1 Botany of Genus *Eucalyptus*

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1. Introduction

Eucalyptus, a well known genus of Australia, belongs to the family Myrtaceae, where *Callistemon, Eugenia, Melaleuca, Psidium, Rhodomyrtus* and *Syzygium* are also members. Regarding the origin of eucalypts in Australia, the theory of plate tectonics, supported by fossil evidence, show that the land mass was once part of a single super-continent Gondwana, comprising what is now known as New Guinea, Antarctica, India, Arabia, Africa, Madagascar and South America. As Gondwana broke up in the Tertiary period, the Australian landmass drifted northwards from Antarctica. It is believed that in the early part of this drift the continent experienced high rainfall and was characterized by a relatively uniform rainforest vegetation. The landmass gradually became drier and the ancient soils lost their fertility. The new land environment became totally unsuited to rainforest and it contracted, largely to the eastern seaboard. However, by the evolution of new adaptable forms some plant families were able to occupy the areas of less certain rainfall and soils of diminishing fertility. Notable examples are Myrtaceae, which spawned the eucalypts, and *Mimosaceae,* the distinctive phyllodinous *Acacia* spp. (Brooker, 2002).

2. Classification

The first specimen of the genus *Eucalyptus* was collected in 1770 by Joseph Banks and his assistant Daniel Carl Solander on the shores of Botany Bay on the east coast of Australia during Capt. James Cook's first voyage to the Pacific Ocean. Before this, however, in 1688 William Dampier found a tree with gummy exudation which he confused with *Calamus draco* which is known as 'Dragon's Tree' and produces a resin called 'dragons blood'.

The genus *Eucalyptus* was described and named by the French botanist L' Heritier in 1788 as *E.obliqua*. The name *Eucalyptus* consists of *Eu* which means true and *calyptus* (*kalypto*) means to cover; referring to the united calyx and corolla

forming lid or operculum which seals the flower till it blooms. Bentham and von Mueller (1866), without studying plants in the field, carefully examined and classified dried plant materials brought from Australia and published 'Flora Australiensis' which is considered, even today, as one of the best classification on the Australian flowering plants.

By 1866, total 149 species of *Eucalyptus* were named. Bentham and von Mueller (1866) classified them into five series based on their anther characteristics with the fifth series, subdivided into nine subseries. Further, Mueller (1879-84) carried out study of eucalypts in the Australian fields which Bentham could not take up. He published several papers and a book 'Eucalyptographica'. However, he was not able to propose a better classification for the eucalypts than the one by Bentham.

Maiden (1903-33) continued studies on eucalypts and published 'A Critical Revision of the Genus *Eucalyptus'* with illustrated descriptions of all taxa known up to that time. But he could not improve the existing order of classification. Blakely (1934) an assistant to Maiden, extended Bentham's antheral classification in his book 'A key to the *Eucalyptus*', a most comprehensive descriptive work ever published comprising 500 species and 138 varieties.

A revision of the names and status of many taxa of eucalypts described by Blakely (1934) was done by Johnston and Marryatt (1962) in their work 'Taxonomy and Nomenclature of *Eucalyptus*'. These names were again revised by Chippendale (1968) in a paper entitled '*Eucalyptus* nomenclature'.

Based on the extensive studies in eucalypts, Pryor and Johnson (1971) published 'A Classification of the Eucalypts' in which the genus *Eucalyptus* of L'Heritier and the closely related genus *Angophora* of Ceur are combined. The classification divides the genus *Eucalyptus* into seven subgenera. The subgenera are divided into sections, series, subseries, super species, species and subspecies; subgenera, sections, number of species in each section (Table 1).

Pyror and Johnson's classification was deliberately extracodical (informal and outside the International Code of Botanical Nomenclature). The system was hierarchical (sections, series, etc.) and contrasts with the formal classification used by Chippendale (1988), where only one infra-genetic rank (series) was used. This latter work, however, made possible the formal reference of all species published up to 1988 to taxonomic series, which is generally required in systematic papers.

The most recent major contribution to classification in the genus *Eucalyptus* was made by Hill and Johnson (1995) who formally published a new genus, *Corymbia*, comprising two of the subgenera of the Pryor and Johnson's classification (1971), namely, *Corymbia* and *Blakella*. The rationale for this step was based on cladistic analyses of all the traditional *Eucalyptus* components at the general 'subgenus' level and is corroborated by molecular studies of Udovicic *et al*. (1995).

Table 1. The classification of Pryor and Johnson (1971) with examples of well-known species in the taxa

Subgenus	Well-known species and species group
Blakella	Ghost gums (e.g. *E. tessellaris*)
Corymbia	Bloodwoods (e.g. *E. citriodora*)
Eudesmia	Includes *E.miniata* and *E. baileyana*
Gaubaea	Comprises *E. curtisii* and *E. tenuipes*
Idiogenes	*E. cloeziana* only
Monocalyptus	White mahoganies (e.g. *E. acmenoides*), stringybarks (e.g. *E. globoidea*), blackbutts (e.g. *E. pilularis*), ashes (e.g. *E. obliqua*), peppermints (e.g. *E. dives*, *E. radiata*)
Symphyomyrtus	Red mahoganies (e.g. *E. robusta*), red gums (e.g. *E. camaldulensis*), mallees (e.g. *E. polybractea*), gums (e.g. *E. globulus*), boxes (e.g. *E. polybractea*), ironbarks (e.g. *E. staigeriana*).

Corymbia Hill and Johnson is a genus of about 113 species of trees. Species of *Eucalyptus* (introduced in India) were shifted to *Corymbia* by Hill and Johnson (1995) and are given below:

Corymbia citriodora (Hook.) Hill and Johnson (syn. *Eucalyptus citriodora* Hook.)
Corymbia ficifolia (F.v.M.) Hill and Johnson (syn. *Eucalyptus ficifolia* F.v.M.)
Corymbia gummifera (Gaertn.) Hill and Johnson (syn. *Eucalyptus gummifera* Gaertn.)
Corymbia intermedia (F.v.M. ex Baker) Hill and Johnson (syn. *Eucalyptus intermedia* F.v.M. ex Baker)
Corymbia maculata (Hook.) Hill and Johnson (syn. *Eucalyptus maculata* Hook.)
Corymbia polycarpa (F.v.M.) Hill and Johnson (syn. *Eucalyptus polycarpa* F.v.M.)
Corymbia terminalis (F.v.M). Hill and Johnson (syn. *Eucalyptus terminalis* F.v.M.)
Corymbia torelliana (F.v.M.) Hill and Johnson (syn. *Eucalyptus torelliana* F.v.M.)

Some ambiguity, however, remains over relationship of the closely related genus *Angophora* Cav. A recent study on the relationships within *Eucalyptus* concluded that *Angophora, Corymbia* and *Blakella* form a monophyletic group (Sale *et al*., 1996). Perhaps all these recent studies should be considered merely as hypotheses that will contribute ultimately to an optimum system with further researches. Brooker (2002) suggested that for a single genus consisting of thirteen subgenera (Table 2), namely, the five major subgenera of Pryor and Johnson (1971),

Table 2. Proposed new classification of the genus *Eucalyptus*

Subgenus *Angophora*
Sungenus *Corymbia sensu* Pryor and Johnson, 1971
Subgenus *Blakella sensu* Pryor and Johnson, 1971
Subgenus (*E. curtisii*)
Subgenus (*E. guilfoylei*)
Subgenus *Eudesmia sensu* Pryor and Johnson, 1971
Subgenus *Symphymyrtus sensu* Pryor and Johnson, 1971
Subgenus (*E. ravertiana, E. brachyandra, E. howittiana, E. deglupta*)
Subgenus (*E. microcorys*)
Subgenus (*E. tenuipes*)
Subgenus *Idiogenus sensu* Pryor and Johnson, 1971 (*E. cloeziana*)
Subgenus (*E. rubiginosa*)
Subgenus *Eucalyptus* (=*Monocalyptus* in Pryor and Johnson, 1971)

Source: Brooker (2002).

the genus *Angophora*, a subgenus comprising the four tropical species with the small fruit, and six single-species subgenera – a system embracing demonstrable morphological distinctions.

While comparative morphology is the basis for estimating natural affinities and resulting classification, the value of characters used varies greatly. Features such as bark have been traditionally used in keys and descriptions, but bark as a character is only of medium reliability as its constant exposure to the elements results in attrition and colour change. Internal characters protected from outside influences are of higher reliability. In this respect, essential oils have been considered as possible acids to testing natural affinities. Little success has been achieved and it may be concluded that the developmental pathways for morphology and for essential oils are not closely associated within the eucalypt plant (Brooker, 2002).

Metro (1955) recognized the name of some taxa which are believed to have hybrid origin (Table 3). Research work conducted at the Forest Research Institute, Dehradun, has resulted in the development of two promising interspecific F_1 hybrids between *E. tereticornis* and *E. camaldulensis*, FRI-4 and FRI-5. These improved varieties have yielded three to five times more wood than the parent species over a ten-year rotation, although the oil composition shows little improvement in commercial terms (Chaudhari and Suri, 1991).

3. Morphology

3.1. Habit

Eucalypts vary in general habit from shrub one metre high to the tallest 90 m high. Similarly the stem on one side are 2.5 cm in diameter whereas on the other side there are buttressed trunks upto 6 m in diameter.

Table 3. *Eucalyptus* of hybrid origin

Taxon	Probable parent
E. affinis Deane and Maiden	*E. albens* x *E. sideroxylon*
E. algeriensis Trabut	*E. camaldulensis* x *E. rudis*
E. antipolitensis Trabut	*E. globulus* x *E. viminalis*
E. bianqularis Simmonds	*E. globulus* x *E. urnigera*
E. bourlierii Trabut	*E. globulus* x ?
E. codieri Trabut	Probble hybrid of *E. nortonii*
E. globulus var. *campacta* Bailey cultivar	
E. gomphocornuta Trabut	*E. gomphocephala* x *E. cornata*
E. huberana Naudin (as applied by Blakely)	Quite common in Australia. *E. viminalis* x several related species giving seven flowered umbels in contrast to the three flowers of *E. viminalis* Chippendale (1976) states that *E. huberana* Naudin is now accepted as a taxon
E. insizwaensis Maiden	*E. globulus* x ?
E. longifolia var. *multiflora* Maiden	*E. longiflolia x E. robusta*
E. maidenii var *williamsonii* Blakely	*E. botryoides* x *E. pseudoglobulus*
E. mcclatchiei Kinney	*E. globulus* x *E. ovata*
E. nortonniana Kinney	*E. pseudoglobulus* x *E. maidenii*
E. occidentalis var. *ornensis* Trabut	Status doubtful
E. oviformis Maiden and Blakely	*E. pseudoglobulus* x *E. tereticornis*
E. patentinervis R.T. Bak.:syn *E. kirtoniana* F.v. M.	*E. robusta* x *E. tereticornis*
E. polulifolia Hook. var. *obconica* Blakely	*E. microtheca* x *E. populnea*
E. trabutti Vilmorin	*E. botryoides* x *E. camaldulensis*

Source: Tewari (1992).

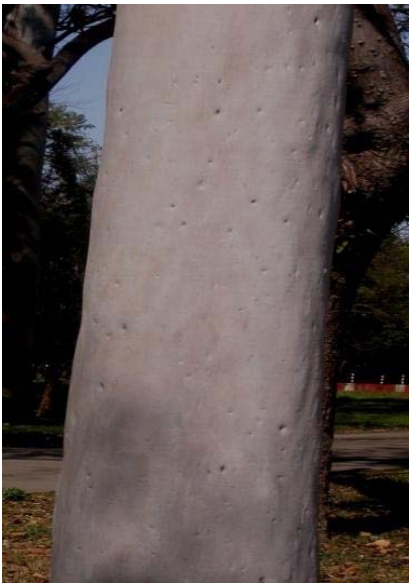
3.2. Bark

Generally speaking, the bark on the young branches of a mature tree is smooth, while on the lower part of the trunk, up to a few metres from the ground, the rhytidom becomes more or less persistent and deeply furrowed. Therefore, when describing the type of bark, neither that of the trunk base nor of the twigs should be taken into account.

Of the distinctions made in Australia, the following which seems most typical, but not, in any case, suitable for extensive interpretations were retained in the chapter.

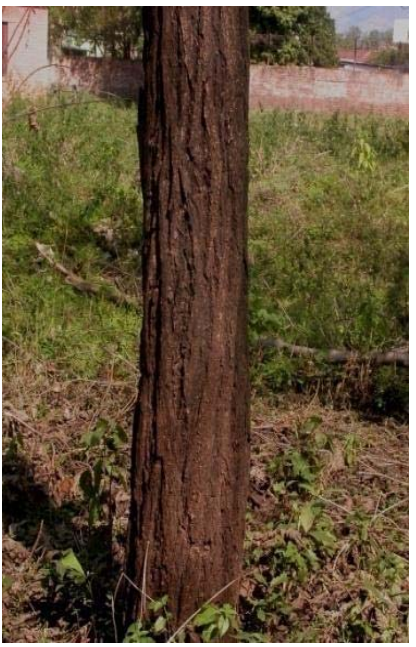
3.2.1. Deciduous bark

Bark peeling off, when each layer is renewed, in long stripes as in *E.globulus*. Peeling off in rather broad plates, as in *E. camaldulensis* and *E. saligna*. Peeling off in very small flakes or scales, as in *E. citriodora* or *E. astringens* (Fig. 1).

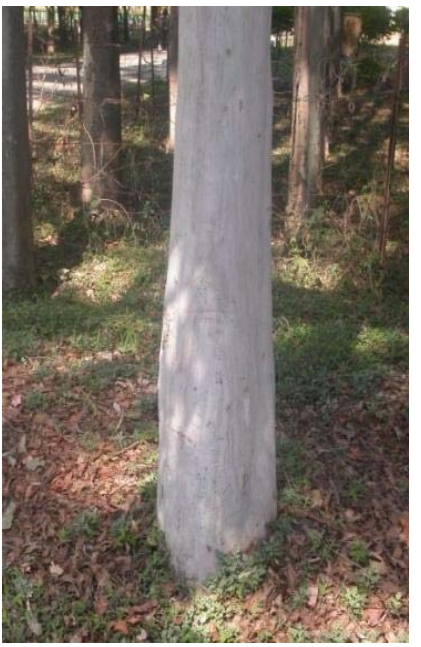


(a) *E. citriodora*

(b) *E. deglupta*



(c) *E. paniculata*



(d) *E. torelliana*

Fig. 1. Barks

It is usually difficult to define the colour and surface texture of such barks because they are often characterized by adjoining patches of varying age, while the newer patches are generally shiny and of fine texture with comparatively bright and varied colouring. The old patches, ready to fall, are comparatively dull gray and less smooth.

All species with deciduous bark are grouped together in Australia under the title 'gums'.

3.2.2. Persistent bark

If the subero-phellodermal layer is not renewed in depth, or if, for any other reason, the external parts of the rhytidom do not strip off periodically from the tree, the bark is called 'persistent'.

When the bark ages, its surface oxidizes, darkens, becomes more or less pulverulent, and loses its specific characteristics. Such characteristics can only be determined by examining the mature bark not at the trunk base, but at one-third of the tree's height.

The simplest way to distinguish four categories of persistent bark is given below:

3.2.2.1. Ironbark type: This bark is hard, with extremely short, or non-fibrous, breaking up into very small polyhedrons of hard corky texture when crumbled, with deep longitudinal furrows. It is usually dark in colour, sometimes contains inclusions of kinos, small masses of gum rich in tannin.

3.2.2.2. Box type, short fibrous, pale in colour: This bark is pale gray, fibrous, finely furrowed or reticulated obliquely on the surface.

3.2.2.3. Long-fibred brown bark: Thick bark is usually more or less dark brown with long or very long fibres, deeply furrowed longitudinally. When the excrescences are pulled off, the long fibrous, often laminated, texture is revealed.

This category includes the 'Transversae', as in *E. robusta* or *E. botryoides*, and 'Stringybarks' as in *E. obliqua* or *E. scabra*.

3.2.2.4. 'Peppermint' and 'bloodwood' types: Dull gray to black bark, hard, with shallow irregular furrowing chiefly in two directions, creates an effect of scales more or less oblong in shape. Examples of these are *E. andreana*, peppermints, and *E. gummifera*, bloodwoods.

4. Leaves

4.1. Juvenile Leaves

One of the essential features of most species of *Eucalyptus* is the presence, sometimes on adventitious branches, of juvenile leaves which are very different from the mature leaves. At times this difference is seen even on the branches themselves. In general, juvenile leaves show a wider range of shape and arrangement than do the mature leaves. It appears, however, that for any given species, the variability of shape is more limited in the case of juvenile than in mature leaves.

In the seedlings of most species the first juvenile leaves are opposite in arrangement. Those which follow are either opposite or alternate according to species, and are still distinct in character from the mature leaves. These leaves can be observed either on nursery plants at five to 50 cm of height, or upon tree shoots.

Two essential types of juvenile leaves have been distinguished in the following descriptions.

4.1.1. Opposite for numerous pairs

Four to six, after that of the very first leaves, mentioned previously.

4.1.2. Alternate

Relating to leaves beyond the sixth pair. Leaf shapes vary considerably but are usually broader than mature leaves. In species with opposite juvenile leaves, the latter are often glaucous or glaucescent, sometimes cordate, amplexicaul or even concrescent and perfoliate. Finally certain groups are characterized by juvenile leaves which are downy or hairy in various forms, thus helping to identify the species.

4.2. Mature Leaves

The mature leaves of the eucalypts are always entire, coriaceous, often thick, stiff, highly cutinized and rich sclerenchyma. Almost always alternate, only occasionally opposite or sub-opposite. Shape may be regarded as lanceolate in general. It varies, however, according to species, from very narrow lanceolate, almost linear to broad lanceolate, elliptical, oblong or even oval and orbicular. The leaves are often falciform. Their dimensions also vary considerably in the same species. Thus, when the length and breadth of the leaves are given, excluding the petiole, not only the average, but also the extreme dimensions should be indicated.

Another useful character to the identification of the eucalypts is knowledge of the leaf venation. Following types can be distinguished.

4.2.1. Pinniveined or spreading

In this type, the fine regular lateral veins are nearly parallel or apparently only slightly reticulated. They make, at least in the central part of the leaf, or on the convex side if the leaves are falciform, an angle of 60º or more with the medium vein. The marginal veining is usually fine and very close to the leaf edge. The leaves characterized by such venation are usually lighter on the underside than on the upper side. The underside carries numerous stomata, the upper hardly any.

4.2.2. Oblique

With this type, the venation is comparatively thick and irregular, often anastomosed, forming, atleast in the middle part of the leaf, or on the convex side if falciform, an angle of less than 60º with the medium vein. The somewhat sinuous marginal veining is

comparatively distant from the leaf edge. This characteristics veining usually have symmetrical faces of the same colour and carry stomata on both sides. A special type of this venation has secondary veins at angles of less than 30º to the median vein, and sometimes even parallel to it. This is the longitudinal type of venation. This secondary veining is more or less obviously visible, and is variously described as distinct, indistinct or intermediate. This is a feature difficult to measure and open to subjective determination.

5. Inflorescences

Eucalypt flowers are rarely single, with the exception of *E. globulus* (Fig. 2). In most cases they are grouped in inflorescences which are sometimes definite, as cymes or axillary umbels; and sometimes indefinite, as panicles or terminal corymbs.

The axillary umbels are enclosed at the outset within envelope-like bracts. These bracts, however, are usually very fleeting, and disappear as soon as the umbel begins to grow. They persist for a fairly long time in a few of the 'box' species. Each flower may be similarly enclosed in bracts. The number of flowers making up each umbel is not fixed. It varies, however, between limits which constitute good determining features.

(a) *E. alba*

(b) *E. citriodora*

(c) *E. deglupta*

(d) *E. globulus*

(e) *E. tereticornis*

(f) *E. torelliana*

Fig. 2. Inflorescences

A certain number of species are characterized by three flowers to each umbel, as in *E. viminalis*. This rule only applies to buds, not to fruits, since a certain production of the buds may not set. The peduncles of the umbels may also constitute a good distinguishing feature; i.e., varying length, cylindrical or flattened, rigid or drooping. The umbels of certain species are sessile as in *E. stellulata*.

6. Buds

It is customary to give the name 'bud' to what in reality is the flower of the eucalypts. The petals are joined in a single piece which covers the whole of the flower and separates at the time of anthesis, which is called operculum. Its tip is often covered by a second tiny cap consisting of the calcycine whorl or the bracteoles, which disappears very early as with *E. camaldulensis* (Fig. 3). The description of the bud comprises, therefore, an account of the shape and diameter of the receptacle, the shape of the pedicel and of the operculum.

It is often impossible to decide where the receptacle begins and pedicel ends. For this reason the length of the buds is not indicated in the descriptions. The shapes of the opercula are described in the following terms.

Conical operculum	-	*E. rudis*
Obtuse conical operculum	-	*E. cladocalyx*
Acute conical operculum	-	*E. tereticornis*
Horned or long operculum	-	*E. occidentalis*
Hemispherical operculum	-	*E. maculata*
Hemispherical apiculate operculum	-	*E. amygdalina*
	-	*E. diversicolor*
Rostrate operculum	-	*E. camaldulensis*
Ovoid operculum	-	*E. salubris*

Opercula of exceptional shape, as biretta, boss-shaped, or flattened.

(a) *E. camaldulensis*

(b) *E. tereticornis*

(c) *E. torelliana*

Fig. 3. Buds

Sometimes in the same species, and often on the same tree, the shape of the operculum is variable and can only be described with the help of at least two or three of the above comparisons.

7. Stamens

The classification of the genus *Eucalyptus* has been based, up to now, upon the characteristics of the stamens. Blakely (1934) divided the species into eight sections each with several subsections, according to the shape of the stamens. It is practically impossible to distinguish between these subsections in the field or often even in the laboratory.

The descriptions which follow have, therefore, been limited to indicating only the section to which each of the stamens examined belongs. The chief characteristics of the principal sections are summarized in the Table 4.

Table 4. Chief characteristics of stamens of eucalypts

Group	Fertility	Tip of filament	Shape of anther	Mouth of sac	Gland
Macrantherae	Stamens almost all fertile	Subulate	Cordate oval, oblong, orbicular	Distinct loculi opening into two lobes of auricular shape	Fairly large, situated in the upper half of the commissure, sometimes visible from the front
Renantherae		Subulate	*Kidney*- or heart-shaped, almost flat	Loculi divergent, sometimes coming together at tip	Very small or not apparent at upper tip
Porantherae	Almost all fertile	Adnate or subulate	Globular or reniform	Fairly distinct loculi opening towards the top or laterally with round pores	Small at the upper tip
Terminales	Numerous filaments without anthers	Adnate or anthers placed obliquely on the filament	Cuneiform rounded or almost square	Distinct loculi opening in terminal oval slits or round pores	No glands

Source: FAO (1965).

8. Fruits

The identification of eucalypt fruits has given rise to a real orgy of comparisons with the strangest objects, and it is well justified to apply a reasonable check to this. The fruit is formed by the development of the receptacle and of the lower ovary adhering to it (Fig. 4). The upper part of the fruit consists of four segments.

The scar left by the operculum after shedding forms an outside ring called the calycine ring. The next ring inwards is the stamina ring. Then follows the disc, the ontogenesis of which has not yet been completely described. Below, and inside the disc is the upper part of the ovary which, on maturity, splits and separates into valves.

In some species, the calycine ring which is comparatively prominent in the flower, disappears completely as soon as the fruit is formed. In other species, as

(a) *E. citriodora*

(b) *E. tereticornis*

Fig. 4. Fruits

in *E. leucoxylon*, the ring is fairly well developed but it is fine, and protrudes clearly beyond the disc. In these species, when the fruit ripens, the ring falls or remains partially attached to one of the fruits.

Consequently, the description of the fruit should cover the shape of the receptacle and that of the pedicel of the disc, and also the position and shape of the valves.

8.1. Shape of the Receptable Proper and Its Pedicel

The shape of the receptacle is more or less merged with that of its pedicel. The latter may be truncated or attenuated. The receptacle proper can usually be classified as globular, ovoid, urceolate, campanulate, hemispherical, cylindrical or conical.

An ovoid or globular receptacle combined with a attenuated pedicel produces a pyriform fruit; combined with a short attenuated pedicel, a turbinate fruit. A cylindrical or urceolate receptacle combined with an attenuated pedicel produces a fruit shaped more or less like a short club. It must be remembered that the size of fruits may vary considerably according to whether they develop and ripen slowly or, on the contrary, mature too quickly.

It is also advisable to be careful with the use of the term ‘striated’. It should be used solely to indicate the striation which appears when the non-sclerous tissue contracts. The term ‘ribbed’ on the other hand is used to indicate the ribs that are clearly visible on fresh specimen.

8.2. Shape of the Disc

In the flowers or the young fresh fruits, the disc is virtually continuous with the upper part of the ovary. When the fruit ripens and desiccates, the distinction

between the two becomes increasingly marked and is unmistakable when the valves open. According to whether the ovary evolves into a capsule, developed more or less than the receptacle so that the disc may become protuberant, remain flat, and usually thin, or become depressed. When protuberant, it may be concave, flat or convex. In the latter case it is usually described as 'dome-shaped'.

8.3. Position and Shape of Valves

The valves may be comparatively short and triangular as in *E. camaldulensis*. In this case they simply represent the upper part of the ovary or they may have sharp points formed by the rupture of the persistent base of the style. These sharp-pointed valves may even be continuous and joined together in a single point owing to the persistence of the whole style as in *E. oleosa*. In certain species the valves are fragile and drop off quickly when the fruit is ripe.

8.4. Exsert Valves

The name 'exsert' is given to those valves the base of which is located noticeably at the level of the calycine ring or clearly above it and when their points are beyond the whole fruit as in *E. camaldulensis*.

8.5. Enclosed Valves

Such valves have their base well below the level of the calycine ring beyond which their summit may project slightly.

8.6. Level Valves

Level valves are those which have their base level with or slightly below the calycine ring, the points being at the level of, or slightly above the latter.

9. Seeds

Eucalyptus seeds vary greatly in size from less than 1 mm in *E. populnea* to more than 2 cm in *E. calophylla*. Their colour varies from black (*E. tereticornis*) to yellow (*E. camaldulensis*), shape of the seeds also differ from being almost spherical as in *E. wandoo* to cuboid in *E. tetrodonta* and subulate in *E. curtisii* and in sculpture from shallowly reticulate in *E. leucoxylon* to deeply pitted in *E. griffithii*. The seeds of many species of the woody fruited blackwoods (subgenus *Corymbia*) are prominently winged; those of the paper-fruited bloodwoods (subgenus *Blakella*) are saucer-shaped and unwinged. Seed lots of subgenus *Monocalyptus* show high uniformity whereas a great deal of variability is exhibited in the seed characteristics of the subgenus *Symphyomyrtus*. The seed may be cuboid, pyramidal, elliptical, etc. smooth or tooth-edged, whitish, grey, yellow, red, brown or black.

10. Distribution

The eucalypts have a natural latitude range extending from 7ºN to 43 º 39' S. Their natural distribution is clearly restricted to the east of the hypothetical line called 'Wallace's line' separating the Indo-Malayan and Austro-Malayan life types. This line passes between Bali and Lombok through the Makassar Strait with Sulawesi on its eastern side, Borneo to the west, then northeast through the Celebes Sea and the southern islands of the Philippines. This line leaves Mindanao on its western side. But, occurrences of *E. deglupta* have been reported from Mindanao. So 'Wallace's line' was amended in 1978 drawing it east of Mindanao. Now the natural occurrence of all eucalypts lies east of this amended line, with the possible exception of *E. alba* in north Bali (Martin and Cossalter, 1975-76).

The number of species under *Eucalyptus* was estimated variously by different authors. However, Chippendale and Johnson (1983) estimated it to be 550-600 more or less distinct forms, plus many hybrids; most of them are endemic to the Australian continent, Brooker (2002) estimated 800 species. The largest diversity is in south-western Australia. Indigenous species of *Eucalyptus* are found in the eastern part of Indonesia, such as *E.deglupta* (from Celebes island), *E.urophylla* and *E.alba* (from East Nusu Tenggara), and *E. pellita* (from West Papua) (Table 5).

Almost all the species of *Eucalyptus* are adapted to a monsoon climate. Many species can even survive a severe dry season, e.g. the cultivated species *E. alba*, *E. camaldulensis*, and *E. citriodora*. Only *E. deglupta* adapt to lowland and lower

Table 5. *Eucalyptus* species from Indonesia and Papua New Guinea

S. no.	Species	Distribution
1.	*E. deglupta* Blume (*incerate sedis*)	New Guinea, Papua, West Irian, New Britain, Ceram Celebes, Mindanao. May have been present in New Ireland
2.	*E. alba* Reinw. ex Blume (series *Subexseratae*)	Timor, Flores, Alor, Wetar, east Papua, Horn Island, also northern Australia
3.	*E. tereticornis* Sam. (series *Exseratae*)	East and West Papua, West Irian. Also eastern Australia, south to Victoria.
4.	*E. papuana* F.v.M.	East and West Papua. Also northern and central Australia
5.	*E. confertiflora* F.v.M. (*series Clavigerae* (Maiden) S.T. Blake)	East and West Papua and West Irian. Also northern Australia
6.	*E. polycarpa* F.v.M. (*series Corymbosae* (Benth.) Maiden)	West Papua, Australia
7.	*E. brassiana*	SW Papua, New Guinea, also Cape York, Queensland, Australia
8.	*E. leptopheleb* F.v.M.	Western Province, Papua, New Guinea (?), Cape York, Australia
9.	*E. pellita* F.v.M.	Western Province, Papua, New Guinea, NSW, Queensland, Australia
10.	*E. tessellaris* F.v.M.	Western Province, Papua, New Guinea (?), Cape York, NSW, Australia.

Source: Carr (1972); Srivastava (1996).

montane rain forest habitats. It does not grow naturally in areas with a pronounced dry season, but it occurs in areas where the annual rainfall is 2,500- 5,000 mm and the monthly rainfall usually exceeds 150 mm.

11. Introduction in India

Eucalypt has long history in India. It was first planted around 1790 by Tipu Sultan, the ruler of Mysore, in his palace garden on Nandi Hills near Mysore. According to one version he received seeds from Australia and introduced about 16 species (Shyam Sunder, 1984). Subsequent to the planting of Nandi Hills, the next significant introduction of eucalypts in India, was in 1843 when most extensive plantations were established on the Himalayan slopes in the vicinity of Shimla, and in the Nilgiri Hills at an altitude of 1,500 to 2,500 m (FAO, 1965). Ahmad (1996) also stated its first introduction in the sub-continent dates back to 1843 as single trees arboreta and roadside plants. Plantations of *E. globulus* were raised to meet the demand for firewood from 1856 (Wilson, 1973). Between 1940 and 1950, due to politico-socio-economic conditions, overgrowing population and increasing demand of industries, necessity arose to raise vast denuded tracts with indigenous forest trees and some fast growing short rotation tree crops which required less care after planting and were capable of growing over different sites. *Eucalyptus* was one such species meeting the desired qualities (Dabral *et al*., 2000). From 1951 to 1954 large scale trials were conducted in Uttar Pradesh, Bihar, Assam, Madhya Pradesh, Maharashtra and Kerala (Chaturvedi, 1976), however, during 1959-1979 the area under eucalypt plantations increased significantly (FAO, 1979). Over 0.1 Mha of eucalypt plantations have been established, mostly be state forest departments and forest development corporations (Palanna, 1996). There are several reasons for raising large scale eucalypt plantations in the country; some are common and some are specific to each state. The most important common reason is to reclothe the denuded and barren hilly areas and replace low value natural forest (FAO, 1979).

Parker (1925) has given the list of over 100 species tried in India. According to Bhatia (1984), 170 species/varieties/provenances of eucalypts have been tried in India upto 2,200 m with an annual rainfall range of 400-4,000 mm. *E. tereticornis* (Nandi Provenance, *Eucalyptus* hybrid of Mysore gum) proved superior in the edaphological adaptation. The species which have received countrywide acceptance are *E. tereticornis*, *E. camaldulensis*, *E. grandis*, *E.citriodora* and *E. globulus*. Sahni and Bahadur (1972) have suggested trial of eucalypts in different climatic zones of India based on their climatological requirements.

Scrutiny of literature and herbarium specimens deposited in the herbarium of Forest Research Institute, Dehradun revealed that the following 70 species (Table 6) of eucalypts were successfully introduced in India.

Table 6. *Eucalyptus* species introduced in India

S. no.	Botanical name	Common name	Place of introduction in India
1.	*E. alba* Reinw. ex Bl. (=*E. platyphylla* F.v.M)	Timor white gum	Dehradun (U.K.)
2.	*E. albens* MiQ.	White box	Nilgiri (T.N.)
3.	*E. albina* Lindl.	Grampians stringy bark	Nilgiri (T.N.)
4.	*E. amygdalina* Labill.	Black peppermint	Chaubbatia (U.K), Nilgiri (T.N.)
5.	*E. bicolor* A. Cunn.	River black box peppermint	Dehradun (U.K.)
6.	*E. bosistoana* F.v.M.	Bosisto's box	Nilgiri (T.N.)
7.	*E. botryoides* Sm.	Bangalay, southern mahogany	Nilgiri (T.N.)
8.	*E. brachypoda* Turcz. *(=E.microthica* F.v.M.)	Flooded box	Dehradun (U.K.), Delhi and Ludhiana (P.B.)
9.	*E. calophylla* R.Br. ex Lindl.	Marri	Nilgiri, Shillong (M.L.), Satna (M.P.)
10.	*E. camaldulensis* Dehnh	Murray red gum, river red gum	Saharanpur (U.P), Nasik (M.H.), Shimla (H.P), Ambala (P.B.), Delhi, Nandi Hills, Mysore, Banglore (K.A.), Haryana
11.	*E. capitellata* Sm	Brown stringy bark	Chakrata (U.K.)
12.	*E. citriodora* Hook.*(Corymbia citriodora* (Hook.) Hill and Johnson	Lemon scented spotted gum	Dehradun (U.K.), Lucknow, Saharanpur (U.P.), Chandigarh, Poona (M.H.), Madhya Pradesh, Sriharikota, (A.P.), Dandeli, Mysore (K.A.), Valpoi, (Goa); Haryana, Tripura.
13.	*E. cladocalyx* F.v.M.	Sugar gum	Nilgiri (T.N.)
14.	*E. crebra* F.v.M.	Narrow-leaved ironbark	Dehradun (U.K.); Punjab; Nandi Hills (K.A.), Nilgiri (T.N.); Haryana.
15.	*E. cosmophylla* F.v.M	Cup gum	Nilgiri (T.N.)
16.	*E. dealbata* A. Cunn.	Trumble down gum	Almora, Ranikhet (U.K.)
17.	*E. deglupta* Blume	Mindanao gum	Dehradun (U.K.)
18.	*E. diversicolor* F.v.M.	Karri	Nilgiri (T.N.)
19.	*E. drepenophylla* F.v.M	Bowen Ironbark	Dehradun (U.K.), Hassan (K.A.); Nilgiri (T.N.)
20.	*E. eugenoides* Sieb. ex Spreng	-	Nilgiri (T.N.), Shimla (H.P.)
21.	*E. eximina* Schau	Yellow blood wood	Shimla (H.P.)
22.	*E. exserta* F.v.M.	Bendo	Saharanpur (U.P.)
23.	*E. ficifolia* F.v.M. *(Corymbia ficifolia* (F.v.M.) Hill and Johnson)	Red flowering gum	Nilgiri (T.N.)
24.	*E. globulus* Labill	Tasmanian blue gum, southern blue gum	Almora, Ranikhet, Pithoragarh, Nawagon (U.K.), Northeast India; Mysore (K.A.), Nilgiri (T.N.); Haryana
25.	*E. grandis* (Hill.) Maiden	Toolur	Dehradun (U.K.), Kerala, Kollimalais and Sevarayans (T.N.), Kerala.
26.	*E. goniocalyx* F.v.M	Spotted mountain gum, Monkey gum, mountain gray gum	Ranikhet, Almora (U.K.)
27.	*E. gummifera* (Gaertn.) Hochr (*E. corymbosa* Sm); *Corymbia gummifera* (Gaertn.) Hill and Johnson)	Blood wood, red blood wood	Nilgiri (T.N.)
28.	*E. hemiphloa* F.v.M	White box, grey iron box, gum topped box	Shimla (H.P.), Nilgiri (T.N.)

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29.	*E. intermedia* R.T. Baker	Pink blood wood	Nandi Hills (K.A.)
30.	*E. kirtoniana* F.v.M.	Bastard mahogany	Dehradun, Ranikhet (U.K.); Lucknow (U.P.)
31.	*E. leucoxylon* F.v.M.	White iron bark, yellow gum, blue gum	Shimla (H.P.), Panchgani, (M.H.), Nilgiri (T.N.).
32.	*E. liniaris* Dehn	White peppermint	Shimla (H.P.)
33.	*E. longifolia* Link and Otto	Woollybutt	Shimla (H.P.), Bangalore (K.A.)
34.	*E. macarthurii* Deane and Maiden	Camden woollybutt, paddy's riverbox	Nilgiri (T.N)
35.	*E. maculata* Hook.	Spotted gum	Dehradun (U.K.), Srirangam island, Nilgiri (T.N), Bilaspur (M.P.).
36.	*E. maculosa* R.T. Baker	Red spotted gum	Shimla (H.P.)
37.	*E. maideni* F.v.M	Maiden's gum, spotted blue gum	Shimla (H.P.)
38.	*E. marginata* Sm.	Jarrah	Nilgiri (T.N.)
39.	*E. melanophloa* F.v.M	Silver leaved iron bark	Mandi (H.P.)
40.	*E. melliodora* A.Cunn.	Yellow box	Dehradun (U.K.), Shimla (H.P.), Nilgiri (T.N.)
41.	*E. microcorys* F.v.M.	Tallow wood	Dehradun (U.K.), Nandi Hills (K.A.)
42.	*E. nova-anglica* Deane and Maiden	New England peppermint	Nandi Hills (K.A.)
43.	*E. obliqua* L'Herit	Messmate, messmate string bark	Nilgiri (T.N.)
44.	*E. ovata* Labil	Swamp gum	Saharanpur (U.P.), Shimla (H.P.)
45.	*E. paniculata* Sm.	Grey iron bark, iron bark	Dehradun, (U.K.), Saharanpur (U.P.), Nilgiri (T.N.), Poona (M.H.), Morni Hills (Haryana)
46.	*E. pauciflora* Sieb. ex Spr. (*E. coriacea* A. Cunn.)	Cabbage gum	Nilgiri (T.N.)
47.	*E. pilularis* Sm.	Blackbutt	Nilgiri (T.N.)
48.	*E. piperita* Sm.	Sydney peppermint	Nilgiri (T.N.)
49.	*E. polycarpa* F.v.M	Longfruited blood wood	Yercad (T.N.)
50.	*E. polyanthemos* Sch.	Red Box	Almora, Dehradun (U.K.); Shimla (H.P.)
51.	*E. propinqua* Daene and Maiden	Small fruited grey gum, grey gum	Dehradun (U.K.), Kollimalais, Nilgiri (T.N.)
52.	*E. punctata* DC.	Grey gum	Dehradun (U.K.), Shimla (H.P); Nashik (M.H.).
53.	*E. radiata* Sieb. ex DC	Grey peppermint	Dehradun (U.K.), Kulu (H.P.); Nilgiri (T.N.)
54.	*E. regnans* F.v.M.	Giant gum	Shimla (H.P.), Nilgiri (T.N.)
55.	*E. resinifera* Sm.	Red mahogany	Dehradun (U.K.), Shimla (H.P.), Nilgiri (T.N.)
56.	*E. risdoni* Hook.f.	Silver peppermint	Shimla (H.P.)
57.	*E. robusta* Sm.	Swamp mahogany, swamp messmate	Ranikhet. Dehradun (U.K.), Barilly, Saharanpur (U.P.), Maharashtra, Nilgiri (T.N.)
58.	*E. rossii* Baker and Sm.	White gum	Nilgiri (T.N.)
59.	*E. rudis* Endl.	Moitch	Dehradun (U.K.), Hassan, Banglore (KA.), Delhi
60.	*E. saligna* Sm.	Syney blue gum, blue gum	Ranikhet, Dehradun (U.K.), Amritsar (P.B), Shimla (H.P.), (M.H.)

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61.	*E. siberiana* F.v.M	Silvertop ash, mountain ash, coast ash	Nilgiri (T.N.)
62.	*E. siderophloia* Benth.	Broad-leaved ironbark	Dehradun (U.K.), Saharanpur (U.P.), Shillong (M.L.), Banglore (K.A.)
63.	*E. sideroxylum* (A.Cunn.) Benth.	Mugga	Dehradun, Ranikhet (U.K.)
64.	*E. staigeriana* F.v.M	Lemon-scented ironbark	Dehradun (U.K.), Saharanpur (U.P.)
65.	*E. stuartiana* F.v.M.	But But or apple	Shimla (H.P.), Dehradun (U.K.)
66.	*E. tereticornis* Sm. (=*E. umbellata* (Gaertn) Domin	Forest red gum, blue gum	Lalkua, Dehradun, Haldwani (U.K.); Saharanpur, Barilly, Lucknow, Plibhit (U.P.), Hazaribagh (C.G.), Mt. abu (R.J.), Srihrikota (A.P.); Hoshiarpur (P.B.), Sambhalpur (O.R.), Delhi, Mysore (K.A.), Ker., Bilaspur, Balaghat, Indore, Shivpuri (M.P.), Raipur (C.G.), Faridabad (Haryana).
67.	*E. terminalis* F.v.M.	Kulch or long fruited Bloodwood	Dehradun (U.K.), Mandla (M.P.)
68.	*E. tessellaris* F.v.M.	Carbeen or Moreton Bay ash	Banglore (K.A.), Coimbatore (T.N.)
69.	*E. torelliana* F.v.M.(*Corymbia torelliana* (F.v.M.) Hill and Johnson)	Cadagi	Dehradun (U.K.), Kollimalais (T.N.); Palghat (K.L.)
70.	*E. viminalis* Labill.	Ribbon gum, manna gum, white gum	Almora (U.K.), Shimla (H.P.)

A.P.= Andhra Pradesh; C.G.= Chattisgarh; H.P.= Himachal Pradesh; K.A.=Karnataka; K.L. Kerala; M.H.= Maharashtra; M.L.= Meghalaya; M.P.= Madhya Pradesh; O.R.= Odisha; P.B.= Punjab; R.J.= Rajasthan; T.N.= Tamil Nadu; U.K.= Uttarakhand; U.P.= Uttar Pradesh

12. Uses

Eucalypt planting is controversial in some countries where it has been planted extensively. Critics assert that it i) has deleterious effect on the hydrological balance; ii) depletes the soil nutrients; iii) has an allelopathic effect leading to inhibition of growth of other plants; and iv) has a deleterious effect on native animals. However, eucalypts have many uses, viz. the wood of eucalypts is used as a general purpose timber. It is suitable for light or heavy construction. In house building, its applications are for doors, window frames, interior finish and both light and heavy duty flooring. Because of its moderate durability and moderate resistance to insect attacks, the timber is also applied for making objects that come in contact with the ground, like railway sleepers, poles and posts. Other applications are in ship and boat building, vehicle bodies, joinery, boxes and crates, vates, carving, turnery, handles, sporting goods and agricultural implements. The timber is suitable for the production of veneer and plywood, particle board, hardboard and wood-wool boards. One of the major uses of eucalypt is the production of pulp for paper manufacture. Eucalypt is also a very important source of firewood, which generally burns very quickly because of the high oil content, while many produce a good-quality charcoal. Several species are being used in reforestration activities.

The leaves and twigs of many *Eucalyptus* species contain eucalypt oil which is an important product for pharmaceuticals (for example as a liniment or cough

medication), perfumes, and soaps and detergents. The oil is also used as a disinfectant and pesticide. Many species of *Eucalyptus* produce gum (kino), which often runs down the bole in large quantities. The bark of some species has tanning properties. The flowers of many species produce good pollen and nectar for honey. Some species are planted as ornamentals.

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