Genus - Hedychium

Sanoj E. “Taxonomic revision of the genus hedychium J. koenig (zingiberaceae) in India” Thesis. Department of Botany, University of Calicut, 2011
The genus *Hedychium* is characterized by the peculiar nature of the inflorescence, well developed labellum and lateral staminodes and prominent and exserted stamen. As per Wood *et al.* (2000) and Kress *et al.* (2010) it is a monophyletic genus and is closely allied to the sister clade of the newly described genus *Larsenianthus* W.J. Kress & Mood. The structure and ontogeny of the family as a whole and the genus has been well studied by many predecessors (Wood *et al.* 2000, Kirchoff 1997, Kong *et al.* 2010). The floral structure of the genus is much modified and is adapted for insect pollination. The brightly coloured flowers also attract the horticulturists world over due to their aesthetic value. Even though it is commonly cultivated in home gardens as an ornamental plant there are some reports on its invasive behaviour (Lowe *et al.* 2000, Csurhes & Hannan-Jones 2008, Sankaran 2008). Apart from their ornamental value a few species are highly priced for their medicinal properties, hence widely used in traditional medicine and Ayurveda.

**Morphology and Ontogeny**

The inflorescence of *Hedychium* is a ‘thyrse’, refers to an inflorescence with a single main axis and cymose lateral branches (Kirchoff 1997). The elements of a branch system are numbered accordingly based on their position. The primary axis bears distichous foliage leaves, and terminate in a spirally arranged inflorescence bracts. The bracts born directly on this axis are known as primary bracts. The primary bracts subtend cincinni that terminate in primary flowers, the first flowers of the cincinni. Secondary bracts are born on the axes that terminate in primary flowers. Secondary bracts subtend secondary flowers, the second flower of the cincinni.
In *Hedychium*, all the flowers in a cincinnus are initiated in such a way that the true stamen backs on the main inflorescence axis, not on the axis of bract that subtends the flower. So the median plane in the odd numbered flowers bisect the anthers, like that the median planes in the even numbered flowers bisect between the staminodes and labellum. To avoid this confusion, Kirchoff (1997) used the term ‘coronal’ for the plane that separates the staminodes with stamen form labellum and the term ‘sagittal’ for the plane that bisects through the stamen and labellum (independent to the orientation of flower on its bracts).

*Labellum, Lateral staminodes and Stamen*

The flowers in Zingiberaceae as a whole and *Hedychium* in particular, consist of five major parts (Kirchoff 1997, Kong et al. 2010), three sepals, three petals, two lateral staminodes, single labellum, single fertile stamen and a single gynoecium. The origin and evolution of six androecial members in the Zingiberaceae have been a matter of controversy since long. Lestiboudois (1829) first proposed the interpretation about the origin and evolution of six androecial members of the genus. But the widely accepted interpretation of the origin of labellum is that of Eichler (1875). Based on this interpretation, two inner antero-lateral androecial members are united to form a labellum, the posterior one form a fertile stamen, two outer postero-lateral androecial members form the two petaloid lateral staminodes. This interpretation of the labellum development is supported by Baillon (1876), Kirchoff (1998), Payer (1857), Rao et al. (1954), Rendle (1930), Tiegham (1868) and Willis (1948).

Brown (1830) regarded the anterior labellum and two postero-lateral lateral staminodes are to be of outer androecial whorl and the two antero-lateral epigynous glands and the single posterior fertile stamen to be of the inner whorl. Schumann (1904) proposed that the distinctly bilobed labellum of the genera (e.g., *Hedychium, Kaempferia*) consists of two inner androecial members, and the
lobeless labellum of the genera (e.g., *Alpinia, Amomum*) consists of one outer androecial member.

Recently, Kirchoff (1997) and Kong *et al.* (2010) described the most acceptable ontogeny in some species of *Hedychium*. According to them, the two inner antero-lateral androecial members are joined by intercalary growth and fuse to produce the two-lobed labellum, while the outer whorl anterior androecial member ceases growth soon after initiation. The one inner and two outer androecial members are initiated on the posterior side of the flower. The one inner posterior androecial member forms the functional stamen. The two outer potero-lateral androecial members form the lateral, petaloid staminodes. This view supports the interpretation of Eichler (1875).

*Epigynous glands*

Brown (1830) regarded the two epigynous glands and the posterior stamen as belonging to the inner whorl, and the antero-lateral segments are reduced to the two epigynous glands. Rao (1963) proposed most acceptable interpretation of epigynous glands of Zingiberaceae based on the ontological studies. As per him, the epigynous glands belong to the gynoecium and not to the androecial whorls at all. The two glandular outgrowths clearly develop near the top of the ovary from the antero-lateral septa, and are continued upwards above the ovary level as the epigynous glands. And the third one is always suppressed on the posterior side.

*Inflorescence development*

Inflorescence is terminal and developed spirally from bottom to top. With the transmission to inflorescence the phyllotaxy begin to change from distichous to spiral. Primary bracts of the inflorescence are initiated on the flanks of the apical dome in a spiral phyllotactic pattern. Soon after initiation the bract primordia become crescent-shaped, the concave side of the crescent opening upward. Cincinnus primordia are initiated in the axils of the primary bracts. As the
inflorescence ages, the inflorescence apex decreases in size relative to the surrounding bracts and finally ceases growth. Near the time of its abortion, the apex bears fewer bracts, and the primary bracts and cincinnus buds begin maturation closer to the apical dome than when the apex is most actively producing bracts (Kirchoff 1997, Kong et al. 2010).

**Cincinnus development**

In the axils of primary bracts, the ellipsoid cincinnus primordia are initiated on the flanks of inflorescence apex. On aging, the young cincinnus widens and produces a transversely elongated primordium. Soon, the primordium becomes more pointed on one side. This point is the secondary bract; and the first floral primordium is initiated on the other side. Later, the secondary bract extends and completely surrounds the cincinnus. In the axil of the secondary bract, the primordia continue the growth of the cincinnus, while the apex of the secondary axis produces a flower. Growth of the cincinnus proceeds in the same pattern. The bract is always initiated away from the flower but in the same transverse plane (Kirchoff 1997, Kong et al. 2010).

**Flower development**

Flower development begins after the initiation of the secondary bract with the transformation of the cincinnus apex into a floral primordium. This primordium enlarges, begins to flatten, and assumes a rounded, obdeltoid appearance in polar view. As growth continues, the floral primordium becomes flatten and the corners of the deltoid become more distinct.

The obdeltoid corners of the floral primordium are the sites of sepal initiation and are initiated clockwise. Following initiation, the sepals extend around the periphery of the floral primordium until the margins of the adjacent sepals become confluent. From this stage, intercalary growth of the sepals produces the majority of the synsepalous calyx.
Along with the sepal initiation, the whole flower primordium continues to enlarge. The periphery of the flower, interior to the sepals, produce a raised ring of tissue that surrounds a central depression. This ring primordium is composed of three common primordia united below into a cylinder of tissue surrounding a central cavity. The cylinder with its enclosed central cavity forms the floral cup, the site of gynoecial initiation.

The common primordia become increasingly distinct as the floral primordium enlarges. First of all, the adaxial common primordium separates from the ring primordium. Then, the two abaxial common primordia begin to separate. The adaxial common primordium is larger than the two abaxial common primordia. Each common primordium then produces a petal to the exterior and an androecial member to the interior. Separation of the three common primordia begins with the fertile stamen and its associated petal, and then the abaxial inner androecial members begin to separate. The adaxial inner androecial member develops into the fertile stamen. During the separation of the common primordia, the thecae of the stamen are visible. The two abaxial inner androecial members are sterile, they unites and constitute the petaloid labellum. The abaxial outer androecial member ceases growth soon after initiation, while the two adaxial members continue to grow and eventually produce two petaloid lateral staminodes.

During the enlargement and separation of the common primordia, the hollow space at the center of the floral cup enlarges and becomes a rounded-triangular apex. The three vertices of this triangle are the sites of outer androecial initiation.

The three primordia of the style and stigma are initiated opposite the petals, below the insertion of androecium. The adaxial primordium is slightly larger than the two abaxial primordia at an early stage of development, suggesting that the adaxial primordium is initiated first. Soon, the primordia extents longitudinally and occupies the full depth of the floral cup. With continued growth of the
gynoecial primordia, the three carpellary primordia grow upward and fuse along their lateral margins to produce a cylindrical style capped by a trilobed stigma primordium (Kirchoff 1997, Kong et al. 2010).

The epigynous glands are typically two in number, and are antero-lateral in position. In some, they are basally connate on the anterior side, and there is no gland on the posterior side. Of the three carpels of the ovary, one is anterior and the other two postero-lateral. Hence, one septum is posterior and the others antero-lateral. Where the loculi of the ovary end at the top of the ovary, the septa separating them thicken proportionately, and each group of processes comprising a gland arises from a broad base correspond to the broadened septum portion. A little higher, two of these glandular areas-those two that are in antero-lateral positions, become separated from the tissue lying to its outside. These two become free, short, somewhat cylindrical epigynous glands. The third gland, which is on the posterior side, does not become free and it disappears a short distance beneath the point of separation of the two other glands (Rao 1963).

**Cytology**

Raghavan and Venkatasubban (1943) observed a wide range of variation in chromosome number and stated the chromosome number of *H. flavescens* (2n = 34), *H. greenii* (2n = 36), *H. flavum* (2n = 52), *H. coronarium* (2n = 54), *H. gardnerianum* (2n = 54) and *H. gracile* (2n = 66). Sharma and Bhattacharyya (1959) studied ten taxa of this genus, of these one is characterized by 2n = 24 (*H. thyrsiforme*), seven by 2n = 34 (*H. villosum, H. coronarium, H. coronarium* var. *maximum, H. coronarium* var. *angustifolium, H. flavum, H. aurantiacum* and *H. gardnerianum*), and others by 2n = 51 (*H. greenii*) and 2n = 52 (*H. flavescens*). They studied the earlier reports of the genus in detail and suggested that, n = 17 can be considered as the haploid set of the ancestral forms of most of the species and which was derived from those with n = 12 at a certain stage in evolution. Mahanty (1970) based upon the meiotic behaviour of pollen mother cells of
H. thrysiforme, stated that, 17 bivalents are found at the first metaphase and the pairing seems to be regular. Ramachandran (1968) determined the chromosome number of two clones of H. coronarium and confirmed the basic number as n = 17.

Anatomy

Jayasree (2007) studied the anatomy of South Indian Zingiberaceae, including three species of Hedychium, viz., H. coronarium, H. flavescens and H. spicatum, and separated them based on the anatomical characters. She identified the intercostal cells of the adaxial epidermis are polygonal with longer axis perpendicular to the longitudinal veins in all species studied. Among the South Indian species, epidermal cells are larger in H. coronarium. Costal cells of the abaxial epidermis are broader in all species, and has maximum width in H. spicatum with oil cells. Trichomes are present on the abaxial epidermis of all species. Lengths of guard cells are almost same in all the three species. Abaxial surface of the sheath are hairy in H. flavescens, whereas in other two species it is glabrous. Calcium oxalate crystals are present in the chlorenchymatous and guard parenchyma cells of H. flavescens and H. spicatum. Starch grains are present in the chlorenchyma cells of H. spicatum. In all the three species studied, there is a continuous hypodermis both abaxially and adaxially. Adaxially it is two layered in H. coronarium and H. flavescens, but it is not consistent in H. spicatum. In all species two layers of palisade cells are present. She concluded that, because of the close resemblances, the anatomical differentiation between H. coronarium and H. flavescens is difficult.

Pollination

As like most of the monocots, Hedychium is also adapted to pollination by animals, mostly insects. Large brightly coloured flowers act as the primary means of attraction. The perianth, especially labellum and lateral staminodes, serves as a landing platform, a guide leading animals to feeding positions appropriate for
pollination. The nectar is present at the base of the long slender corolla tube to favour relatively long proboscised insects (Box & Rudall 2006). Production of floral scents as a means of secondary attraction is widespread in *Hedychium* with few exceptions (Larsen *et al.* 1998). The presence of downwardly directed hairs inside the tube restricts the entry of small insects like ants. In general Zingiberaceae have avian, hymenopteran and lepidopteran pollinators such as hummingbirds and euglossine bees (Box & Rudall *l.c.*). A fail-safe attachment of pollen upon the visitor’s body is crucial in this monantherous *Hedychium* flower. The mucilage produced by the connective serves to attach pollen masses firmly on the visitor (Vogel 1998).

**Phytochemistry**

Many chemical constituents of Zingiberaceae, especially *Hedychium* were investigated. From the rhizomes of many species of *Hedychium* several monoterpenes, diterpenes and sesquiterpenes were isolated. Zhao *et al.* (2003) isolated two new diterpenoids, *viz.*, Hedyforrestin-B and Hedyforrestin-C, from *H. forrestii*, which is having cytotoxic properties. Nakatani *et al.* (1994) isolated three new diterpenoids from *H. coronarium*, *viz.*, Coronarin-B, Coronarin-D, and Isocoronarin-D. The rhizome extracts of *H. spicatum* were tested by Bisht *et al.* (2006) for their antibacterial and antifungal activities. Dixit and Verma (1979) studied the effect of essential oil of *H. coronarium* and *H. spicatum* on central nervous system on rats, and found that, oils possess mild tranquilling action. The peak action of the essential oils was recorded 30 minutes after their administration. The essential oil also potentiated pentobarbitone induced hypnosis and marked analgesia.

Gopanraj *et al.* (2005) studied the composition of essential oil from the rhizomes of *Hedychium larsenii* M. Dan & Satish by GC-FID and GC-MS techniques and identified 99% of the oil consisted of Monoterpenoids and Sesquiterpenoids were present only in negligible quantities. Linalool and 1,8-cineole were identified
as the major components of the essential oil. The oil showed moderate antibacterial activity against Gram-positive and Gram-negative bacteria. Dan et al. (2007) studied the rhizome oils of four Hedychium species, viz., H. coronarium, H. flavescentis, H. spicatum var. acuminatum and H. venustum, of South India by GC-FID and GC-MS. They identified the oil yield is highest in H. venustum (0.16%) with fifty-seven constituents and lowest in H. flavescentis (0.05%) with twenty five constituents. In H. spicatum var. acuminatum and H. coronarium oil yield is 0.13% with twenty five and twenty three constituents respectively. The major constituent in these species were the monoterpenes 1,8-cineole, β-pinene and linalool, constituting 70-75% of these oils.

There are many reports for the antibacterial and antifungal activities of rhizome extracts of Hedychium. Medeiros et al. (2003) tested the antimicrobial activity of essential oil from the species H. gardnerianum, and found that it is having a good activity against Staphylococcus aureus and S. epidermis. Xiao et al. (2001) isolated one new diterpene, 'Villosin', from H. villosum, and its structure has been elucidated by spectroscopic methods including mono and bi-dimentional NMR. Sharma et al. (1976) isolated a new Furanoditerpene, ‘7-Hydroxyhedychenone’, from the rhizomes of H. spicatum. It is substantiated by spectroscopic data using NMR spectrum. Sharma et al. (1975) isolated one Furanoid Diterpene, ‘Hedychenone’, from H. spicatum rhizomes, deduced on the basis of spectroscopic and chemical evidences.

Cultivation

The Hedychium has more popular among the horticulturists mainly because of their easy mode of propagation and relatively disease and pest free nature. Paxton (1838) provided a detailed account on cultivation of some species of Hedychium. In the tropical climate of India, this can be easily propagated using rhizome cuttings, seeds or rarely by bulbils. Many species produce massive rhizomes, which can be used a propagule. A portion of rhizome with at least one
old and young aerial shoot constitutes a planting unit. Large rhizomes can be split into small pieces of convenient size and can be planted in pots containing potting mixture with the composition of 1:1:1 sand, soil and farm yard manure and allow to grow in shades. The best season for planting in India is from May onwards, i.e., just after pre-monsoon showers. Deep planting of rhizomes should be avoided as many species are subterranean in nature. It may also result in the suppression of the growth of new shoots and cause death of plants due to decaying of underground rhizomes. Irrigation at regular intervals is required for proper growth and development of plants. A regular schedule of cultural practices consisting of weeding, mulching, trashing, shade regulation, manuring and irrigation is to be taken up.

Uses

Hedychium is the genus with much horticultural importance. At present, over 100 horticultural varieties have been bred world-wide (Gao et al. 2008). At least seven species are widely traded as garden ornamentals around the world, namely: H. densiflorum (ornamental cultivars include ‘Assam orange’ and ‘Stephen’), H. coronarium (ornamental cultivars include ‘Gold spot’), H. flavescens, H. gardnerianum (ornamental cultivars include ‘Tara’, ‘Extendum’ and ‘Compactum’), H. coccineum, H. spicatum and H. greenii (Csurhes & Hannan-Jones 2008). A number of flowers are produced at a time, the brilliant coloured and delightfully fragrant flowers on terminal spike make the plant much attractive. Free inter-specific hybridization and ease of cultivation and propagation makes it much interesting genus for horticulturists. Flowers are valued as a perfume by the Arabs and Persians and also Hindus used it for the worship of God (Sawar 1894), and for the decoration of hair. It is also used as a symbol of love, when belles sent flowers of this plant as a present to a young man, is meant to reproach him with inconstancy in love (Smith 1811). H. coronarium is widely cultivated in Brazil for paper making (Beadle 1917). In Hawaii, flowers and roots of H. coronarium are
used as a remedy for fetid nostrils (Nagata 1971), also used for making leis and also as a source of perfume, rhizomes are stimulant and carminative. The flower of *H. coronarium* is eaten as vegetable. It is also a source of perfume (Sirirugsa 1998). In Thailand the rhizome of *H. coronarium* is used as a stimulant and carminative and a decoction of the stem is gargled for tonsillitis. The roots of *H. longicornutum* Griff. ex Baker, is used for the treatment of earache, and the pounded root or the whole plant is a remedy for intestinal worms (Sirirugsa *l.c.*). In India, rhizomes of *H. coronarium* are used as a febrifuge, anti-rheumatic, tonic and gargle in Folk system of medicine (Udayan & Balachandran 2009). *Hedychium spicatum* rhizomes are one of the ingredients of Ayurvedic preparations. It is used for the treatment of cardiac failure, splenic disease, asthma, hiccup, cough, digestive impairment, constipation, anaemia and pain in urinary bladder, sacral region, anus and female genital tract (Saraswathy *et al.* 2009). The therapeutic activity of the rhizome is due to its essential oil. The rhizome in powder form is sprinkled as an antiseptic agent and also used as a poultice for various aches and pains. It is a carminative and bronchodilator. The drug is an ingredient of some Ayurvedic preparations but rarely used in Unani system (Joy *et al.* 1998). Besides the medicinal properties the fruits are cooked and eaten in savoury dishes with lentils and also used for essential oil and incense (Bhatt *et al.* 2009).

**Invasiveness**

Without knowing the negative impact on indigenous flora, *H. gardnerianum* was introduced around the world through horticultural trade. It has become a dangerous invasive weed and later included under the list of ‘100 of the World’s Worst Invasive Alien Species’ (Lowe *et al.* 2000). It is now distributed throughout the tropics by invading natural forest ecosystems and causing threat to the indigenous species. The affected countries include Federated States of Micronesia, Fiji, New Caledonia, Cook Islands, Australia, French Polynesia, Hawaii, New Zealand, La Reunion Island (France), South Africa and Jamaica (Sankaran 2008).
H. coronarium is naturalised in south-east Queensland and in North Queensland, though it shows slow growth, it may develop into a troublesome weed like H. gardnerianum in future. H. flavescens is another popular garden plant that has become a major threat in New Zealand and Hawaii (Csurhes & Hannan-Jones 2008).

Phylogeny and Evolution

Kress (1990) derived a new classification of the order Zingiberales based on the cladistic studies. Among the eight families only ginger group is monophyletic, but the banana group is paraphyletic. Musaceae at the base of the phylogenetic tree. Lowiaceae and Strelitziaceae form a clade, paraphyletic to Heliconiaceae. Later, cladistic analysis of the rbcl sequence data (Smith et al. 1993) also recognized eight families under Zingiberales. But they identified, except Musaceae, all seven families are monophyletic, but Musaceae is paraphyletic with the Cannaceae.

Phylogenetic studies based on the ITS sequence well supported the monophyly of the genus Hedychium (Wood et al. 2000) with a bootstrap value of 100%, and resulted in the four moderately supported clades. But its affinity with Cautleya, Pommereschea Wittm., Rhynchanthus and Roscoea is weekly supported, as expected on the morphology. They concluded that, the genus Hedychium is monophyletic and includes the genus Brachychilum. They also proposed four clades, viz., Clade I, Clade II, Clade III, Clade IV. Of which Clade IV (three to five flowers per bract) and Clade II (one flower per bract), have a natural circum-himalayan distribution; where as Clade I (one or two flowers per bract) occur only in the Malay Peninsula, Philippines, Borneo, Sumatra, Java, Sulawesi, and the Moluccas. The position of Clade III (H. acuminatum) is uncertain but probably includes H. venustum on the basis of morphology. The molecular phylogenetic classification (Wood et al. 2000) is contrary to Schuman’s (1904) classification based on morphology in many cases. This analysis emphasised that the most important factor in the evolution of this genus is geographic and ecological
isolation. They also suggested that tribal concepts need to be re-evaluated in the Zingiberaceae.

Phenetic studies on this genus by Wood (1996) suggested that there is a significant genetic distance between the circumhimalayan terrestrial species and the Southeast Asian and Indonesian lowland epiphytic species. Based on this he hoped to establish two subgenera Himalayanum T. Wood and Malesianum T. Wood. He himself did not follow this classification in his future works.

Evolutionary studies by Kress et al. (2005) indicate that the Zingiberales originated in the Jurassic, 158 Ma, with an ancestral distribution in the Americas, Africa and Southeast Asia (i.e., tropical Gondwanaland). It suggests that this specialized group of plants had an early origin in angiosperm history with a broad tropical distribution. The three main lineages of the banana-families originated about 97 Ma in the early Cretaceous although the split between the Lowiaceae and the Strelitziaceae did not occur until 49 Ma in the middle Eocene. The ginger-families began to diversify 88 Ma with the Costaceae diverging from the Zingiberaceae and Marantaceae from the Cannaceae 83 Ma and 80 Ma respectively. Therefore by the end of the Cretaceous six of the eight currently recognized families had become independent lineages with the final two families (Strelitziaceae and Lowiaceae) diverging in the early Tertiary. In the ginger families within-family lineages began to diverge in the late Cretaceous and Tertiary at 65 Ma in the Zingiberaceae.