Chapter 4. GENERAL OBSERVATIONS AND ANALYSIS

COMPARATIVE MORPHOLOGY

Bor (1953) has given a general account on the morphology of Indian and Myanmarese (Burmese) species of the subtribe Dimeriinae s. str. The subtribe is mostly with majority of the species having uniform morphological characteristics except some species display seasonal variations within and among populations.

A detailed account on morphology of Dimeriinae is presented here, which is largely based on the study of Peninsular Indian taxa, where it exhibits maximum diversity. This is the first comprehensive study on the taxonomy and morphology of the subtribe.

Vegetative features

In general, vegetative features are very uniform among the species of Dimerias and provide few useful taxonomic characters.

Habit

Veldkamp (1973) pointed out the importance of the life-span of the species in grass taxonomy. Of the 42 taxa of Dimeriinae (under two genera) treated here, 34 are more or less annuals and 9 species are perennials.
In Peninsular India, true annuals grow along drier parts of the region, mostly in lateritic soil or rocky substrata. They are more or less erect but sometimes geniculate at lower nodes (*D. connivens*). They do not have roots at lower nodes, stolons, and rootstocks. Most species are with gregarious or sub-gregarious flowering habit and some are with mat-forming (*D. hohenackeri* var. *kodagensis*). Culms are usually slender and, solitary or few, sometimes tufted (*D. raizadai*). Culm length may vary from 15 cm (*D. woodrowii*) to 60 cm in height.

True perennials have cataphylls and may have stolons (*D. mahendraergiriensis*) but are usually erect with rootstocks. Most of the species show rooting at lower nodes. They are usually found along forest margins of the Western Ghats region and sometimes the sandy soils along river margins with thick rootstocks (*D. fusescens*). They do not have gregarious growth and are sporadic in their habitat.

Some species are neither true perennials nor annuals but possess thick rootstocks. Based on the nutrient availability, they usually grow exhibiting tufted habit and up to 1.5 m in height (*D. kurumthotticalana* s. l.).

Rarely, culms bent at uppermost node (*Ravia santapauli* s. str.).

Some of the representative habits and culm types in Dimeriinae are shown in the figures 1 and 2(i).
Fig. 1. Diagrammatic representation of different habits in Dimeriinae. A. Caespitose, Annual or Perennial (D. trimeni); B. Tufted, Annual (D. lawsonii); C. Slender, single, branched (D. ornithopoda); D. Slender, single, not branched D. pubescens); E. Geniculate, few culms from the base (D. connivens); F. Procumbent, Annual (D. hohenackeri var. kodagensis); G. Stoloniferous, Perennial (D. namboodiriana).
**Indumentum**

Conveniently, terms like ‘ciliate’, ‘bearded’, ‘scabrid’ and ‘bulbous-based hairs’ etc., have been here refereed under indumentum, whereas sometimes ‘pubescent’ has also been included rarely. Attempts were made to group the indumentum studied here. There are two types of hairs are present among the species of Dimeriinae.

1. Thin and uniseriate type.  
2. Thick and multiseriate type.

The uniseriate hairs are fine with smooth walls and are often appressed. These simple hairs usually occur on nodes, callus, margins of the raceme-rachis and along the keel/surface of the glumes. These hairs are more hyaline along the margin of the glumes and lower lemma.

The multiseriate hairs are bulbous-based and are known as bulbous-based or tubercle-based hairs (tbh), and usually occur on the leaf surfaces mainly at the junction of leaf-sheath and lamina (Plate 1).

**Leaf morphology**

Leaves are usually arranged all along the culm or rarely grouped at the base of the culms. The leaf blades in all species of Dimeriinae found in Peninsular India are usually linear-lanceolate. In general, the blades of the upper leaves shorter. There is also
variation in absolute leaf blade size, from short leaves of *D. woodrowii* (4–6 cm x 0.2–0.3 cm) to the long wide leaves of *D. fuscescens* (25–30 cm x 0.5–0.8 cm). The surface of leaf blade is usually glabrous and margin scaberulous. Sometimes, scattered bulbous-based hairs are present along the surface as well as margins. Rarely, leaves are pubescent throughout the culm and leaf surface (*D. pubescens*). The junction of the leaf-sheath and lamina (Collar) is usually ornamented with bulbous based hairs in most species and sometimes without (*D. agasthyamalayana*). The different collar types are shown in figure 2(ii).

Ligule is found at the collar region and is continuous with the hyaline margins of the sheath. It is membranous, and ranges from 0.5–1 mm in length. It is truncate in shape, and lacerate or fimbriate along the margins.

The sheath is closely enclosing the culm and usually shorter than internodes. The leaf sheath is of interest only in those few species (*D. pubescens*) which bear bulbous-based hairs throughout the surface. In some species like *D. fuscescens*, the sheath is much longer than internodes. Rarely, the culm may slip away from the sheath (*D. lehmannii*).

**Reproductive features**

**Inflorescence**

The inflorescence is composed of racemes, consisting of rachises, bearing numerous pedicelled spikelets on their adaxial
surface. The raceme structure of Dimeriinae is unique in the tribe Andropogoneae due to the absence of ‘spikelet-pairing’. They are with only pedicelalled spikelets on tough raceme-rachises. Spikelets are usually packed compactly arranged and are alternately in 2-rows on each raceme (Fig. 3).

Each peduncle terminate with usually two racemes but it may vary from 1 (D. fischeri), to 3 (D. connivens) and up to 11 (D. gracilis). Rarely, the number of racemes may also vary within a species (e.g., 1 to 4 in D. raizadae). The number of racemes occurring within the Peninsular Indian taxa is shown in the table 5. The racemes are comparatively larger in perennial species (8–12 cm) and shorter in annuals (3–5 cm). The number of spikelets present in each raceme usually ranges from 30 to 80. But in Dimeria sect. Capillares, it ranges from 10–25 and in Ravia, number of spikelets varies between 6 and 8.

The racemes are usually sub-digitately arranged, rarely digitately (D. gracilis) but solitary racemes are also found in some annual species (D. fischeri, D. lawsonii, etc.). The raceme pair is usually divergent, but in species like D. agasthyamalayana, D. trimeni, they appear as forked (or V-shaped). In D. connivens, non-divergent racemes hardly exert from the sheath of the peduncle (Fig. 4, G). Rarely, the divergent racemes may be with erect apical portion grow again upward towards the apex and exhibiting an U-shaped appearance (D. kanjirapallilana).
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<tbody>
<tr>
<td>Raceme 1</td>
<td>D. woodrowii</td>
<td></td>
<td>D. acutipes</td>
<td>D. kurumthotticalana</td>
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<td></td>
<td>D. veldkampii</td>
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<td>D. avenacea</td>
<td>var. kurumthotticalana</td>
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<td>var. idukkiensis</td>
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<td>2</td>
<td>D. woodrowii</td>
<td>D. aristata</td>
<td>D. mooneyi</td>
<td>D. balakrishnaniana</td>
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<tr>
<td></td>
<td></td>
<td>D. connivens</td>
<td>var. mooneyi</td>
<td>var. balakrishnaniana</td>
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<td></td>
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<td>D. deccanensis</td>
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<td>D. thwaitesii</td>
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<td>D. fuscescens</td>
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<td>D. kanjirapallilana</td>
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<td>D. lawsonii</td>
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<td>D. orissae</td>
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<td>D. mahendragiriensis</td>
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<td>D. trimeni</td>
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<td>D. lehmannii</td>
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<td>D. bialata</td>
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<td>D. ornithopoda</td>
<td>var. gracillima</td>
<td>var. sivarajanii</td>
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<td></td>
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<td>var. kodiagensis</td>
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<td>3</td>
<td>D. woodrowii</td>
<td>D. hohenackeri</td>
<td>D. ornithopoda</td>
<td>D. raizadae</td>
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<td></td>
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<td>var. kodagensis</td>
<td>var. ornithopoda</td>
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<td>var. khasiana</td>
<td>D. pubescens</td>
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<td>D. copei</td>
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<td>4 or 5</td>
<td>D. hohenackeri</td>
<td>D. gracilis</td>
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<tr>
<td></td>
<td>var. hohenackeri</td>
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<td></td>
<td>D. gracilis</td>
<td>D. stapfiana</td>
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<td>6 to 11</td>
<td>D. gracilis</td>
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In *Dimeria* sect. *Annulares*, the racemes coiled or rolled to form a ‘globule’ (*D. woodrowii*) (Fig. 4, I) or ‘ringlet’ (*D. veldkampii*) (Fig. 4, H) at maturity. In some species, having more than two digitate racemes, they are widely divergent (*D. raizadae*).

In *Ravia*, the racemes are usually intertwined (when 2 racemes present), because of the twisted raceme-rachis.

Different types of racemes structures are shown in the figure 4.

Fig. 4. Diagrammatic representation of different raceme types in *Dimeria*. A. Raceme solitary, long exerted (*D. fischeri*); B. Racemes widely divergent (*D. raizadae*); C. Raceme U-shaped (*D. kanjirapallilana*); D. Raceme digitate, hardly divergent (*D. pubescens*); E. Raceme fork-shaped (*D. trimeni*); F. Raceme sub-digitate, not divergent (*D. gracilis*); G. Raceme hardly exerted, not divergent (*D. kurzii*); H. Raceme ringlet-shaped (*D. veldkampii*); I. Raceme globule-shaped (*D. woodrowii*).

In *Dimeria* sect. *Loriformes*, the spikelets are firmly appressed to the raceme-rachis at an angle of less than 45°, and arranged
distichously making the rachis adaxially visible (Fig. 5B, C). Sometimes spikelets are facing towards one side of raceme (*D. fischeri*). In *Dimeria* sect. *Capillares*, spikelets slip away from the rachis and are distantly arranged at an angle of more than 45° with the rachis (Fig. 5D). In *Dimeria* sect. *Dimeria*, especially perennial species, the spikelets are firmly appressed to the rachis and are arranged overlapping with one another (imbricate), making the rachis adaxially, non-visible (Fig. 5A).

Fig. 5. Schematic presentation of spikelet-arrangement on rachises in *Dimeria*. A. Secund, close and imbricate (*D. fuscescens*); B. Secund, close but not imbricate (*D. kurunthotticalana*); C. Secund, close and glumes spread apart (*D. raizadae*); D. Secund, distant and spikelets slips away from rachis (*D. hohenackeri*).

**Rachis of raceme**

Bor (1953) basically used the texture of raceme-rachis in the delimitation of the sections under the genus, which is conveniently used as an important diagnostic feature. In *Dimeria*, raceme-rachis are usually tough, linear or zig-zag and bears the spikelets in its
adaxial surface. Three main types of raceme-rachises can be recognized.

1. Rachis flattened (Fig. 6 D; Plate 2, D–F): The midrib of the rachis is flattened and corky or coriaceous; accompanied by a broad wing along its margins. These wings usually scabrous to ciliate, but rarely glabrous (D. ravii). In some species like D. pubescens, longitudinal nerves parallel to the rachis can be clearly seen in the wings. Rachis-internodes ca. 0.5 – 1mm long. In cross section, rachis appears flat. Rarely, rachis is convex on abaxial surface (D. copei). The width of the rachis may vary from 0.75 to 1.5 mm.

2. Rachis trigonous (Fig. 6 A, B; Plate 2, A): The midrib of the rachis is never flat but definitely triqueterous and coated. The angles usually scaberulous, and sometimes ciliate (D. aristata). Usually, abaxial angles of the rachis are minutely winged along rachis-internode. Internode ca. 0.5 mm long. In cross section, rachis appears triangular, and the width is ca. 0.5 mm in diameter. Rarely, rachis is twisted (Ravia sp.).

3. Rachis capillary and angular (Fig. 6, C; Plate 2, B): The midrib is filiform and usually terete or triangular in cross section, and scarious. Wing less. Usually glabrous, but rarely scaberulous along abaxial angles (D. hohenackeri). Rachis-internode 2.5 – 3.5 mm long. The width of the rachis may vary from 0.1 to 0.3 mm in diameter.
4. Rachis abxially and adaxially convex (Plate 2, C): This type of rachis is exclusively found in *Dimeria* sect. *Annulares*. The midrib of the rachis is neither flattened nor triqueterous but slightly compressed and corky. In transverse section, rachis appears somewhat ellipsoid, and minutely winged along the rachis-internode. Internode 1–1.5 mm long and the rachis width is ca. 0.75 mm. Margin of the rachis usually glabrous but rarely sparsely ciliate. In this type, the rachis circinately incurved or coiled at maturity. This type of rachis may adapt to the unusual coiling phenomena, and in turns helps to taxa disperse their diasposes more effective than other members of the Dimeriinae, and is considered as the advanced character in the subtribe.

In most of the species, the rachis is markedly zigzag in appearance (*D. trimeni, D. fusescens, D. copeana*, etc.) which has little taxonomic value because this condition is variable within the species of different populations. The texture of the rachis is of great taxonomic importance, as it provides major diagnostic characters by which the sections of the genus are primarily delimited.

**Pedicel**

In contrast to other andropogonoids, the members of Dimeriinae do not have a distinct pedicel for the spikelets, but with a pedicel-like extension from the tough rachis are present, on which the spikelets are borne. In other andropogonoid grasses, the rachis is
fragile and jointed, and get detached at the time of maturity. Here, each disarticulation unit usually consists of spikelet with rachis-joint and pedicel (e.g., *Ischaemum* spp.) or with rachis-joint only (*Arthraxon* spp.). In *Dimeria*, the rachis is tough and continuous, and disarticulation unit consists of spikelets only, leaving the pedicel in the rachis. So here, the extension of the rachis is termed as ‘pedicel’.

The ‘pedicels’ are alternately arranged on both sides of the rachis. In *Dimeria* sect. *Dimeria*, pedicels are formerly appressed to rachis where as in *Dimeria* sect. *Loriformes* it become more or less adnate to the rachis-wing. In *D. pubescens* Bor, pedicel is completely attached to the wing of the rachis. In *Dimeria* sect. *Annulares*, they are widely diverging from the rachis. The different types of pedicels are shown in the figure 6 and Plate 2.

Pedicels are usually clavate when the rachis is capillary; but usually flattened when rachis is compressed or trigonous. In *Ravia santapauai*, the pedicel is obconical in appearance.

The flattened pedicels are often ciliate on the outer margins but obconical pedicels are usually glabrous. The lip of the pedicels are best seen after the spikelet has fallen off, has some taxonomic value. Four types may be distinguished,

1. Pedicel with flat and oblique lip (e.g., *D. avenacea*, *D. acutipes*, and *Ravia santapauai*)

2. Pedicel with transverse lip (e.g., *D. woodrowii, & D. veldkampii*)
3. Pedicel with discoid or concave lip (e.g., *D. pubescens*, etc.)

4. Pedicel with cupuliform lip (e.g., *D. stapfiana*, *D. gracilis*, etc.).

**Spikelet morphology**

The schematic representation of morphology of a single spikelet is given in the figure 7.

![Diagram of spikelet morphology](image)

**Callus**

The spikelets of Dimeriinae are strongly compressed, and with a definite callus at the base. The presence of callus and its structure in a few species is a useful diagnostic taxonomic character. The shape of the callus is usually compressed with truncate base (*Dimeria mahendragiriensis*), but sometimes it may be cuneate, and
inserted (*Dimeria stapfiana*). In some instance, it is strongly oblique with pointed or pungent base (*Ravia santapauï*). In most of the species, length of the callus varies from 0.3–0.5 mm, but in species like *D. acutipes* it may go up to 1.5 mm. The callus is usually bearded, but often glabrous (*D. agasthyamalayana*), rarely densely hairy (*Ravia santapauï*).

**Glumes**

The glumes are usually coriaceous to subcoriaceous, but a crustaceous texture is found in some perennial species, rarely cartilaginous (*Ravia santapauï*). Colour of the mature spikelets varies from pale yellow to brown, often reddish-brown (*Dimeria trimeni*) or dark-red (*Ravia santapauï*). The size of the glumes, awned or unawned nature of apices, dorsal keeled nature of the glumes, and winged or wingless nature of the keels are the important diagnostic features helping species delimitation.

There is difference between the lengths of two glumes, and normally the upper is the longer. Nearly all species, the lower glume makes it an angle of 45° with the upper glume during anthesis. In *Dimeria hohenackeri*, glumes widely spread apart (nearly angle of 90°). The glumes are very thin along the margins, but almost coriaceous towards the middle line. Both glumes usually possess a keel on its dorsal side, which is either completely winged or winged on the upper half or it may be wingless. In *D. ornithopoda*, wing is completely absent where as in *D. deccanensis* it is minutely winged
at the apex of the glume. The wings are usually papery in nature, but sometimes they are thickened and corky (D. mooneyi, D. stapfiana, etc.). This corky nature of the glume seems to be variable and it is not uniform even in the spikelets of same raceme. The presence or absence of wing is the important taxonomic value for the glumes. The winged nature of the keel may sometimes vary in the spikelets of the same raceme (D. kurumthotticalana). The distribution of upper glume features within the Peninsular Indian species are tabulated below (Table 6).

In Ravia, the glumes are not keeled and wingless. Here, the apical portion of both sides of the glumes has a wing like hyaline auricle.

The texture of the lower glumes has little taxonomic value and is usually wingless or minutely winged towards apex, except in D. mooneyi in which it is winged all along the keel.

The shape of the upper glume apices is taxonomically significant and it may vary from species to species. Mostly, the shape of apex varies from acuminate to aristate (D. josephii), and acute in D. lehmannii. The apex is rarely awned up to 3 mm long as in D. acutipes and D. lawsonii. Often, the apex of the glumes is recurved (D. kurumthotticalana).

The different type of spikelets and their glumes are shown in figure 6.
Table 6. The distribution of “Upper glume” features of the spikelet within the Peninsular Indian species of the sections of *Dimeria*.

<table>
<thead>
<tr>
<th>Sections of Dimeria</th>
<th>Upper glume wingless</th>
<th>Upper glume winged at apex only</th>
<th>Upper glume winged all along</th>
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<tbody>
<tr>
<td>Sect. Annulares (Rachis rolled)</td>
<td>D. veldkampii</td>
<td>D. woodrowii</td>
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<tr>
<td>Sect. Capillares (Rachis capillary or wiry)</td>
<td>D. hohenackeri</td>
<td>D. gracilis</td>
<td>D. stapfiana**</td>
</tr>
<tr>
<td>Sect. Dimeria (Rachis trigonous or triquetrous)</td>
<td>D. acutipes*&lt;br&gt;D. ornithopoda&lt;br&gt;D. kanjirapallilana</td>
<td>D. orissae&lt;br&gt;D. copeana&lt;br&gt;D. trimeni</td>
<td>D. avenacea*&lt;br&gt;D. agasthyamalayana&lt;br&gt;D. lehmannii&lt;br&gt;D. fusescens&lt;br&gt;D. aristata&lt;br&gt;D. connivens</td>
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<tr>
<td>Sect. Loriformes (Rachis flat)</td>
<td>D. deccanensis</td>
<td>D. ravii&lt;br&gt;D. josephii&lt;br&gt;D. kurumthotticalana&lt;br&gt;D. raizadae*&lt;br&gt;D. thwaitesii*&lt;br&gt;D. kurzii</td>
<td>D. lawsonii*&lt;br&gt;D. namboodiriana&lt;br&gt;D. mahendragiriensis&lt;br&gt;D. copei*&lt;br&gt;D. jainii (wing not reached at apex)<strong>&lt;br&gt;D. balakrishmaniana</strong>&lt;br&gt;D. fischeri&lt;br&gt;D. pubescens&lt;br&gt;D. mooneyi**&lt;br&gt;D. bialata**</td>
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* Upper glume awned  ** Upper glume having corky wing

**Florets**

Each spikelet contains two florets. In Dimeriinae, the lower floret is always reduced and consists of hyaline lemma only. The lower lemma is usually oblanceolate in shape, with a rounded or acute ciliated tip. It is empty and the palea is absent.
The upper floret is bisexual, and contains a complete flower. The upper lemma is subhyaline with two short lobes between which the awn arises. The awn is perfect or imperfect, which arises between the two lobes of upper lemma, consists of two parts (Fig. 6, E). The basal short and thick column, which is hygroscopic in nature and usually twisted in mature spikelets. The upper most, very long slender bristle is retrosely barbed. The column is always glabrous, but in Ravia, it is puberulent. Rarely, column is absent in some species (D. agasthyamalayana, D. woodrowii, etc.). Upper lemma is usually accompanied by a minute palea which is ca. 0.5 mm long, very hyaline in nature and rarely absent. The floret contains a hermaphrodite flower, which consists of two lodicules, two stamens and a pistil. Lodicles are usually very thin and minute, ca. 0.25 mm long and truncate, toothed at apex. The number of stamens is always two. Brown (1810) mistakenly pointed out the presence of more than two stamens, when he made the generic description of Dimeria based on the type species D. acinaciformis R. Br. During the present study, this specimen (Banks & Solander, s.n.) (Plate 3) was thoroughly examined and confirmed that only two stamens are found in the above species. Bor (1953: 554) also pointed out this correction and he suspected that “possibly Robert Brown dissected one of the abnormal spikelet of the species and gave three as the number of stamens in the diagnosis of his new genus.” Anthers are usually yellowish brown in colour and the filaments are dorsifixed. Anthers
dehisce by longitudinal slits. The length of the anther varies from 1 – 2.5 mm long. Styles are two in number with reddish brown coloured, stigma plumose and project laterally from the sides of the spikelet at maturity.

Grain a caryopsis, and its character seems to have little taxonomic value. It is ellipsoid but slightly compressed laterally and usually brownish red in color. The embryo is about one third or almost half the length of the grain consisting of a basal hilum.

**PHYTOGEOGRAPHY**

In Dimeriinae, about 90% of the known world species can be found in the following three areas, *viz*. Peninsular India, Sri Lanka and Southern China. Most of the species are having restricted distribution in one of these 3 regions.

The distribution pattern inferred from the literature and herbarium data indicates that subtribe Dimeriinae was naturally distributed in the southern erstwhile Gondwanaland region, an area composed of Madagascar, India, Sri Lanka, Australia and South East Asia especially Malesian region. Earlier, Ridd (1971) had proposed a direct connection between India and South East Asia in Gondwanaland.

Three species are restricted to Madagascar, and all of them are endemic. These geographical isolation of Malagasy species from other
species of *Dimeria* by approximately 2000 km, indicate an interesting
direct phytogeographical link between Peninsular India and
Madagascar. Some species are also found in volcanic soils of
Mascarene Islands. This distribution supports the geological data
which indicated that the archipelagic connections existed between
the Indian plate, the Mascarene plateau, Madagascar and Africa until
75 million YBP (Schuster, 1976).

**Distribution of Dimeriinae in Peninsular India**

In Peninsular India, Dimeriinae is mostly distributed from
Maharashtra to Kerala (along Western Ghats region) in the west to
eastern regions of Tamil Nadu, to Orissa (along Eastern Ghats
region) in the North-East. Occasionally, scattered populations are
seen in Deccan region. Greatest diversity and most species are found
in Western Peninsular India in general, and low altitude regions of
Western Ghats along Maharashtra, Goa, Karnataka, Kerala states in
particular.

**Species diversity and endemism**

Peninsular India harbours maximum species of Dimeriinae
and high percentage of endemism. Out of the 65 recognized taxa in
the World, 42 are reported from Peninsular India. The subtribe
shows a high percentage of endemism within Peninsular India with
24 species and 6 varieties (under two genera), which are exclusively
known from this region. There are 10 species considered near-
endemic to Peninsular India, of which 9 species are distributed from Peninsular India to Sri Lanka, and one species (*D. kurzii*) is with extended distribution in Myanmar.

Members of Dimeriinae are particularly abundant in the Western Peninsular India, which includes the Northern Western Ghats and its coastal zone and the Southern Western Ghats region. The highest concentration of species is found in Southern Western Ghats. In fact 28 of the 42 Peninsular Indian taxa (including 7 varieties) can be found in this small region from the South of Goa, Karnataka, Kerala to Tamil Nadu states. 17 taxa are exclusively endemic to this region.

Eight species are found in Northern Western Ghats region along Maharashtra and Goa States, of which 3 species are found endemic to this region.

Three species are restricted to Eastern Ghats region and 6 taxa are found scattered over Western Ghats, Eastern Ghats and Deccan region.

The species diversity of Dimeriinae represented by the sections of *Dimeria* and the genus *Ravia* on different phytogeographic regions of Peninsular India is shown in the map 5.
Phytogeographical affinity with Sri Lanka

The biogeographical connection between the Western Ghats and the Sri Lankan hills has long been obvious (Mani, 1974). Mani (l.c.) divided India into five regions of which one included the Indian East Coast (Coromandel) and the eastern parts of Sri Lanka and another included Malabar and most of the hilly parts of Sri Lanka. However, Sri Lanka is often considered as a separate region or subregion. The distribution of Dimeriinae indicates that the Southern Western Ghats has close phytogeographical link with the Sri Lankan Hills, but not the Northern Western Ghats. More or less, seven near-endemic species of the Southern Western Ghats, viz. *D. aristata*, *D. lehmannii*, *D. pubescens*, *D. trimeni* s. l., *D. kurumthotticalana* s. l., *D. thwaitesii*, *D. avenacea*, are also found in Sri Lankan region.

The distribution of Dimeriinae along the regions of the Peninsular Indian Grass Domain and Sri Lankan region are shown in Table 7.

Widespread species

Extra-peninsular India

Thirteen species are distributed as extra-peninsular Indian taxa. *D. ornithopoda* var. *ornithopoda* is distributed throughout the Tropical Asia and Australasia. *D. aristata*, *D. avenacea*, *D. fuscescens*, *D. gracilis*, *D. lehmannii*, *D. trimeni*, *D. kurumthotticalana* s. str., *D. pubescens*, *D. ornithopoda*, and *D. thwaitesii* are also
reported from Sri Lanka. *D. fuscescens* is distributed along Nepal, Sri Lanka and Malaysia. *D. kurzii* is reported from Myanmar. *D. ornithopoda* var. *khasiana* is reported from Assam region, which is endemic to India.

**Peninsular India**

Only one taxa (*Dimeria ornithopoda* var. *ornithopoda*) is distributed in almost all regions of Peninsular India as well as India. *D. connivens* is also distributed in all regions of Peninsular India and also along the arid zone of Rajasthan State.

Table 7. Distribution of the species of Dimeriinae along different regions of Peninsular India and Sri Lanka.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Taxa</th>
<th>Peninsular Indian region</th>
<th>Sri Lanka</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>S. W. Ghats</td>
<td>N. W. Ghats</td>
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<td>1</td>
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<td>3</td>
<td>4</td>
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<tr>
<td>1</td>
<td><em>Dimeria R. Br.</em></td>
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<tr>
<td>2</td>
<td><em>Dimeria sect. Annulares</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td><em>D. veldkampii</em></td>
<td>-</td>
<td>o</td>
</tr>
<tr>
<td>2</td>
<td><em>D. woodrowii</em></td>
<td>-</td>
<td>o</td>
</tr>
<tr>
<td>3</td>
<td><em>Dimeria sect. Capillares</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td><em>D. stapfiana</em></td>
<td>-</td>
<td>o</td>
</tr>
<tr>
<td>4</td>
<td><em>D. hohenackeri</em></td>
<td>x</td>
<td>x</td>
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<tr>
<td>5</td>
<td><em>var. kodagensis</em></td>
<td>o</td>
<td>-</td>
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<tr>
<td>6</td>
<td><em>D. gracilis</em></td>
<td>-</td>
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<tr>
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<td><em>Dimeria sect. Dimeria</em></td>
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<tr>
<td>7</td>
<td><em>D. acutipes</em></td>
<td>-</td>
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<td>8</td>
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<td>o</td>
<td>-</td>
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<tr>
<td>9</td>
<td><em>D. aristata</em></td>
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</tr>
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<td><em>D. avenacea</em></td>
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<td>-</td>
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<tr>
<td>11</td>
<td><em>D. connivens</em></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>12</td>
<td><em>D. copeana</em></td>
<td>o</td>
<td>-</td>
</tr>
<tr>
<td>13</td>
<td><em>D. fuscescens</em></td>
<td>x</td>
<td>-</td>
</tr>
</tbody>
</table>
14. *D. kanjirapallilana* *  
15. *D. lehmannii*  
16. *D. ornithopoda*  
17. *var. gracillima*  
18. *var. khasiana*  
19. *D. orissae*  
20. *D. trimeni*  

dimera sect. Loriformes  
21. *D. balakrishnaniana*  
22. *var. sahyadricum*  
23. *D. bialata*  
24. *var. sivarajani*  
25. *D. copei*  
26. *D. deccanensis*  
27. *D. fischeri*  
28. *D. jainii*  
29. *D. josephii*  
30. *D. kurumthotticalana*  
31. *var. idukkiensis*  
32. *D. kurzii*  
33. *D. lawsonii*  
34. *D. mahendragiriensis*  
35. *D. mooneyi*  
36. *var. borii*  
37. *D. namboodiriana*  
38. *D. pubescens*  
39. *D. raizadae*  
40. *D. ravii*  
41. *D. thwaitesii*  

genus ravia (ined.)  
42. *Ravia santapau*  

*= endemic to Peninsular India.  
O = endemic to the region.  
X = regional distribution.

**Distribution of allied genera**

Earlier workers (Hartely, 1958; Mehrothra & Jain, 1980) suggested that Peninsular India exhibits greatest diversity of the
tribe Andropogoneae. It is noticed that there are eight Andropogonoid genera endemic to the Western Peninsular India, including *Pogonachne*. The subtribe is somewhat distantly related to *Pogonachne* Bor, a monotypic genus endemic to Northern Western Ghats of Maharashtra State. The generic relationships will be discussed under Chapter 4.

**Discussions**

Being the first comprehensive work on subtribe the following observations and comments on the Phytogeography of Dimeriinae would be very significant.

1. Two broad centers of the species concentration in Peninsular India are evident based on observations of species distribution and area of endemism. The one is on the Northern Western Ghats zone of the Peninsular India, have a strong tendency of narrow endemism in Dimeriinae. The other is on the Southern Western Ghats zone. The taxa occurring in the Southern most region (Southern Western Ghat subzone - south beyond the `Palakkad-gap`) often have restricted distribution and have shown a strong affinity with Sri Lankan elements.

2. The main centre of diversity of Dimeria in Peninsular India is the Southern Western Ghats region in Kerala, Karnataka and Tamil Nadu States.
3. Among the four sections of *Dimeria*, the sect. Annulares, which is represented by two species, is exclusively endemic to Peninsular India especially to Northern Western Ghats. The section considered as near-endemic to Peninsular India is sect. *Capillares*, distributed from the Peninsular India to Sri Lanka.

4. The high degree of endemism in the Peninsular Indian region (especially in Western Ghats), both within Dimeriinae and among its allies, suggests that the subtribe originated in this area.

5. In Dimeriinae, the highest species diversity occurs in Peninsular India. The genus demonstrates a high degree of regional endemism, with 70% of the species endemic to Peninsular India. Of these, 50% are endemic to one of the four regions of Peninsular India (Southern Western Ghats); 24% are near-endemics with distribution in Sri Lanka and Myanmar; and 5% (*D. woodrowii* & *D. veldkampii*) are exclusively endemic to Northern Western Ghats region. Therefore, it is hypothesized that that Peninsular India is the centre of diversity for Dimeriinae, based on the criteria proposed by Willis (1922).

6. A further study is proposed whole country and employing molecular studies in addition to thorough systematic studies to bring out the origin and phylogenetic aspects of the group.
ECOLOGY

Habitat

The members of Dimeriinae commonly found in humid as well as wet areas of low altitude belt, i.e., from sea-level to ca. 200 m above MSL. Some species are found in areas with its natural situation from 500m to ca. 1000 m altitude (Dimeria aristata, etc.), and rarely localized up to 1600m in Peninsular India (D. trimeni).

The favourable zone for most species seems to be the lateritic or red-soil grasslands and margins along evergreen forest, or secondary habitats adjacent to these; a few taxa prefer more marginal habitats such as very steep cliffs, and alluvial soil plains.

Substrata is one of the most important ecological factors, which determines the distribution of ecological groups of plants such as Psamophytes (on sand), Lithophytes (on rock surfaces), and Chasmophytes (on rock crevices) (Raunkaiaer, 1934). Most annuals of Dimeria are seen on dry lateritic rocky plains (Lithophyte), some species on wet rocks (Lithophytes) (D. kurumthotticalana var. kurumthotticalana), and rarely grow naturally on coastal alluvial plains (D. copei) (Psamophytes); perennials like D. namboodiriana, usually prefer rock crevices (Chasmophytes) and some prefer wet sandy places along forest margins (Psamophytes) (D. fusescens).

Some of the habitats of Dimerias are shown in Plate 4.
The sprouting, flowering and fruit-setting of annual species occur within a period of 4 months. In lateritic plains of Peninsular India, the Dimerias usually sprouts during October and completely dry out by the end of February. The seeds that fall and deposited in the crevices of laterite remains there for almost 10 months and on getting the post monsoons rain the seeds germinate.

**Morphological adaptations**

The annual Dimerias are usually adapted to the lateritic habitats exhibiting following vegetative morphological features:

a. Solitary (or few) and slender annuals: These inhabit dry grassy plains usually growing gregariously. Rarely, some species are adapted to the clay soil condition (e.g., *Dimeria copei*).

b. Tufted annuals: Usually growing in rocky crevices in dry or wet conditions and are sub-gregarious (e.g., *Dimeria agasthyamalayana*).

c. Branched and mat forming annuals: Inhabits wet grassy plains of Peninsular India (e.g., *D. hohenackeri* var. *kodagensis*).

Perennials are adapted to wet rocky meadows and coarse sandy areas along water bodies, and exhibit the following:

a. Tufted perennials: Inhabits rocky meadows of high altitude as well as in river sand. They possess strong rootstock and thick elongated fibrous roots for effective anchorage in the river-bed. (e.g., *D. fuscescens*).
b. Stoloniferous and creeping perennials: Growing along forest margins along wet rocky places. They usually show rooting at lower nodes which helps in creeping (e.g., *D. namboodiriana*).

**Climate and Vegetation**

Climate plays an important role in the occurrence and diversity of Dimeriinae in Peninsular India. Dimerias enjoy monsoon climate in general, and are localized along the Tropical wet region of Western Peninsular India.

All species except *D. ornithopoda* var. *ornithopoda* are restrictedly distributed along the tropical wet and dry region. Among these, 36 taxa are occurring in wet region of Western Ghats. The distribution of Dimeriinae represented by various sections of *Dimeria* and the genus *Ravia* in different climatic zones of Peninsular India is shown in the map 6.

The life cycle of annual Dimerias is confined to a rather short period especially for post-monsoonal species. The growth begins after the monsoon (early winter) and completes its life cycle at the end of winter, after which the seeds fall and lie dormant in the lateritic substrata. In contrast, the perennials prefer rocky meadows of forest margins with a yearly vegetative cycle and the flowering and fruiting occur during the late winter period.

During post monsoon period (November–December), the species of *Dimeria* display a remarkable vegetative domination over
the surrounding winter grasses in the ghat regions of Peninsular India, especially along lateritic hilly slopes. In some grassy lateritic plains, Dimerias grow gregariously and occupy a large area after the North-West monsoon (monsoon-retreat). Interestingly, Dimerias show remarkable colour changes as they grow from the juvenile to mature stage. In some areas the colour of the vegetation shows a gradual change from green to golden yellow, and from green to reddish brown in some other places. This is attributed to the formation of pigments called anthocyanins (Bor, 1953). The regions and their respective taxa of Dimeriinae, which form the characteristic ‘Dimeria field’ in Peninsular India, are the following:

1. Northern Western Ghats (Maharashtra, Goa): *Dimeria hohenackeri/ D. stapfiana/ D. woodrowii.*

2. Central Western Ghats (Karnataka): *D. hohenackeri/D. ornithopoda var. ornithopoda.*


4. Southern Western Ghats (Central Kerala): *D. lawsonii/D. kurumthotticalana*

5. Southern Deccan region (Tamil Nadu): *D. deccanensis/D. ornithopoda.*

The characteristic colour changes in the vegetation during the lifecycle of some Dimerias are shown in plate 5.
Dimerias usually grow in regions of high rainfall in Peninsular India, where the minimum temperature during winter season falls to 20°C.

**Substrata and exposure**

*Dimeria* biotopes are mainly with well exposed lateritic soil or rocky places, typically with cracks and crevices of sloping rocks, the cliffs, and the coarse sand near the waterways. They can be also found in dry, more or less stony meadows where they flourish locally. Some species (e. g., *D. trimeni*) are even more frequent in wet highland meadows than in low altitude dry grasslands.

The preferential chemical nature of the substrata that accommodate *Dimeria in situ* is almost the same as that for rocky as well as laterite-species and doesn’t seem really specific, either for the pH (i.e., the level of alkinity or acidity) or for the mineral composition. However, laterite-substrata are rich in aluminium and iron content for which the annual species are having more affinity.

The lateritic rocky substrata of Southern Western Ghats are poor in iron content whereas the Northern Western Ghats are usually rich in iron content and the species distribution and abundance vary accordingly. Most of the species are endemic to their respective regions with few exceptions (e. g., *D. hohenackeri*).

The heliophilous character of Dimerias is rather well marked, although the perennial species usually prefer to grow in the shade. It
is noted that Dimerias generally grow in good winter brightness and prefers the direct sun, which is quite exceptional. However, occasional rains or a sudden seasonal change will jeopardise the plant growth and cause marked morphological variations in vegetative features as in species like *Dimeria copei*, *D. bialata*, *D. deccanensis* and *D. kurumthotticalana*, in which slender or tufted culm habits.

**Physiological adaptations**

The Dimerias are primarily C₄ grasses, which exclusively prefer the natural tropical climate. The adaptation to the hot climate is partially aided by the presence of narrow linear leaves which reduces excess transpiration. The formation of anthocyanin pigments during growth period by the end of monsoon, cause the gradual change in colour from green which retards photosynthesis thereby limiting vegetative growth and promoting rapid flowering and fruit setting.

**Associate Plants**

Dimerias frequently grow as pure and isolated populations especially in laterite rocky crevices where they succeed the other monsoon plants and appear as last dominant elements of the post monsoon vegetation along with other grasses. The ability of Dimerias to quickly establish in laterite hilly slopes during the post monsoon period facilitates their gregarious growth.

More generally, the annual Dimerias grow in their sites in association with numerous other post-monsoon grasses and certain
non-grasses. Associate plants vary from dry laterite substrata to wet rocky area. Most often, they are found in high altitude meadows, or among the loose sandy soil cover in open sunny places. Rarely, they are solitary and subgregarious and occur along forest margins, in shady zones.

Common associates of Dimerias in dry regions are several post monsoon grasses, viz. *Arundinella mesophylla* Nees ex Steud., *Aristida setacea* Retz., *Bhidea fischeri* Sreek. & Shetty, *Chrysopogon tadulingamii* Sreek. *et al.*, *Glyphochloa acuminata* (Hack.) Clayton, *Heteropogon contortus* (L.) P. Beauv., *Ischaemum indicum* (Hoult.) Merrill, *Dichanthium annulatum* (Forssk.) Stapf, *etc*. Most of these companion grasses are found to be endemic to Peninsular India.

The companion plants of some species of *Dimeria*, very often include other species of *Dimeria* as well, forming specific associations between them as in the case between *Dimeria ornithopoda* and *D. kurumthotticalana*, *D. hohenackeri* and *D. bialata*, *D. hohenackeri* and *D. stapfiana*, *D. hohenackeri* and *D. woodrowii*. However, in these cases, any natural hybrids between these species haven’t been observed.

Generally, polyploidy and hybridization are common among grasses which pave the way for speciation (De Wet & Harlan, 1970; Stebbins, 1972). Likewise, this might be occurring in Dimerias as well. In fact, a detailed study on the associations with companion plants and their diversity including the above aspects requires
further investigation, and literature regarding these aspects among grasses completely lacking, making it a matter for further research.

**Fruit dispersal**

Fruit dispersal in grasses occurs in different ways, *viz.* by wind, by water, by termites, ants, birds, fish, and by means of physical contacts with animals including human, by means of ballistic movements (Pijl, 1972; Davidse, 1987; Sendulsky, 1993). The dispersal units (diaspores) usually consist of caryopsis protected by lemma, glumes or even whole spikelet itself.

In Dimeriinae, the mature fruit-carrying spikelet or whole raceme are serves as diaspores. The diaspores are usually dispersed by the following three ways: Firstly, by wind (*anemochory*), which is common in grasses. Secondly, the awns of the diaspore readily get attached or adhere to clothes, skin or feathers of passing animals and birds promoting successful dispersal and establishment (*epizoochory*). This happens to the diaspores of most perennial species of *Dimeria*. The third type of dispersal of diaspores is through *anemogeochory* (Pijl, 1972). The spikelet and raceme modifications of the annual species facilitate this kind of dispersal. In these case, the diaspore usually consists of a single spikelet or whole raceme. There are two types of *anemogeochory* observed in Dimerias.

1. Spikelet as whole diaspore: Many annual species of Dimeriinae manifest this type of dispersal mechanism. The mature spikelet bearing caryopsis has a characteristic awn that propels the fruit
along the ground by hygroscopic movements of awns. The flexing and coiling nature of the awn-column by means of atmospheric moisture helps to outburst the diaspore unit from the parent plant. The diaspore then reaches far away by wind with the help of retrolessly barbed bristle.

2. Whole raceme as diaspore: In members of *Dimeria* sect. *Annulares*, the rachises at first circinately coil or roll, and finally form a ‘globule’ or a ‘ringlet’. At maturity rolled racemes fall off and function as diaspores. The diaspores roll over the lateritic plateau by wind and get deposited at crevices having soil where the seeds germinate during favourable climatic conditions. This kind of dispersal is effective in the spread of the species on dry lateritic grassy-plains.

In the case of *D. woodrowii*, the shedding of the spikelets take place from the diaspores only later and delayed dispersal mechanism is termed as ‘bradychor’ (literally means slow or delayed dispersal) (Dixon, 1933). In the case of *D. veldkampii* the spikelet disarticulation is immediately after the shedding-off of the diaspores from the plant, and is termed as ‘tachychory’ (literally means fast or rapid dispersal) (Dixon, *l.c.*).

The bradychorous and tachychorous nature of diaspore dispersal in grasses was previously unknown; it is hoped that the present observations on these modes of dispersal in the andropogonoid grasses will serve as a guide for further research.
Discussions

Present ecological study resulted in the following elucidations and conclusions as well as the identification of significant areas for further research on Dimeriinae of the World in general, and Peninsular India in particular.

1. In Peninsular India, most of the Dimerias (80%) are annuals, majority of which are laterite-loving, though some rarely favor alluvial soil; whereas perennials prefer rocky crevices along mixed forest margins, rarely in high altitude meadows, or wet sandy planes along water courses.

2. Monsoon plays a major role in the establishment and diversity of Dimeriinae in general. The humid tropical wet climate favours the successful growth, maximum diversity and endemism in Peninsular India.

3. Physiological adaptations like C₄ plant anatomy enables the successful establishment of Dimerias in tropical regions like Peninsular India. The remarkable ‘colour change’ owing to the formation of pigments is a matter of further study.

4. The detailed study on the common associate plants and their interventions requires further research, which would bring out information on naturalization, hybridization, polyploidy and speciation within Dimeriinae.

5. In contrast to other Poaceae members, Dimeria exhibits effective fruit dispersal by means of three main types of
mechanisms, viz. anemochory, epizoochory, anemogeochory (bradychory & tachychory). This aspects makes to put forward two critical questions - Dimeriinae belongs to an advanced subtribe in grass family, and do these dispersal mechanisms have any evolutionary significance in the grass family as a whole?

Further research on phytokeography, ecology, phylogeny, and genetic diversity based on molecular systematic are needed for a complete understanding of Dimerias and its taxonomically related taxa. During the present study, in collaboration with University of Missouri, USA, a molecular study on selected species has been initiated to find out the phylogenetic relationships of subtribe. Also, an attempt on the world revision of the genus is in progress as a continuation of the present work.

ECONOMIC USES

Though the species of *Dimeria* have only little economic value, some members are used as fodder which are readily eaten by cattle after the shedding of spikelets. The awned spikelet may be harmful to cattles.

In many places of northern Kerala, where they are called as “Neyypullu” are found abundantly during post monsoon season, and *D. thwaitesii*, and *D. deccanensis* are given to the cattles after a ‘salt treatment’. Salt solution is sprinkled over the cut and dried grass and kept overnight. The next day it is given to the cattles as fodder.
SYSTEMATIC POSITION

GENERIC DELIMITATION

Dimeriinae is considered as one of the little known group of tribe Andropogoneae and is hitherto represented by a single genus *Dimeria*. The sub tribe occupies rather anomalous position in the classification due to its unique morphological characteristics like presence of continuous tough rachis with persistent pedicel, laterally compressed spikelets, etc. The taxonomic concept of the subtribe is mainly based on the combination of above morphological characteristics (Bor, 1960; Clayton, 1994). With these features, the subtribe affords no hint of affinity with any other genera of the tribe and certainly a peculiar branch with uncertain relationships to other subtribes of Andropogoneae. So, the subtribe Dimeriinae is hitherto considered as enigmatic group under andropogonoids (Keng, 1939; Clayton & Renvoize, 1986). According to Clayton and Renvoize (l.c.) Dimeriinae might have evolved from Ischaeminae by suppression of the sessile spikelet. During the course of the present study, this view is corroborated (discussed later) and found that *Dimeria* shows a distant relation with the genus *Pogonachne* Bor of Ischaeminae through a newly described evolutionary intermediate genus *Ravia* Kiran Raj et Sivad. (*ined.*). The new genus has been segregated from *Dimeria* R. Br., and well placed under Dimeriinae.
The subtribe Dimeriinae has never been subjected to a critical analysis for elucidating its generic relationships. For the proper delimitation of the genera of subtribe, a proper understanding of the systematic position of the Dimeriinae in the tribe Andropogoneae is necessary. Hence, a critical evaluation of the representative subtribes of the tribe based on the gross morphology is attempted here.

**Comparative floral morphology of Andropogoneae**

Roux and Kellogg (1999) studied the floral development in the tribe andropogoneae. They found that almost all members of the tribe have paired spikelets (one sessile and the other pedicelled) with paired florets. The two spikelets, each with two florets (bifloral), may differ in their sex expression. Sometimes, unifloral condition can be also seen. A diagrammatic representation of the spikelet structure in the tribe is shown in the Figure 8.

Clayton and Renvoize (1986) also pointed out that sex of the spikelet especially of the pedicelled spikelet, has a great taxonomic value in the subtribal classification. In Saccharinae, both of the paired spikelets retain their fertility and the rachis internodes are unspecialized. In Germainiiinae, sessile spikelet is male or barren, and pedicelled one fertile. In Sorghinae, raceme triad of 1 sessile and 2 pedicelld spikelets is formed, of which sessile spikelet retains fertility.
Fig. 8. Schematic presentation of spikelet structure in the tribe Andropogoneae showing the paired spikelet condition. (PS – Pedicelled spikelet; SS – sessile spikelet; lg – Lower glume; lm – Lower lemma; ug – Upper glume; ul – Upper lemma; p – palea; F1 – Upper floret; F2 – Lower floret. Dissected region represents the jointed portion or abscission point.) (Source: modified from Roux & Kellogg, 1999)

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<th>(ss) &amp; +ps</th>
<th>ss &amp; (ps)</th>
<th>(ss) &amp; ps</th>
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<td>Sorghinae</td>
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<td>Rottboelliinae</td>
<td>Ischaeminae</td>
<td>Andropogoninae</td>
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<td>Anthistiriinae</td>
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Fig. 9. Schematic representation of morphological affinities and trends within the subtribes. ( ) = fertile, bisexual; + ) = fertile, unisexual /bisexual; + = fertile, unisexual.
In Ischaeminae, Andropogoninae, Rottboelliinae, and Anthistiriinae the sessile spikelet bisexual and pedicelled spikelet either unisexual or bisexual. In Chionachninae, Coicinae and Tripsacinae, both spikelets are unisexual. In Dimeriinae, only the pedicelled spikelet retains fertility with bisexual upper floret and the rachis internodes are tough. Based on these observations, an attempt has been made to illustrate the morphological affinities within the subtribes proposed, which are shown in the figure 9.

The above hypothetical evolutionary ‘tree’ is primarily based on the sexuality of spikelets and discloses that Saccharinae can be considered as primitive and Dimeriinae as advanced. This visualization seems to be less significant in taxonomic interpretations but in a useful aid for discussion on interrelationships of Dimeriinae.

Gross morphological analysis of the subtribes of Andropogoneae

Clayton and Renvoize (1986) established 11 subtribes under the Tribe andropogoneae based on the gross morphological features. They also postulated certain evolutionary lines within the group, which are mainly based on the following morphological characters and its states:

1. Habitat establishment: occasional* → gregarious*
2. Raceme texture: paniculate → digitate* → paired* → solitary*
3. Pedicels and Rachis texture: filiform* → flat*
4. Pedicel type: Short* → long
5. Spikelets occurrence: Sessile + Pedicelled → Pedicelled*
6. Mode of compression of spikelet: Dorsally compressed → rounded → laterally compressed*
7. Callus of the spikelet: obtuse, inserted* → oblique, pungent *
8. Lower glume back: rounded → 2-keeled → 1-keeled*
9. Upper glume of the spikelet: awnless* → awned*
10. Lower floret of the Pedicelled spikelet: Male flowered → reduced with palea only → palea absent*
11. Number of stamens: Three → Two*

The asterisks denote the character, which is found in Dimeriinae. This indicates the possible evolutionary position of Dimeriinae in the tribe Andropogoneae and it can be considered as quite advanced when compared to other members of the tribe.

The classification of subtribes within the Andropogoneae has been regarded difficult, as more morphological data is needed (Clayton & Renvoize, 1986; Kellogg, 2000).

**Generic relationships**

Here is the first attempt to delimit the generic relationships of Dimeriinae. It is necessary to examine the closely related genera of the tribe Andropogoneae in detail, which helps to arrive at a satisfactory definition and delimitation of the subtribe. They may be defined as those members having solitary, paired or digitate racemes,
laterally compressed pedicelled non-paired spikelets, the fertile lemma awned from the sinus of its 2-lobed tip and the lower floret of the spikelet reduced to a barren lemma. It is necessary to examine all andropogonoid genera with ‘non-paired’ spikelets.

**Allied genera of Subtribe Dimeriinae**

In the tribe Andropogoneae, the ‘non-paired’ spikelet condition has been encountered in 8 genera, *viz.* *Arthraxon* P. Beauv., *Cleistachne* Benth., *Dimeria* R. Br., *Mnesithea* Kunth, *Ophiuros* Gaertn., *Oxyrhachis* Pilger, *Pogonachne* Bor, and *Thaumastochloa* C. E. Hubb. (Clayton & Renvoize, 1986). The genera like *Mnesithea*, *Ophiuros*, *Oxyrhachis*, and *Thaumastochloa* (all under subtribe Rottboelliinae) have only well developed sessile spikelets. Here, pedicelled spikelet is completely suppressed. In raceme-segment, the rudimentary pedicel, lower glume of the spikelet and internode are together forming a 3-sided barrel-shaped box, which is enclosing the sessile spikelet. Morphologically, these genera are placed far from Dimeriinae.

**Cleistachne** Benth. and Dimeriinae

During the phylogenetic study of tribe Andropogoneae, Kellogg and Watson (1993) placed Dimeriinae close to *Cleistachne* (subtribe Sorghinae). But, their morphological observations were meager, because they compared the floral characters of Dimeriinae and *Cleistachne* as “...the subtribe of having two fertile florets, rather..."
than one fertile and other reduced, consistently appears as the sister genus of *Cleistachne*. Spikelets of Dimeriinae have an upper fertile floret only and the lower floret is reduced, and represented by a lemma only. Other distinctive morphological characters of Dimeriinae and *Cleistachne* are summarized in table 9. The affinity between the two is ambiguous (Fig. 10).

Table 9. Comparison of diagnostic features of *Cleistachne* and Dimeriinae

<table>
<thead>
<tr>
<th>Cleistachne</th>
<th>Dimeriinae</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Inflorescence a panicle,</td>
<td>Inflorescence a single or</td>
</tr>
<tr>
<td>rachis jointed</td>
<td>subdigitate or digitate raceme,</td>
</tr>
<tr>
<td></td>
<td>rachis continuous</td>
</tr>
<tr>
<td>2. Spikelets dorsally</td>
<td>Spikelets usually laterally</td>
</tr>
<tr>
<td>compressed</td>
<td>compressed</td>
</tr>
<tr>
<td>3. Glumes 7–9-veined</td>
<td>Glumes 3-viened</td>
</tr>
<tr>
<td>4. Lodicules ciliate</td>
<td>Lodicules glabrous</td>
</tr>
<tr>
<td>5. Stamens 3</td>
<td>Stamens 2</td>
</tr>
</tbody>
</table>

*Arthraxon* P. Beauv. and Dimeriinae

In the genus *Arthraxon* (Andropogoninae), the inflorescence is sub-digitate or a single raceme, usually having well developed sessile spikelets. Rarely, in some species spikelets are in paired condition, and pedicellated spikelets are developed, but it becomes reduced. Occasionally, the species of *Arthraxon* are confused with the members of *Dimeria s. str.* in external morphology. A comparison of diagnostic features is shown in Table 10.
Spikelet awned

<table>
<thead>
<tr>
<th>Inflorescence with sessile spikelets</th>
<th>Inflorescence with pedicelled spikelets</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Arthraxon</strong></td>
<td><strong>Pogonachne</strong></td>
</tr>
<tr>
<td>ANDROPOGONINAE</td>
<td>ISCHAEMINAE</td>
</tr>
<tr>
<td>± 10 spp.; T. Asia (mainly P. India)</td>
<td>1 sp.; P. India</td>
</tr>
<tr>
<td><strong>??</strong></td>
<td><strong>Ravia</strong></td>
</tr>
<tr>
<td><strong>Cleistachne</strong></td>
<td>(1 sp.; P. India)</td>
</tr>
<tr>
<td>SORGHINAE</td>
<td><strong>Dimeria</strong></td>
</tr>
<tr>
<td>1 sp.; P. India, T. Africa</td>
<td>[ca. 65 spp.; T. Asia (mainly P. India), Madagascar, Australasia]</td>
</tr>
</tbody>
</table>

Spikelet awnless

<table>
<thead>
<tr>
<th><strong>ROTTBOELLIINAE</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Mnesithea</em> (1 sp.; T. Asia)</td>
</tr>
<tr>
<td><em>Ophiuros</em> (4 spp.; P. India, T. Africa, S. China, Australia)</td>
</tr>
<tr>
<td><em>Oxyrhachis</em> (1 sp.; Africa, Madagascar)</td>
</tr>
<tr>
<td><em>Thaumastochloa</em> (7 spp.; Australia, New Guinea)</td>
</tr>
</tbody>
</table>

**Fig. 10.** Diagram showing the distribution (based on spikelet morphology) of andropogonoid genera having unpaired spikelets. Affinities between members of subtribe Dimeriinae and allied genera are also shown, based on phytogeographical and morphological considerations. (*Arrow marks*: Probable evolutionary trends between taxa; *Shaded region*: Raceme-rachis tough; P. India = Peninsular India; T. Asia = Tropical Asia; T. Africa = Tropical Africa; S. China = Southern China; ?? = doubtful affinity)
Table 10. Comparison of diagnostic features of *Pogonachne* Bor and Dimeriinae

<table>
<thead>
<tr>
<th>Arthraxon</th>
<th>Dimeriinae</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Raceme-rachis fragile</td>
<td>Raceme-rachis tough</td>
</tr>
<tr>
<td>2. Spikelets sometimes paired</td>
<td>Spikelets always solitary</td>
</tr>
<tr>
<td>3. Callus glabrous</td>
<td>Callus usually bearded</td>
</tr>
<tr>
<td>4. Glumes 5–20-nerved</td>
<td>Glumes 3-viened</td>
</tr>
</tbody>
</table>

The following features are common to both the groups: occurrence of paired or sub-digitate racemes, pedicelled spikelets, laterally compressed spikelets, glumes keeled or not, reduced lower floret, absence of lower palea, and number of stamens 2. Affinities and probable line of evolution morphological and phytogeographical affinity of *Arthraxon* and Dimeriinae are shown in Fig. 10.

In genera like *Pogonachne* (Ischaeminae) and *Dimeria* s.l., the inflorescence is composed of single or digitate racemes and possess only well developed pedicelled spikelets. Observations on an attempt on the study of possible interrelationships of *Pogonachne* and Dimeriinae have been presented below:

*Pogonachne* Bor and Dimeriinae

It has been observed that members of the subtribe Dimeriinae (*Dimeria* and *Ravia* gen. nov.) show distant relation with *Pogonachne* Bor, an endemic genus of Northern Western Ghats of Maharashtra.

Spikelet morphology of *Dimeria, Pogonachne* and *Ravia* was more closely investigated and elucidates the following observations.
The pedicelled spikelets of *Dimeria* are borne on tough raceme-rachises. The genus *Pogonachne* belongs to the subtribe *Ischaeminae*, and its fragile raceme-rachis bears only pedicelled spikelets. The spikelets of *Ravia* (Fig. 11, B) slightly resemble that of *Pogonachne* (Fig. 11, A) in having keel-less glumes and the upper lemma with a stout awn, but differs in having smaller spikelets with a long callus and in the absence of a median tuft of hairs along dorsal side of the upper glume but with the apical hairs. In *Dimeria*, the spikelets are laterally compressed and have dorsally keeled glumes. Within the genus *Dimeria*, the spikelets of the species of *Dimeria* sect. *Loriformes* (Fig. 11, D) differ from that of *Dimeria* sect. *Capillares* (Fig. 11, C) in having keel all along the dorsal side of the glumes. The probable spikelet evolution in *Pogonachne*, *Ravia* and *Dimeria* is schematically shown in the figure 11, A–D. All these genera have unifloral spikelets. A comparison of spikelet structure of *Pogonachne* and Dimeriinae is given in the Figure 12.

The close morphological resemblance of the inflorescences of *Dimeria* and *Ravia* and the occurrence of the two in the same geographical region, made to presume that *Dimeria* is closely related to *Ravia* and distantly related to *Pogonachne*, despite the differences in other floral characters. A comparison of other diagnostic features of *Pogonachne*, *Ravia* and *Dimeria* is shown in table 11.
Fig. 11. The probable line of evolution of spikelets of *Pogonachne*, *Ravia* and *Dimeria*: A. Spikelet of *Pogonachne racemosa* Bor; B. Spikelet of *Ravia santapaui* (N.C.Nair *et al.*) Kiran Raj et Sivad.; C. Spikelet of *Dimeria gracilis* (*Dimeria* sect. *Capillares*); D. Spikelet of *D. kurumthotticalana* s.l. (*Dimeria* sect. *Loriformes*).

Fig. 12. Schematic presentation of spikelet structure *Pogonachne* and *Dimeriinae*: A. *Pogonachne*; B. *Dimeriinae*. (F1 – Upper floret; lg – lower glume; lm – lower lemma; p – palea; PS – Pedicelled spikelet; ug – upper glume; ul – upper lemma; Broken region represents the jointed portion or disarticulation point)
Table 11. Comparison of diagnostic features of *Pogonachne*, *Ravia*, and *Dimeria*.

<table>
<thead>
<tr>
<th></th>
<th><strong>Pogonachne</strong></th>
<th><strong>Ravia</strong></th>
<th><strong>Dimeria</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Inflorescence a raceme, terminal or auxiliary.</td>
<td>Inflorescence single or paired raceme, terminal.</td>
<td>Inflorescence single, paired or digitate raceme, terminal.</td>
</tr>
<tr>
<td>3</td>
<td>Spikelets coriaceous.</td>
<td>Spikelets cartilaginous.</td>
<td>Spikelets coriaceous rarely chartaceous.</td>
</tr>
<tr>
<td>4</td>
<td>Callus cuneate, bearded, base truncate.</td>
<td>Callus oblique, densely bearded, base pungent.</td>
<td>Callus cuneate or square, base truncate/inserted.</td>
</tr>
<tr>
<td>6</td>
<td>Upper glume keeled at apex only, not winged.</td>
<td>Upper glume not keeled, not winged.</td>
<td>Upper glume keeled, winged or not.</td>
</tr>
<tr>
<td>7</td>
<td>Upper glume with dorsal median tuft of hairs.</td>
<td>Upper glume glabrous throughout.</td>
<td>Upper glume with hairs all along the keel, or glabrous.</td>
</tr>
<tr>
<td>8</td>
<td>Upper lemma with stout awn, 30-40 mm long.</td>
<td>Upper lemma with stout awn, 20-30 mm long.</td>
<td>Upper lemma with slender awn, 12-15 mm long</td>
</tr>
<tr>
<td>9</td>
<td>Column of the awn present, 10-15 mm long, twisted, glabrous.</td>
<td>Column of the awn present, 8-10 mm long twisted, sparsely pubescent.</td>
<td>Column of the awn present or absent, 2-4 mm long, twisted, glabrous.</td>
</tr>
<tr>
<td>10</td>
<td>Lower palea present.</td>
<td>Lower palea absent.</td>
<td>Lower palea absent.</td>
</tr>
</tbody>
</table>
All genera (with non-paired spikelets) are having jointed (discontinuous) raceme-rachis except in *Dimeria* and *Ravia*. The interrelationships and probable line of evolution based on phytogeographical and morphological considerations are shown diagrammatically in the figure 10.

The figure 13 is showing the raceme-segments of relevant andropogonoid genera, and their possible interrelationships with Dimeriinae.

The interrelationships of genera with non-paired spikelets of the Tribe Andropogoneae can also be distinguished and separated by the following key, which is the modification of the key provided by Clayton and Renvoize (1986: 323 & 328).

**Key to the genera with ‘non-paired spikelets’ of the tribe Andropogoneae**

1a. Inflorescence with pedicelled spikelet only; pedicel well developed, rarely persistent with rachis (in Dimeriinae) ..........................6

1b. Inflorescence with sessile spikelets only; pedicels rudimentary or suppressed (in *Arthraxon*). ..................................................... 2

2a. Inflorescence a panicle; spikelets awned. ................. *Cleistachne*

2b. Inflorescence sub-digitate or single raceme; spikelets awnless....3

3a. Peduncle deciduous ........................................... *Thaumastochloa*

3b. Peduncle not deciduous. ......................................................4

4a. Raceme dorsi-ventral; spikelets all on the same side in single row ...................................................................................... *Mnesithea*
4b. Raceme symmetrical, the spikelets on same side in two opposite rows ................................................................. 5
5a. Lower lemma eapeate ........................................... *Oxyrhachis*
5b. Lower lemma paleate ........................................... *Ophiuros*
6a. Raceme-rachis fragile.................................................. 7
6b. Raceme-rachis tough ................................................... 8
7a. Raceme single, subtended by spatheoles; upper glume with median tuft of hairs .................................................. *Pogonachne*
7b. Raceme usually sub-digitate, never subtended by spatheoles; upper glume usually glabrous ................................... *Arthraxon*
8a. Spikelets cartilaginous; callus strongly oblique, base pungent, glabrous or bearded; glume-margins auricled at apex; awn-column stout, puberulent. .............................................. *Ravia*
8b. Spikelets usually coriaceous; callus cuneate or truncate, base blunt, densely hairy; glume-margins entire; awn-column slender, glabrous .................................................. *Dimeria*

**Tribe Paniceae and subtribe Dimeriinae**

Clayton (1969) pointed out the possible affinity of subtribe Dimeriinae with tribe Paniceae of Panicoideae. Raceme with continuous rachis is one of the diagnostic features of Tribe Paniceae. Also, in external morphology, Dimeriinae are sometimes confused with some Paniceae members like *Digitaria* Haller. All members of the subtribes of andropogonoids having jointed rachis (with continuous
raceme-rachis), except in members of Dimeriinae. But based on
general morphological features, Dimeriinae can be easily separated
from Paniceae. A comparison of diagnostic features is given in table
12. The affinity between these two groups is also doubtful.

Table 12. Comparison of diagnostic features of Tribe Paniceae and
Dimeriinae.

<table>
<thead>
<tr>
<th>Paniceae</th>
<th>Dimeriinae</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Spikelets usually dorsally compressed or</td>
<td>Spikelets usually laterally</td>
</tr>
<tr>
<td>rounded.</td>
<td>compressed.</td>
</tr>
<tr>
<td>2. Glumes small, sometimes absent; smaller</td>
<td>Glumes large and prominent;</td>
</tr>
<tr>
<td>than lemmas.</td>
<td>larger than lemmas.</td>
</tr>
<tr>
<td>3. Upper lemma usually awnless</td>
<td>Upper lemma awned.</td>
</tr>
<tr>
<td>4. Lower lemma large; chartaceus to</td>
<td>Lower lemma small, hyaline.</td>
</tr>
<tr>
<td>cartilaginous.</td>
<td></td>
</tr>
</tbody>
</table>

INFRAGENERIC DELIMITATION

Due to the presence of obviously related species, it is little
difficult to make a very clear infra-generic delimitation. Since the
Peninsular India holds majority of the World taxa, it is necessary to
give a better system of classification for clear-cut delimitation of the
infrageneric categories.

Dimeria s.str.

Bor (1953) had first attempted to accommodate the species of
Dimerias under 3 sections. He found that the shape of raceme rachises, the orientation and time of disarticulation of spikelets, and the type of pedicels are of great diagnostic significance and his sections are based on these features. He grouped the species of India, Myanmar and Sri Lanka into the following sections. The sections of *Dimeria* and the included species as recognized and treated by Bor (1953) are provided below with the diagnostic features (as given by him) of the sections given in parenthesis.

**Dimeria sect. Annulares** (Rachis of the raceme on both sides a little convex, at first straight, afterwards at maturity ring-shaped, carrying the spikelets on the inside; spikelets slowly separating from the pedicels at maturity)

*D. woodrowii* Stapf

**Dimeria sect. Capillares** (Rachis of the raceme capillary, very thin or trigonous; in section nearly triangular, not winged; pedicel conical or compressed at all, spikelets at maturity free from the pedicels)

*D. ballardi* Bor
*D. blatteri* Bor
*D. fuscescens* Trin.
*D. gracilis* Nees *ex* Steud.
*D. hohenackeri* Hochst. *ex* Miq.
*D. stapfiana* C. E. Hubb. *ex* Pilger
*D. velutina* Bor

**Dimeria sect. Loriformes** (Rachis of the raceme flat and compressed, in section elliptical or plano-convex, dorsally flat or little convex, winged or not; pedicels distinctly compressed)

*D. acutipes* Bor
During this work on the peninsular Indian species, it appeared that the infra generic subdivision rose by Bor (l.c.), based above limited characters, is unsatisfactory. It was found that species were accommodated in sections where they clearly did not agree with the sections, and that few sections couldn’t be distinguished from each other satisfactorily due to the overlapping of characters. He neither appointed the types to the respective sections nor explained the sectional characters in detail.

Re-evaluation of the infrageneric classification of Dimeria

As far as the relative structure of raceme rachises, the morphology and orientation of the spikelets and the texture of the pedicels are concerned, it has been observed that these features are of great significance delimiting and distinguishing sections. With the help of more data obtained from overall morphological features of the
taxa from Peninsular India, a revised and updated sectional treatment is provided.

Bor’s Dimeria section Annulares is characterized by an unusual coiling of racemes and was represented by a single species. One more species (Kiran Raj & Sivadasan, 2008) has been added to the section during the present study.

The other two sections of Dimeria (sect. Capillares and sect. Loriformes) recognized by Bor have been critically evaluated and realignment of the constituent species have been made.

From these two sections, the species with strictly triqueterous raceme rachises, overlapping spikelets, and pedicels closely appressed to the rachis are excluded and are placed in the type section Dimeria. During the present work, the holotype of the D. acinaciformis R. Br., which is the type species of the genus, has been consulted at BM (Plate 3) which was collected from north-eastern Australia by Sir Joseph Banks and Daniel Carl Solander in 1770.

The remaining taxa in Dimeria section Capillares (s.l.) recognized by Bor have racemes with strictly terete pedicels with filiform rachises, which agrees with the diagnostic characters of the proper sect. Capillares. The section has been lectotyped here.

The remaining taxa in Bor’s section Loriformes (s.l.) have racemes with flattened rachises and compressed pedicels, which together defines the proper sect. Loriformes. This section has also
been lectotyped here.

It is confirmed that the species of the four sections recognized here exhibit a definite overall similarity between the members of all the sections. A number of species with morphologically intermediate characters of other sections also are present and are considered as the intermediate taxa linking the sections. The revised sectional treatment of Peninsular Indian *Dimeria* with more static and reliable characteristic features is given below.

**Dimeria** Sect. **Annulares** Bor, Kew Bull. 7(4): 556.1953. – Type: *Dimeria woodrowii* Stapf

Annuals. Raceme 2(–3), rolled, as a whole shed off at maturity; raceme-rachis slightly compressed, a little convex on both sides, at straight when young, wingless, coiled or rolled at maturity, carrying the spikelets inside; rachis-internodes ca. 1.5 mm long; pedicel short, flat, diverging from rachis; spikelets distantly arranged along the rachis; Glumes never diverging at anthesis, upper glume winged at apex of the keel only, wing papery.

2 species in Peninsular India; Endemic to lateritic plains of Northern Western Ghats.

* D. veldkampii* Kiran Raj & Sivad.
* D. woodrowii* Stapf

**Dimeria** Sect. **Capillares** Bor, Kew bull. 7(4): 556.1953. – Lectotype: *Dimeria hohenackeri* Hochst. ex Miq. (designated here)
Annuals or Perennials. Racemes (3-)4–8(-11), straight; raceme-rachis capillary or wiry, nearly triangular or terete in cross section, flaccid, wingless; rachis-internode 2.5–3.5 mm long; pedicels up to 1.5 mm long, clavate, diverging form rachis; spikelets distantly arranged along rachis, not imbricate; glumes widely diverging at anthesis. Upper glume winged all along keel or wingless, wing corky or papery.

3 species in Peninsular India.

*D. stapfiana* C. E. Hubb. ex Pilger

*D. hohenackeri* Hochst. *ex* Miq.

*D. gracilis* Nees *ex* Steud.

**Dimeria** Sect. **Dimeria** – *Type: Dimeria acinaciformis* R. Br.

Annuals or perennials. Racemes (1–)2–3, stright; raceme-rachis triqueterous, trigonous in cross section, rigid, occasionally zig-zag in profile, usually wingless, if winged only at the rachis-internode only; rachis-internode ca. 0.5 mm long; pedicels up to 0.5 mm long, cuneate or truncate, flat, closely attached to rachis; spikelet coriaceous, often fuscous, compactly packed along rachis, imbricate; glumes never diverging at anthesis; upper glume winged usually towards the apex of the keel or wingless; wing papery.

12 spp. in Peninsular India.

*D. acutipes* Bor

*D. agasthyamalayana* Kiran Raj & Ravi

*D. aristata* Hack.

*D. avenacea* (Retz.) C. E. C. Fisch.
D. connivens Hack.
D. copeana Sreek. et al.
D. fuscescens Trin.
D. kanjirapallilana K. C. Jacob
D. lehmannii (Nees & Steud.) Hack.
D. orissae Bor
D. ornithopoda Trin.
D. trimenii Hook. f. (linking species, with sect. Loriformes)

**Dimeria** Sect. **Loriformes** Bor, Kew bull. 7(4): 556.1953. – Lectotype: *Dimeria pubescens* Hack. (designated here)

Mostly annuals. Racemes 1–2(–3), straight; raceme-rachis compressed; flattened in cross section, stiff but not rigid, distantly winged; rachis-internodes 0.5–1 mm long; pedicels 0.3–0.5 mm long, distinctly compressed, flat, somewhat attached to the wing of the rachis; spikelets coriaceous or chartaceous, compactly arranged along the rachis, early disarticulating with the pedicels; glumes diverging at anthesis; upper glume winged usually all along the keel or the apex, wing corky or papery.

16 spp. in Peninsular India.

- *D. balakrishnaniana* Ravikumar et al.
- *D. bialata* C. E. C. Fisch.
- *D. copei* Ravi
- *D. deccanensis* Bor (linking species, with sect. *Dimeria*)
- *D. fischeri* Bor
- *D. jainii* Sreek. et al.
- *D. josephii* Ravi & Mohanan
- *D. kurumthotticalana* K. C. Jacob
D. kurzii Bor
D. lawsonii (Hook. f.) C. E. C. Fisch.
D. mahendragiriensis Ravi et al.
D. mooneyi Raiz ex Mooney
D. namboodiriana Ravi & Mohanan
D. pubescens Hack.
D. raizadae V. J. Nair et al.
D. ravii Kiran Raj, Sivad. & Jomy (ined.)
D. thwaitesii Hack.

Phylogenetic considerations

The Dimeria sect. Capillares probably lies close to the ancestral line, for the species have primitive characters (the Ravia-like capillary raceme-rachis of D. gracilis). The supposed affinities and phylogenetic considerations rest mainly on the raceme-rachis structure. Four points emerge from a consideration of morphological affinities:


(2) Sect. Dimeria and sect. Loriformes: The sect. Dimeria are so closely related morphologically with linking species like D. deccanensis and D. trimeni of sect. Loriformes. These species with features like abaxially flattened triqueterous raceme-rachis must be considered as intermediate between the two sections.

(4) Sect. *Annulares*: The inflorescence of the members of sect. *Annulares* shed off as a whole at maturity so as to perform the effective dispersal of seeds. The coiled raceme-rachis must be presumably regarded as an advanced character among members of the sections of *Dimeria*.

Therefore, *Dimeria* sect. *Annulares* should be regarded as phylogeneticaly advanced than other sections of the genus and other members of the subtribe.

The overall relationships among the sections and species, according to the morphological affinities is displayed in the figure 14.

**TAXONOMIC & PHYTOGEOGRAPHIC ANALYSES**

**Diversity of the subtribe Dimeriinae in Peninsular India**

Bor (1953) recognized only one genus, viz. *Dimeria* R. Br. with 25 species under the subtribe Dimeriinae *s.str.* from India, Sri
Fig. 14. Morphological affinities and probable origin and interrelationships in Dimeriinae: A. Ravia; B. Dimeria sect. Capillares; C. Dimeria sect. Dimeria; D. Dimeria sect. Loriformes; E. Dimeria sect. Annulares. (Each box represents the individual species or species complexes. Arrow represents affinity and probable relation between the taxa. Distance between boxes represents the percentage of affinity. Broken arrow = doubtful affinity. Broken circle = True perennials, with stolon. Box in gray colour = Taxa with upper glume-awn. Broken lined box = Perennial, without stolon. Dark-outlined box = Taxa with corky glume-wing)
Lanka and Myanmar, of which 20 are represented in Peninsular India. Out of the 8 species described as new by Bor, 5 are from Peninsular India. In the present study, an additional genus, viz. *Ravia* has been recognized as new and a total of 35 species and 7 varieties have been recognised from Peninsular India alone.

Dimeria is the third largest grass genus in India and its high proportion of endemic taxa and species diversity in Peninsular India is unparallel to that of any other grass genera. Peninsular Indian region represents all the known Indian Dimerias.

Compared to other *Dimeria*-occurring regions like Sri Lanka, South China, North-east Russia, Taiwan, Japan, Vietnam, South Korea, Myanmar, Madagascar, Australia, Malesian region and Pacific Islands, Peninsular India holds high species diversity and have shown high degree of endemism.

The analysis on diversity and distribution provided some important findings on endemism and rarity of the taxa under subtribe Dimeriinae in Peninsular India (Table 13).

The recognition of the new genus *Ravia* Kiran Raj et Sivad. (*ined.*) with its characters having alliance with that of the *Pogonachne* Bor, an endemic genus of Western Ghats, India, more or less clears the incongruity and anomalousness felt so far in the placement of genera of Dimeriinae under Andropogoneae. The occurrence and diversity of *Pogonachne* and Dimeriinae in the same geographical region, made to presume that *Dimeria* is closely related
to *Ravia* and distantly related to *Pogonachne*, despite the differences in other floral characters.

Table 13. Diversity of the subtribe Dimeriinae in Peninsular India, percentage of endemism, and taxa known only from one locality.

<table>
<thead>
<tr>
<th></th>
<th>Number of taxa</th>
<th>% of taxa in P. India</th>
<th>% of P. Indian taxa among the World taxa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peninsular Total Indian</td>
<td>42*</td>
<td>-</td>
<td>63</td>
</tr>
<tr>
<td>Peninsular Indian Endemics</td>
<td>30</td>
<td>70</td>
<td>45</td>
</tr>
<tr>
<td>Common endemics in P. India &amp; Sri Lanka</td>
<td>9</td>
<td>22</td>
<td>15</td>
</tr>
<tr>
<td>Taxa known from one locality</td>
<td>14</td>
<td>34</td>
<td>22</td>
</tr>
</tbody>
</table>

P. India = Peninsular India; * including 7 varieties

**Distribution and phytogeographical significance**

A phytogeographic study of Dimeriinae in Peninsular India indicates that the region harbours maximum species of the subtribe and high percentage of endemism. Out of the 65 recognized taxa in the World, 42 (including 7 varieties) are reported from Peninsular India. The subtribe shows a high percentage of endemism within Peninsular India with 24 species and 6 varieties (under two genera), which are exclusively endemic to this region. There are 10 species considered near-endemic to Peninsular India, of which 9 species are distributed from Peninsular India to Sri Lanka, and one species (*D.*
kurzii) is with extended distribution in Myanmar. The highest concentration of species is found in Southern Western Ghats. In fact, 28 of the 42 Peninsular Indian taxa (including 7 varieties) can be found in this small region from the South of Goa, Karnataka, Kerala to Tamil Nadu states. A total of 17 taxa are exclusively endemic to this region. Eight species are found in Northern Western Ghats region along Maharashtra and Goa States, in which 3 species are found endemic to this region. Three species are restricted to Eastern Ghats region and 6 taxa are found scattered over Western Ghats, Eastern Ghats and Deccan region. Thirteen species are having extra peninsular Indian distribution.

Among the four sections of Dimeria, the sect. Annulares, which is represented by two species (Dimeria veldkampii Kiran Raj & Sivad. and D. woodrowii Stapf), is exclusively endemic to Peninsular India especially to Northern Western Ghats. Dimeria sect. Capillares, distributed from the Peninsular India to Sri Lanka, is considered as near-endemic to this region. The high degree of endemism in the Peninsular Indian region (especially in Western Ghats), both within Dimeriinae and among its allies, suggests that the subtribe originated in this area.

**Ecology and habitat specificity**

During the ecological study of Dimeriinae, it has been found that most of the Dimerias (80 %) are annuals, majority of which are laterite-loving, where as perennials prefer rocky crevices along mixed
forest margins, rarely in high altitude meadows, or wet sandy plains along water courses. Monsoon plays a major role in the establishment and diversity of Dimeriinae in general. The humid tropical wet climate favours the successful growth, maximum diversity and endemism in Peninsular India.

**Dispersal mechanisms**

An interesting dispersal mechanism - anemogeochory - of some members of the subtribe, is found to be very unique among the members of the grass family and can be considered as an advanced feature of morphological adaptation for effective dispersal and establishment. Interestingly, in Dimerias the fruit dispersal takes place by three types of mechanisms, viz. anemochory (by wind) epizoochory (by animals), and anemogeochory (coiled racemes roll over the ground blown by wind and get dispersed). Anemogeochory by means of two sub-types, bradychory (delayed dispersal) and tachychory (early dispersal). Due to the occurrence of these dispersal mechanisms, the present study believes that Dimerias belongs to an advanced group in the tribe Andropogoneae.

A world revision of the genus is needed to have a thorough knowledge on the exact diversity, phylogeny and interrelationships of the genus, and the work is in progress as a continuation of the present study.
Peninsular India, the center of diversity of Andropogonoids? - A hypothesis

The andropogonoids are considered as the advanced group among the grasses as they successfully occupy the warm tropical and subtropical regions especially in the Old World regions. The presence of $C_4$ photosynthetic pathway with NADP-ME (MS Type) metabolism (Chapman & Peat, 1992), vide array of reproductive systems especially andromonoecious habit (Connar, 1981), and breeding habit etc. are the important ecological adaptations of this group. Based on the preliminary critical study of the group, it is found that Peninsular India, especially Western Ghats region may be consider as the center of origin and diversity of Andropogonoids.

Phytogeographic as well as taxonomic considerations are the major criteria behind this assumption, which in turn lead to the following observations.

(1) High Generic diversity: Peninsular India is having the highest number of genera compared to other major Andropogonoid centers of the World (Tropical America, Tropical Africa, Sri Lanka, SE. Asia, and Australia) and is represented by 56 % of the World genera.

(2) High degree of generic endemism: Peninsular India having the highest number of endemic genera (8). Among these eight genera, only three genera - Bhidea (2 spp.) Lophopogon (2 spp.) and Glyphochloa (11 spp.) are widely distributed. The remaining 5 genera
viz., *Pogonachne, Trilobachne, Pseudodichanthium, Triploptogon* and *Manisuris* have only very narrow distribution, and are confined to the Western Ghats region and are monotypic ones.

(3) *Relatively high species diversity and endemism:* 25% of the World species are found in Peninsular India. Only few genera have been well studied so far so that the species diversity the remaining genera are yet to be ascertained. Among the total estimated species, 45% are strictly endemic to Peninsular India (Hartley, 1958; Mehrothra & Jain, 1980). Genera like *Arthraxon* (60%), *Chrysopogon* (52%), *Dichanthium* (55%), *Dimeria* (54%), *Heteropogon* (100%), & *Ischaemum* (60%) have maximum species diversity and endemism (Jain, 1986; Kiran Raj *et al.*, 2003). The details on andropogonoid genera having high species diversity and endemism in Peninsular India are shown in table 14.

(4) *The occurrence and diversity of the Tribe Arundinelleae:* Recent phylogenetic study on andropogonoids supports the monophyly of the subtribe and the relationship with Andropogoneae and *Arundinella* (Mathews *et al.*, 2002). Arundinelleae is one of the smallest tribes of the subfamily Panicoideae and is well represented in Peninsular India with 3 genera, *viz.* *Arundinella, Jansenella* and *Chandrasekharania*. *Arundinella* is represented by 25 species in India (51% of the world spp.) with more than 15 endemics. Out of the total species in India, 17 species are found in Peninsular India with 13 endemics. *Jansenella* and *Chandrasekharania* are monotypic
genera; former is exclusively found in Indian subcontinent and the latter endemic to Southern Western Ghats. The occurrence and diversity of these closest relatives of andropogonoids have also supported the above hypothesis.

(5) **Occurrence and diversity of primitive as well as advanced subtribes**: Clayton and Renvoize (1986) found that subtribe Saccharinae is primitive under the tribe. This group is well represented in Peninsular India with 13 genera (out of 15) including one endemic genus, *viz. Lophopogon*. The subtribe Dimeriinae is represented in Peninsular India with 2 genera (one endemic) and 70% of the world species. The subtribe is considered as the advanced group in the tribe and is hypothesised that Peninsular India is the primary center of origin of *Dimeria* (present study).

(6) **Phytogeographic considerations**: Many workers observed the phytogeographical similarity between India and Africa (Fischer, 1934; Mehrotra & Jain, 1980; Nayar & Ahemedulla, 1984; Singh et al., 2002). It is observed that the tribe became most dominant in the grass flora of Peninsular India, Tropical Africa, Sri Lanka and Australia compared to that in the other regions of the World. These regions were the part of historic Gondwanaland before the Cretaceous breaking. The genera like *Vossia, Thelepogon, Cleistachne* (all monotypic), etc have shown common endemism and *Arthraxon, Saccharum*, etc. have shown maximum species diversity in Tropical Africa and Peninsular India. On a preliminary study, it is reasonably
observed that savannah of Africa shows a close affinity with that of Indian savannah as both are having the predominant members of the Tribe Andropogoneae.

A critical study based “on a phylogenetic framework, to see if the endemic genera and species of Peninsular India are basal or derived, where their sister taxa fall and so on …..” (Strömberg, pers. comm.) would bring out the actual conclusion on the center of diversity of andropogonoid grasses.

Table 14. Andropogonoid genera of Peninsular India (endemic and near-endemic) and their species diversity, endemism and distribution.

<table>
<thead>
<tr>
<th>Genera</th>
<th>Distribution</th>
<th>No. of World species / No. of species in P. India (*) / Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apluda</td>
<td>Tropical Asia</td>
<td>3spp./3 spp. (2) / P. India-center of diversity (?); a close relative of <em>Ischaemum</em> L.</td>
</tr>
<tr>
<td>Arthraxon</td>
<td>Old world Tropics</td>
<td>20 spp./12 spp.(8)/ P. India-center of diversity (?)</td>
</tr>
<tr>
<td>Bhidea</td>
<td>Endemic to P. India</td>
<td>(2 spp.)</td>
</tr>
<tr>
<td>Bothriochloa</td>
<td>Old World Tropics</td>
<td>35 spp./14 spp.(9)</td>
</tr>
<tr>
<td>Capillipedium</td>
<td>Tropical Asia, Africa</td>
<td>14 spp./7 spp. (3)/ P. India-Primary or secondary centre of diversity (?)</td>
</tr>
<tr>
<td>Chrysopogon</td>
<td>Old World Tropics</td>
<td>29 spp./15 spp.(10)/P. India-Primary or secondary centre of diversity (?)</td>
</tr>
<tr>
<td>Cleistachnae</td>
<td>T. Africa, India</td>
<td>1 sp.</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>-----</td>
<td>----------------------------------------</td>
<td>------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Cymbopogon</strong></td>
<td>Old World Tropics + 40 spp./ + 20 (5)/ Major savanna element; P. India- Primary or secondary centre of diversity (?)</td>
<td></td>
</tr>
<tr>
<td><strong>Dichanthium</strong></td>
<td>Old World Tropics + 20 spp/ + 10 spp.(7)/ P. India-Centre of diversity (?)</td>
<td></td>
</tr>
<tr>
<td><strong>Dimeria</strong></td>
<td>Tropical Asia, + 65 / ca. 40 spp. (26)/ P. Australia India - center of diversity **</td>
<td></td>
</tr>
<tr>
<td><strong>Glyphochloa</strong></td>
<td>Endemic to P. India (11 spp.)</td>
<td></td>
</tr>
<tr>
<td><strong>Heteropogon</strong></td>
<td>Old World Tropics 6 spp./ 6 spp. (3)/P. India- Centre of diversity (?)</td>
<td></td>
</tr>
<tr>
<td><strong>Ischaemum</strong></td>
<td>Tropical Asia ca.85/ 60 spp.(35)/ P. India-center of diversity (?)</td>
<td></td>
</tr>
<tr>
<td><strong>Lophopogon</strong></td>
<td>Endemic to India 3 spp. / extending to Andaman &amp; Nicobar Islands</td>
<td></td>
</tr>
<tr>
<td><strong>Manisuis</strong></td>
<td>Endemic to P. India (2 spp.)</td>
<td></td>
</tr>
<tr>
<td><strong>Ophiurus</strong></td>
<td>P. India, T. Africa, 4 spp./3 spp. (1)/ P. India- Australia Primary or secondary centre of origin (?)</td>
<td></td>
</tr>
<tr>
<td><strong>Pogonachne</strong></td>
<td>Endemic to P. India (1 sp.)</td>
<td></td>
</tr>
<tr>
<td><strong>Pseudodichanthium</strong></td>
<td>Endemic to P. India (1 sp.)</td>
<td></td>
</tr>
<tr>
<td><strong>Ravia</strong></td>
<td>Endemic to P. India (1 sp.)*</td>
<td></td>
</tr>
<tr>
<td><strong>Sehima</strong></td>
<td>Old World Tropics 5 spp./ 3 spp.</td>
<td></td>
</tr>
<tr>
<td><strong>Thelepogon</strong></td>
<td>P. India, T. Africa (1 sp.)</td>
<td></td>
</tr>
<tr>
<td><strong>Themeda</strong></td>
<td>Tropical Asia, Africa 18 spp./15 spp. (5)/ P. India- Primary or secondary Centre of origin (?) ; Dominant savanna element.</td>
<td></td>
</tr>
<tr>
<td><strong>Trilobachnae</strong></td>
<td>Endemic to P. India (1 sp.)</td>
<td></td>
</tr>
<tr>
<td><strong>Triplopo gon</strong></td>
<td>Endemic to P. India (1 sp.)</td>
<td></td>
</tr>
<tr>
<td><strong>Vossia</strong></td>
<td>P. India, T. Africa 1 sp.</td>
<td></td>
</tr>
</tbody>
</table>

Genera shown in bold letters requires thorough systematic studies in Peninsular India; *= Number of endemic species in Peninsular India. ** = Data based on the present study. P. India = Peninsular India. T. Africa = Tropical Africa.