonum* type (Maheshwari, 1950).

DISCUSSION

Earlier literature on the embryology of all the investigated species of the family Arecaceae showed that, the structure and development of their microsporangium and male gametophyte, megasporangium and female gametophyte are essentially uniform with minor variations (Davis, 1966; Johri et al., 1992; Krishna Kumar, Ramaswamy, 2003; Krishna Kumar, 2021). The anther is tetrasporangiate with hypodermal origin of the archesporium. The archesporial cells undergo periclinal division to form primary parietal and the primary sporogenous layers. The parietal cells divide by anticlinal and periclinal divisions to form a wall of 3–4 layers. The developmental pattern of the microsporangium wall is of monocotyledonous type (Davis, 1966). In *Calamus prasinus*, the anther wall comprises 4 layers with one middle layer as in most other investigated species of *Calamus*. However, 4–5 layered anther walls have been noticed in *Calamus gamblei* and *C. rotang* (Krishna Kumar, Ramaswamy, 2003). In contrast to this, 6–8 layered anther walls were reported in *Cocos nucifera* L. (Juliano, Quisumbing, 1931). Mahabale and Chennaveeraiah (1957) found a 5–6 layered anther wall in *Hyphaene indica* Becc. In *Dypsis decaryi* (Jum.) Beentje & J. Dransf. 5 layered anther walls have been noticed with two middle layers (Krishna Kumar, 2021).

The tapetum is one of the important layers in the anther, which nourishes the developing pollen mother cells. The secretory type of tapetum has been observed in the present study as in other investigated species of Palms (Rao, 1959b; Mahabale, Biradar, 1968; Biradar, 1968; Biradar, Mahabale, 1968; Shirke, Mahabale, 1972; Kulkarni, Mahabale, 1974; Robertson, 1976a; Krishna Kumar, Ramaswamy, 2003; Krishna Kumar, 2021). The cells of the tapetum contains single nucleus in the beginning but at later stages of its development they become 2–3 nucleated. Binucleated tapetal cells were observed in the earlier works on *Calamus stolonifer*, *C. nagbettai*, *C. rotang* L., *Hyphaene indica*, *Areca catechu* L., *Chrysalidocarpus lutescens* H. Wendl., *Phoenix sylvestris* (L.) Roxb. and *Dypsis decaryi* (Rao, 1959a; Johri et al., 1992; Krishna Kumar, 2021). Krishna Kumar, Ramaswamy (2003) re-

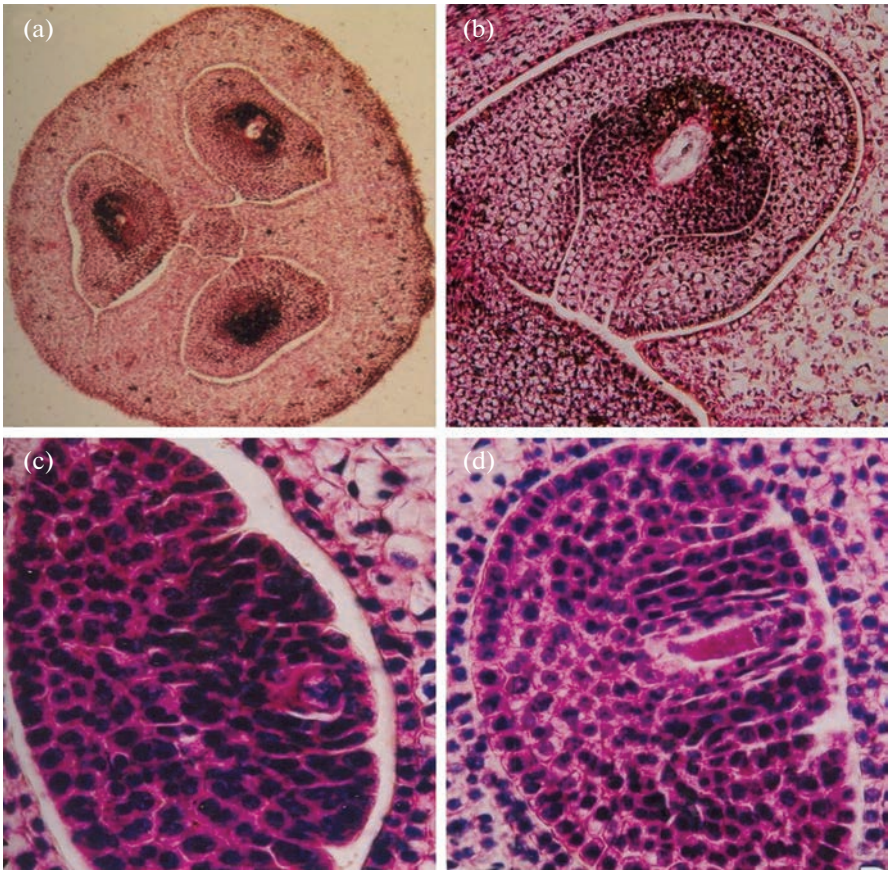

Fig. 3. Structure and development of the ovule in *Calamus prasinus*. a – T.S. of a female flower showing sections of 3 ovules on an axile placenta. ×400. b – longitudinal section (hereinafter L.S.) part of a female flower showing anatropous ovule. ×400. c, d – L.S. of ovule to show megaspore mother cell at the early (c) and late (d) stages of development. ×400.

ported 2–3 nucleated tapetal cells in *Calamus travancoricus*. The fusion of nuclei and polyploidization in tapetal cells was noticed in *Calamus gamblei* and *C. stolonifer* (Krishna Kumar, Ramaswamy, 2003). Such a feature has not been observed in the presently investigated species. In *Calamus prasinus* disorganization of the tapetal cells has been noticed before the commencement of meiosis in the pollen mother cells. This is essential for providing nutrition to the pollen mother cells. The present investigation showed that the walls of the tapetal cells stretch radially and start breaking down as in other investigated species of *Calamus* (Krishna Kumar, Ramaswamy, 2003).

The development of fibrous secondary wall thickenings was observed in endothecium. The same was reported in other investigated species of Palms (Johri et al., 1992; Krishna Kumar, Ramaswamy, 2003; Krishna Kumar, 2021). In *Calamus prasinus* the cells at the connective side also start to develop fibrous thickenings in addition to the endothecium, as in *Calamus gamblei* (Krishna Kumar, Ramaswamy, 2003). Krishna Kumar (2021) reported that, the cells of the connective completely filled with tannins at the early stages of development in *Dypsis decaryi*. The same was observed in the tribe Ceroxylinae (Rao, 1959b). In *Calamus prasinus*, the epidermal layer in the young microsporangium is very prominent and at the later stages of its development, the cells become non-nucleated as in other investigated species of Palms (Krishna Kumar, Ramaswamy, 2003; Krishna Kumar, 2021).

The pollen mother cells undergo successive type of microsporogenesis as in other investigated species of *Calamus* (Krishna Kumar, Ramaswamy, 2003). However, *Chrysalidocarpus lutescens* and *Dypsis decaryi* have the simultaneous type of microsporogenesis (Rao 1959b; Krishna Kumar, 2021). The isobilateral and tetrahedral microspore tetrads have been observed in the present work. The same was reported in *Phoenix*, *Caryota urens* L. and *Dypsis decaryi* (Mahabale, Biradar, 1968; Biradar, 1968; Biradar, Mahabale, 1968; Shirke, Mahabale, 1972; Krishna Kumar, 2021). In the present investigation, occasionally T-shaped and linear tetrads have also been observed as in *Hyphaene indica* (Mahabale, Chennaveeraiah, 1957). In *Areca catechu* and *Chrysalidocarpus lutescens* isobilateral, decussate and tetrahedral tetrads were recorded (Rao, 1959b). In *Dypsis decaryi* and *Hyphaene indica*,

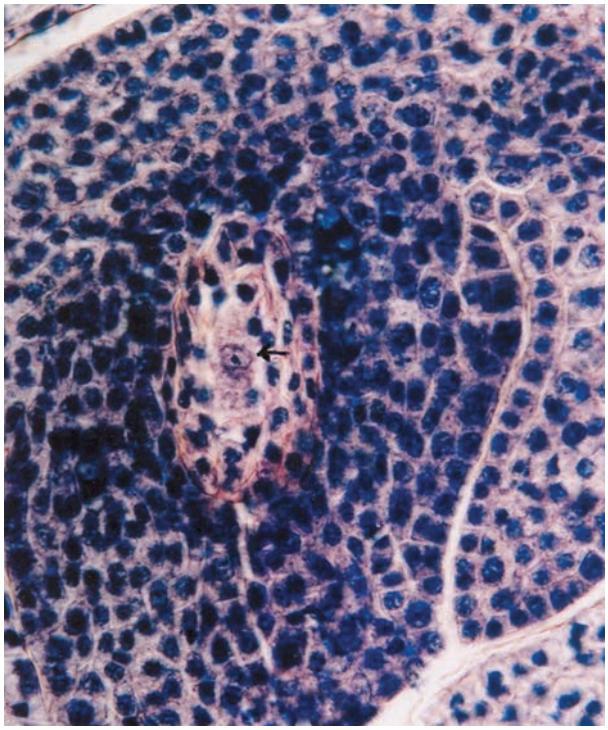

Fig. 4. Ovule with functional megaspore in *Calamus prasinus* L.S.; functional megaspore is shown by arrow. ×400.

a rare instance of polyspory was observed (Mahabale, Chennaveeraiah, 1957; Krishna Kumar, 2021). In general, between the two adjacent microsporangia a stomium of thin-walled cells is organized. In *Calamus prasinus*, the anther dehisces at the region of stomium and releases the pollen grains as in other investigated palms (Johri et al., 1992). The pollen grains are shed at 2-celled condition as in most investigated species of Palms (Johri et al., 1992; Krishna Kumar, Ramaswamy, 2003; Krishna Kumar, 2021). However, Krishna Kumar and Ramaswamy (2003) reported 2 and 3 celled pollen grains at the time of shedding in *Calamus gamblei* and *C. rotang*, 2-celled pollen grains are predominant.

In all the investigated species of palms the ovary is superior, tricarpellary syncarpous and trilocular with a single ovule in each locule on an axile placenta (Johri et al., 1992; Krishna Kumar 2021). The same has been observed in the presently investigated species of *Calamus*. The ovule of *Calamus prasinus* is bitegmic, crassinucellate and anatropous as in the majority of the investigated palms (Johri et al., 1992). The same was reported by Mahabale and Biradar (1968) in *Phoenix sylvestris*. However, the ovules in *Dypsis decaryi*, *Chrysalidocarpus* and *Areca* are bitegmic, crassinucellate and hemianatropous (Rao, 1959b; Krishna Kumar, 2021). In *Howea* Becc. and *Actinophloeus* Becc. Rao (1959b) reported orthotropous and pendulous ovules. Mahabale and Chennaveeraiah (1957) observed orthotropous ovules in *Hyphaene indica*. In the species of *Cocos* L., *Areca concinna* Thwaites, *Phoenix sylvestris* and *Livistona chinensis* R. Br., the integumentary tapetum like cells were observed (Rao, 1959a, b; Mahabale, Biradar, 1968; Kulkarni, Mahabale, 1974).

In the ovular primordium, a single hypodermal cell differentiates as the archesporium. The archesporial cell divides periclinally to form a primary parietal cell and a sporogenous cell. The sporogenous cell directly functions as megaspore mother cell. The same was observed in majority of the investigated species of palms (Davis, 1966; Johri et al., 1992; Krishna Kumar, 2021). However, in *Dypsis decaryi*, *Elaeis guineensis* Jacq. and *Phoenix sylvestris* occasionally two megaspore mother cells were noticed in each ovule (Krishna Kumar, 2021; De Poerck, 1950; Mahabale, Biradar, 1968). The twin embryo sacs were noticed in *Elaeis guineensis* (Kajale, Ranade, 1953). The megaspore tetrads are linear and the three megaspores present on the micropylar side degenerate at later stages of its development. The same was reported in majority of the investigated species of palms (Johri et al., 1992; Krishna Kumar, 2021). Both linear and T-shaped tetrads were observed in *Caryota mitis* Lour., *Chrysalidocarpus lutescens* and *Caryota urens* (Rao 1959a; Shirke, Mahabale, 1972). In contrast, four different kinds of megaspore tetrads such as linear, isobilateral, T-shaped and inverted T-shaped tetrads were observed in *Elaeis guineensis* (Kajale, Ranade, 1953). The chalazal functional megaspore undergoes three successive mitotic divisions without cytokinesis that result in the formation of an 8-nucleate embryo sac as in most investigated palms (Johri et al., 1992; Krishna Kumar, 2021). The pattern of development of female gametophyte conforms to the monosporic 8-nucleate *Polygonum* type Maheshwari (1950). However, Mahabale and Chennaveeraiah (1957) reported a bisporic 8-nucleate *Allium* type of female gametophyte development in *Hyphaene indica*.

CONCLUSION

The present investigation on development of male and female reproductive structures in *Calamus prasinus* revealed that, the pattern of development of pollen grains and the embryo sac is essentially similar as in most investigated members of the Arecaceae. The family Arecaceae is characterized by a wide diversity of traits in the development of the reproductive structures. The anther wall in most investigated species (*Actinophloeus macarthurii* Becc. ex A. Raderm., *Areca catechu*, *A. triandra* Roxb. ex Buch.-Ham., *Caryota urens*, *Chrysalidocarpus lutescence*, *Cocos plumosa* Lodd. ex Loudon, *Howea belmoreana* (C. Moore & F. Muell.) Becc., *Licuala* Wurmb, *Phoenix sylvestris*, *P. pusilla* Lour., *P. acaulis* Roxb., *P. reclinata* Jacq., *Livistona chinensis*, *Caryota urens*, *Calamus gamblei*, *C. nagbettai*, *C. rotang*, *C. stolonifer*, *C. travancoricus* and *Dypsis decaryi*) are 4–5 layered. On the other

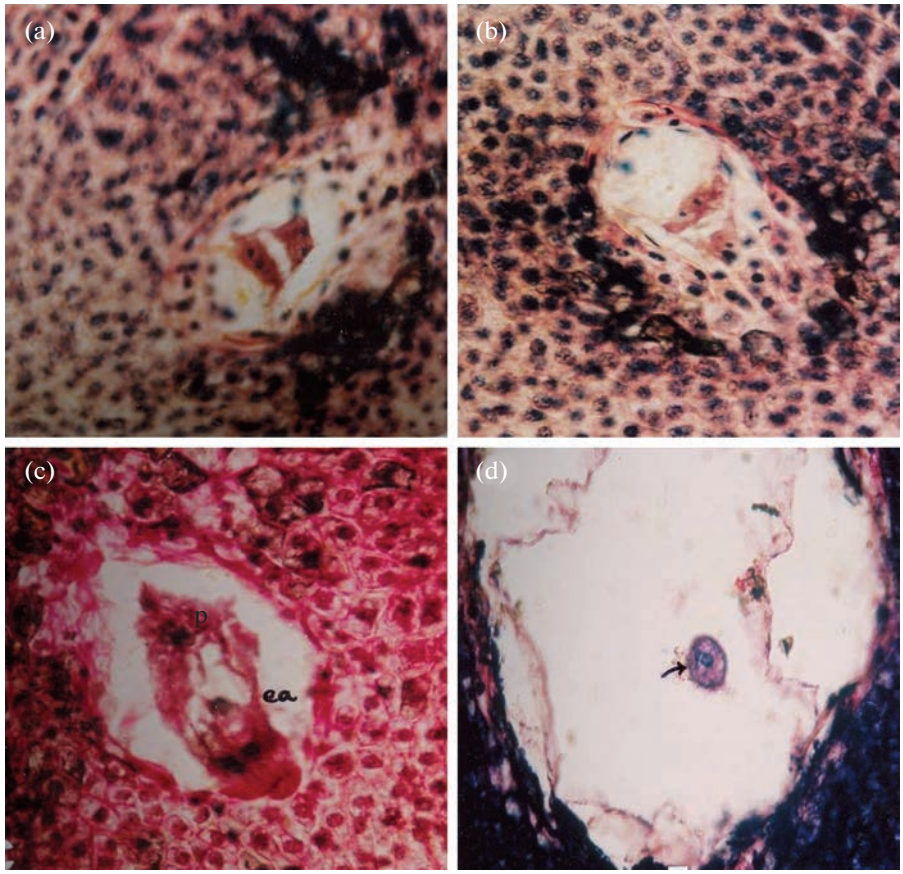

Fig. 5. Embryo sac development in *Calamus prasinus*. a, b – adjacent sections to show 8-nucleate embryo sac. ×400. c – L.S. part of ovule to show egg apparatus and polar nuclei. ×400. (ea – egg apparatus, p – polar nuclei) d – L.S. part of ovule to show secondary nucleus (Arrow). ×400.

hand, 6–8 layered anther walls was found in *Cocos nucifera*, *Borassus flabellifer* L., *Pritchardia* Seem. & H. Wendl., and *Hyphaene indica*. In all the investigated members of Arecaceae, the tapetum is of the secretory type. The tapetal cells are uninucleate initially subsequently they become 2-nucleate in most of the investigated species such as *Calamus stolonifer*, *Calamus nagbettai*, *Calamus rotang*, *Hyphaene indica*, *Areca catechu*, *Chrysalidocarpus lutescens*, *Phoenix sylvestris* and *Dypsis decaryi*. Nuclear fusions and polyploidization of tapetal cells is observed in *Calamus gamblei* and *C. stolonifer*.

Simultaneous division of the pollen mother cells were observed dominated in majority of the investigated species such as *Chamaedorea sartorii* Liebm. in Mart., *C. glaucophylla* Hort., *C. karwinskyana* H. Wendl., *C. corallina* Hook. f., *Cocos nucifera*, *C. plumosa*, *Hyphaene indica*, *Actinophloeus macarthurii*, *Areca catechu*, *A. triandra*, *Chrysalidocarpus lutescence*, *Howea belmoreana*, *Caryota urens* and *Dypsis decaryi*. In contrast, successive type of division of pollen mother cells were observed in few species viz., *Nypa fruticans* Wurmb, *Phoenix sylvestris*, *Calamus gamblei*, *C. nagbettai*, *C. rotang*, *C. stolonifer*, *C. prasinus* and *C. travancoricus*. Isobilateral, tetrahedral and decussate tetrads are commonly found in all the investigated species. In *Calamus prasinus*, occassionly T-shaped and linear tetrads were observed as in *Hyphaene indica* and *Dypsis decaryi*. Pollen grains are 2-celled at the time of shedding in all the investigated species. However, rarely 3-celled pollen grains were observed in *Calamus gamblei* and *C. rotang*.

Different types of ovules were found in palms. In some species ovules are bitegrnic, crassinucellate and anatropous i.e., *Phoenix sylvestris*, *Johannesteijsmannia lanceolate* J. Dransf., *Livistona chinensis*, *Pritchardia*, *Washingtonia* C. Winslow, *Licuala* and *Trachycarpus* H. Wendl. On the other hand, orthotropous ovules were found in *Hyphaene indica*, *Howea*, *Actinophloeus*, *Bactris* Jacq. ex Scop. and *Caryota* L. In contrast, hemianatropous ovules were observed in *Livistona rotundifolia* Mart., *Sabal* Adans., *Chrysalidocarpus*, *Areca* and *Dypsis decaryi*. The monosporic, 8-nucleate *Polygonum* type of embryo sac development is commonly found in most investigated species of palms viz., *Chamaedorea concolor* Mart., *Actinophloeus macarthurii*, *Areca catechu*, *A. consinna*, *A. triandra*, *Actinophloeus*, *Pritchardia*, *Licuala*, *Livistona*, *Caryo-*

ta, *Trachycarpus*, *Washingtonia*, *Sabal*, *Phoenix sylvestris*, *P. pusilla*, *P. acaulis*, *P. reclinata*, *P. robusta* and *Dypsis decaryi*. However, *Allium* type of embryo sac development is found in *Hyphaene indica*. Adoxa type of embryo sac development was observed in *Nypa fruticans*, *Caryota urens*, *Livistona chinensis*, *Cocos nucifera* and *Elaeis guineensis*.

The development of reproductive structures in studied *Calamus prasinus* occurs very similarly to other *Calamus* species as well as to other genera of Arecaceae, for example *Calamus gamblei*, *C.nagbettai*, *C. rotang*, *C. stolonifer*, *C. travancoricus*, *Nypa fruticans*, *Chamaedorea concolor*, *Actinophloeus macarthurii*, *Areca catechu*, *A.consinna*, *A.triandra*, *Actinophloeus*, *Pritchardia*, *Licuala*, *Livistona*, *Caryota*, *Trachycarpus*, *Washingtonia*, *Sabal*, *Phoenix sylvestris*, *P. pusilla*, *P. acaulis* and *P. reclinata*, *P. robusta* and *Dypsis decaryi*. The present study revealed that male and female reproductive structures in the studied species develop normally, without abnormalities suggesting their high potential for fertilization and development of viable seeds, the study of which will be the subject of future research.

ACKNOWLEDGEMENTS

The author is thankful to Mahajana Education Society, Mysuru for facilities.

REFERENCES

Ahmedullah M., Nayar M.P. 1986. Endemic plants of the Indian region Vol. 1. Botanical survey of India. Calcutta. P. 203–204.

Bailey L.H. 1946. The palm herbarium. – Gentes Herb. 7: 153–180.

Biradar N.V. 1968. Studies on Palms: Embryology of *Phoenix pusila* Gaertn., *P. acaulis* Buch. and *P. reclinata* Jacq. – Proc. Ind. Acad. Sci. 67: 165–173.

Biradar N.V., Mahabale T.S. 1968. Studies on Palms: Embryology of *Phoenix robusta* Hook. – Proc. Ind. Acad. Sci. 67B: 1–8.

Davis G.L. 1966. Systematic embryology of Angiosperms. New York. 528 p.

De Poerck R.A. 1950. Contribution a petude de Palmier a huile Africain *Elaeis guineensis*. – Oleagincux. 5: 623–628.

Hajra P.K., Sharma B.D., Sanjappa M., Sastry A.R.K. 1996. Flora of Inida-Introductory volume (PartI). Botanical Survey of India, Calcutta.

Johri B.M., Ambegaokar K.B., Srivastava P.S. 1992. Comparative Embryology of Angiosperms. **2**. Berlin. P. 944–950.

Juliano J.B., Quisumbing E. 1931. Morphology of the male flower of *Cocos nucifera* L. – Philipp. J. Sci. 45: 449–458.

International Plant Names Index (IPNI) database https://www.ipni.org/

Kajale L.B., Ranade S.G. 1953. The embryo sac of *Elaeis guineensis* Jacq. A reinvestigation. – J. Indian Bot. Soc. 32: 101–107.

Krishna Kumar H.N. 2021. Embryology of *Dypsis decaryi* (Arecaceae). – Bot. Zhurn. 106 (9): 898–901.

Krishna Kumar H.N., Ramaswamy S.N. 2004. Studies on the Distributional and Phenological aspects of *Calamus* L. in Karnataka. – Indian Forester. 130 (2): 224–230.

Krishna Kumar H.N., Ramaswamy S.N. 2003. Contributions to the Study of Microsporogenesis in *Calamus* L. (Arecaceae). – Taiwania. 48 (3): 180–193.

Kulkarni K.M., Mahabale T.S. 1974. Studies on Palms: Embryology of *Livistona chinensis* R. Br. – Proc. Ind. Acad. Sci. 67: 1–17.

Lakshmana A.C. 1993. Rattans of South India. Evergreen Publishers, Bangalore. 178 p.

Mahabale T.S., Chennaveeraiah M.S. 1957. Studies on *Hyphaene indica* Becc. I. Morphology. – Phytomorphology. 7: 184–194.

Mahabale T.S., Biradar N.V. 1968. Studies on palms: Embryology of *Phoenix sylvestris* Roxb. – Proc. Ind. Acad. Sci. 67 (2)B: 77–96.

Maheshwari P. 1950. An introduction to the Embryology of Angiosperms. New York, London. 453 p.

Quisumbing E., Juliano J.B. 1927. Development of Ovule and Embryo sac of *Cocos nucifera*. – Bot. Gaz. 84: 279–293.

Rao C.V. 1959a. Contributions to the embryology of Palmae I. Sabaleae. – Proc. Nat. Inst. Sci. India. 29: 134–164.

Rao C.V. 1959b. Contributions to the embryology of Palmae II. Ceroxylineae. – J. Indian. Bot. Soc. 37: 47–75.

Renuka C. 1992. Rattans of Western Ghats. A taxanomic manual. Kerala Forest Research Institute, Peechi, Kerala.

Robertson B.L. 1976a. Embryology of *Jubaeopsis caffra* Becc. 1. Microsporangium, Microsporogenesis and Microgametogenesis. – J. S. Afr. Bot. 42: 97–108.

Schnarf K. 1931. Vergleichende Embryologie der Angiospermen. Gebruder Borntraeger, Berlin. P. 279–280.

Shirke N.S., Mahabale T.S. 1972. Studies on palms: Embryology of *Caryota urens* L. – In: Advances in Plant Morphology. Sarita Prakashan, Meerut. P. 218–232.

Takhtajan A. 1987. Systema Magnoliophytorum. Moscow. 439 p. (In Russ.).

Uhl N.W., Dransfield J. 1987. Genera *Plamarum*. Allen Press, Lawrence, Kansas, USA.