CYCAS

Distribution and Habitat

- There are **20** species of *Cycas* distributed in tropical and sub-tropical regions of eastern hemisphere of the world. 4 species occur naturally in our country.
- *Cycas revoluta* (Crozier *Cycas*) grows in dry deciduous forests of **southern India**.
- *Cycas beddomei* (Madras *Cycas*) grows in **Eastern Ghats** of our country.
- *Cycas pectinata* (Nepal *Cycas*) grows in **eastern** India.
- *Cycas rumphii* (Rumphious *Cycas*) grows in **Andaman** and **Nicobar** islands.
- *Cycas revoluta* (Sago *Cycas*) is Japanese species grown as ornamental in India.
- Two species grow naturally in our state. They are *C.beddomei* on Tirumala hills and *C. circinalis* in Eastern Ghats.

External Morphology

- *Cycas* plant is slow growing, long-lived, evergreen, arborescent sporophyte.
- It grows up to a height of **2 – 5** meters.
- It has unbranched woody stem with a crown of **unipinnate** and **paripinnate** compound leaves at its apex. Stem is described as **Caudex**.

Stem

- Younger stems are **tuberous**, underground, stout and short.
- Older stems are unbranched, woody, and aerial with armour of woody, **persistent leaf bases**.

Leaf

- *Cycas* shows **habitual heterophylly** with morphologically two different types of leaves. These leaves are foliage leaves and scale leaves.

Scale leaves

- These are **small, rough, dry, triangular** and **densely** covered with brown hair known as **ramenta** (Fern character).
- They are **more than foliage leaves**, persistent and protective in function.
- They protect the younger foliage leaves, stem apex and other organs.
- These are arranged in close spiral succession alternate to the foliage leaves.

Foliage leaves

- Foliage leaves are spirally developed as **terminal crowns**.
- **One** or **two** crowns are developed every year.
- Each leaf is **1 – 3 cm** in length, unipinnate paripinnate and attached to the stem by transversely broadened **rhomboidal leaf base**.
- Rachis has **50 – 100** pairs of leaflets.
- Rachis has several vascular bundles arranged in the shape of **inverted omega** ( ).
- Each leaflet is sessile, leathery, stiff, and lanceolate with only midrib and without lateral veins. Margin is **entire** or **revolute** with **acute** or **spinous** apex.
- Some of the lower leaflets are modified into **spines**.
- The younger leaflets and leaves are coiled around themselves and it is known as **Circinate vernation**. It is a fern character.
- The leaf bases are persistent and the alternating clusters of leaf bases of foliage and scale leaves give a **rugged** appearance to the stem.
- Number of alternating clusters of young and foliage leaves is an indication of ***Cycas* age**.
- At the basal most part of relatively older stem is **smooth** and has scars of the leaf bases.

Root

- It has two types of roots known as **normal roots** and **coralloid roots** (Dimorphic roots).

Normal root

- Tap root system is developed at the beginning and in course of time it is replaced by adventitious root system arising from the base of stem.

Coralloid roots

- These are **apogeotropic**, **dichotomously** branched, **rough** surfaced, **coral like** lateral roots arising from the lateral sides of normal roots reaching up to the surface of the ground.
- They are inhabited by blue green algae such as *Anabaena cycadacearum* and *Nostoc punctiformae*. Hence these are **symbiotic** and show **nitrogenous nutrition**.
- **Lenticels** present on coralloid roots help in **respiration**.

ANATOMY OF *CYCAS* :

Internal structure of Primary stem

- In T.S., *Cycas* stem is differentiated into Epidermis, Cortex and Stele.

Epidermis

- It is circular in younger stems and shows rugged appearance in older stems due to the presence of persistent leaf bases.
- It is continuous with cuticle in younger stems. It looses continuity in leaf bases.

Cortex

- It is extensive, parenchymatous and filled with **starch**.
- It has **girdle** shaped leaf traces (characteristic feature) and **mucilaginous ducts** (act as water reservoirs).
- Endodermis is indistinct.

Stele

- It has indistinct pericycle.
- It has **eustele** because the vascular bundles are arranged in the form of a ring.
- Each vascular bundle is **conjoint**, **collateral**, **open** and **endarch** type.
- Xylem has tracheids and xylem parenchyma. **Vessels** are reported from *C. revoluta*.
- Phloem has sieve cells and phloem parenchyma. Companion cells are absent.
- Medulla is large, parenchymatous, **starch rich** and traversed by many **mucilage canals**.
- **Medullary rays are broad** and extended between the vascular bundles.

Leaf traces

- These are vascular supply to the leaf from the stem.
- There are two types of leaf traces in *Cycas* known as **direct** and **girdle shaped** leaf traces.
- Each leaf receives **two normal** and **one girdle** shaped leaf trace.
- Direct leaf traces arise from the same side of vascular bundle and enter into the leaf.
- A girdle shaped vascular bundle arises at opposite side of the insertion of leaf, dichotomously branched in the cortex; both branches encircle the stem in the form of girdle in opposite direction and come closer before entering into the leaf base.
- In the leaf the leaf traces divide and redivide to form large number of bundles before entering into the rachis.

T. S. of Leaflet or Pinnule

- In T.S., leaflet shows the presence of Epidermis, Mesophyll and Vascular bundle.

Epidermis

- It is the outermost layer of leaflet present on adaxial and abaxial sides.
- It is thick walled and surrounded by thick cuticle.
- Stomata are sunken and confined to lower epidermis.

Mesophyll

- It is present between upper and lower epidermis and has hypodermis, palisade, spongy tissue and transfusion tissue.

Hypodermis

- It is sclerenchymatous and present below the upper and lower epidermis.
- In the wing region, it is one or two layered in the adaxial side and one layered in the abaxial side. In the midrib region it is **2** or **3** layered.
- It acts as **heat screen** and protects the plant from over heating and excessive transpiration.

Palisade tissue :

- It is present below the upper hypodermis and has cylindrical cells with more number of chloroplasts. It takes part in photosynthesis.
- It is confined to only wing region in *C. circinalis*. In *Cycas revoluta*, it is extended into the midrib region.

Spongy tissue

- It is present towards the abaxial side below the hypodermis.
- It has small oval or irregularly shaped and irregularly arranged chloroplast-containing cells with broad intercellular spaces.
- It acts as photosynthetic and aerating tissue.

Transfusion tissue

- It is of two types known as **primary** and **secondary transfusion** tissue.
- Primary transfusion tissue is present in the ground tissue of midrib region around vascular bundle in parallel manner. It has **tracheid like cells** with bordered **pits** connected to the secondary transfusion tissue of the midrib region.

- Secondary transfusion tissue is present in the wing region in between palisade and spongy tissue. It is 3-4 layered with **tracheid** like parenchymatous transversely elongated cells. It runs parallel to the surface of the leaflet from midrib to the margin. Cells have **bordered pits** in their radial walls. It helps in the lateral conduction of mineral water and compensates the absence of lateral veins.

Vascular Bundle

- It is present in the midrib region surrounded by parenchymatous ground tissue. It is surrounded by sclerenchymatous bundle sheath.
- It is conjoint, collateral, open, **diploxylic** and has **pseudomesarch** condition**.**
- Centripetal xylem is larger, triangular and present towards the **adaxial** side. Its protoxylem is towards lower surface and metaxylem towards upper surface.
- Cetrifugal xylem is in two small lateral groups present towards **abaxial** side with metaxylem towards the lower surface and protoxylem towards upper epidermis.
- Phloem is present towards the lower epidermis.
- A strip of **non-functional cambium** may be present between the centrifugal xylem and phloem.

Xerophytic Adaptations of Leaflet

- Presence of thick cuticle.
- Epidermis with thick walled cells.
- Sclerenchymatous hypodermis.
- Presence of sunken stomata.
- Poorly developed spongy parenchyma.
- Presence of transfusion tissue.

T. S. of Coralloid root

- In internal structure, coralloid root shows the presence of epidermis, cortex and stele.
- Epidermis of younger coralloid root is single layered, thin walled. It soon replaced by **periderm** with **lenticels** due to secondary growth.
- Cortex is extensive, parenchymatous and differentiated into three distinct zones such as outer cortex, middle cortex and inner cortex.
- Outer and inner cortex are made of thin walled parenchyma with **mucilage ducts, tannin cells** and cells with **druses**.
- Middle cortex is disorganised and it is inhabited by symbiotic nitrogen fixing blue-green algae such as *Anabaena cycadacearum* and *Nostoc punctiformae*. Hence this is called as **algal zone**. Cortex has single layered endodermis.
- Stele has **2-3** layered pericycle, radial vascular bundles and xylem shows **exarch** and **triarch** condition.
- In normal root, the cortex is homogenous and shows **diarch to tetrarch** condition and periderm is absent.

Reproduction

- It reproduces vegetatively by **bulbils** or **adventitious** buds formed at the base of the stem.
- During the germination of bulbils, adventitious roots are formed.
- It reproduces through seeds only after **10 years** of vegetative growth.
- *Cycas* is **dioecious** and **heterosporous**. It produces both microspores and megaspores.
- Microspores are produced in microsporangia of microsporophyll that together form male cone.
- Megaspores are formed in the ovule, which in return are formed on megasporophylls. These are arranged loosely and do not form female cone.

Male cone

- It is **singly** formed every year at the apex of male plant after 10 years of vegetative growth of the plant.
- During its formation the apical meristem is completely consumed and further growth is continued by a lateral bud present at the base of the cone. Hence the stem shows monopodial growth up to **10^{th} year** and later sympodial growth (Cymose).
- It is long, compact, **oval** or **fusiform** and has short stalk. It is surrounded by a crown of young leaves.
- It woody and has **20 – 60 cm** length.
- Its axis has several compactly, spirally and acropetally arranged microsporophylls.
- Some microsporophylls of apical and basal regions are sterile and do not produce microsporangia.

Microsporophyll

- It is flattened triangular structure with **3 – 3.5 cm** length and **1.2 – 2.3 cm** width.
- It has middle fertile and basal and apical sterile regions.
- The apical sterile broad gradually tapering structure arranged parallel to the cone axis is called as **Apophysis**.
- The remaining portion of the sporophyll is perpendicular to the cone axis.
- **700 – 1000** microsporangia are borne as **sori** on the abaxial surface of middle fertile portion of sporophyll.
- Each sorus has **2 – 6** microsporangia intermixed with **1 or 2** celled **indusial hairs**. It is a fern character.

Microsporangium

- It is oval or elliptical with short stalk. It develops in **eusporangiate** manner.
- It has 5 – 6 layered wall with outer most layer with fibrous wall thickenings known as **Exothecium** and innermost layer **Tapetum**.
- Tapetum completely encircles the sporogenous tissue. Sporogenous cells divide and redivide mitotically and form the last generations of cells known as microspore mother cells.
- Microspore mother cells divide meiotically and form haploid microspores in tetrads. These are separated from tetrads and rounded off as pollen grains.
- At maturity the tapetum and the inner walls degenerate and only **exothecium** remain.
- The microspores are liberated from microsporangium at **3** – celled stage due to vertical splitting of exothecium.

Megasporophyll

- These are loosely, acropetally and spirally arranged around the stem apex like vegetative leaves.
- Since the apical meristem of the stem is not completely utilised and unaffected the growth of the stem is described as **monopodial** through out its life span (Racemose).
- Megasporophyll is **pinnate** or **ovate-lanceolate** or rhomboidal in shape.
- It is **15–24 cm** in length, dorsiventral and flattened structure.
- It has basal sterile stalk like structure, middle fertile ovule bearing portion and apical sterile variously lobed or serrate or pinna like divided region.
- It is covered by dense mass of hairs, which are shedded off as the ovules attain maturity.
- Upon coming in contact with the archegonial neck, the male gamete cilia and membrane are stripped off and only the male nucleus is sucked into the venter. It fuses with the egg nucleus and forms the diploid zygotic nucleus.
- A thick wall is secreted around the nucleus to form **Oospore** or **zygote**.
- Fertilisation is both siphonogamous and zooidogamous. **Zooidogamy** accompanies **siphonogamy**.

Ovule or Megasporangium

- It is the **largest ovule** in the plant kingdom with **6** × **4** cm in size.
- It is **orthotropous** with massive nucellus surrounds by single integument differentiated into outer fleshy **sarcotesta**, middle hard **sclerotesta** and inner fleshy **sarcotesta**.
- Nucellus and sarcotesta have **vascular tissues**.
- Nucellus and the surrounding integument are fused except at the distal end leaving a narrow passage known as **micropyle**.
- Nucellus is extended into the micropyle as a beak known as **nucellar beak**.
- Cells of the nucellar beak degenerate and form **pollen chamber**.
- The substance formed due to degeneration is secreted out through micropyle as a drop known as **pollination** or **nectar drop**.
- Nectar drop helps in trapping the pollen grains carried through the agency of wind.
- One of the cells of nucellus behaves as **archesporial cell** by showing enlargement.
- It may directly behave as **megaspore mother cell** or divides to form a **parietal cell** and megaspore **mother cell**.
- Megaspore mother cell divides meiotically and forms **4 haploid** megaspores in a **linear tetrad**. The upper 3 micropylar megaspores degenerate and only the lower one is functional.
- The functional megaspore has a thick outer papillate exospore and thin fibrillar inner endospore.

Gametophytes

- Spore are the first cells of gametophytes.
- *Cycas* has both male and female gametophytes.

Male gametophyte

- Microspore is the first cell of male gametophyte. Male gametophyte is partially developed in the microsporangium.
- Microspore is uninucleate and unicellular. It has thick **exine** and thin **intine**.
- It divides unequally and forms **small prothalial cell** and **larger antheridial cell**. prothalial cell does not divide further.
- Antheridial cell divides unequally and forms **smaller generative cell** and **larger vegetative cell** or **tube cell**.
- At this **3** celled stage the microspores are liberated. During this, the **cone axis is elongated** and the closely placed sporophylls are far separated for easy liberation of microspores.

Female gametophyte

- Megaspore is the first cell of female gametophyte.
- Its nucleus undergoes many free nuclear divisions. Cell walls are formed in centripetal manner around the nuclei to form multicellular female gametophyte or **female prothallus**.

- It utilises the nucellus for its development and **nutritive in function** for the development of embryo. Hence this haploid structure is also referred as **endosperm**.
- The space formed by the degeneration of nucellus cells between pollen chamber and female gametophyte is known as archegonial chamber.
- **2 – 8** archegonia are formed from the lining layer cells of nucellus in contact with archegonial chamber.
- Each arechegonium has a projected neck extended into the archegonial chamber with 2 neck cells and without neck canal cells. It has no venter but has an egg nucleus and venter canal nucleus embedded in the common cytoplasm lined by female gametophyte cells.
- Egg cell of *Cycas* is the **largest** in the plant kingdom.

Pollination

- The pollen grains are carried by wind (**Anemophily**) and caught by pollination drop secreted by ovule. Pollination is direct.

Development of male gametophyte after pollination

- The pollination drop is dehydrated and the pollen grains are sucked into the pollen chamber.
- Pollen grains take rest for some time in the pollen chamber.
- During the germination of pollen grain the exine is ruptured and the inner intine comes out in the form a tube like structure known as pollen tube.
- At this time the **generative cell divides and forms a larger**, upper **body cell** and smaller, lower **stalk cell**.
- The pollen tube acts as **haustorium** to absorb food materials from the nucellus besides as **sperm carrier**.
- The body cell divides and forms two naked, top shaped, motile, **multiciliated antherozoids**. The cilia are in **4 – 5** spirals.
- The male gametes of *Cycas* are **180 – 210 μ** in size and **largest** in the plant kingdom.
- The pollen tube apex is ruptured and the male gametes are released into the **archegonial chamber**.
- Presence of multiciliated male gametes is the **fern character** shown by *Cycas* male gametophyte.

Fertilisation

- By the time the male gametes are released into the archegonial chamber the venter canal nucleus of venter is degenerated.
- The male gametes released into the archegonial chamber swim in the archegonial chamber fluid before coming in contact with the neck.
- **Hypostomatous** condition and sunken stomata.
- Sclerenchymatous hypodermis.
- Well developed palisade and **poorly developed spongy** tissue.
- Presence of transfusion tissue.

Embryo

- Zygote is the first cell of sporophytic generation.
- It shows free nuclear divisions and cell wall formation around the nuclei in centripetal manner to form multicellular proembryo.
- **Proembryo** has upper elongated suspensor region and lower embryonal region.
- Suspensor region later shows the formation of **haustorium** at its tip.
- The embryonal region differentiates into a radicle surrounded by a hard pad of tissue known as **coleorrhiza** (Monocot character), a plumule and **two cotyledons** (Dicot character).
- There is formation of **2 – 8** embryos in the seed based on the number of archegonia developed in the female gametophyte. It is known as **Polyembryony**. It is **simple polyembryony**.

Seed

- Seeds of *Cycas* are exposed. These are **reddish brown** or **reddish orange** coloured.
- Its seed coat has only **testa** with almost used up (for embryo development) inner sarcotesta and nucellus (**Perisperm**) in the form thin layers. The outer sarcotesta is **fleshy** and helps in seed dispersal by birds (**ornithochory**).
- The embryo is surrounded by fleshy nutritive gametophyte or haploid endosperm.
- Seed has a small pore which is nothing but micropyle of the ovule.
- It has three generations of tissues. They are seed coat and perisperm of parental sporophyte, endosperm belongs to female gametophyte and embryo belongs to daughter sporophytic generation.
- Embryo of the seed has a radicle surrounded by coleorrhiza, hypocotyls, cotyledons and plumule in the embryonal region, an elongated suspensor and haustorium at the tip of the suspensor.
- Seed are perispermic, endospermic and polyembryonic.

Seed germination

- Seed dispersal is through birds. It is known as **Ornithochory**.
- Seed undergoes a period of dormancy due to physiological immaturity or without any dormancy the seeds germinate.
- During germination, the cotyledons remain in the soil. Hence germination is hypogeal (Monocot character).
- The radicle develops into taproot which later replaced by adventitious roots.
- Plumule develops into underground tuberous stem and gives out few aerial leaves with circinate vernation.
- The growth of stem is very slow and eventually becomes aerial with first crown of leaves developed after few years.

Life cycle

- The dominant stage in the life cycle is sporophyte and gametophytes are highly reduced and parasitic on sporophyte. Hence life cycle is described as **Diplohaplontic life cycle**.
- Both gametophytes and sporophyte are morphologically dissimilar. Because of this the alternation of generations are described as **heteromorphic**.

Fern characters of *Cycas*

- Circinate vernation of younger leaves.
- Rhizomatous stem.
- Presence of Ramenta.
- Multicilate male gametes.
- Formation of archegonia in the female gametophyte.
- Formation of microsporangia in groups on the lower surface of microsporophyll.
- Sori surrounded by Indusial hairs.
- Mesarch xylem in the leaves.

Pinnate compound leaves.