SYSTEMATIC STUDIES ON THE GENUS *GLYPHOCHLOA* W. D. CLAYTON (POACEAE)

THESIS
SUBMITTED TO GOA UNIVERSITY
FOR THE AWARD OF DEGREE OF

DOCTOR OF PHILOSOPHY
IN BOTANY

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BY

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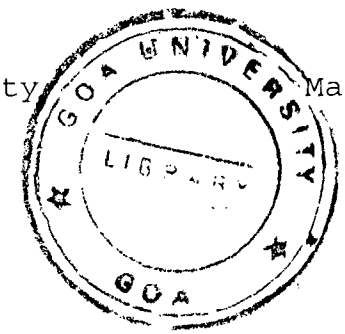
STATEMENT

I state that the present thesis "Systematic studies on the genus *Glyphochloa* W. D. Clayton (Poaceae)" is my original contribution and the same has not been submitted on any previous occasion for any other degree or diploma of this University or any other University / Institute. To the best of my knowledge, the present study is the first comprehensive work of its kind from the area mentioned. The literature related to the problem investigated has been cited. Due acknowledgements have been made wherever facilities and suggestions have been availed of.



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CERTIFICATE

This is to certify that the thesis entitled "Systematic studies on the genus Glyphochloa W. D. Clayton (Poaceae)" submitted by Mrs. Maria A. A. R. Fonseca for the award of the degree of Doctor of Philosophy in Botany, is based on her original and independent work carried out by her during the period of study, under my supervision.

The thesis or any part there of has not been previously submitted for any other degree or diploma in any University or Institute.

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Research Guide

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Chapter 1

INTRODUCTION

The family Poaceae (nom. alt. Gramineae) forms one of the largest families of flowering plants. It comprises of about 10,000 species (Mabberley, 1987) and 793 genera (Watson & Dallwitz, 1994). It is by far the most dominant family from an ecological viewpoint. The members of the family occupy a wide and varied ecological range and form an essential component of almost every type of vegetation ranging from major grasslands to the densely canopied evergreen glades. The ecological diversity of the grasses is amply complemented by the great genetic diversity. The grasses contribute to the mankind in the form of staple food, fodder for cattle, thatching and building material, medicine etc. According to Nayar (1986) the present civilization stands squarely on the family Poaceae.

The family is represented in India by 241 genera and 1243 species of which 180 species and 21 varieties are endemic to Peninsular India (Nayar, l.c.). Of the 180 endemic grass species of Peninsular India, as many as 93 species belong to the tribe Andropogoneae which reflects the high degree of endemism of the tribe. Hartley (1958)

has shown that Peninsular India is one of the two main centres of high concentration of the grasses of the tribe Andropogoneae.

The genus *Glyphochloa* W. D. Clayton of subtribe Rottboelliinae, tribe Andropogoneae and subfamily Panicoideae (Watson and Dallwitz, l.c.) is a paleoendemic genus (Nayar, 1996) restricted to Peninsular India. All the species of the genus *Glyphochloa* were earlier recognised under *Manisuris* L. Revisions or some new species have been added by Bor (1960), Rao and Hemadri (1968), Jain and Deshpande (1969), Jain and Hemadri (1969), Kulkarni and Hemadri (1974). Jain (1972) provided a taxonomic account of this genus. Clayton (1981) reduced this to a single species and transferred the others to the genus *Glyphochloa*. Janarthanam et al. (2000) added yet another species bringing total number of species under the genus to nine with five varieties recognized under them.

The phenomenon of paleoendemic species becoming epibiotic through vicariad speciation in different ecological niches is seen in the endemic genus *Glyphochloa* (Nayar, l.c.). Most of the species of *Glyphochloa* are succulent and occupy rocky habitat taking a different

course of evolution as compared to their allied genera in the tribe.

In the regions on the border line between zones of adequate moisture and of deficient moisture, even small climatic shifts and species migration will bring together related species which previously were isolated from each other and thus will promote hybridization between differently adapted types. Thus climatic and edaphic diversity occurring in ecotones or border regions between different biotic provinces are factors which most actively promote the evolution and differentiation of species of higher plants (Stebbins and Major, 1965). The paleoendemic genus *Glyphochloa* forms one such group where the habitats occupied by its species are adjacent. Though an attempt has been made to understand the taxonomy of this group (under the genus *Manisuris*) by Jain (l.c.) based on morphological characters, further attempts have not been made to understand its systematics in a comprehensive manner. Hence, the detailed studies on the systematics and phylogeny of the genus *Glyphochloa* had been undertaken.

Objectives:

The objective of the study was to analyse the variations between and within the species, to correlate the variations with their ecology, understand the systematics in a comprehensive manner and to interpret the phylogeny of the endemic genus *Glyphochloa*.

Chapter 2

REVIEW OF LITERATURE

'Endemic' is a term ascribed to any taxonomic unit or taxon occurring in a restricted area, usually isolated by geographical or temporal barriers. The term `endemism' was coined by Decandolle (1855) for the distribution of an organism in a limited geographical area. All endemics are classified on the basis of phytogeography irrespective of political boundaries. Engler (1882) recognised two kinds of endemism. One based on the preservation of ancient forms, which may have originated in entirely different regions and the other based on the development of new, entirely autochthonous forms.

The distribution of endemics follows biogeographic provinces, pattern of unique ecological features, topographical and climatic interfaces (Nayar, 1996). Endemic taxa restricted to a particular peninsula, mountain range, an island or a mountain peak may well be remnant of an ancient flora, which in the course of geological and climatic changes found refugium in isolated or restricted geographical regions. This antiquity can be their

phylogeny, taxonomic isolation, nature of habitat and possible fossil history.

Stebbins and Major (l.c.) renamed two types of endemics proposed by Engler (l.c.) as paleoendemics and neoendemics. Wherry (1944) classified endemic plants into primary and secondary endemics. Favarger and Contrandrypoulos (1961) proposed a classification of endemics based on cytological data. They are: 1) Paleoendemics-those elements, which are isolated taxonomically, show no variations and occur in isolated refugia. 2) Schizoendemics - the endemics produced by gradual speciation having common origin but isolated in different ecological niches and usually they occur in widely different ecological niches available in mountain chains with altitudinal and latitudinal differences and they have identical chromosomes. 3) Patro-endemics - the parent endemics, i.e. diploids which give rise to polyploids and 4) Apoendemics - the polyploids usually of hybrid origin, arising from widely distributed diploids.

Bramwell (1972) characterised paleoendemics as: 1) taxonomically isolated complements having no closely related species. 2) Presence of woody life forms in

isolated taxa occuring in islands and mountain summits. 3) Low level of polyploidy in the endemic flora. 4) Major disjunction in the distribution of many of the endemic taxa and possible fossil evidence.

Neoendemics develop through geographical speciation, quantum speciation and sympatric speciation. According to Stebbins (1938) polyploidy is stronger for herbaceous perennials. Richardson (1978) proposed that all species start as neoendemics and end up as paleoendemics. Neoendemics tend to behave as holoendemics - these are endemics that are in an intermediate stage between neoendemics and paleoendemics (Nayar, l.c.) and may lead to the formation of paleoendemics through the following steps: origin, expansion, stabilization, diversification, migration, fragmentation, contraction and later extinction. Taxa passes along the evolutionary pathway at different rates and a holoendemic could only be one step removed from the ancestor of the group while a contemporaneous relic would only be many steps removed.

Endemism in Peninsular India:

The history of flora of Peninsular India is one of the floristic impoverishments due to flow of deccan lavas

during cretaceous-eocene times and spreading aridity in miocene-quaternary period causing depletion of its characteristic flora leaving few related taxa (Nayar, 1977). Most of the endemics of penisnsular India are paleoendemics, found in favourable ecological niches in the hill ranges on either side of Western Ghats and Eastern Ghats. Subramanyam and Nayar (1974) considered that the Western Ghats hilltops resemble islands so far as the distribution of endemic species is concerned. The Peninsular India, bordered in the north by the Bundlekhand and Rajmahal hills has a characteristic true Indian flora which is reflected in its components.

Peninsular India is a part of the Gondwana land mass with a geographical lineage of great antiquity. It is seen that the Indian plate of the Gondwana land detached itself during middle Eocene and moved northwards from its original position near Madagascar in southern latitude to crash against Laurasia in northern tropical latitude during late Oligocene. Raven and Axelrod (1974) are of the opinion that the Indian plate was subjected to different climatic stresses during its passage northwards resulting in the improvement of its flora. Also the closing of the Tethys sea and opening of the Indian ocean brought about new

climatic patterns of trade winds and monsoon regimes which contributed to the preservation of a few endemic taxa in the mountain systems of Peninsular India.

Turrill (1964) observed that next to islands the Peninsular regions provide favourable conditions for endemism. Peninsular Indian region has high degree of endemism making it the second richest endemic centre after Himalayas. On the basis of the distribution of endemic plants the following regions (Nayar, 1996) Southern Western Ghats and Northern Western Ghats were considered as mega centres of endemism in Peninsular India.

Nayar (1987) estimated about 2015 endemic flowering species in Peninsular India which represent about 12% of Indian flora. In Peninsular India, there are no endemic phylogenetically primitive families, but there are about 60 endemic genera of which 49 are monotypic. The families with the largest representatives of endemic genera to Peninsular India are Poaceae (13 genera) and Acanthaceae (10 genera).

Nayar (1977, 1980) summarised the history of the flora of Peninsular India and its floristic impoverishment due to flow of deccan lava. Chatterjee (1940) listed the endemic

dicotyledonous genera from Peninsular India. Subramanyam and Nayar (1974) enumerated characteristic endemic species of Western Ghats. Ahmedullah & Nayar (1987) examined the endemism of angiosperms in Peninsular India in detail. Meusel (1952), Carlquist (1965) studied woody habit in endemic trees. A book on "Hot spots of endemic plants of India, Nepal and Bhutan" (Nayar 1996) gives an account of endemic plants in India in the Himalayas, Peninsular India and Andaman & Nicobar Islands. Rajkumar (2001) worked on systematics and biology of endemic tree genera of Western Ghats, Joshi (2000) investigated taxonomy and phytogeography of endemic plants of Western Ghats with special reference to Goa. Gopalan and Henry (2000) worked on strict endemics of Agasthiyamalai of Western Ghats.

Endemic grasses:

Hooker (1896) reported about 135 genera, 734 species, 2 subspecies and 39 varieties of grasses from the areas of the present day India (Sreekumar and Nair, 1991). Bor (1960) reported about 220 genera and 1165 infrageneric taxa from the present boundary of India, which include about 370 infrageneric taxa. Karthikeyan (1983) stated that 16 genera, 299 species, 2 sub-species and 43 varieties are found to be endemic to India. According to Nayar (1980)

Poaceae and Acanthaceae have the largest number of endemic genera in India. It is estimated that about 16 genera of Poaceae are endemic to India (Karthikeyan, 1983; Shukla, 1983). Two more genera have been added by Sreekumar and Nair (l.c.).

Grasses endemic to Peninsular India:

Out of the 18 genera endemic to India, about 13 are found endemic to Peninsular India. They are: *Bhidea, Chandrasekhariana, Danthonidium, Glyphochloa, Hubbardia, Indopoa, Limnopoa, Normanboria, Pogonachne, Pseudodichanthium, Silentvalleya, Trilobachne* and *Triplopogon*.

IUCN status:

The Red Data Book of Indian Plants (Nayar and Sastry, 1987, 1988) assigned the following IUCN categories to the species of *Glyphochloa*. *Glyphochloa divergens* (Hook.) W. D. Clayton collected nearly 135 years after type from Mercara, Karnataka was assigned status 'Rare' (R). *G. talboti* (Hook.f.) W.D. Clayton was collected only 4 times till the assessment since its first collection in 1891 by Talbot. This was assigned the status 'Vulnerable' (V). *G. santapaui* (Jain and Desh.) W. D. Clayton was assigned the status

'Rare' and it occurs only in Ratnagiri district of Maharashtra state.

Taxonomic works on grasses of India:

Hooker (1896) dealt with about 700 species of grasses in 130 genera in his pioneering work on 'The Flora of British India'. Lisboa (1896) dealt with Bombay grasses and their uses.

At regional level Cooke (1901-1908) dealt grasses along with other families in his 'Flora of the Presidency of Bombay'. This was followed by 'The Bombay grasses' by Blatter and McCann (1935) with a fine account of grasses of the region with illustrations. Achariyar and Mudaliyar (1921) dealt published an account of South Indian grasses; Fischer (1934-36) in Gamble's 'Flora of Presidency of Madras' described more than 350 species of grasses in 126 genera. Kanjilal and Dass (1940) dealt with the grasses of erstwhile Assam in their Flora. Mitra (1958) also covered grasses of North East India. Bor (1960) provided a synoptic account of the grasses of Burma, Ceylon, India and Pakistan. Some of the major works at regional level include Grasses of Madhya Pradesh by Roy (1984), Grasses of Marathwada by Patunkar (1980) and Taxonomic account of

grasses of Kerala by Sreekumar and Nair (1991), Karthikeyan (1989) in Florae indicae enumeratio - Monocotyledonae listed about 1225 species of grasses. Grasses and bamboos of India by Moulik (1997) forms one of the recent accounts.

Anatomical data on grasses:

Metcalfe (1960) in Anatomy of the Monocotyledons Vol.I provides the anatomical and characteristic general account for each group of grasses with illustrated diagrams. Achariyer (1921) in his handbook of some South Indian grasses deals with anatomical features in most grasses. Smith, (1968) classified several native North American grasses as starch or fructosans accumulators in relation to taxonomy. Renvoize (1982) did the survey of leaf blade anatomy in grasses of Andropogoneae. Amarsinghe and Watson (1988) studied the comparative ultrastructure of micro-hairs in grasses. Peterson (1989) worked on comparative leaf anatomy of the annual *Muhlenbergia* (Poaceae). Papp, (1999) investigated comparative morphological and anatomical features on *Poa pratensis* L. and *Poa augustifolia* L. Kanitzia and showed the ecotypes differing mainly on shape and anatomy of the basal leaves. Krishnan et. al. (1999) studied the Phytoliths of Indian grasses and their potential use in identification.

Taxonomic studies on *Glyphochloa*:

The genus *Glyphochloa* was carved out by Clayton 1981, from *Manisuris*. Earlier these species were treated under *Rottboellia*, *Peltophorus* and *Manisuris*. Hooker (1896), Lisboa (1896) and Cooke (1908) described three species of *Glyphochloa* under Rottboellia viz *Rottboellia acuminata* Hack., *Rottboellia divergens* Hack., *Rottboellia talboti*. Blatter & McCann (1935) referred them under *Peltophorus* (*Peltophorus divergens* (Hack.) Camus, *Peltophorus acuminatus* (Hack.) Camus, *Peltophorus talboti* (Camus). Bor (1960) treated three species of present *Glyphochloa* under *Manisuris*, they are *Manisuris acuminata*, *Manisuris forficulata* and *Manisuris talboti*. The former two with two varieties each.

Fischer (1933) described a new variety *Manisuris forficulata* var. *hirsuta*, but his description was based on the mixture of two distinct grasses, therefore an error was created

Jain (1970) gives an account of eigth species and three varieties with illustrations and brief descriptions. Clayton (1986) dealt with world grasses where *Glyphochloa* is breifly described. Watson and Dallwitz (1992) gives the

descriptive and anatomical account of the grasses of the world, He deals with the general characters of *Glyphochloa* and states its physiology as C_4:XyMs.

Revisions or some new species have been added by Bor (1960), Rao and Hemadri (1968), Jain and Deshpande (1969), Jain and Hemadri (1969), Kulkarni and Hemadri (1974). Jain (1972) provided a taxonomic account of this genus. Clayton (1981) reduced this to a single species and transferred the others to the genus *Glyphochloa*.

Glyphochloa is also dealt in different local Floras: Sharma et al. (1984), mention about the species of *Glyphochloa* and their distribution in Karnataka. Nair (1989) recorded three species of *Glyphochloa* for Tamil Nadu, but based on earlier literature, as the specimens were not available for Tamil Nadu in Herbaria. Almeida (1990) contributed to the study by recording seven species of *Glyphochloa* under *Manisuris* for Sawantwadi district. Sreekumar (1991) recorded three species of *Glyphochloa* for Kerala. Lakshminarasimhan (1996) breifly describes eight species of *Glyphochloa for* Maharashtra. A new species *G. henryi* from Goa is described by Janarth. et. al.(2000).

Chapter 3

MATERIALS AND METHODS

Collection:

Specimens were collected from different localities and preserved in the form of herbarium using conventional techniques (Lawrence, 1951) for morphological studies and wet preserved in 60% alcohol for anatomical studies and some specimens were air dried for flavonoid studies. The leaves were collected and kept in vials containing silica gel for RAPD studies.

Morphological studies:

The vegetative and floral morphological characters of different species of *Glyphochloa* and its related genera were studied and described using herbarium or fresh specimens and illustrations of the dissected floral parts were drawn using Leica wild M3Z stereo microscope and drawing tube. Herbarium speciemens at BSI, JCB and MH were also referred to study variation and distribution.

Anatomical Studies:

Free hand sections of leaf, leaf sheath, culm and root were taken using a sharp blade, the sections were stained

with safranine for 1 to 2 minutes, washed and processed for permanent mount. All the stained sections were observed under Olympus CH30 compound microscope. Photographs were take using Nikon Eclipse E800.

Leaf Peeling:

Leaf peelings were obtained using Schultze's Maceration process. Small leaf pieces were taken in a test tube along with concentrated HNO_3 and a pinch of potassium chlorate crystals were added, the test tube was heated until air bubbles were evolved and allowed the reagent to act until the material became white. The content of the tube was poured in a dish of water. The leaf peels obtained were washed and neutralized using NaOH, washed in water for 2 or 3 times, stained in safranine or crystal violet stain and observed under Olympus CH30 compound microscope for detailed studies of stomata, epidermal cells and silica / cork cells. Average size and frequency of stomata was calculated for all the species of *Glyphochloa* and its related genera and graph was plotted of length v/s breadth.

Mycorrhiza:

Preserved roots (60% alcohol) were used for the study of mycorrhiza. The root samples were washed with water,

cleared with 10% KOH, acidified in 1N HCl and then stained in lactoglycerol trypan blue (0.05%) according to Phillips and Hayman (1970). Stained roots were mounted and observed under compound microscope (40 X -100 X). Quantification of arbuscular mycorrhizal fungal colonization was carried out using the slide method (Govannetti and Mosse, 1980).

Slide Method:

Stained roots were cut into 1 cm length. A single root bit was mounted in 1% glycerine on a microscope slide and covered with 35 mm cover-slip. Root bits were crushed applying slight pressure and then observed under light microscope. Hundred root segments for each sample per plant species were randomly selected for microscopic observation. A segment was considered mycorrhizal when it showed the presence of hyphae or arbuscule or vesicle.

The percentage of colonization was determined by the following method

$$\text{Percentage} = \frac{\text{No. of mycorrhizal segments}}{\text{No. of segments screened}} \times 100$$

Isolation of AM fungal spores/sporocarps, was carried out using wet sieving and decanting method (Gerdemann and Nicolson, 1963).

Wet seiving and decanting method:

- Hundred grams of rhizosphere soil was suspended in 1000 ml of tap water. The mixture was stirred for 10-15 seconds and the coarse particles were allowed to settle in water for 1-2 minutes.
- The soil water mixture was decanted through sieves arranged in decending order of mesh pore size (500 μm - 45 μm)
- Debris were then filtered through whatman No. 1 filter paper
- The filter paper was then placed on petriplate and care was taken to see that it remained moist.
- The content of the filter paper were examined for the spores and sporocarps under stereo-microscope.

Quantification of spore density was carried out as described by Gaur and Adholeya, (1994). Only few of the soil samples were worked for fungal spores.

- Whatman No. 1 filter paper was given two folds
- Then the filter paper was opened and divided into four quadrants

- One half of the paper was divided into approximately 15 columns by drawing lines that are 0.5 cm apart. Each column was numbered and the direction was marked
- The filter paper was folded such that only the marked surface receives the samples during filtration. The spores were collected on the marked surface and the other portion of the filter paper remained free from spores.
- The filter paper was spread on a petriplate examined under stereo-microscope.
- While counting spores two lines were focussed and the space between them was followed by moving the petriplate.

Starch Grains:

Starch grains were studied from herbarium / wet preserved specimens. The caryposis was dissected and observed under stero dissecting microscope Leica M3Z. The endosperm was removed and then crushed on a slide using scalpel and stained with Iodine - Potassium iodide solution and studied for the shape of starch grains using Olympus CH30 compound microscope (40X). Scatter diagram was drawn using SPSS package.

Numerical Taxonomy:

The characters (internal & external morphology) were scored in a binary mode and dendograms were constructed using squared Euclidean distance and average linkage between groups using SPSS package.

Flavonoids:

Harborne (1973) method was employed using air-dried material. All the species of *Glyhochloa* and its related genera were screened for flavonoids and flavonoid spectrum plotted for comparison of different species.

Two grams of air dried leaf material was taken and immersed in 2M HCl and heated in a test tube for 30-40 minutes at 100°C, the cooled extract was then filtered and extracted with ethyl acetate. The ethyl acetate was concentrated to dryness, taken up in drops of ethanol and aliquots chromatographed, (Paper chromatography and TLC) using BAW (n-butanol-acetic acid-water, 4:1:5, top layer is taken) or forestal (acetic acid - concentrated HCl - water, 30:3:10). Spectrophotometeric readings were taken using ethanol as solvent and absorption spectrum and spectral patterns were obtained in the wave length from 190-450 nm using, Shimadzu UV-1601, UV-visible spectrophotometer.

Pollen:

Modified (Nair 1970) Acetolysis (Erdtman 1952) method was used for pollen morphological studies.

Acetolysis:

Pollens (anthers) were collected in acetic acid and fixed for 24 hours, centrifuged at 2000 RPM, supernatant discarded, centrifuged 3 times using distilled water. $1/4^{th}$ sample was taken after centrifuging and safranine was added to it and kept aside as sample **A.** For the remaining $3/4^{th}$ sample acetolysis mixture (9 ml acetic anhydrite + 1 ml concentrated sulphuric acid-freshly prepared) was added. The test tube now was kept in water bath for 10 minutes at 100°C, cooled at 32°C temperature and then centrifuged, from this ½ sample was kept aside as sample **B**. While for the remaining ½ sample saturated solution of potassium chlorate (to bleach and enlarge) was added, washed in water and ½ the sample removed as sample **C**. In the remaining sample methyl green was added, washed and kept aside as sample **D**. All the samples **A, B, C** and **D** were mixed together in 10% glycerine, centrifuged. The centrifuged tube was kept inverted after the supernatant was discarded. It was then mounted on a slide and sealed with wax.

RAPD:

◊ Young leaves (150 mg) were washed with distilled water and blotted with tissue paper to remove water (surface sterilized with alcohol if heavy microbial load was expected).

◊ Leaf material was placed in sterile mortar and pestle with sufficient liquid nitrogen and ground to a fine powder. The powder was immediately transferred into a microcentrifuge tube and 400 µl of pre-warmed (56°C) extraction buffer was added and mixed gently. The mixture was incubated at 37°C in a water bath for 2 hours.

◊ 400 µl of Chloroform: isoamylalcohol (24:1) was added and mixed by inversion for about 15 minutes.

◊ Then the mixture was centrifuged at 10000 RPM for 10 minutes at 25°C to 30°C temperature.

◊ The upper clear aqueous layer was carefully transferred to a fresh micro centrifuge tube.

◊ 150 µl of 5M NaCl was added and properly mixed.

◊ 0.6 volume of isopropanol was added and the mixture was allowed to stand at room temperature for 1 hour, after which slow and careful mixing resulted into floating of

fibrous nucleic acids which were scooped and transferred to 1.5 ml microcentrifuge tube and centrifuged

- ◊ Alternatively mixing isopropanol the samples were centrifuged at 10000 RPM for 10 minutes at 25°C to 30°C.
- ◊ The supernatent was discarded and pellets washed with 80% ethanol.
- ◊ The pellets were dried in vacuum for 15 minutes and dissolved in 400 µl of high salt TE buffer.
- ◊ Extraction was done with equal volume of Chloroform: isoamyl alcohol (24:1).
- ◊ The aqueous layer was transferred to a fresh 1.5 ml micro centrifuge tube and 2 volumes of cold ethanol was added.
- ◊ Centrifugation was carried out at 10000 RPM for 10 minutes at 25° C to 30° C temperature.
- ◊ The pellets were washed in 80% ethanol and then dried in vacuum and dissolved in 200 µl of sterile double distilled water.
- ◊ DNA concentrations were measured by running the aliquots on 0.8% agarose gel or taking the absorbance at 260 nm.
- ◊ About 2 µg DNA was taken for restriction, digestion and about 20 ng of DNA for PCR amplification.

PCR for DNA Amplification:

◊ The genomic DNA was diluted to get the final concentration of 20 ng/µl.

◊ The reaction mixture was set up (25 µl reaction volume) as per the table given below.

◊ The mixture was gently mixed and the polymerase chain reaction was carried out in the Thermal cycler using the following conditions:

Step 1	-	Denaturation at 94°C for 5 minutes
Step 2	-	Denaturation at 94°C for 1 minute
	-	Annealing at 35°C for 1 minute
	-	Extension at 72°C for 2 minutes
Step 3	-	Extension at 72°C for 5 minutes

◊ Step 2 was repeated 45 times.

Resolving the PCR for RAPD profiling:

The amplified samples were prepared by adding appropriate amount of 6 X loading dye.

1.5% agarose Gel was prepared in 1 x TAE.

The amplified products were run on the gel with molecular weight marker (λ Hind III or λ Eco RI - Hind III digest).

Agarose gel electrophoresis:

◊ 0.8% / 1.5% agarose gel was prepared in 1 x TAE buffer containing 0.5 µg/ml ethidium bromide.

◊ Molecular Weight (MW) marker (λ Hind III or λ RI + Hind III double digest) was prepared along with DNA samples by adding required amount of water and 6 X loading dye to each tube.

◊ The sample was loaded and electrophoresis was carried out at 5-6 V/cm gel for 4-5 hours. The separated DNA bands were visualized under UV light using UV transilluminator. They were then photographed and analysed using Vedio Gel Documentation System.

Analysis for similarity indices and matrices:

The Nei's and Li's similarity index (SI) between two individuals was calculated using the formula

$$SI = 2 \times \frac{\text{Number of common bands}}{\text{Number of total bands}}$$

Construction of dendrogram:

The Nei's and Li's similarity index between each genotype and samples was used with UPGMA alogarithm to construct the dendrogram.

Chemicals and preparations:

Tris-HCl pH 8 (1.0 M); EDTA pH 8 (0.5 M); NaCl (5.0 M); CTAB (20%); Chloroform: Isoamyl alcohol (24:1 v/v); Polyvinylpyrrolidone and β mercaptoethanol.

DNA Extraction Buffer:

2.5% CTAB (Cetyl Trimethyl Ammonium Bromide)

100 mM Tris - HCl (pH 8)

20 mM EDTA (Ethylene diamine tetra acetic acid - sodium salt) pH 8

1.4 mM NaCl

1% Polvinylpyrrolidone

High Salt TE:

10 mM Tris HCl (pH 8)

1 mM EDTA (pH 8)

1 M NaCl

50 X Stock TAE:

242 g Tris base

57.1 ml glacial acetic acid

100 ml 0.5 M EDTA (pH 8)

Water to make 1 litre.

Ethidium Bromide: Stock 5 mg/ml in Water

6 X loading dye: 0.25% bromophenol blue

0.25% Xylene Cyanol and

30% glycerol in water.

Reaction mixture for DNA amplification:

Stock	Reagents	Final Concentration	Vol./ Reaction
	Water	-	: 19.30 µl
10 X	Polymerase Buffer	1 X	: 2.50 µl
10 mM	d ATP	100 µM	: 0.25 µl
10 mM	d GTP	100 µM	: 0.25 µl
10 mM	d CTP	100 µM	: 0.25 µl
10 mM	d TTP	100 µM	: 0.25 µl
3 U/µl	Taq DNA Polymerase	0.6 U	: 0.20µl
-	Primer (Decamers) Operon kit "E"	5 pmole	: 1.00 µl
-	Genomic DNA	20 ng	: 1:00 µl

Preparation of Agarose gel in 1 X TAE:

Weighed 2.5 g agarose and 150 ml of 1 X TAE added to it. Boiled for 5 minutes with gentle intermittent mixing. Added 0.5 µg/ml ethidium bromide when agarose solution

cooled down to about 50°C, mixed properly and poured in gel tray with comb, after placing on leveled surface. It was seen that no air bubbles were trapped and allowed to cool for settling.

Phylogeny:

The morphological and anatomical characters scored in binary mode were used to construct the cladogram and obtain relations between the species and its related genera. PHYLIP information package (ver. 3.1 alpha 3), a free ware by Felsenstein (2002) was used for cladistics. PENNY and DRAWGRAM programs of PHYLIP package were used. Separate cladograms were constructed using *Manisuris* and *Ophiuros* as outgroup.

Threat Status:

The status of each species of *Glyphochloa* was assessed using IUCN red list categories (2000). Both field and herbarium data and data from published literature was used for the purpose. The major categories are Extinct (EX), Critically endangered (CR), Endangered (EN), Vulnerable (VU), and Low risk (LR).

Distribution:

The distribution of each species of *Glyphochloa* is shown using dot mapping. Field, Herbarium and literature data was considered for dot mapping. The distribution was scored in binary mode and dendogram drawn for average linkage within groups using SPSS package and component plots drawn on its distribution.

Chapter 4

OBSERVATIONS, RESULTS AND DISCUSSION

(A) MORPHOLOGY

Morphologically the genus *Glyphochloa* is distinguished from all the related genera by the presence of sessile spikelet, callus turbinate with central knob, lower glume ovate or oblong, crustaceous, smooth or more often elaborately sculptured with ridges, spines, flaps or columns, with broad membranous wings above, 1-2 awned, pedicelled spikelet, as large as sessile spikelet and pedicel fused to internode.

The species of *Glyphochloa* and representative species of related genera were studied for their morphology. Based on critical study *Glyphochloa divergens* var *hirsuta* has been elevated to the rank of a species, viz. *Glyphochloa hirsuta*.

The genus *Glyphochloa* can be divided into two groups based on single or two awned. The single awn species are *G.acuminata* (Hack.)Clayton var. *acuminata*, *G.acuminata* (Hack.)Clayton var. *stockii* (Hook.f.)Clayton, *G.acuminata*

(Hack.)Clayton var. *woodrowii* (Bor)Clayton, *G.goaensis (Rao & Hem.)* Clayton, *G.henryi* Janarth. et. al., *G.santapaui* (Jain & Desh.)Clayton, *G.talbotii* (Hook.f.)Clayton and *G.veldkampii* M A Fonseca & Janarth., the latter group includes *G.divergens* (Hack.)Clayton, *G.forficulata* (Fisch.)Clayton, *G.hirsuta* M A Fonseca com. Nov., *G.mysorensis* (Jain & Hem.)Clayton and *G.ratnagirica* (Kulk.& Hem.)Clayton. These groups show distinct characters.

Generally species are distinct in the genus with characteristic morphological features. Considerable morphological variations are also seen in few species of *Glyphochloa*. The height of the plants may vary from 5-8 cm as in *G. divergens* and *G. mysorensis* to very tall as in *G. goaensis* and *G. acuminata* which may grow up to the height of 70 cm. Often the variation in height can be noted in same population.

The glume provides key features for segregating different species. These features are consistent in most of the species. However it varies in some species between populations, within population and even in the same inflorescence. Considerable variation in lower glume of sessile spikelet is seen in *G. acuminata var. acuminata* and

G. acuminata var. *woodrowii*. The size of the awn in *G. acuminata* var. *acuminata* may vary from awnless condition to long awn of about 8 mm long and the ornamentation on back of glume may vary from shallow to deep ridges as also seen by Jain (1970) within the same inflorescence from base to apex (Fig. 3b & Table 1 under systematic treatment). The variations are also noted in the same plant but on different inflorescence apart from within population and between populations. The lower glume of pedicelled spikelet vary to a lesser extent.

Similar variations are also seen in *G.acuminata* var. *woodrowii* where the lower glume of sessile spikelet shows smooth to shallow ornamentation pattern and awn from awnless to less than 7 mm. *G. acuminata* var. *stocksii*, shows no variation in the lower glume of sessile spikelet, but the lower glume of pedicelled spikelet show variation in size of its awn from short to long in the same inflorescence.

The number of ridges might vary from awnless ½, 1, 2 or 3 within the same population as in *G. goaensis* and *G.talbotii* (Fig.1) also mentioned by Jain (l.c.) which are single awned species. Occasionally the ridges are

completely absent in these species. *G. henryi* shows variation in lower glume of sessile spikelet with single or double ridges (collar) in different populations.

Among the two awned species not much variation is seen in *G. ratnagirica, G. mysorensis, G. divergens* and *G. hirsuta* except for *G. forficulata,* which generally shows presence of tubercles or hooks on back and margin which transforms to complete transverse ridge like structures on back of glume. However little variation is seen again in the same plant (Fig. 1 & 3a and table 1 & 3 under systematic treatment).

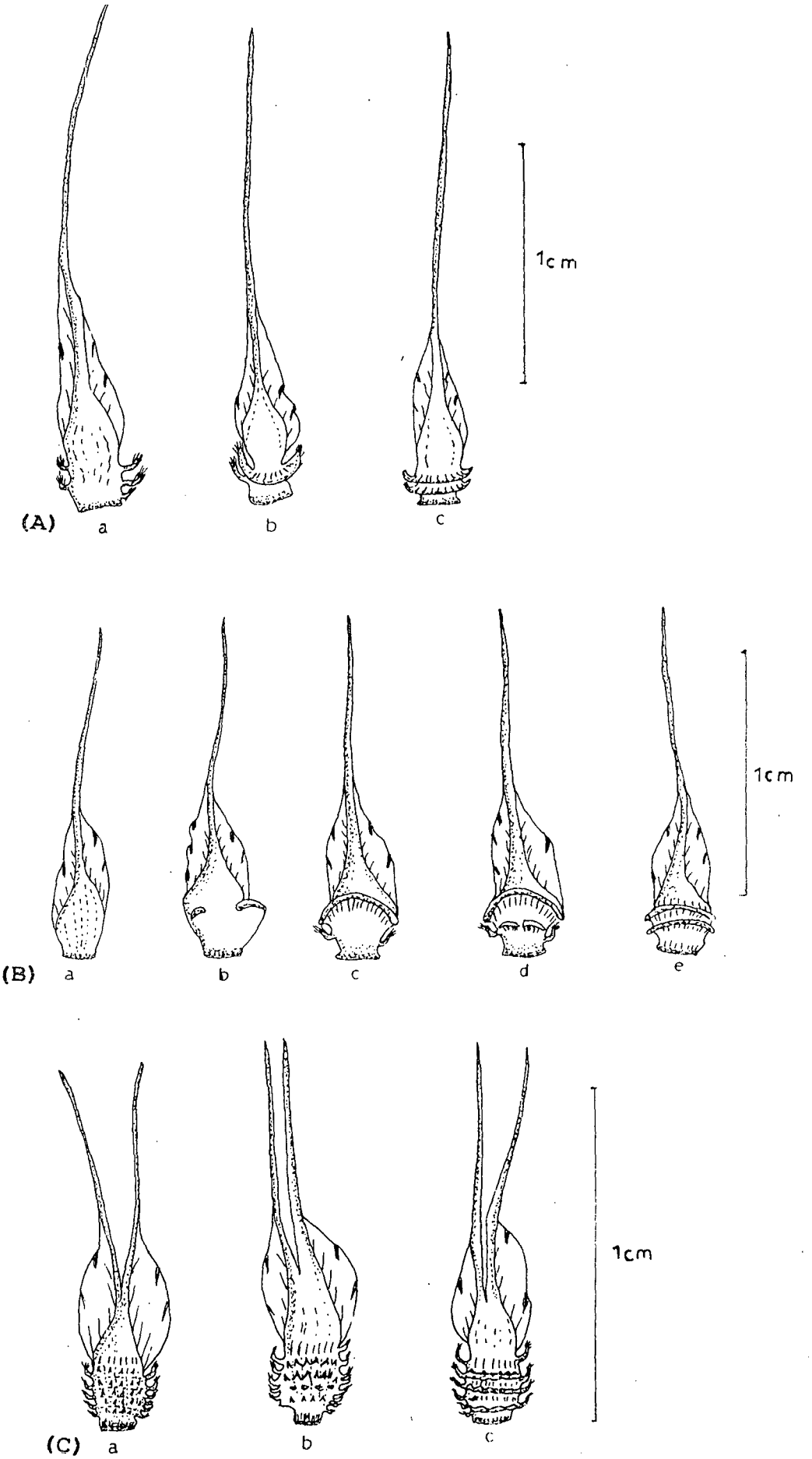


Fig 1 :Variation in Lower glume of sessile spikelet:
A) a-c: *G. goaensis;* B) a-e: *G. talbotii;* C) a-c: *G. forficulata.*

SYSTEMATIC TREATMENT

KEY TO THE GENERA OF SUBTRIBE ROTTBOELLIINAE IN PENINSULAR INDIA

1. Lower glume of sessile spikelet long awned (one or two or shortly aristate . . . . . ***Glyphochloa***

1. Lower glume of sessile spikelet awnless:

    2. Sessile spikelet in pairs at each node:

        3. Lower glume of sessile spikelet winged on all sides, smooth, (butterfly shaped) . . . . . ***Manisuris***

        3. Lower glume of sessile spikelet globose, ornamented and wings absent . . . . . ***Mnesithea***

    2. Sessile spikelet solitary at each node:

        4. Spikelets paired, one sessile and other pedicelled . . . . ***Rottboellia***

        4. Spikelets solitary, pedicelled spikelets absent . . . . . ***Ophiuros***

Glyphochloa W. D. Clayton

Type: *Glyphochloa forficulata* (C.E.C. Fischer) W. D. Clayton

Annual; herbaceous, branched above or at base; culms 10-70 cm high, erect, shallowly ridged; nodes swollen when fresh, constricted on drying. Leaf sheath keeled on either side, covering ¼ to entire internode; leaf blade linear with base narrow or truncate in few cases with acute apex; ligule torn up or form a fringe of hairs. Plants bisexual; hermaphrodite and staminate or neuter. Inflorescence a raceme, terminating the culm branches, spatheate; spikelet bearing axis solitary, disarticulating transversely or obliquely at the joints; joints and pedicel fused, inflated, clavate, turbinate or linear with basal callus knob; spikelets paired with the sessile in two alternating rows on one side of the rachis and pedicel on the other side of the rachis, pedicelled spikelets fused with rachis. Sessile spikelet: lower floret male or neuter; upper floret hermaphrodite; lower glume single or two awned, generally ornamented and winged; upper glume convex or boat shaped, smooth, awnless and smaller than lower glume; lower and upper lemmas awnless, 0-2 nerved, hyaline, usually boat shaped; lower and upper palea hyaline, smaller than lemma,

boat shaped or flattened. Style and stigma two, plumose, ovary/grain ovate to oblongoid. Pedicelled spikelet: lower glume smooth, single awned, unilaterally winged; upper glume 3-5 nerved, boat shaped, winged at median region or apex or wing absent, awned or awnless, sometimes florets incomplete. Upper and lower lemma and upper and lower palea more or less similar to sessile spikelet. Lodicules present or absent. Stamens 3.

Distribution: Endemic to Central and Peninsular India.

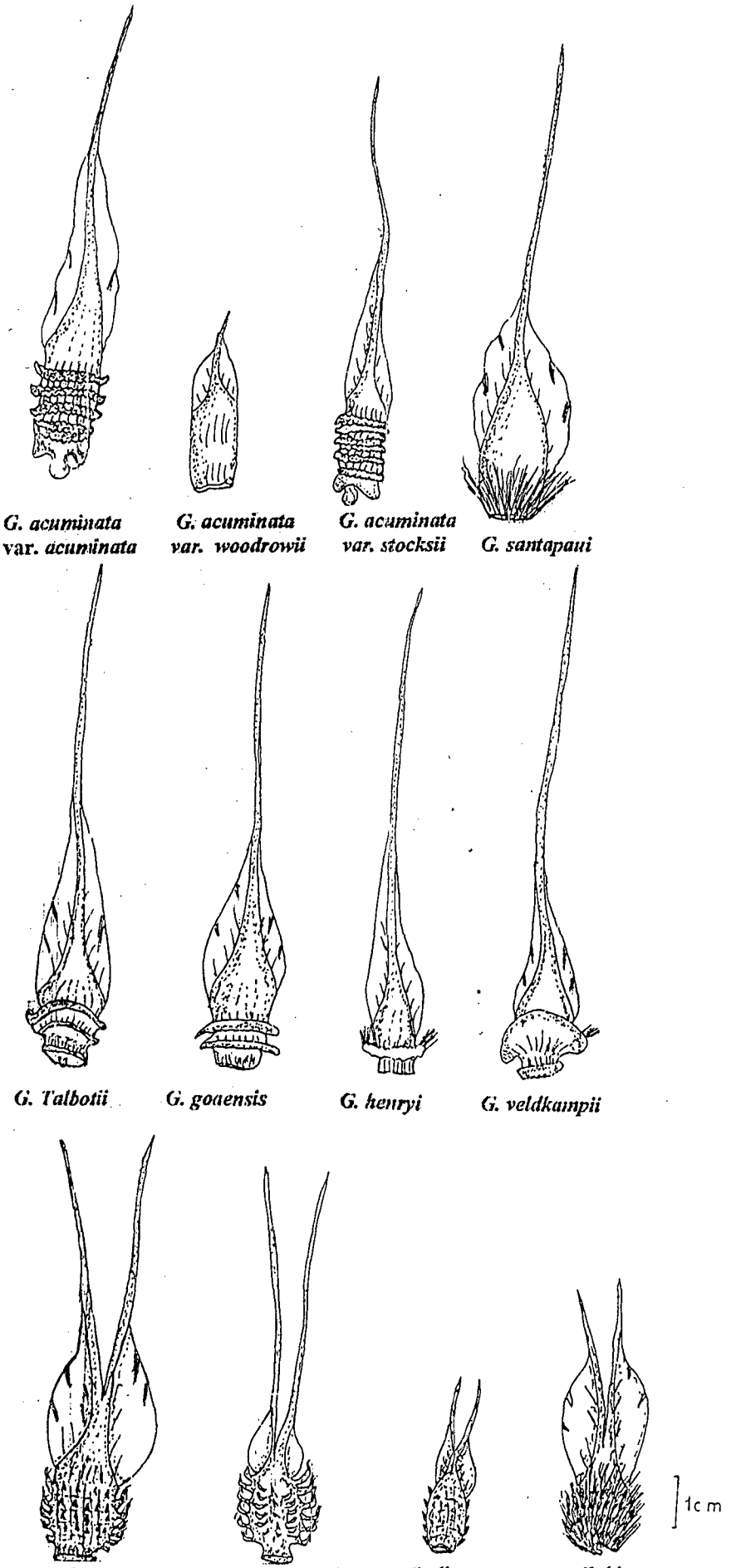


Fig. 2: Lower Glume of sessile spikelet in different species of *Glyphochloa*

KEY TO SPECIFIC AND INFRASPECIFIC TAXA OF *GLYPHOCHLOA*

1. Lower glume of sessile spikelet single awned:

   2. Lower glume of sessile spikelet smooth with tufts of long white hairs at base . . . . . *G. santapaui*

   2. Lower glume of sessile spikelet with transverse or vertical and transverse ridges:

      3. Back of the lower glume of sessile spikelet with only transverse ridges:

         4. Transverse ridges on glume pointing upwards:

            5. Ridges on back straight to form one or two collar like structures, tubercled at margins . . . . . *G. henryi*

            5. Ridges on back oblique:

               6. Oblique ridge single, forming a flap like structure . . . *G. veldkampii*

               6. Oblique ridges up to 3, without cap or flap but overlapping . . . . . *G. talbotii*

         4. Transverse ridges on glumes pointing downwards . . . . . *G. goaensis*

      3. Back of the lower glume with both vertical and transverse ridges:

            7. Transverse and vertical ridges on glume prominent; glumes long awned (>7mm):

               8. Ridges on glumes directed

upwards, 3 - 4 in number; lower glume of pedicelled spikelet short awned (< 1 mm) . . . . . .*G. acuminata* var.*acuminata*

8. Ridges on glumes directed downwards, 3-5 in number; lower glume of pedicelled spikelet long awned (>1 mm) . . . . . *G. acuminata* var.*stocksii*

7. Transverse and vertical ridges on glumes not prominent but form shallow structures or depressions; glumes short awned (< 7mm) . . . . . *G. acuminata* var.*woodrowii*

1. Lower glume of sessile spikelet two awned:

9. Lower glume of sessile spikelet smooth or densely hairy:

10. The lower glume of sessile spikelet smooth . . . . . *G. ratnagirica*

10. The lower glume of sessile spikelet densely hairy . . . . . *G. hirsuta*

9. Lower glume of sessile spikelet pitted or tubercled:

11. Lower glume small (< 1 cm) with pits, short awned (< 4 mm) . . . *G. divergens*

11. Lower glume large (> 1 cm) with tubercles, long awned (> 4 mm):

12. Pedicel and joint equal, wings of glumes large . . *G. forficulata*

12. Pedicelled and joint unequal, wings of glumes small . . . . . *G. mysorensis*

Glyphochloa acuminata (Hack.) W. D. Clayton in Kew Bull. 35: 815. 1981.

Key to the varieties

1. Transverse and vertical ridges on glume prominent; glumes long awned (>7mm):

   2. Ridges on glumes directed upwards, 3 - 4 in number; lower glume of pedicelled spikelet short awned (< 1 mm) . . . . . .***G. acuminata*** var.***acuminata***

   2. Ridges on glumes directed downwards, 3-5 in number; lower glume of pedicelled spikelet long awned (>1 mm) . . . . . ***G. acuminata*** var.***stocksii***

1. Transverse and vertical ridges on glumes not prominent but form shallow structures or depressions; glumes short awned (< 7mm) . . . . . .***G. acuminata*** var.***woodrowii***

1(a) Glyphochloa acuminata (Hack.) W. D. Clayton **var acuminata**; W. D. Clayton in Kew Bull. 35: 815. 1981; Sharma et. al., Fl. Karnataka,332. 1984; Kulkarni, Fl. Sindhudurg 532. 1988; Henry et. al., Fl. Tamil Nadu 119. 1989; Sreekumar & Nair, Fl. Kerala 106. 1991;

Lakshminarasimhan in Sharma et al., Fl. Maharashtra 499. 1996; Moulik, Grasses and Bamb. India, 191. 1997. *Rottboellia acuminata* (Hack.) in DC. Monogr. Phan. 6: 291. 1889; Hook. f. Fl. Brit. India 7· 155. 1896; Fischer in Gamble, Fl. Madras 1761. 1934; Cooke, Fl. Bombay 3: 471. 1958. *Manisuris acuminata* (Hack.) O. Kuntze. Rev. Gen. Pl. 2: 779. 1891; Bor, Grass. India, 191. 1960; Jain in Bull. Bot. Surv. Ind. 12: 9. (1970) 1972; Rao, Fl. Goa 507. 1986; Almeida, Fl. Savantwadi, 148. 1990. *Peltophrous acuminatus* (Hack.) A. Camus, Bull. Mus. Hist. Nat. Paris 27: 371. 1921; Blatter & Mc Cann Bom. Nat. Hist. Soc. 32: 29. 1927 & Bomb. Grass., 34, t. 24. 1935.

Type: Maisur & carnatic, Hook.f.& thoms. (type)

An annual, tufted herb up to 40 cm high, branching at base; culm slender, erect, shallowly ridged; nodes 3-5 noded, glabrous, swollen. Leaves crowded at base, linear-lanceolate, acuminate, 5-28 x 0.5 cm, linear; leaf sheath *ca* 3-7 cm; ligule truncate, *ca* 2 mm long, membranous, torn, with fringe of hairs. Inflorescence a raceme, spicate, *ca* 5 cm long, delicate; joint and pedicel fused, *ca* 3 mm long, narrow at centre, swollen at both ends. Sessile spikelet: lower glume 8-9.2 mm long, ovate to lanceolate, acuminate, coriaceous, awn single, long, 3-6 ridged, rarely without

ridges in basal spikelets, winged along the margins in the upper half of the glume, wings broader on one side, upper glume *ca* 3 x 0.1 mm, boat shaped or oblong-lanceolate, 3-nerved; lower floret empty or male: upper floret hermaphrodite; lower lemma *ca* 2.3 x 0.6 mm, ovate to lanceolate, delicate, hyaline, faintly nerved; lower palea 1.5-2 x 0.5 mm, ovate to oblong, delicate, hyaline, 2-nerved; upper lemma *ca* 2.6 x 0.6 mm, ovate to broadly ovate to lanceolate, delicate, hyaline, 2-keeled; upper palea 2 x 0.7- 0.8 mm; lodicules 2, *ca* 0.5 mm long. Stamens 3; anthers 0.5-1.5 mm long, violet. Ovary oblongoid; styles plumose, pinkish. Grains *ca* 1.4 x 1mm, ovoid. Pedicelled spikelet: lower glume, 7-9 mm long, oblong to lanceolate, chartaceous, 3-7 nerved; upper glume 3-3.8 x 1-1.5 mm boat shaped or ovate-oblong, keeled on back, winged along the keel to $1/4^{th}$ portion. The florets male or empty; lower lemma *ca* 2.3 x 0.6 mm, oblong, lateral margins incurved; lower palea *ca* 2.1 x 0.4-0.5 mm, ovate to lanceolate, incurved; upper lemma *ca* 2.5 x 0.6 mm, ovate with acute apex, apical margins incurved; upper palea *ca* 2 x 0.5-0.7 mm ovate, lateral margins incurved. (Fig. 3)

Fl. & Fr.: September-November.

Habitat: Lateritic rocks and moist soil.

Distribution: Endemic to Goa, Karnataka, Kerala, Maharasthra and Tamil Nadu.(Fig. 29)

Notes: The plant shows lot of variations within the inflorescence on the same plant, within the populations and also between the populations. The variation is seen in the lower glume of sessile spikelet. The lower glume of sessile spikelet may show shallow grooved ridges and their number may vary from 3-6 in few cases. The size of the awn varies from short to long (size) from the base of the inflorescence to the apex. It differs from *G. stocksii* in its short awned (<3.5 mm) lower glume of pedicelled spikelet and from *G. woodrowii* where the size of the awn is less than 7 mm long as compared to *G. acuminata* in which the size of the awn is 7-8 mm or more. (Fig. 3a,3b and Table 1).

IUCN threat status: LC

Specimens examined:

Goa : Porvorim, 8-11-1963, R S Rao, 59692(BSI); Military Camp, Chimbel, 9-11-1963, R S Rao, 92890(BSI); Caramboli near Castle rock, 14-11-1963, K C Kanodia, 93018(BSI);

Bambolim, 03-09-1997, M A Fonseca, 1009(GUH); Goa University campus, 09-09-1997, M A Fonseca, 1014(GUH); Bambolim, 02-10-1997, M A Fonseca, 1017(GUH).

Karnataka : Dharwar, 15-9-1891, W A Talbot, Acc. No. 924(BSI).

Kerala : Beemanadi, Kasargod dt., 27-09-1982, R Ansari, 74341(MH); Beemanadi, Kasargod dt., 27-09-1982, R Ansari, 74331(MH); Bela, Kasargod dt., 01-10-1982, R Ansari, 74429(MH).

Maharashtra : Kanyachi Rai, Bedshi, Ratnagiri, 5-11-1964, B M Wadhawa & B G Kulkarni, 119497(BSI); Kaziwada Sada, Achre, Ratnagiri, 23-2-1970, B G Kulkarni, 120262(BSI); Adari, Malwan, Ratnagiri, 29-9-1970, B G Kulkarni, 121266A(BSI); Naringre, Dahibar, Deogad, Ratnagiri, 21-8-1971, B G Kulkarni, 131828(BSI); Ratnagiri, 15-10-1990, C B Salunkhe, 8594(SUH); Malwan, 3-10-1993, C B Salunkhe, 8688(SUH); Saurav, 16-09-1999, M A Fonseca & M K Janarthanam, 1023(GUH).

Tamil Nadu: No collection for Tamil Nadu distribution based on Gamble's flora.

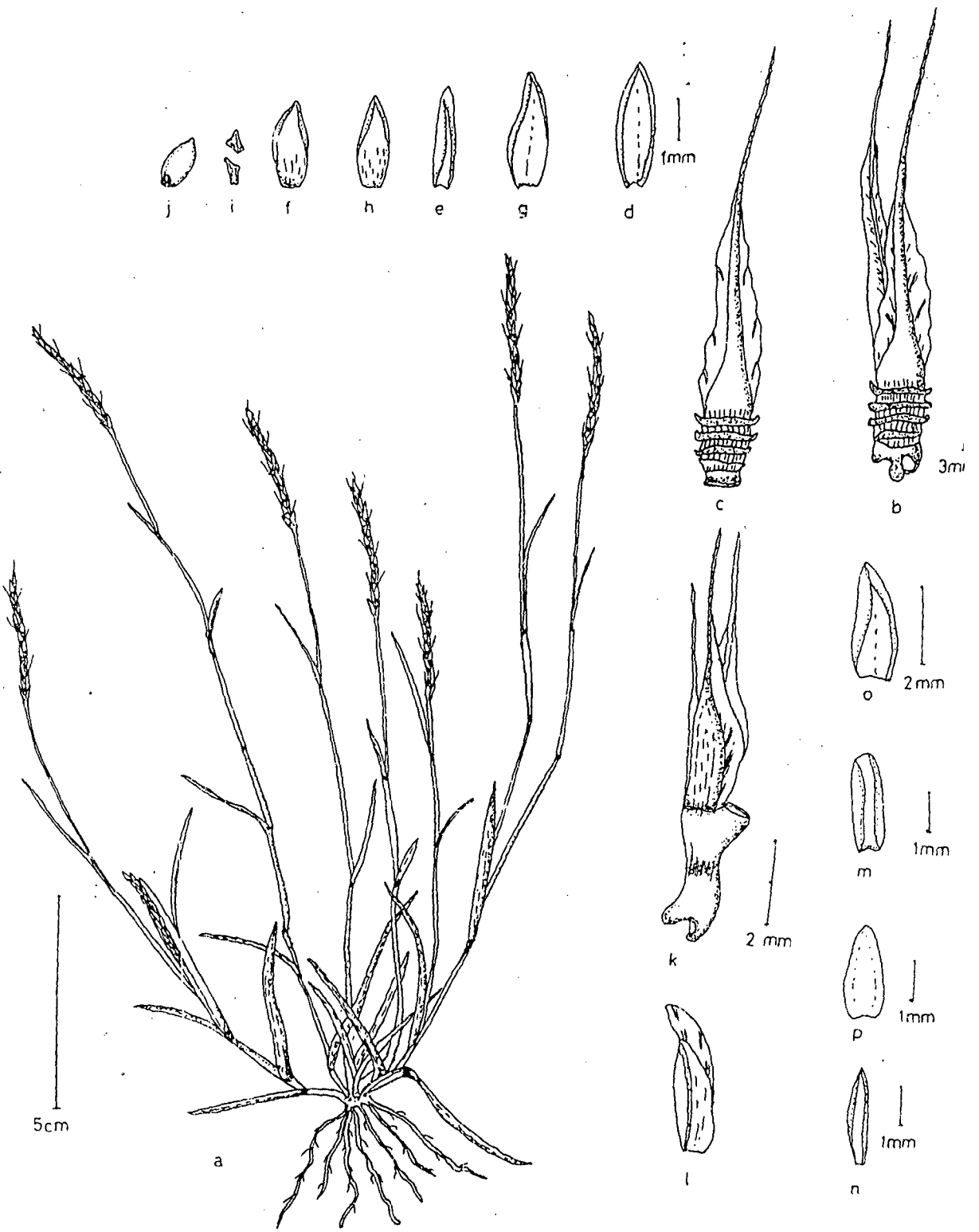


Fig 3a:*Glyphochloa acuminata* (Hack.) Clayton **var. *acuminata***
a) Habit; b) Spikelet; (c-j): Sessile spikelet; c) Lower glume; d) Upper glume; e) Lower lemma; f) Lower palea; g) Upper lemma; h) Upper palea; i) Lodicules; j) Grain; (k-p): Pedicel spikelet; k) Lower glume with joint & pedicel; l) Upper glume; m) Lower lemma; n) Lower palea; o) Upper lemma; p) Upper palea.

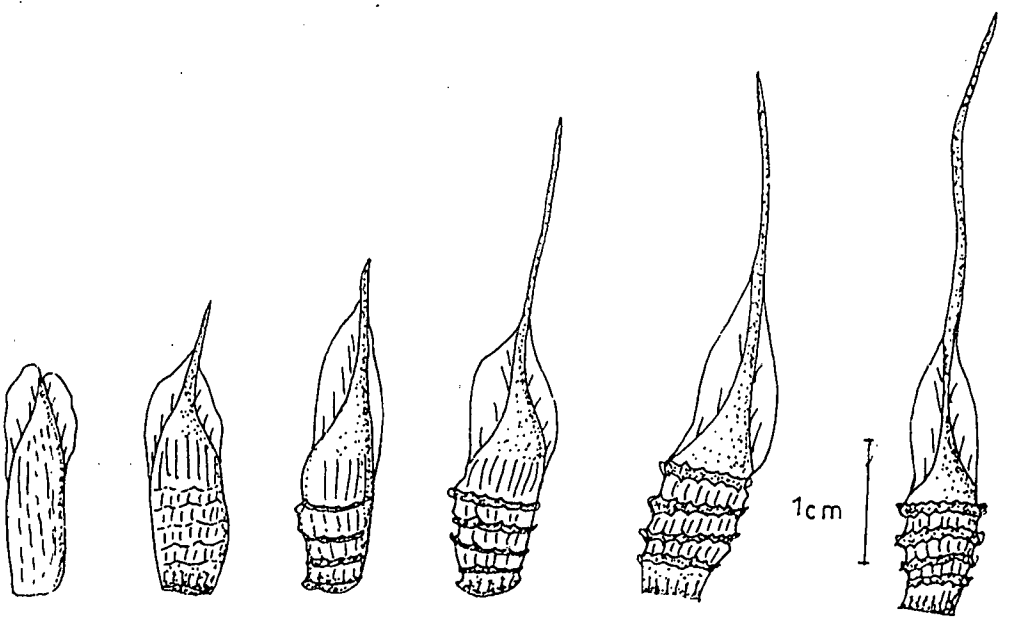


Fig3b : *G. acuminta* var *acuminata* (Hack.) Clayton
Variation in lowert glume of sessile spikelet in different individuals.

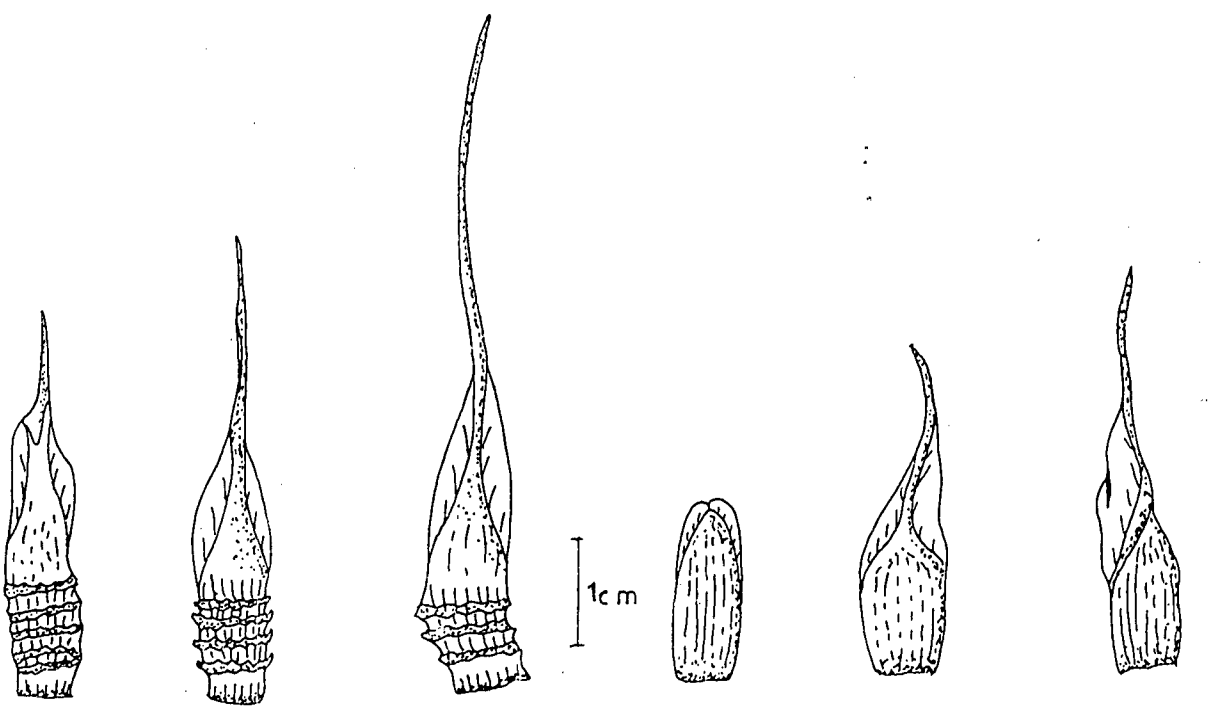


Fig 3c : *G acuminata* var. *acuminata* (Hack.) Clayton
Variation in lower glume of sessile spikelet and lower glume of pedicelled spikelet in same inflorescence (from base to apex).

1(b) Glyphochloa acuminata (Hack.) W. D. Clayton **var. stocksii** (Hook.f.) W. D. Clayton in Kew Bull. 35: 815. 1981; Sharma et. al., Fl. Karnataka, 332. 1984; Henry et al. Fl. Tamil Nadu 119. 1989; Lakshminarasimhan in Sharma et al., Fl. Maharashtra, 500. 1996. *Rottboellia acuminata* Hack. var. *stocksii* Hook.f. Fl. Brit. India 7: 155. 1896. *Manisuris acuminata* (Hack.) Kuntze var. *stocksii* (Hook .f.) Jain in Bull. Bot. Surv. Ind. 12: 9 (1970) 1972.

Type: Malwar, Stocks (holotype CAL). No number

An annual tufted herb, up to 40 cm high, branching at base; culms 4 or 5 noded, cylindrical, ridged and channeled on one side; internode *ca* 8 cm. Leaf sheath covering $3/4^{th}$ portion of the internode, keeled on either side, membranous and papery; ligule 1 mm long, entire or dentate or torned up or with fringe of hairs; leaf blade 5-10 x 0.5 cm, linear, lanceolate to acute. Racemes *ca* 10 cm long, compressed and slender; joints and pedicel fused, 3.5-4 x 1 mm at base, 2 mm at apex, broader at either ends and narrow at the center. Sessile spikelet: hermaphrodite and male or neuter; lower glume single awned, *ca* 1.3 cm (including awn) long, winged equally on either side, with 4 or 5 prominent transverse and longitudinal ridges on back, awn scabrid;

upper glume *ca* 3 x 1.2 mm, 3-nerved, boat shaped with acute apex; lower floret male or neuter; lower lemma *ca* 2 x 0.75-1 mm, lanceolate, margins incurved (apical); lower palea 1.5-2 x 0.5 mm, ovate, boat shaped margins (one) incurved; upper floret hermaphrodite; upper lemma *ca* 2 x 1 mm hyaline, boat shaped, apical margins incurved; upper palea *ca* 1.5 x 0.6 mm, margin incurved on either side; lodicules 2, 0.4 - 0.5 mm. Grain *ca* 1.5 mm long, oblongoid. Pedicelled spikelet: Lower floret male; lower glume short or long awned, *ca* 9 mm long, winged on one side, other margin prolonged into a scabrid awn, 4 or 5 nerved; upper glume *ca* 4.5 x 1-1.5 mm (including awn), body of glume *ca* 3 x 1.2 mm, 3-nerved, boat shaped, keeled with unequal margin, winged at apex, wing *ca* 0.5 mm long, prolonged into a short awn, awn 1-1.5 mm long; lower lemma *ca* 2 x 0.5 mm, apical margins incurved, hyaline, lanceolate; lower palea *ca* 1.75 x 0.4 mm, one margin incurved, hyaline; upper floret staminate or empty; upper lemma *ca* 2.4 x 0.6-0.75 mm, margins incurved on both sides, linear to lanceolate; upper palea *ca* 2 x 0.4 mm, both margins inflexed to form a boat shaped structure; lodicules 2, *ca* 0.5 mm long. (Fig. 4)

Fl. & Fr. : September - October.

Habitat: Hard lateritic rocks.

Distribution: Endemic to Goa, Karnataka, Maharasthra, and Tamil Nadu.(Fig. 29)

Notes: It is closely related to *G. acuminata var. acuminata* and *G. acuminata var. woodrowii*. It differs from them in its ornamentation of the lower glume of sessile spikelet. In *acuminata* var. *stocksii* the ridges are pointing downwards and in other two varieties the ridges are either pointing upwards or not prominent. (Table 2)

IUCN threat status: LC

Specimens examined:

Goa : Mapusa, 04-11-2002, M A Fonseca, 1054(GUH).

Maharashtra : Sindhdurg, Malwan, Ratnagiri , 28-9-1970, B.G. Kulkarni, 121205(BSI); 29-9-1970, B.G. Kulkarni, 121266(BSI); Koloshi, Nandagaon, Ratnagiri, 6-10-1970, B G Kulkarni, 121482(BSI); Pawas, 29-9-1991, C B Salunkhe, 8685(SUH); Malwan, 3-10-1993, S. R. Yadav, 8776(SUH); Vengurla, 10-10-1993, C B Salunkhe, 8520(SUH); Kasarde, 16-09-1999, M. A. Fonseca & M. K. Janarthanam, 1024(GUH); Way

to Rajpur, 16-09-1999, M.A. Fonseca & M.K. Janarthanam, 1025(GUH); Ratnagiri, 16-09-1999, M. A. Fonseca, 1029(GUH).

Karnataka : No collection for Karnataka distribution based on Sharma, 1984. Flora Karnataka: Analysis.

Tamil Nadu : No collection for Tamil Nadu distribution based on Henry, 1989., Flora Tamil Nadu.

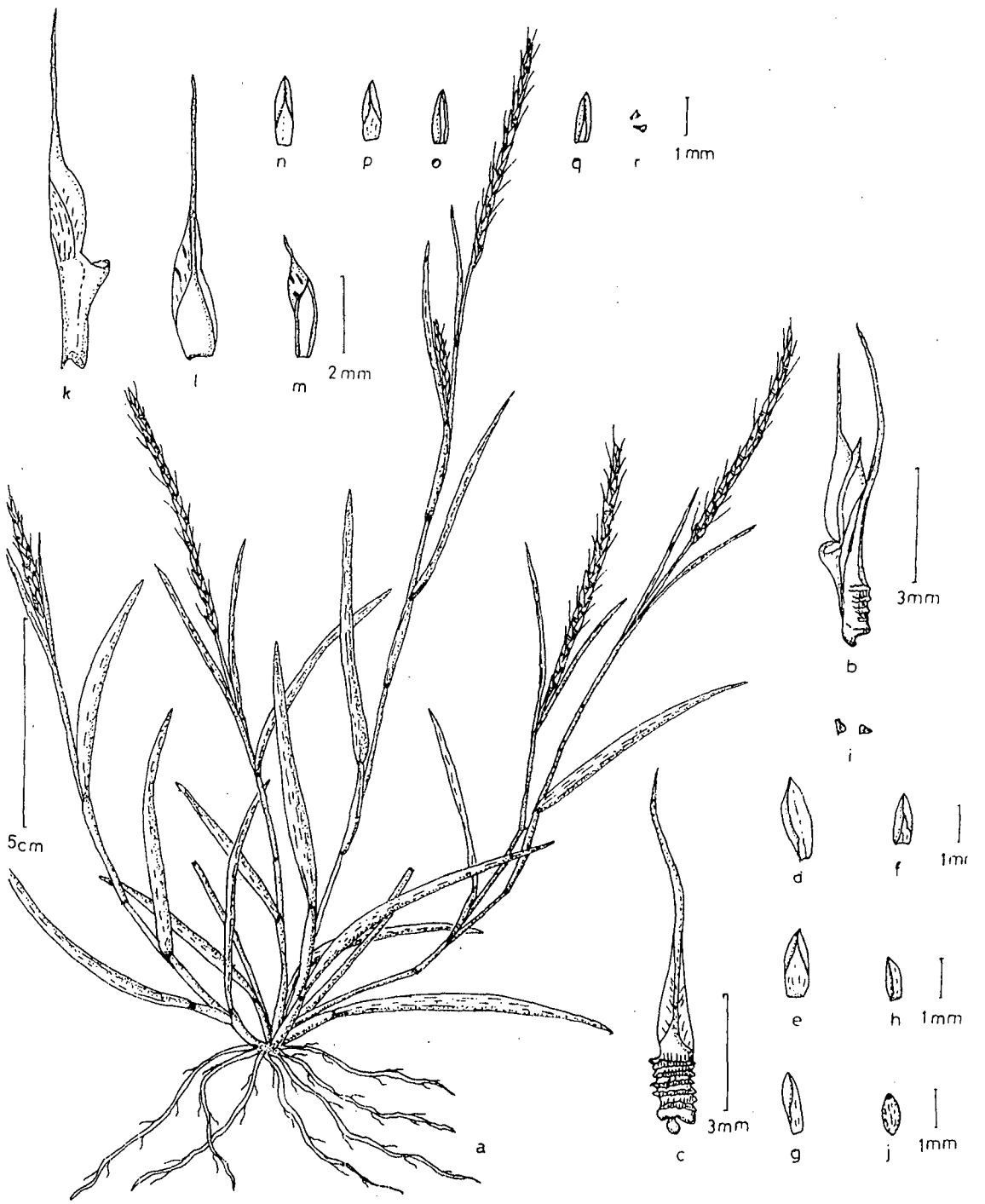


Fig 4: ***Glyphochloa acuminata*** (Hack.) Clayton **var.** ***stocksii*** (Hook.) Clayton
a) Habit; b) Spikelet; (c-j): Sessile spikelet; c) Lower glume; d) Upper glume; e) Lower lemma; f) Lower palea; g) Upper lemma; h) Upper palea; i) Lodicules; j) Seed (grain); (k-r): Pedicel spikelet; k) Lower glume with pedicel; l) Lower glume; m) Upper glume; n) Lower lemma; o) Lower palea; p) Upper lemma; q) Upper palea; r) Lodicules.

1(c) Glyphochloa acuminata (Hack.) W. D. Clayton var. **woodrowii** (Bor) W. D. Clayton in Kew Bull. 35: 815. 1981; Sharma et. al., Fl. Karnataka, 333. 1984; Kulkarni, Fl. Sindhudurg 532. 1988; Lakshminarasimhan in Sharma et al., Fl. Maharashtra, 500. 1996. *Manisuris acuminata* (Hack.) O. Kuntze var. *woodrowii* Bor, Grass. India. 191. 1960; Jain in Bull. Bot. Surv. Ind. 12: 10.(1970) 1972; Rao, Fl. Goa 507. 1986; Almeida, Fl. Savantwadi, 148. 1990.

Type: Bombay, Bhide (holotype CAL)

An annual much tufted herb, up to 70 cm high; branching at base, culms angular, ascending, slender; internodes 4.5-8.5 cm long, shallowly ridged; nodes glabrous, swollen, constricted on drying. Leaf sheath covering 1/2 to 3/4th portion of the internode; ligule *ca* 2 mm long, membranous, entire or dentate or torn up; leaf blade *ca* 5 x 0.3 cm, linear, flat or conduplicate, acuminate, fleshy, glabrous. Peduncle *ca* 5 cm long, with broad apex and narrow base; racemes terminal, erect, thin, solitary, fragile, scarious; joint and pedicel fused, *ca* 2.3 x 1 mm long, broad at either ends and narrow in the middle; spikelets paired, dissimilar in shape, one sessile and hermaphrodite and another pedicelled, male or neuter.

Sessile spikelet: lower glume 3-3.5 x 1 mm, awnless or with a short awn or aristate, awn less than 7 mm long, winged on apical portion; wing short; back of glume with shallow transverse and horizontal 3-4 ridges, rarely smooth; upper glume *ca* 2 mm long, boat shaped, 3-nerved; lower lemma 1.5-1.75 mm long, ovate with acute apex, margins inflexed; lower palea *ca* 1.2 mm long, ovate, hyaline, flat; stamens *ca* 1.2 x 0.2 mm, stigma plumose; upper lemma *ca* 1.3 x 1.4 mm, boat shaped, both margins inflexed; upper palea *ca* 1.2 mm long, ovate, flat. Pedicelled spikelet: lower glume ovate to lanceolate, awnless or awn less than 1 mm, boat shaped, 6-7 nerved winged on one side; upper glume *ca* 2.3 x 0.5 mm, boat shaped, keeled on back, winged at apical $1/4^{th}$ portion, wing very small; lower lemma *ca* 2 x 1 mm lanceolate to oblong; lower palea *ca* 1.6 x 0.5 mm, both margins incurved at apical region; lodicules 2, 0.4 mm long, triangular; stamens *ca* 1.2 mm long; upper lemma *ca* 1.4 x 0.5 mm, oblong with one margin incurved; upper palea *ca* 1.5 mm long, lanceolate. Grain 0.25-0.5 mm, ovoid. (Fig. 5)

Fl. & Fr: September- November.

Habitat: on lateritic rocks and rarely amidst bushes.

Distribution: Endemic to Goa, Karnataka and Maharasthra.(Fig. 29)

Notes: The plants usually grow on lateritic rocks and those found along the bushes in moist soil grow up to 70 cm high. The plants growing in moist conditions show short aristate awn. It is very similar to *G. acuminata* var. *acuminata* and *G. acuminata* var. *stocksii* from which it can be differentiated as shown in the table. (Table 2)

Table 2: Morpological features differentiating varieties of *G. acuminata*

Characters	*G. acuminata* var. *acuminata*	*G.acuminata* var. *stocksii*	*G. acuminata* var. *woodrowii*
Lower glume of Sessile spikelet	Long awned more than 7 mm	Long awned more than 5 mm	Awnless or short awned less than 7 mm
Lower glume of pedicelled spikelet	Short awned less than 3.5 mm	Long awned more than 3.5 mm	Short awned awnless or less than 1 mm

IUCN threat status: LC

Specimens examined:

Goa: Marmagoa, 15-10-1891, W A Talbot, Acc. No. 926(BSI); Porvorim, 8-11-1963, R S Rao, 92851(BSI); Moira, 13-10-1965, J Pallithanam, G-437(BSI); Mapusa, 4-11-1969, B M Wadhwa, 119443(BSI); 11-01-1977, John Cherian, 106173(BSI); Taleigao, 03-10-1996, V C Joshi & Rajkumar, 354(GUH); Bambolim, 21-08-1997, M A Fonseca, 1006(GUH); Goa University Campus, 09-09-1997, M A Fonseca, 1013(GUH); Mapusa, 17-10-2001, M A Fonseca, 1040(GUH).

Karnataka : Castle Rock, 20-10-1909, Raishish, Acc No. 3128 & 3129(BSI); Castle Rock, 26-02-1975, Raishish, 3122, 3123, 3124 and 3125(BSI).

Maharashtra : Dodamarg, Bhedshi, Ratnagiri, 1-11-1969, B M Wadhwa, 119636(BSI); Adari, Malwan, Ratnagiri, 29-09-1970, B G Kulkarni, 121266(BSI); Ganpatipule, 28-9-1991, C B Salunkhe, 8309(SUH); Ratnagiri, 29-09-1991, S R Yadav, 8786(SUH); Pawas, 29-9-1991, C B Salunkhe, 8528(SUH); Devgad, 4-10-1992, S R Yadav, 8640(SUH); Malwan, 3-10-1993, C B Salunkhe, 8063(SUH).

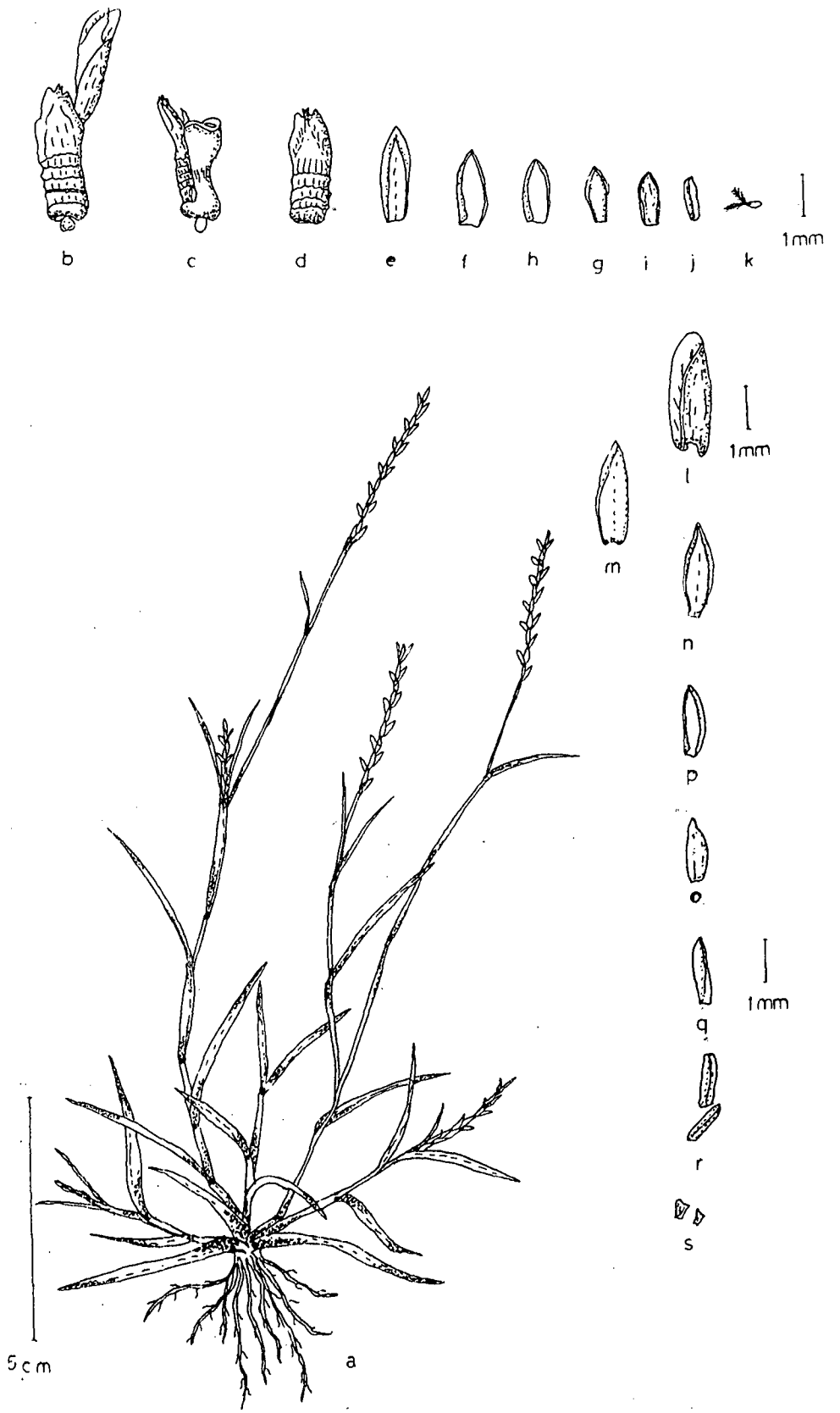


Fig 5: ***Glyphochloa acuminata*** (Hack.) Clayton **var.** ***woodrowii*** (Bor) Clayton.
a) Habit; b) Spikelets; c) Pedicel with sessile spikelet; (d-k): Sessile spikelet; d) Lower glume; e) Upper glume; f) Lower lemma; g) Lower palea; h) Upper lemma; i) Upper palea; j) Stamens; k) Pistil; (l-s): Pedicel spikelet; l) Lower glume; m) Upper glume; n) Lower lemma; o) Lower palea; p) Upper lemma; q) Upper palea; r) Stamens; s) Lodicules.

2. Glyphochloa divergens (Hack.) W.D. Clayton in Kew Bull. 35: 815.1981 **var. divergens** W.D. Clayton in Kew Bull. 35: 815, 1981; Sharma et. al., Fl. of Karnataka 333. 1984; Nayar, Red data book of Ind. Plants 301. 1987; Salunkhe & Yadav in Indian Bot. Reptr. 8: 143. (1989) 1990; Sreekumar & Nair, Fl. Kerala-Grass. 108. 1991; Lakshminarasimhan in Sharma et al., Fl. Maharashtra 501. 1996; Moulik, The Grass. & Bamb. of India, 191. 1997; Yadav & Sardesai, Fl. Kolhapur 583. 2002. *Rottboellia divergens* Hack. in DC. Monogr. Phan. 6: 292. 1989. *Manisuris divergens* (Hack.) O. Kuntze. Rev. Gen. Pl. 2: 794. 1891; Bor, Grass. Ind. 701. 1960; Jain in Bull. Bot. Surv. India 12: 10. (1970) 1972.

Type: Mysore, Huegel (No holotype).

An annual herb, up to 10 cm in height; culms slender, shallowly ridged, sparingly branched, glabrous, 2 or 3 noded; nodes swollen when fresh, constricted on drying, bearded. Leaf sheath 1-1.5 cm long, keeled on either side, adpressed, covering $3/4^{th}$ to entire portion of the culm; ligule *ca* 1.5 mm long, membranous, torn up with fringe of hairs. Peduncle swollen at apex, base narrow, ridged; racemes 1.75-2.5 cm long, erect, slender, glabrous, pale

green in colour; joint-pedicel 1.5-2 mm long, equal, fused, broad at apex, narrow at base with tufts of hairs at rim. Sessile spikelet: hermaphrodite and male or empty; lower floret male; lower glume 4-5 x 1-1.5 mm, broadly oblong, bifid, the two lobes each extending into scabrid awn of *ca* 3 mm long, winged on either side, wing *ca* 1.1 x 0.4 mm; upper glume *ca* 2 x 0.8-1 mm, boat shaped, both margins incurved with an acute apex, 3-nerved; lower lemma *ca* 2 x 1-1.5 mm, obovate, hyaline, both margins incurved; lower palea 1.1-1.5 x 0.75 mm, ovate, hyaline, both margins incurved; upper lemma *ca* 1.5 x 1 mm, obovate, hyaline, margins incurved; upper palea *ca* 1.1 x 0.75-1 mm, both margins incurved; lodicules two, small, cuneate; stamens 3; ovary small, style plumose. Pedicelled spikelet: staminate or empty; lower glume *ca* 5.5 x 0.75-1 mm (including awn), single awned, winged on one side, wing *ca* 1.5 mm long; upper glume *ca* 3.5 x 0.5 mm, boat shaped, winged on back, *ca* 1 mm long; florets empty; lemma *ca* 1.2 x 0.5 mm, boat shaped; palea absent. (Fig. 6)

Fl. & Fr.: November-December.

Habitat: Lateritic Pleateaus/Table lands of high altitudes of Western Ghats.

Distribution: Endemic to Karnataka, Kerala, and Maharasthra. (Fig. 30)

Notes: Plants very small compared to all the species of *Glyphochloa*. Inflorescence narrow and small. Lower glume of sessile spikelet with pits and shallow depressions. Pedicelled spikelet incomplete. It shows few similarities with *G. forficulata, G. ratnagirica* & *G. mysorensis*. (The differences given in table 4)

IUCN threat status: LC

Specimens examined:

Karnataka : Kemmangundi, Chikmagalur, 18-10-1974, R. S. Raghavan, Coll. No. 132366(BSI); Kalhatti, Chikmagalur, 19-10-1974, R S Raghavan, Coll. No. 132416(BSI); Sukkalhatti, Chikmangalur, 6-11-1974, R S Raghavan, Coll. No.134368(BSI); Talacauvery, Coorg, 04-11-2002, M K Janarthanam, 1056(GUH).

Kerala : No specimen from Kerala. (MH single collection from the hill slopes of Peermade, Idukki).

Maharashtra : Poona, Mushi, Panda, 12-10-1956, S. K. Jain, 7614(BSI); Amboli, 11-1987, C B Salunkhe & S R Yadav, 3602(SUH).

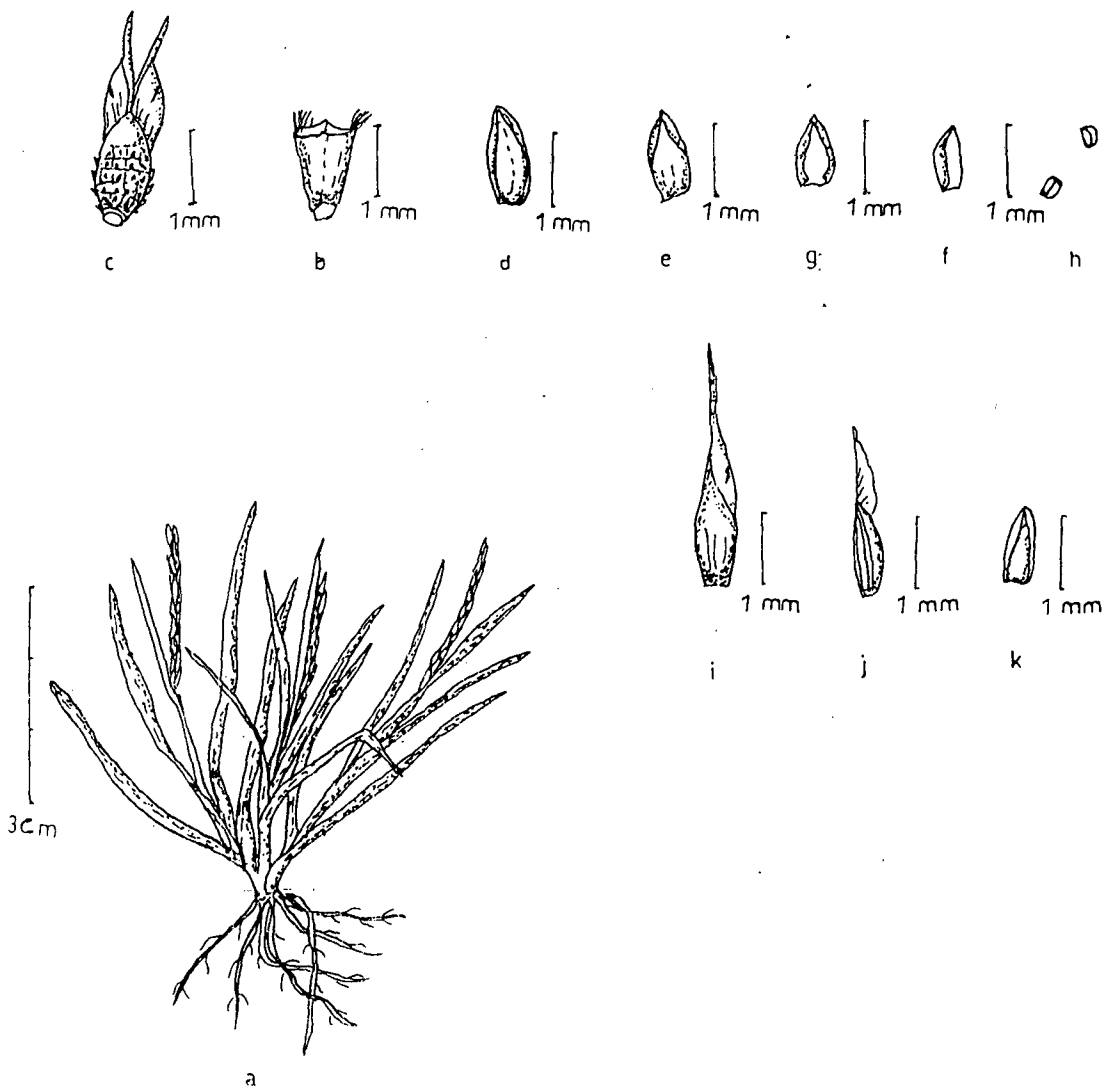


Fig 6: ***Glyphochloa divergens*** (Hack.) Clayton.
a) Habit; b) Pedicel and joint; (c-h): Sessile spikelet; c) Lower glume; d) Upper glume; e) Lower lemma; f) Lower palea; g) Upper lemma; h) Stamens; (i-k): Pedicel spikelet; i) Lower glume; j) Upper glume; k) Lemma.

3. Glyphochloa forficulata (C.E.C. Fischer) W. D. Clayton in Kew Bull. 35: 815. 1981; Sharma et. al., Fl. Karnataka 333. 1984; Kulkarni, Fl. Sindhudurg, 533. 1988; Henry, et al., Fl. Tamil Nadu 119. 1989; Sreekumar & Nair, Fl. Kerala - Grass. 109. 1991; Lakhminarasimhan, Fl. Nasik 561. 1991; Lakshminarasimhan in Sharma et al., Fl. Maharashtra 501. 1996; Moulik, The Grass. & Bamb. Ind. 191. 1997. Yadav & Sardesai, Fl. Kolhapur 583. 2002. *Manisuris forficulata* C.E.C. Fischer in Kew Bull. 1933: 353. 1933, p.p., et in Gamble, Fl. Madras 1761. 1934; Bor, Grass. Ind. 192. 1960; Jain in Bull. Bot. Surv. Ind. 12: 12. (1970) 1972; Saldanha, Fl. Hassan 740. 1976; Hemadri, Grass. Junnar 82. 1980; Mukherjee, Fl. Pachmarchi 364. 1984; Roy, Fl. Madhya Pradesh 109. 1984; Almeida, Fl. Savantwadi 148. 1990. *Rottboellia divergens* auct non Hack. 1889; Hook. f. Fl. Brit. India 7: 155. 1896; Cooke, Fl. Bombay 3: 470. 1958 (repr. ed.). *Peltophorous divergens* sensu Blatter & McCann, Bombay Grass. 34. 1935, p.p.

Type: Mahabaleshwar, Lisboa (holotype CAL). No number.

An annual tufted herb, villous, up to 15 cm long, spreading widely, coarse to touch; culms erect or ascending, slender, 2 or 3 noded, branching from 2nd and

3rd node, much branched, terminating into solitary racemes at same level; nodes swollen, constricted on drying; internodes *ca* 3.5 cm long, glabrous or with few hairs, cylindrical and ridged. Leaf sheath covering internode to 3/4th portion, villous, keeled and hairy along the margin, upper part spathaceous and densely villous; ligule 1-1.5 mm long, membranous, with a fringe of hairs; leaf blade up to 9 x 0.6 cm, longer than the internode or projecting beyond the inflorescence, linear, flat or conduplicate, acute to acuminate, upper leaves shorter, villous. Peduncle densly villous, cylindrical, ridged, covered by spathaceous leaf sheath; racemes 3-3.5 x 0.4-0.5 cm, terminal, broad, erect, solitary, pale in colour, scarious and papery; joints and pedicel 2-2.5 mm x 1.5 mm, with tufts of hairs, at apex subclavate; spikelets paired, one sessile and hermaphrodite and other pedicelled and male or neuter, dissimilar in shape. Sessile spikelet: lower glume with two divergent awns, 10-11 mm x 2 mm (including awn) with short glabrous callus, oblanceolate or oblong oval, wings 1-1.2 mm broad, thinly coriaceous, glabrous, 4-6 grooved, margin and often lower convex portion (back) with number of tubercles or hooks scattered over the back or form regular ridge like structures, ciliate at tips; awn antrorsely barbellate; upper glume *ca* 3 x 1 mm long, elliptic to lanceolate, with

acute margin, narrowly inflexed, thinly membranous, faintly 3-nerved; lower floret neuter; lemma *ca* 2.3 x 1 mm long, oblong to lanceolate, hyaline, small; palea *ca* 2 x 1.1 mm ; upper floret hermaphrodite; lemma *ca* 2 x 0.5-0.10 mm, elliptic to ovate, acute, hyaline; upper palea *ca* 2 x 0.5 mm, oblong to ovate, subacute, hyaline; lodicules 2, small; stamens 3; anthers *ca* 0.5 mm long; styles 2; stigma plumose. Grain elliptic-oblongoid. Pedicelled spikelet: (including awn) 11-12 mm long; lower glume *ca* 6 mm long excluding awn, including wing oblong-lanceolate, flat on back, 6 or 7 nerved, margins narrowly inflexed, one margin with thin, membranous, hyaline wing of 1 to 1.7 mm long, other margin produced into a slender barbellate awn; upper glume excluding the wing ovate, acute, *ca* 3 mm long, including wing *ca* 5.5 x 1 mm, 3-nerved, strongly keeled, boat shaped, apex prolonged into a slender antrorsely barbellate awn of 5 mm long; lower floret empty; lemma oblong, lanceolate, obtuse, 2-3 x 1 mm, hyaline; palea hyaline, small or 0; upper floret male or neuter; lemma hyaline, subacute, *ca* 2.8 x 0.6 mm; palea similar but smaller; stamens 3, 1.5 mm long, versatile. (Fig. 7)

Fl. & Fr.: October-November.

Habitat: Open lateritic rocks with sufficient amount of soil.

Distribution: Endemic to Peninsular India and distributed in Goa, Karnataka, Kerala, Madhya Pradesh, Maharasthra and Tamil Nadu. (Fig. 30)

Note: Plants are bushy and spreading, profusely branched at base. Racemes very fragile; lower glume of sessile spikelets with lot of variation. The lower glume may show tubercles on back and along margin and often the tubercles may merge together to form ridge like structures. It differs from *G. mysorensis* which also occurs at high altitudes by its fused pedicel and joint, awn with small tubercles and large wings. (For differences refer Table 4).

According to Jain *Rottboellia divergens* was described by Hooker (1896), Lisboa (1896) and Cooke (1908). Later it was described under *Peltophorus divergens* by Blatter & McCann (1935) but it was not *Rottboellia divergens* Hack. Fischer (1933) gave the name *Manisuris forficulata* Fischer to the grass referred by Hooker & others; the described specimen was a mixture of two grasses. Jain (1970) gave a detailed

description of *Manisuris forficulata* based on different specimen collected from Mysore.

IUCN threat status: LC

Specimens Examined :

Goa : Goa,18-10-1905, W A Talbot, Acc. No. 927(BSI); Surla, 14-10-2001, M A Fonseca, 1038(GUH).

Karnataka: Hassan dt., Mysore, 07-10-1970, Gevikalbetta et. al., HFP 896(JCB); Bababudan, Chikmagalur, 18-10-1974, R S Raghavan, Coll. No. 132426(BSI)

Kerala: Peermede, Travancore dt., 03-12-1941, K Cherian, 20244(MH); Shola, Ayyappan Kovil, Palghat dt.,27-10-1976, E Vajravelu,48715(MH).

Maharashtra: Mahabaleshwar, 16-10-1905, W A Talbot, Acc. No. 928(BSI); Mulshi, Poona, 12-10-1956, S K Jain, 7614(BSI); Mahabeleshwar, 5-10-1957, G S Pari, 25651(BSI); Bhimashankar, 16-10-1957, J A Vasavada, 29052(BSI); Machutar Forest, Satara, Mahabeleshwar, 10-10-1960, M Y Ansari, 67577 & 67541(BSI); Bhimashankar, Khed, 9-10-1962, K P Janardhanan, 81735(BSI); Kalamal, Khed, 10-10-1962, K P Janardhanan, 81846(BSI); Satara, Mulshi, Poona, 7-9-1964, B

Venkata Reddi, 99095(BSI); Mulshi, 8-9-1964, B V Reddi, 99130(BSI); Sakarpatham, Lonavla, Poona, 27-9-1964, B Venkata Reddi, 98765(BSI); Sinhagad, 21-10-1964, M Y Ansari, 101691(BSI); Durgakhilla Plateau, 29-10-1964, K Hemadri, 104244(BSI); Raligaon, Junnar, 24-9-1965, K Hemadri, 93326(BSI); Amba Plateau, 4-10-1965, K Hemadri, 107584(BSI); Mulshi - Poona, 8-9-1968, B Venkata Reddi, 99130(BSI); Washala, 21-9-1968, K H Billore, 115307(BSI); Junnar, 22-9-1968, K Hemadri, 117964(BSI); Kadarnath Hill, 18-11-1968, K H Billore, 115674(BSI); Khandala, 24-2-1969, B Venkata Reddi, 111781(BSI); Ratnagiri, 27-10-1969, B G Kulkarni, 19105(BSI); Ratnagiri, 27-10-1969, B G Kulkarni, 119106(BSI); Ratnagiri, 28-10-1969, B G Kulkarni, 119142 and 119143(BSI); Amboli, Ratnagiri, 29-10-1969, B G Kulkarni, 119189(BSI); Drikar Ghat, 24-9-1970, B M Wadhwa, 127524 & 127547(BSI); Panchai, Harichani, 25-9-1970, B M Wadhwa, Coll. No. 127645 & 127656(BSI); Piprichaunam-Harichandragarh, 29-9-1970, B M Wadhwa, 127880(BSI); Ratnagarh, Ratanwadi, 1-10-1970, B M Wadhwa, 127924(BSI); Phonda Ghat, Ratnagiri, 4-10-1970, B G Kulkarni, 121438(BSI); Kalsambai Hills, 8-10-1970, B M Wadhwa, 128287(BSI); Mahadeogod, Amboli, Ratnagiri, 9-10-1970, B G Kulkarni, 121558(BSI); Ratnagiri, 12-10-1970, B G Kulkarni, 121641(BSI); Inglum, Hethi, Poona, 17-10-1970, B M Wadhwa,

Coll. No. 128549(BSI); Phonda Ghat, Ratnagiri, 25-10-1970, B G Kulkarni, 121879(BSI); Gaganbawda, 3-10-1989, S R Yadav, 8538(SUH); Mahabaleshwar, 7-10-1990, S R Yadav, 7823(SUH); Pawas, 29-09-1991, C B Salunkhe, 8798(SUH); Pusegaon, Chandkhana Hills, 30-09-1992, C B Salunkhe, 7132(SUH); Malwan, 3-10-1993, C B Salunkhe, 8655(SUH); Rachanagari, 1-10-1994, C B Salunkhe, 8434(SUH); Kas, 1-9-1997, C B Salunkhe, 8716(SUH); Ambolim, 11-11-1998, M A Fonseca, 1018(GUH); Ambolim, 16-09-2001, M A Fonseca, 1033(GUH); Tillari, 16-09-2001, M A Fonseca, 1034(GUH).

Madhya Pradesh: Hoshangabad, 8-10-1960,J Joseph, 11336(MH).

Tamil Nadu: No collection from Tamil Nadu distribution based on flora.

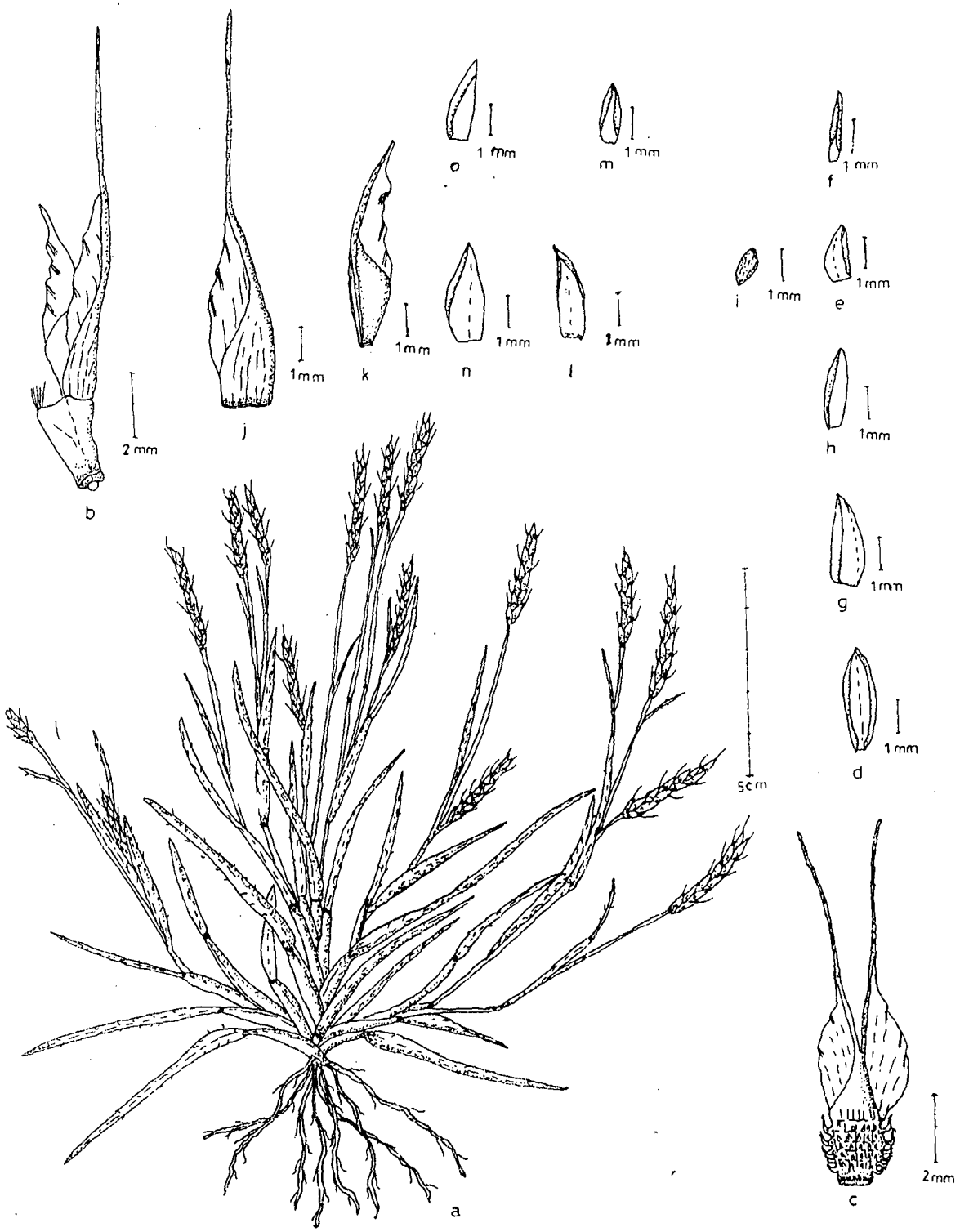


Fig 7: ***Glyphochloa forficulata*** (C. E. C. Fisch.) Clayton.
a) Habit; b) Spikelet; (c-i): Sessile spikelet; c) Lower glume; d) Upper glume; e) Lower lemma; f) Lower palea; g) Upper lemma; h) Upper palea; i) Pistil; (j-o): Pedicel spikelet, j) Lower glume; k) Upper glume; l) Lower lemma; m) Lower palea; n) Upper lemma; o) Upper palea.

4. Glyphochloa goaensis (Rao & Hemadri) W. D. Clayton in Kew Bull. 35: 815. 1981; Kulkarni, Fl. Sindhudurg, 533. 1988; Lakshminarasimhan in Sharma et al., Fl. Maharashtra, 501. 1996. *Manisuris goaensis* Rao & Hemadri in Bull. Bot. Surv. Ind. 10: 106. (1968) 1969; Jain in Bull. Bot. Surv. India 12 : 14. (1970)1972; Rao, Fl. Goa, 507. 1986; Almeida, Fl. Savantwadi, 148. 1990.

Type: Goa, Verna, Rao, 8/11/1962 844474A (Holotype CAL).

An annual grass; culms up to 40 cm high, slender, erect, branching at base; nodes dark, swollen, becomes constricted on drying, a ring of hairs at the nodes when young, hair 0.2-0.4 mm long; internodes 2.5-9 cm long, cylindrical, faintly ridged on all sides with one prominent curvature; peduncle ridged equally on all sides, sparsely hairy. Leaf sheath covering the culm, keeled, margins hairy; ligule 1.2-2 mm, membranous with a fringe of hairs; leaf blade 3-12 x 0.7 cm, linear to lanceolate, acute, younger leaves hairy along margin. Racemes 1-7 cm long, solitary; joints and pedicel fused 4-5 x 1.5 mm with hairy margins. Sessile spikelet: lower glume 1.2-2 cm x 0.16-0.2 cm, ovate to lancelote, single awned, long, with 2 or 3 marginal tubercles, awned; tubercles angular, curved upward

with tufts of hairs at its tip, back of glume, 1-3 ridged, rarely smooth, winged on both the sides; wing unequal, larger *ca* 3 x 0.5 mm; upper glume 2.6-3 x 1 mm, ovate-oblong, membranous, slightly winged or no wing at apex; lower floret staminate; lemma 2.5-3 x 0.8-1 mm, hyaline, ovate to oblong; palea 2.1-2.4 x 0.5 mm; anthers 2, 1-1.5 mm long; upper floret hermaphrodite; lemma 2.5-3 mm x 0.8-1 mm long, ovate, margins incurved; palea 2-2.4 x 0.5-0.6 mm; hyaline, ovate; anthers *ca* 1 mm long; styles 2, ovary 0.2 mm long, small, globose to oblongoid, stigma plumose. Pedicelled spikelet: Pedicel 4-5 mm long, fused along the rachis, distinct; lower glume (including awn) *ca* 13 mm x 1.5-1.75 mm, dorsally smooth, glabrous or puberculous, ending in scabrid awn; winged one side along margin, wing *ca* 3.5 x 0.6 mm; upper glume *ca* 5 x 1 mm, membranous, boat shaped, winged on the back, ending into a small scabrid awn of 1 mm long, wing *ca* 2 x 0.5 mm; lower lemma 2.1-3 mm x 0.8 mm, oblong, hyaline; palea *ca* 2 x 0.6 mm long, hyaline, ovate; anthers *ca* 1.2 mm long; upper lemma *ca* 3 x 0.8 mm long; palea of lower and upper florets similar or slightly smaller, ovate-oblong, hyaline *ca* 2.5 x 0.6 mm. (Fig. 8)

Fl. & Fr.: September-November

Habitat: Found growing on hard rocky lateritic plateaus, with or without thin layer of soil.

Distribution: Endemic to Goa and Maharasthra on low lateritic rocks. (Fig. 29)

Notes: The plant grows to about 40 cm in height, variations are seen in lower glume of sessile spikelet showing transverse ridges varying from 1-3 in number or rarely absent. It is similar to *G. talbotii* and *G. santapaui* but differs from them by its joint and pedicel which is narrow at center and broad at apex and absence of hairs at base of lower glume of sessile spikelet respectively. These plants occurs at low altitudes. (Table 3 & 5).

IUCN threat status: LC

Specimens Examined :

Goa : Verna, Cortalim, Madgao, 8-11-1962, S R Rolla, 84474C-Isotype(BSI) Paratype; Loliem, 10-09-1997, V C Joshi and Raj Kumar, 943(GUH); Porvorim (Nr. Sanjay School), 20-9-1997, M A Fonseca, 1015(GUH); Sirsaim, 20-9-1999, M A Fonseca, 1020(GUH); Sirsaim, 20-9-1999, M A Fonseca, 1021(GUH); Pernem Railway, 16-09-2001, M A Fonseca,

1035(GUH); Pernem - Colvale, 16-09-2001, M A Fonseca, 1036(GUH); Ponda near E-Merck, 14-10-2001, M A Fonseca, 1039(GUH); Ponda - Usgao, 21-10-2001, M A Fonseca, 1044(GUH).

Maharashtra : Pawas, 15-10-1990, C B Salunkhe, 8672(SUH); Ratnagiri, 15-10-1990, S R Yadav, 8659(SUH); Malwan, 3-10-1993, C B Salunkhe, 8802(SUH); Banda, 20-09-1999, M A Fonseca, 1022(GUH); Vengurla, 20-9-1999, M A Fonseca, 1030(GUH).

Table 3: Variation in *G. goaensis* from different localities

Characters	Porvorim	Pernem	Ponda	Vengurla
Height	13 - 18 cm	17 - 20 cm	up to 30 cm	up to 18 cm
Joint & Pedicel	0.5 X 0.2 cm	0.4 - 0.6 X 0.2 cm	0.4 - 0.5 X 0.15cm	0.35-0.4 X 0.1-0.15 cm
Lower glume of sessile spikelet	single / double ridged (1.3-1.5 cm)	0, 1, 1 1/2, 2 ridged with marginal tubercles (1 - 1.8 cm)	one prominent ridge (1.2 - 1.3 cm)	2 complete ridges (1 - 1.4 cm)
Lower glume of pedicelled spikelet	1 - 1.2 cm	1 - 1.8 cm	1.2 - 1.3 cm	0.9 - 1 cm
Leaf size	ca 7 X 0.4 cm	ca 12 X 0.6 cm	ca 13 X 0.4 cm	ca 9 X 0.4 cm
Leaf sheath	2.3 - 3.5 cm long centre solid with lateral cavities	ca 2.6 cm long centre solid with lateral cavities	ca 3.5 cm long cavities in mid & central part	ca 2.5 cm long No cavities
Mesophyll thickness in leaf	1 - 2 cells	4 - 6 or absent	1 - 4 cells	absent

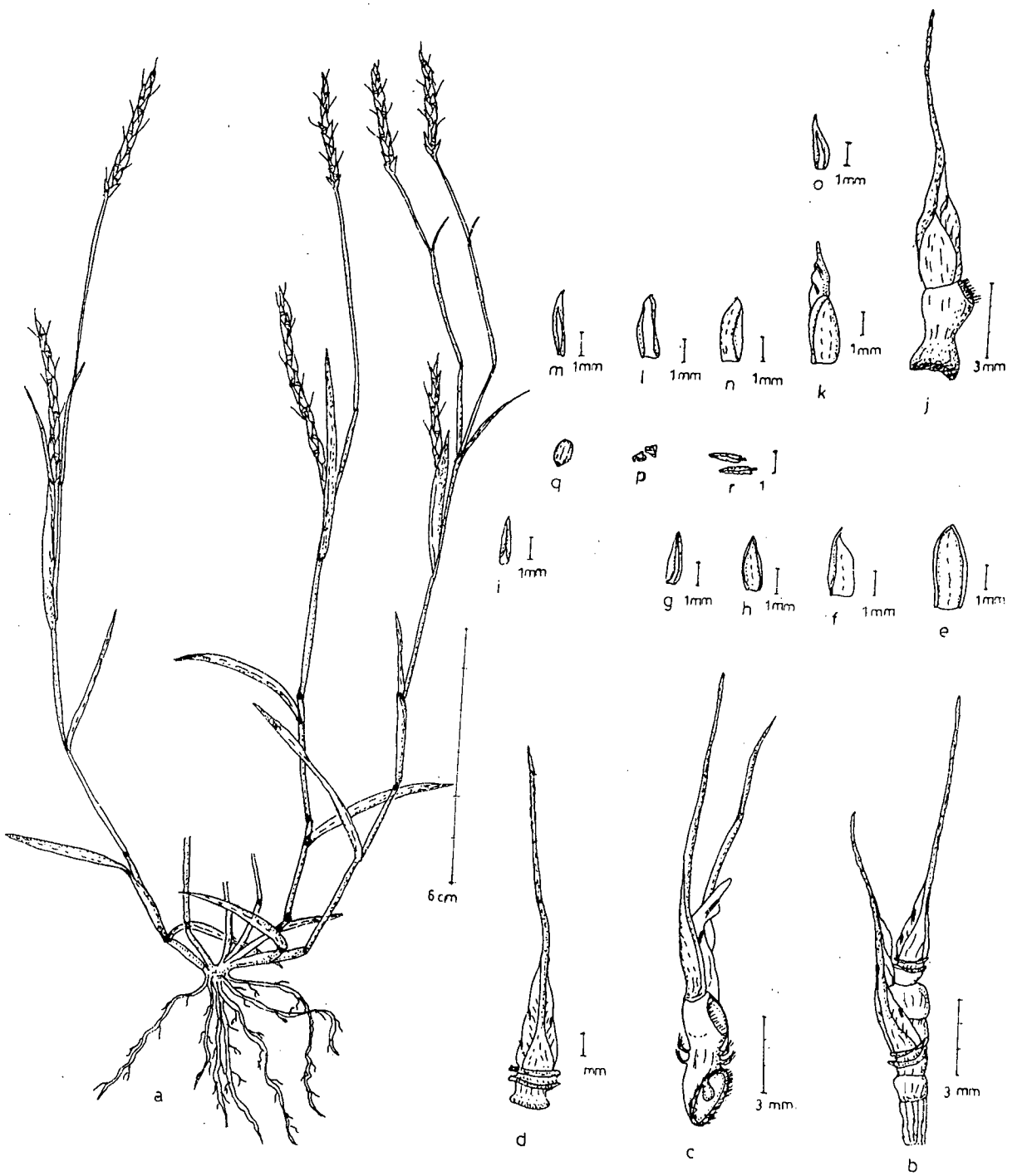


Fig 8: ***Glyphochloa goaensis*** (Rao & Hemadri) Clayton.
a)Habit; b) Part of inflorescence; c) Spikelets; (d-l): Sessile spikelet; d) Lower glume; e) Upper glume; f) Lower lemma; g) Lower palea; h) Upper lemma; i)Upper palea; (j-r): Pedicelled spikelet; j) Lower glume; k) Upper glume; l) Lower lemma; m) Lower palea; n) Upper lemma; o) Upper palea; p) Lodicules; q) Pistil; r) Stamens.

5. **Glyphochloa henryi** Janarth., Joshi et Rajkumar, Rheedea 10: 99-102. 2000.

Type: India, Goa, Tisk - Usgao, Janarthanam & Rajkumar, 27-09-1998. 1661 (Holotype CAL). Cotigao sanctuary, 11-11-1998. 1690 (Paratype - GUH).

An annual tufted herb, up to 90 cm high or more, profusely branched at base with long branches; culms erect, cylindrical, glabrous, 5 or 6 noded; nodes swollen, glabrous, constricted on drying, yellowish green to purplish when fresh, bent at basal region. Leaf blade large, up to 17 x 0.8 cm, truncate at base, entire along margins, acute at apex, prominently 7 or 8 nerved, glabrous; leaf sheath up to 5.8 cm long, keeled on either side, hyaline; ligule *ca* 0.15 cm long, small, membranous, hyaline, torn up or forms a fringe of hairs. Racemes 9-10 cm long, solitary, cylindrical; peduncle cylindrical, narrow at base, apex slightly swollen with long ciliate hairs; joints and pedicel fused, *ca* 0.3 cm long, straight, narrow at base, ciliate at both ends. Sessile spikelet: lower glume 1.4-1.5 x 0.25 cm (including awn), single or rarely two transverse prominent ridges present at base

extending end to end, facing upwards along the margins forming a collar, margins wavy, lateral edges ciliate, rarely with 2 lateral hooks below the ridge containing tufts of hairs at ends; upper glume 3-3.4 x 1.2 mm, oblong, 3-nerved; lower floret staminate; lower lemma 2-2.5 x 1 mm long, hyaline, oblanceolate, margins incurved, sparsely hairy along the margins, 2-nerved; palea 2.1-3 x 0.8-1 mm, ovate, hyaline; anthers 1 mm long, purple to yellowish; upper floret: hermaphorodite; upper lemma 2-3 x 0.7-1 mm, ovate, acute at apex; upper palea 1.8-2.3 x 0.5-1.1 mm, ovate, hyaline; anthers 3, 2 mm long. Ovary obovoid; stigma 2, 2 mm long, plumose. Pedicelled spikelet: lower glume *ca* 1.5 cm (including awn) long, winged on one side, glabrous; upper glume *ca* 6 x 2 mm, strongly keeled at median position, margins unequal, winged on one side; wings broad at base and apex, narrowing in the middle, undulate at apex, hyaline; lower floret staminate; lemma *ca* 3.1 x 1.1 mm, oblong, 3-nerved, hyaline; palea *ca* 3.1 x 6 mm, lanceolate with acute apex, hyaline; upper floret hermaphrodite; lemma *ca* 3.1 x 1.1 mm, lanceolate, faintly 3-nerved, hyaline; palea *ca* 3 x 8-1 mm. Grains brown.(Fig. 9)

Fl.& Fr.: September-November.

Habitat: Found on hard lateritic rocks in open places.

Distribution: Two places in Goa. (Fig. 29)

Notes: The plants are tall, leaves with prominent truncate base, inflorescence broad, long. Lower glume of sessile spikelet with single or double collar. It differs from closely related *G.veldkampii* in its ornamentation of lower glume of sessile spikelet.(Differences can be seen in Table 6)

IUCN threat status: EN D

Specimens Examined:

Goa: Usgao, Tisk, 27-09-1998, & Raj Kumar, 1661(GUH); Ponda (Nr. MRF), 21-10-2001, M K Janarthanam & M A Fonseca, 1041(GUH); Usgao - Tisk, 21-10-2001, M A Fonseca & M K Janarthanam, 1042(GUH); Chorala Ghat, 25-10-2002, G G Potdar s.n.

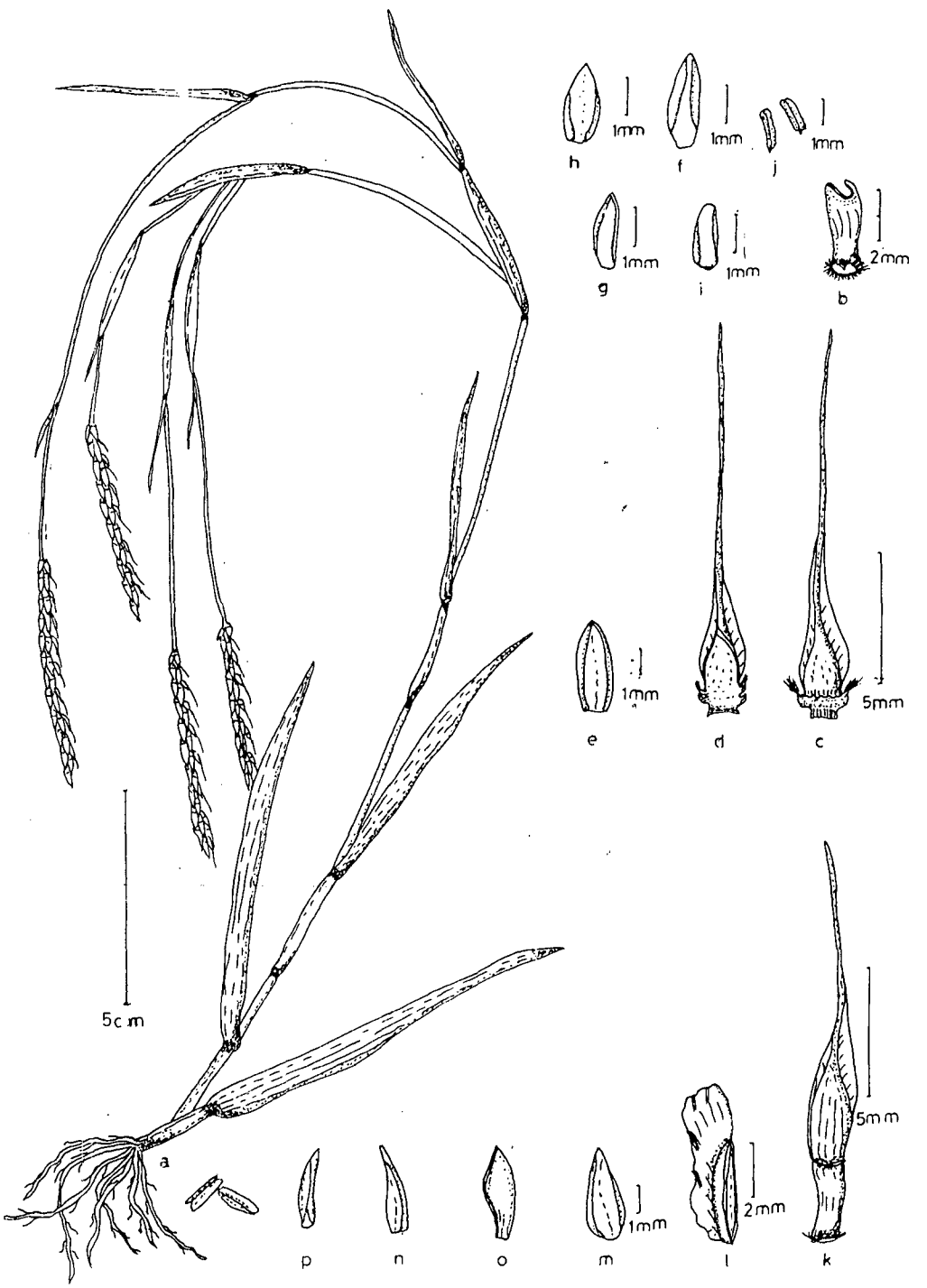


Fig 9: ***Glyphochloa henyri*** Janarth. et. al
a) Habit; b) Spikelet; (c-j): Sessile spikelet; c) Lower glume (adaxial view); d) Lower glume (abaxial view); e) Upper glume; f) Lower lemma; g) Lower palea; h) Upper lemma; i) Upper palea; j) Stamens; (k-q): Pedicel spikelet, k) Lower glume; l) Upper glume; m) Lower lemma; n) Lower palea; o) Upper lemma; p) Upper palea; q) Stamens.

6. Glyphochloa hirsuta (C. E. C. Fischer) M. A. Fonseca stat et comb. nov. *Manisuris forficulata* var. *hirsuta* C. E. C. Fischer in Kew Bull. 1933: 357. 1933; Bor, Grass. Ind. 192. 1960; Bole and Almeida in J. Bombay Nat. Hist. Soc. 84: 386. 1987. *Manisuris divergens* var. *hirsuta* (C. E. C. Fischer) Jain in Bull. Bot. Surv. India 12: 12. (1970) 1972; Lakshminarasimhan in Sharma et. al. Fl. Maharashtra 376. 1996.

Type: Kalhatti, Meebold 10559 (type: CAL).

An annual, up to 7 cm, hairy; internodes *ca* 1.7 cm long; branching rare and apical; nodes constricted on drying. Leaves 4-5 cm long. Pedicel broad at apex, *ca* 2.1 x 1.5 mm, fully hirsute; hair 1-1.5 mm long; lower glume 5-6 x 2 mm (including awn), awn 2 mm, divergent, winged on either side, wings almost equal, *ca* 2.5 mm long; upper glume 2.5-3 x 0.5-1 mm, ovate, acute at apex, 3-nerved, boat shaped; lower lemma ovate-obovate, 2-2.2 x 0.6-1 mm, hyaline, both margins incurved; lower palea 1.75-2 x 0.5-0.75 mm, ovate, hyaline; upper lemma 1.75-2.2 x 0.85 mm long, hyaline, margins incurved; upper palea absent; lodicules 0.5-0.75 mm long, triangular; stamens 0.3-0.5 mm.

Ovary *ca* 0.5 mm long; stigma plumose. Pedicelled spikelet: lower glume *ca* 5.5 x 0.75-1 mm. (including awn), single awned, awn *ca* 1.5 mm long, winged on one side; upper glume *ca* 3.5 x 0.5 mm, boat shaped, winged on back, wing 1 mm long from median to tip of the glume; florets empty: (One lemma may be seen) lemma *ca* 1.2 x 0.5 mm, ovate, boat shaped, margins incurved. (Fig. 10)

Fl. & Fr.: October-December.

Habitat: At higher altitudes.

Distribution: Endemic to Karnataka and Maharasthra.(Fig. 30)

Note: Pedicels and lower glume of sessile spikelet densely hirsute. Only two collection so far found at BSI, Pune and one at JCB. It is distinct from *G. divergens*, being completely hirsute on back of lower glume and wings of lower glume more expanded. It is being raised to the species level *G.hirsuta* M A Fonseca, earlier *G. hirsuta* was included as a variety under *M.forficulata* Fischer var. *hirsuta* Fischer which was later changed as *M. divergens* var. *hirsuta* (Fischer) Jain.(Table 4)

IUCN threat status: DD

Specimens Examined:

Karnataka: Kalhatti, Chikmagalur, 19-10-1974, R S Raghavan, Coll. No. 132416(BSI); Chikmagalur dt., 02-12-1978, S R Ramesh and K R Keshavamurthy, KFP11000(JCB).

Maharashtra: No specimen collected from Maharashtra (Satara) distribution is based on Bole & Almeida 1987.

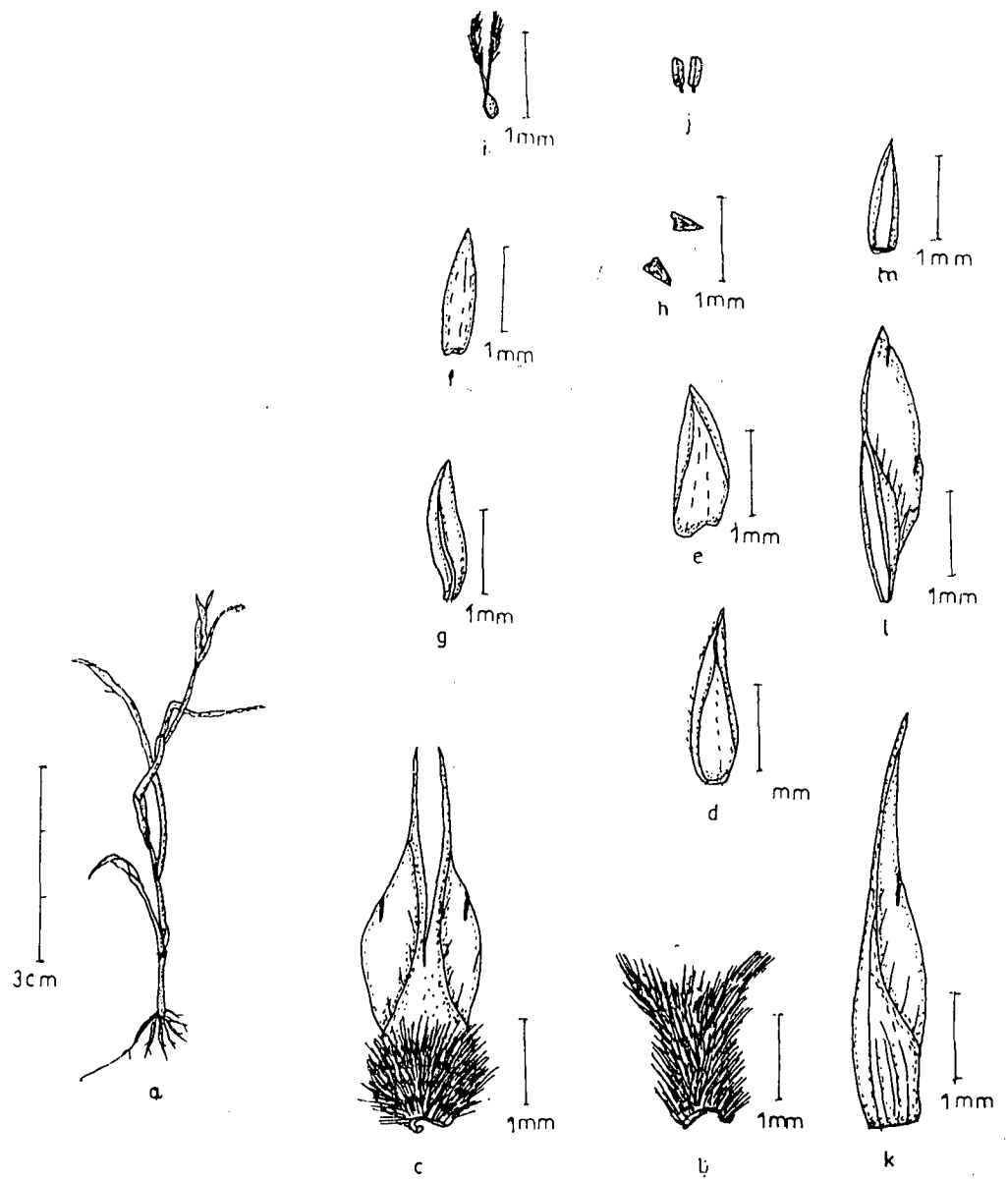


Fig 10: ***Glyphochloa hirsuta*** M. A. Fonseca, comb. et stat. nov.
a) Habit; b) Pedicel and joint; (c-j): Sessile spikelet; c) Lower glume; d) Upper glume; e) Lower lemma; f) Lower palea; g) Upper lemma; h) Lodicules; i)Pistil; j) Stamens; (k-m): Pedicel spikelet; k) Lower glume; l) Upper glume; m)Lemma.

7. Glyphochloa mysorensis (Jain & Hemadri) W.D. Clayton in Kew Bull. 35: 815. 1981; Sharma et. al., Fl. of Karnataka 333. 1984; Kulkarni, Fl. Sindhudurg 534. 1988; Lakshminarasimhan in sharma et al., Fl. Maharashtra, 502. 1996. Yadav & Sardesai, Fl. Kolhapur 583. 2002. *Manisuris mysorensis* Jain & Hemadri in Bull. Bot. Surv. Ind. 10: 280. (1968)1969; Jain in Bull. Bot. Surv. India 15. 1970; Almeida, Fl. Savantwadi 2: 149. 1990.

Type: Mysore:Castle Rock, Gammie 25-10-1992 15643A.(Holotype CAL).

An annual, tufted herb, up to 18 cm high; culms erect or ascending, slender, shallowly ridged on all sides with one deep groove on one side, branching from the 2nd node, sparingly to densely branched and terminating in solitary racemes, 2-4 noded; nodes swollen when fresh, constricted and brownish on drying. Leaf sheath long, covering 3/4th or more portion of the internode, hairy, margins keeled and membranous, upper leaf sheath spathaceous and densely villous; ligule 1-2 mm long, ovate, entire to fringe of hairs, membranous; leaf blade 3-10 cm x 0.2-0.5 cm, linear, acute, flat or conduplicate, not constricted at base, villous, faintly 5 or 6 nerved. Peduncles bearing the

racemes densely villous, ridged; racemes 1-4 x 0.3-0.5 cm, solitary, erect, pale, glabrous, very fragile; joints 1.75-2 mm long, subclavate, concave at tip, unequally fused with the pedicel, devoid of tufts of hairs at tip; pedicel 3 mm, subclavate; spikelets paired. Sessile spikelet: 1.3-1.5 cm long, dorsally compressed, ovate (including the awn); florets 2, lower male or neuter, upper hermaphrodite; lower glume 1.3-1.5 x 0.1-0.12 cm, divergent, elliptic to lanceolate including the awn, coriaceous, puberculous, margins of glume bearing 5-10 long hooks spreading out to about 0.5 mm on each side and often with tuft of small hairs at their tips, back of the glume 3-5 ribbed with hooks, the apex of the glume cleft bearing two short 1-2 mm long wings, inner margin of the wings prolonged into two divergent, tender, antrorsely barbellate, 5-8 mm long awns; upper glume *ca* 2 x 0.75 mm long, elliptic to lanceolate, acute or accuminate, margin narrowly inflexed, thinly membranous, faintly 3-nerved; lower floret neuter, lower lemma 2.5-2.75 mm long, oblong- lanceolate, obtuse, hyaline; lower palea 1-2 x 0.5 mm, hyaline, sterile anthers 3 or 0; upper floret hermaphrodite; upper lemma 2-2.4 x 0.6 mm, elliptic-ovate, subclavate, hyaline, margins narrowly inflexed; upper palea *ca* 2 x 0.6 mm long, oblong to obtuse, hyaline; lodicules 2, *ca* 0.5 mm long, cuneate,

hyaline. Stamens 3; anthers 1 mm long. Style 2, stigma plumose. Grain elliptic, oblong, slightly compressed, *ca* 1.5 mm long. Pedicelled spikelet: oblong to ovate, florets 2, lower empty, upper male or neuter; lower glume *ca* 1.4 cm long ovate, thinly coriaceous, flat on back, glabrous or puberculous, prominently 3 or 4 nerved, margins narrowly inflexed, One margin with thin membranous hyaline wing,other margin produced into antrorsely barbellate 8-10 mm long awn; upper glume 3-4.5 mm long (excluding awn), including wing and awn 7 mm long, ovate, acute, 3-nerved, keeled, boat shaped, apex prolonged into a slender, 3 mm long awn, keel winged from a little above the base to beyond the apex of the glume; lower lemma 2.5-2.75 mm long, oblong-lanceolate, obtuse, hyaline; lower palea *ca* 2 x 0.5-1 mm long, hyaline; upper floret male or empty; upper lemma *ca* 2.3 x 0.6 mm, oblong, hyaline, margins incurved; upper palea *ca* 1.5 x 0.5 mm, ovate, hyaline.(Fig. 11).

Fl. & Fr.: October-November.

Habitat: Lateritic rocks or grasslands with sufficient amount of soil at high altitude.

Distribution: Endemic to Karnataka and Maharasthra.(Fig. 30)

Notes: The plant grows up to 15 cm, sparingly to densely branched, sessile spikelet of lower glume long and with spreading hooks or tubercules on back. Wing of glume small. This is the only species of *Glyphochloa* with unequal joint and pedicel, and differs from *G. forficulata* and *G. divergens* on the basis of this above character. (Fig. 11). (Table 4).

IUCN threat status: LC

Specimens Examined:

Karnataka: No specimen distribution is based on flora & holotype.

Maharashtra: Amboli, 10-9-1989, C B Salunkhe, 8691(SUH); Pawas, 15-10-1990, C B Salunkhe, 8797(SUH); Kas, 1-9-1991, S R Yadav, 7451(SUH); Mahabaleshwar, 15-9-1991, C B Salunkhe, 8526(SUH); Ambolim, 16-09-2001, M A Fonseca, 1031(GUH); Tillari, 16-09-2001, M A Fonseca, 1032(GUH).

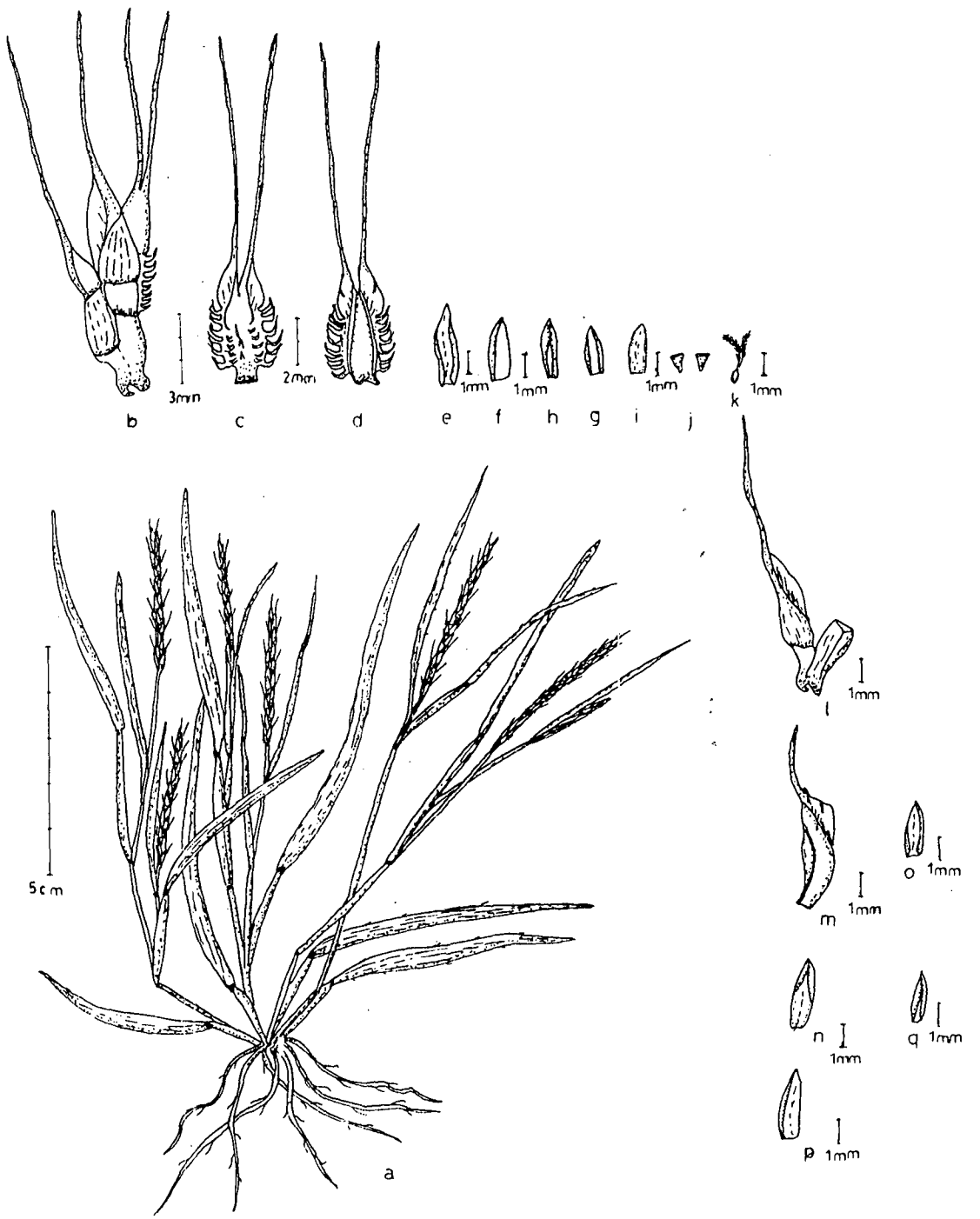


Fig 11:*Glyphochloa mysorensis* (Jain & Hemadri) Clayton.
a) Habit; b) Part of inflorescence; (c-k): Sessile spikelet, c) Lower glume (adaxial view); d) Lower glume (abaxial view); e) Upper glume; f) Lower lemma; g) Lower palea; h) Upper lemma; i) Upper palea; j) Lodicules; k) Pistil; (l-q): Pedicel spikelet; l) Lower glume with joint; m) Upper glume; n) Lower lemma; o) Lower palea; p) Upper lemma; q) Upper palea.

8. Glyphochloa ratnagirica (Kulkarni & Hemadri) W. D. Clayton in Kew Bull. 35: 815. 1981; Kulkarni, Fl. Sindhudurg, 534. 1988; Lakshminarasimhan in Sharma et al., Fl. Maharashtra, 502. 1996. *Manisuris ratnagirica* Kulkarni & Hemadri in Ind. Forester 100: 250. 1974; Almeida, Fl. Savantwadi 2: 149. 1990.

Type: Ratnagiri, Kulkarni 121638 (Holotype CAL).

An annual tufted herb, up to 30 cm high, branching at top portion from 3rd node, 3 or 4 branches arising from a single node, each branch terminating in a raceme, bushy appearance on top; culms cylindrical, slender, ridged, 3-5 noded; nodes angular, glabrous. Leaf sheath *ca* 3 cm long, keeled, ligulate, shorter than internode (covering 1/2 the internode); ligule *ca* 0.4 mm long, entire to dentate, membranous, hyaline or forms a fringe of hairs; leaf blade 9-10 x 0.5 cm, linear with acute apex, pilose with fine hairs on the margins, 5 or 6 nerved. Peduncle long, ridged, hairy; raceme 3-5 cm long, erect, slender, straight, faintly hairy, pale green; joints-pedicel fused and of same size, 2.5-3 mm long, linear, subclavate, margins with tufts of white hairs. Sessile spikelet: Oblong, with a short callus; lower glume bifid, two awned, *ca* 7 x 1.2 mm

(including awn), scarious, scabrid, margins with 6-9 small tubercles, curved upward rarely with tubercles on back, 7-nerved, margins narrowly inflexed winged on either side, wings equal, hyaline; upper glume *ca* 3 x 1 mm, margins inflexed, boat shaped, 3-nerved; lower floret empty or staminate; lower lemma *ca* 3 x 1 mm, oblong to lanceolate, apical margins inflexed; lower palea 2-2.2 x 0.3-0.5 mm, both margins inflexed, hyaline; upper floret hermaphrodite; upper lemma 2-2.2 x 0.5 mm, oblong to lanceolate, margins inflexed at apex; upper palea *ca* 2 x 0.2 mm, lanceolate, both margins incurved; lodicules 2, 0.5 mm long ; anthers 3, *ca* 1.2 mm with short filament; ovary small, style plumose 2. Grain *ca* 0.7 mm long, ovoid. Pedicelled spikelet: pedicel 2.5 mm long; lower glume 10 - 11 mm long, winged on one side, other side drawn into a long scabrid awn, 3 or 4 nerved; upper glume *ca* 4 x 0.5-0.75 mm, boat shaped, keeled, margin unequal, winged on back to $3/4^{th}$ its length; wing *ca* 1.5 mm long, hyaline; lower floret empty, lower lemma 2-2.3 x 1 mm, hyaline, slightly boat shaped; lower palea 2-2.3 x 0.5 mm, hyaline, ovate; upper floret staminate; upper lemma 2-2.3 x 0.75 mm; upper palea 2-2.3 x 0.5 mm; anthers *ca* 0.6 mm, small; lodicules 2, *ca* 0.3-0.4 mm long.(Fig. 12).

Fl & Fr: September-November.

Habitat: Open lateritic rocks or clayey soil with sufficient amount of soil.

Distribution: Endemic to South Western Maharashtra.(Fig. 30)

Note: The branching of *G.ratnagirica* is of peculiar type differing from all the species, 3 or 4 branches arising from a single node normally from 3rd or 4th node. All branches arising more or less at same level, and the inflorescence (racemes) are narrow as compared to all the species. It differs from G. divergens, *G. forficulata*, *G. hirsuta* and *G. mysorensis* in having smooth back of lower glume of sessile spikelet only with marginal fine tubercles and awn not very scabrous not spreading. Joint and pedicel fused, straight as in *G. forficulata*, *G. mysorensis* unlike *G. divergens*. (Table 4).

IUCN threat status: LC

Specimens Examined:

Maharashtra: Amboli, 10-9-1989, C B Salunkhe, 8703(SUH); Amboli, 10-09-1989, C B Salunkhe, 8701 & 8702(SUH); Ambolim, 09-11-1998, M A Fonseca, 1019(GUH); Surla, 07-11-2001, M A Fonseca, 1046(GUH); Surla, 07-11-2001, M A Fonseca, 1047 & 1048 (GUH).

Table 4: Comparison of morphological features in divergent awned species.

Characters	*G.forficulata*	*G.mysorensis*	*G.ratnagirica*	*G.divergens*
Lower glume of sessile Spikelet	Short(1mm) tubercles pointing upwards	Long (>1mm) tubercles pointing upwards	Back Smooth, tubercles absent	Pits present, tubercles absent
Lower glume Of sessile Spikelet Margin	Short marginal tubercles pointing upward	Long prominent tubercles pointing upward	Short tubercles pointing upward	Small Spines pointing upwards
Wing of lower glume	Large	Small	Small	Small
Joint & Pedicel	Fused, equal	Fused, unequal	Fused, equal	Fused, equal
Lower glume of Pedicelled Spikelet	Broad & big	Narrow & small	Narrow	Small

Fig 12: ***Glyphochloa ratnagirica*** (Kulk. & Hem.) Clayton
a) Habit; b) Spikelet; c) Pedicel; (d-i): Sessile spikelet; d) Lower glume; e) Upper glume; f) Lower lemma; g) Lower palea; h) Upper lemma; i) Upper palea; (j-p): Pedicel spikelet, j) Lower glume; k) Upper glume; l) Lower lemma; m) Lower palea; n) Upper lemma; o) Upper palea; p) Grain.

9. **Glyphochloa santapaui** (Jain & Deshpande) W. D. Clayton in Kew Bull. 35: 815. 1981; Kulkarni, Fl. Sindhudurg, 536. 1988; Nayar, Red data book of Ind. Plants 2: 185. 1988; Lakshminarasimhan in Sharma et al., Fl. Maharashtra, 502. 1996. *Manisuris santapaui* Jain & Deshpande in Bull. Bot. Surv. Ind. 10: 277. (1968)1969; Jain in Bull. Bot. Surv. India 12: 15. (1970)1972.

Type: Maharashtra state, Ratnagiri, Saldanha 15/09/1961 CS 7130A. (Holotype CAL).

An annual tufted herb, up to 30 cm high; culms erect or ascending, slender, cylindrical, ridged, 3 or 4 noded, glabrous, sparingly branched; branches terminating into racemes; nodes swollen, becoming constricted and dark on drying; internodes 3.5-5.5 cm long. Leaf sheath shorter than internode, upper spathaceous; ligule 1.5-2 mm long, ovate, entire or dentate (torned up) membranous, hyaline; leaf blade 5-11 x 0.15-0.3 cm, linear, acute, flat or conduplicate, usually 5-nerved. Peduncle 3-9 cm long, villous (hairy); racemes 4.5-6.5 cm long, solitary, thickly villous (white hairs), pale in colour, erect, compressed and fragile; joint and pedicel 2.5-3 mm long, fused to form a stout structure, like high heeled military boot, densely

villous on margins and tip, oblique with a concavity above. Spikelets paired, one sessile and hermaphrodite and other pedicelled and male (staminate), dissimilar in shape. Sessile spikelet: up to 11.5 mm (including the awn), 3.5-4.5 mm long (excluding the awn), with a small thick ciliate callus, compressed dorsally, oblong; florets two, lower neuter and upper hermaphrodite; lower glume 2.5-3 x 1.15 cm excluding wing, oblong-ovate, thinly coriaceous, flat on back, densely ciliate on the margins and back, winged on either side; wings equal / unequal, thinly membranous, hyaline; awn slender, flexuous or straight, antrorsely barbellate, 3.5-8 mm long; upper glume 2.75-3 x 1-2 mm, oblong, lanceolate, acute, boat shaped, keeled at tip, margins inflexed, membranous, faintly 3- nerved; lower lemma 2-3 x 1 mm, oblong- ovate, hyaline; palea 2.5-0.8 mm, lanceolate, subacute, hyaline, margin narrowly inflexed at base. Upper floret hermaphrodite; upper lemma 2.7-3 x 0.8 mm, oblong, hyaline; palea, *ca* 2.4 x 0.5 mm, lanceolate, subacute, margins inflexed, hyaline; lodicules 2, *ca* 0.5 mm long, cuneate, hyaline; styles 2, 1.5 - 2 mm, compressed, brown; stigma 1-1.5 cm long, plumose, purple. Pedicelled spikelet 4 - 5 mm long (including awn 10 mm long), oblong-ovate; lower florets empty, upper male (staminate); lower glume 2.5-3 x 1.5-2 mm long (including wing, excluding

awn), oblong-lanceolate, slightly oblique, coriaceous, 5-nerved, flat and glabrous on back, winged on one side; wing membranous, hyaline, up to the base; other margin produced into a slender, antrosely barbed, 5-6 mm long awn; upper glume 2 - 3 mm long (excluding awn), ovate-lanceolate, faintly nerved, keeled, boat shaped, margins unequal, keel with a broad wing; wing 2 - 4 x 2.5 - 3 mm, gradually narrowing at base, thinly membranous; lower lemma *ca* 3.1 x 0.7 mm, both margins inflexed, acute; lower palea 2.5-2.75 x 0.5 mm, hyaline, apical margins incurved; lodicules 2, small crenate; anthers 3, 2 mm long; upper lemma *ca* 3.1 x 1 mm with inflexed margins, lanceolate; upper palea *ca* 3 x 0.5 mm, one margin inflexed; anthers 3, 1.1 mm long.(Fig. 13).

Fl. & Fr.: August - October.

Habitat: Moist lateritic soil.

Distribution: Endemic to Ratnagiri and Sindhudurg districts of Maharasthra.

Notes: It is the only species with tuft of long white hairs at base of lower glume of sessile spikelets and is

restricted in its distribution to only Ratnagiri and Sindhudurg district of Maharasthra. It is similar to *Glyphochloa talbotii* and *Glyphochloa goaensis*. It was listed as Rare (Nayar 1988) but this status is not applicable according to new IUCN categories (2000). (Table 5)

IUCN threat status: LC

Specimens examined:

Maharashtra: Ratnagiri, 15-10-1961, C Saldhana SJ, C5/7130B-Isotype(BSI); Ratnagiri, 29-9-1991, S R Yadav, 8363(SUH); Pawas, 29-9-1991, C B Salunke, 8580(SUH); Devgad, 4-10-1992, S R Yadav, 8363(SUH); Malwan, 3-10-1993, C B Salunke, 8722(SUH); Kasarde, Sawantwadi, 20-09-1999, M A Fonseca, 1027(GUH); Ratnagiri, 20-09-1999, M A Fonseca, 1028(GUH).

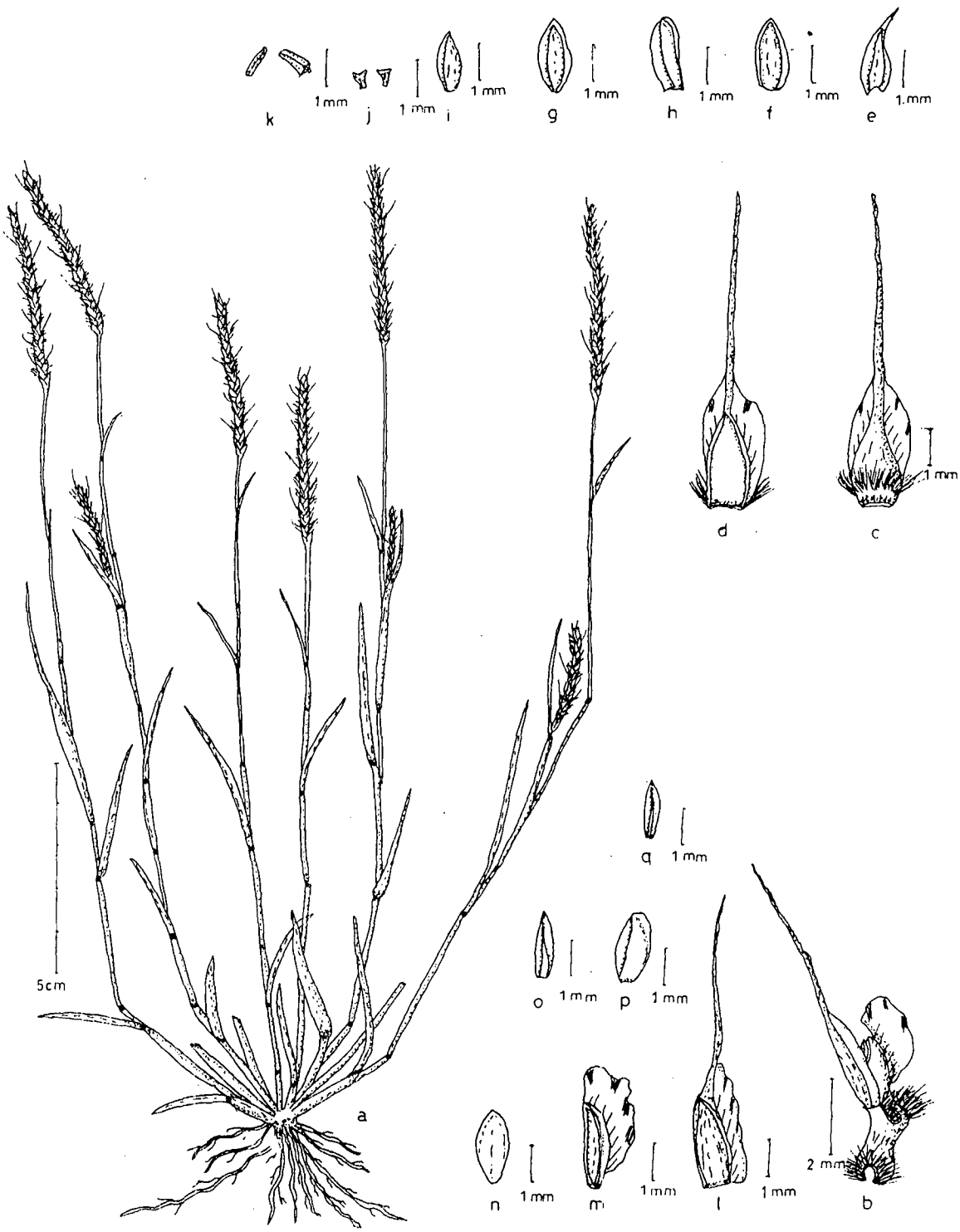


Fig 13: ***Glyphochloa santapaui*** (Jain & Desh.) Clayton
a) Habit; b) Spikelet; (c-k): Sessile spikelet, c) Lower glume (adaxial view); d) Lower glume (abaxial view); e) Upper glume; f) Lower lemma; g) Lower palea; h) Upper lemma; i) Upper palea; j) Lodicules; k) Stamens; (l-q): Pedicel spikelet, l) Lower glume; m) Upper glume; n) Lower lemma; o) Lower palea; p) Upper lemma; q) Upper palea.

10. Glyphochloa talbotii (Hook.f.) W. D. Clayton in Kew Bull. 35: 816. 1981; Nayar, Red data book of Ind. Plants 1: 302. 1989; Lakshminarasimhan in Sharma et al., Fl. Maharashtra, 503. 1996. *Rottboellia talbotii* Hook.f. Fl. Brit. India 7: 155. 1896; Cooke, Fl. Bombay 3: 471. 1958 (repr.ed.). *Manisuris talbotii* (Hook.f.) Bor, Grass. Burm. Ceyl. Ind. & Pak. 192. 1960; Jain in Bull. Bot. Surv. India12: 16 (1970) 1972; Rao, Fl. Goa 507. 1986; Almeida, Fl. Savantwadi 148. 1990. *Peltophorus talbotii* (Hook.f.) A.Camus in Bull. Mus. Hist. Nat. Paris 27: 371. 1921; Blatter & Mc Cann, Bombay grass. 35. 1935.

Type: Goa, Talbot 2572 (holotype CAL).

An annual tufted herb, up to 30 cm high, branching at base, spreading to solitary; culms prostrate to erect, cylindrical, ridged, 3 or 4 -noded branches terminating in solitary racemes; nodes swollen, constricted on drying, brownish to reddish when fresh; internodes 2-5 cm long. Leaf sheath 2-4 cm long, covering 3/4th or the entire internode, keeled on either sides; ligule *ca* 2 cm, entire or torned up, with a fringe of hairs, hyaline; leaf blade *ca* 11 x 0.5 cm, glabrous, lanceolate, conduplicate, sparsely villous. Peduncle cylindrical, ridged, narrow,

hairs very few or absent; racemes 3-4 cm long, compressed, terminal, very fragile; joint and pedicel *ca* 2.5 x 2 mm, tumid, stout. Sessile spikelet: lower floret staminate, upper floret hermaphrodite; lower glume (along with awn) 1.3-1.6 cm long, transverse ridge on back one, two or three, overlapping, pointing upward or rarely absent, winged on either side, sometimes wing on one side larger, *ca* 1 mm broad; upper glume *ca* 3 x 1 mm, 3-nerved, boat shaped; lower lemma *ca* 2 x 1 mm, 3-nerved, margin incurved; palea *ca* 1.7 x 0.7 mm, either side incurved, hyaline; anthers 3, 0.4 mm long, upper lemma *ca* 2.5 x 1 mm, margins keeled, slightly greenish at apex or incurved, 3-nerved, hyaline; upper palea *ca* 2.1 x 0.6 mm, margins on either side incurved; anthers 3, 1-1.2 mm long; lodicules 2, *ca* 0.4 x 0.4 mm; Stigma feathery (plumose), 2 mm long. Grain *ca* 1.1 x 0.6 mm, oblongoid. Pedicelled spikelet: lower floret staminate or empty, upper floret staminate; lower glume 1-1.5 mm long, 3-4 nerved, winged on one side; upper glume *ca* 3 x 1.5 mm (along with awn), boat shaped, keeled with a wing on back at the apical $1/4^{th}$ portion, wing *ca* 0.6 mm long, awn small; lower lemma *ca* 3 x 1 mm, margins incurved, keeled, boat shaped; lower palea 3, *ca* 1 mm long, one margin incurved, hyaline; stamens 0.5 mm; upper lemma

ca 2.5 x 1 mm, one margin incurved; upper palea *ca* 3 x 0.6 mm, margin incurved, stamens 1-1.2mm long.(Fig. 14)

Fl. & Fr. : August-November.

Habitat: open hard lateritic rocks with thin crust of soil.

Distribution: Endemic to Goa and Maharasthra. (Fig. 29)

Notes: Inflorescence thick and stout, lower glume of sessile spikelet showing variation in glume, back of glume without or with 1/2, 1, 2 and 3 ridges, all pointing upwards. Pedicel and joint stout and boot like. More closely related to *Glyphochloa goaensis* and *Glyphochloa santapaui*. (Table 9).

IUCN threat status: LC

Specimens Examined:

Goa: Marmagao, 15-10-1891, R S Rao, Acc. No. 1433-Isotype (BSI); Aronda, 4-9-1994, C B Salunkhe, 8632(SUH); Bambolim, 17-08-1997, M A Fonseca, 1003(GUH); Goa University Campus, 17-08-1997, M A Fonseca, 1004(GUH); Bambolim, 21-08-1997, M

A Fonseca, 1005(GUH); Bambolim, 03-09-1997, M A Fonseca, 1008(GUH); Goa University Campus, 09-09-1997, M A Fonseca, 1011(GUH); Goa University Campus, 09-09-1997, M A Fonseca, 1012(GUH); Bambolim, 02-10-1999, M A Fonseca, 1016(GUH).

Maharashtra: No collection from Maharashtra distribution based on S M Almeida (1990).

Table 5: Morphological differences between *G.talbotii* and related species.

Characters	***G.talbotii***	***G.goaensis***	***G.santapaui***
Lower glume of sessile Spikelet	Horizontal ridges 0,1/2,1-3 pointing upwards	Horizontal ridges 0,1-3 pointing downwards	No horizontal or vertical ridges
Tufts of hairs at base of glume	Absent	Absent	Present
Marginal Tubercles on lower glume of sessile spikelet	Absent	Often present	Absent
Lower glume of pedicelled Spikelet	Median keeled with a small awn	Median keeled, awnless	Median keeled, awnless with undulate wings
Joint & Pedicel	Stout, boot-like	Narrow at centre, base & apex broad	High heeled military boot

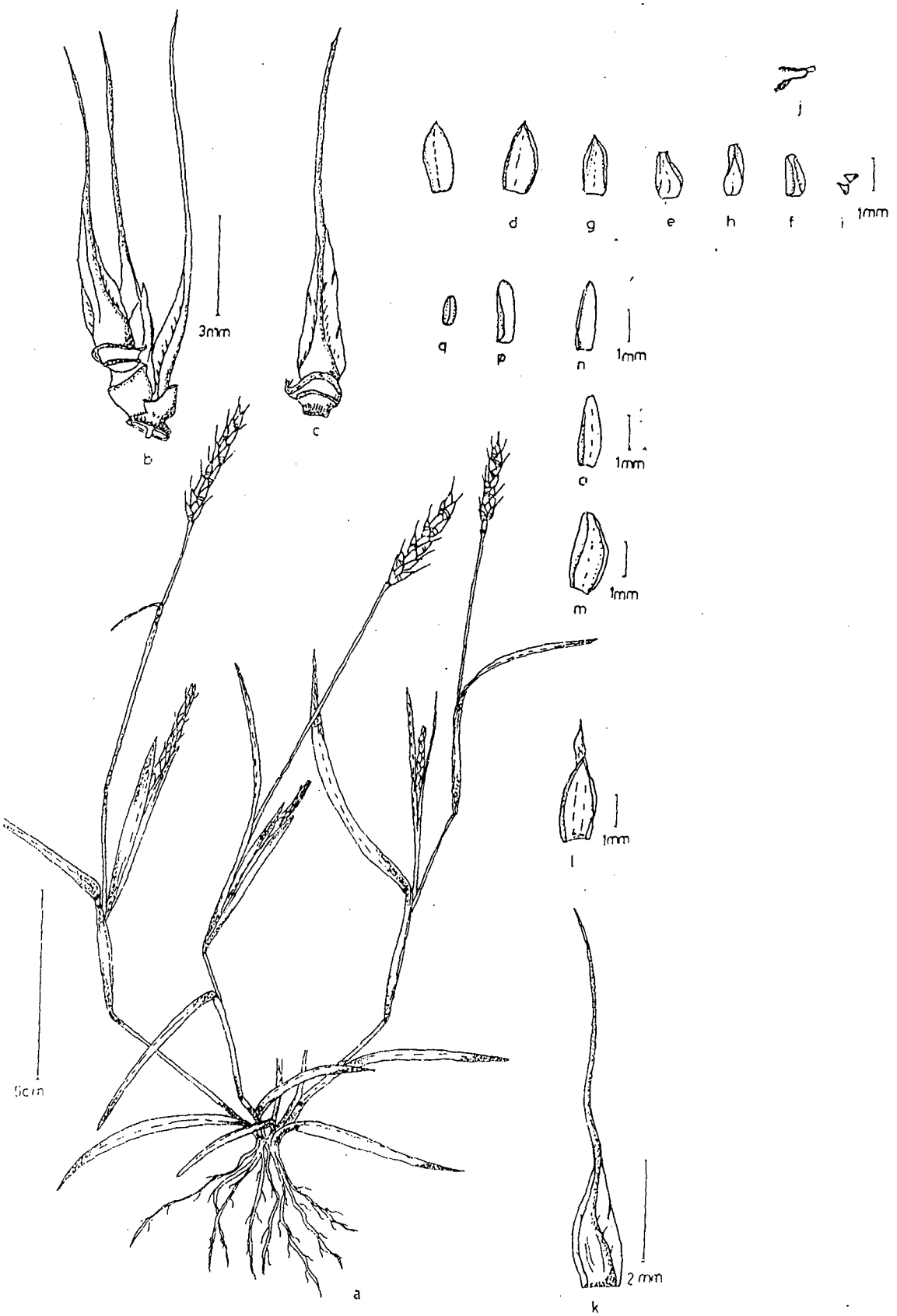


Fig 14: ***Glyphochloa talbotii*** (Hook. f.) Clayton

a) Habit; b) Spikelets; (c-j): Sessile spikelet; c) Lower glume; d) Upper glume, i-adaxial view, ii-abaxial view; e) Lower lemma; f) Lower palea; g) Upper lemma; h) Upper palea; i) Lodicules; j) Pistil; (k-q): Pedicel spikelet; k) Lower glume; l) Upper glume; m) Lower lemma; n) Lower palea; o) Upper lemma; p) Upper palea; q) Stamens.

11. Glyphochloa veldkampii M.A. Fonseca et M. K. Janarthanam, sp. nov.

Glyphochloa talbotii et G. henryi similis, a priori collo unico prominenti pileato in spiculae sessilis gluma inferiore, articulis subtumidis, spiculae pedicellatae gluma inferiore ala longa, a posteriori collo unico pileato prominenti in spiculae sessilis gluma inferiore differt.

Type: India, Goa, Kasauli, along the Panaji-Belgaum highway (NH 4A) in the outskirts of the Mollem Wildlife Sanctuary, 15°21`30.9``N & 74°11`37.1`` E, c. 85 m, 21 October 2001, *Janarthanam* & *Fonseca* 1901 (Holo- CAL; Iso- BSI, MH).

An annual tufted herb, up to 50 cm high; culms erect to geniculate at base, branching at the 3rd and 4th node, channeled, ridged, 4 or 5-noded; nodes swollen, constricted on drying, yellowish to faintly pink when fresh and brown on drying; internodes 1-11 cm long. Leaf sheath 1.5-5.5 cm long, covering often up to 1/2 potion of the internode; ligule membranous with fringe of hairs, *ca* 1.5 cm long; leaf blade linear, up to 12 x 0.9 cm, truncate at base, 5-9 nerved, glabrous. Racemes solitary, 4.5-7 cm long, *ca* 5 mm wide; peduncle 6-4 cm long, distally gradually enlarging,

whorled ciliate at the junction of raceme and peduncle. Joints and pedicels fused, subtumid, 2.5-3 mm long, apex *ca* 2 mm broad, edge ciliate. Sessile spikelet: lower glume *ca* 1.5 cm (including awn) long, with a single transverse collar (at base) and 9 or 10 faint vertical furrows at base; collar pointing upward, cap-like, erect-patent with a gap between the body of the glume and the collar, entire or broken at one place, ciliate on the lateral edge, rarely with two lateral hooks; upper glume *ca* 3x 0.75 mm, hyaline, 3-nerved, elliptic-oblong, margins incurved at apex; stamens 3, anthers *ca* 0.6 mm long. Upper lemma *ca* 2 x 1 mm, ovate, apex, acute; palea *ca* 1.75 x 0.75 mm; lodicules *ca* 0.5 mm long, triangular, hyaline; anthers 1.2-1.5 mm long; ovary obovate, stigma *ca* 2 mm long, feathery at apex. Pedicelled spikelet: Pedicel *ca* 2.5 mm long. Lower glume *ca* 1.2 x 0.2 cm (including awn without pedicel), winged on one side; upper glume *ca* 5 x 2 mm, strongly keeled, boat-shaped, margins unequal, dorsally winged, wing *ca* 2 mm long, broad at apex with waxy margin, hyaline; florets 2, staminate; lower lemma *ca* 2.5 x 1 mm, margin incurved at apex, hyaline; lower palea *ca* 2 x 1 mm, lanceolate, margins incurved, hyaline; Upper lemma *ca* 2.5 x 1 mm, lanceolate, margins incurved, upper palea *ca* 2 x 1 mm, oblong, hyaline; anthers *ca* 1.5 mm long. (Fig. 15 a)

Note: Similar to *G. talbotii* (Hook.f.) Bor and *G. Henryi* Janarth., et al. but differs from the first in having a prominent single transverse cap-like collar on the lower glume of the sessile spikelet, sub-tumid joints and the long wing on the lower glume of the pedicelled spikelet, and differs from the later by its prominent single transverse cap-like collar on the lower glume of the sessile spikelet.(Fig. 15b & Table 6)

Table 6: Comparison between *G. veldkampii* sp. nov. and related species.

Characters	*G. talbotii*	*G. veldkampii*	*G. henryi*
Habit	12-25 cm high	25-50 cm high	25-90 cm high
Internode	0.5-5 cm long	1-11 cm long	1-10 cm long
Joints and Pedicel	Fused to form a tumid stout structure	Fused to form a sub-tumid Structure	Fused to form a long, straight structure
Lower glume Of sessile Spikelet	With ½,1,2,or 3 Transverse Overlapping Collars pointing upward	With a single cap-like transverse erecto-patent collar	With a broad transverse ridge at base turning upwards along the margin
Wing of upper Glume of Pedicelled Spikelet	ca. 0.5 mm long from apex	ca. 2 mm long from apex	ca. 2 mm long from apex

Habitat: 'Lateritic rocks in open areas at the periphery of the moist deciduous forest, at an altitude of 85 m.

Etymology: The new species is named after Dr. J F Veldkamp, The Netherlands for his contribution towards agrostology.

Note: The species is so far known only from the type material. Now it is observed that the hard lateritic rocks of type locality has been covered with soil to 1 m high probably for afforestation. Efforts should be made to locate the species in adjacent areas.

IUCN threat status: EN C2a(i)D

Fig 15: ***Glyphochloa velu'kampii*** M. A. Fonseca
a) Habit; (b-k): Sessile spikelet; b) Lower glume (adaxial view); c) Lower glume (abaxial view); d) Upper glume; e) Lower lemma; f) Lower palea; g) Upper lemma; h) Upper palea; i) Lodicules; j) Stamens; k) Pistil; (l-t): Pedicelled spikelet; l)Pedicel spikelet with joint; m) Lower glume with pedicel; n) Upper glume; o) Lower lemma; p) Lower palea; q) Upper lemma; r) Upper palea; s) Lodicules; t) Stamens.

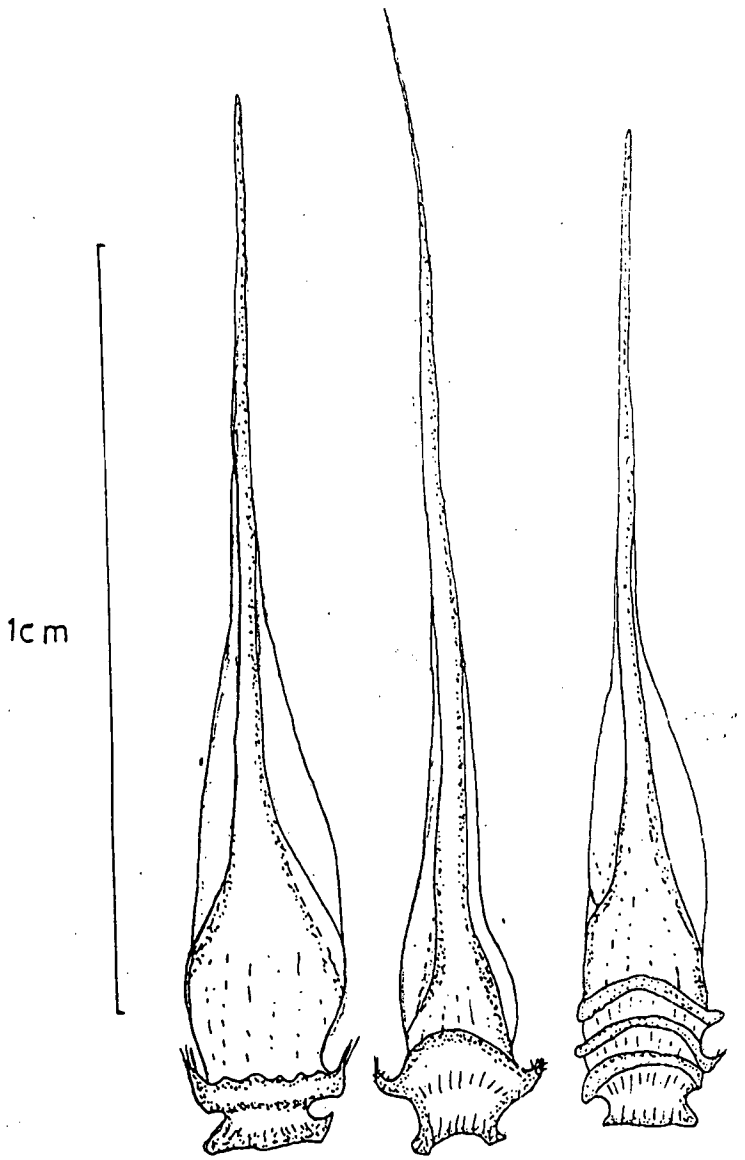


Fig. 15.1: Distinct lower glumes of sessile spikelets of related species:

(B) GENERAL ANATOMY

The anatomy of root, culm, and leaf have been studied in relation to their taxonomy and ecology.

Root:

All the *Glyphochloa* species show similar anatomical features in root transverse section without significant differences among them. The root is externally bounded by a piliferous layer bearing root hairs and this layer may become thickened or may become detached due to drying up and withering. Hypodermis in *Glyphochloa* species is generally composed of one or two layers of thick walled cells and in rare cases another layer of thin walled cells is also seen as in *G. acuminata* var. *stocksii*. Thick walled hypodermis is also a feature seen in *Andropogon* and *sorghum* as pointed by Achariya (1921). Cortex consist of parenchymatous cells with intercellular spaces. As the girth increases these develop into radiating plates of cells with large intercellular cavities between them. The number of cortical layers varies from 4-5 in most of the species or more than 5 layers as in *G. goaensis*. Some cells in contact with endodermis are conspicuous due to their fibrous thickening in their inner tangential and radial end

walls. Metaxylem is conspicuous in the stele which is surrounded by endodermis as seen in most of the grasses. According to Metcalfe (1960) the endodermal cells may show passage cells in few grasses not prominent in *Glyphochloa*. The number of vessels in metaxylem varies with the diameter of the root. The protoxylem vessels are much smaller in diameter than the metaxylem and alternate with small strands of phloem in all species of *Glyphochloa* (which is inconspicuous). The ground tissue of the stele consist of thin walled pith, which become thick walled in older roots. Pericyle is not conspicuous. The stele in *Manisuris*, a related genus is large and fibrous as compared to *Glyphochloa*.

Culm:

Culm is usually solid or become loose and spongy without actually breaking down to become hollow in the central ground tissue. It is completely solid at the node (solid nature helps to withstand bending stress). Sheathing leaf bases protect the portion of the culm that are in most need of mechanical support.

Component tissue of the culm:

Transverse section of the culm is made essentially of parenchymatous ground tissue, some of which contains chloroplasts and serves for photosynthesis while the mechanical support is provided by fibers and other cells with thickened walls.

Mechanical tissue:

Ring of sclerenchymatous cells are present below the chlorenchymatous region or below the epidermis. The species of *Glyphochloa* show 2 to 4 layered, thickened hypodermal cells. Single awned species with 2 layered & two awned with 3-4 layered cells. They provide support in resisting the stresses and strains to which the culm is subjected (Metcalfe l.c.). The inner ground tissue consists of large thin walled parenchymatous cells with intercellular spaces and these occupy the centre of the culm. The central ground tissue is loose and spongy in all the species of *Glyphochloa* as in *Miscanthus condensalus* (Metcalfe l.c.) where the cells do not break down completely to become a hollow.

Chlorenchyma:

Culms of grasses are usually green owing to the presence of chlorenchyma. Chlorenchyma is in the form of continuous or discontinuous cylinders sub adjacent to the epidermis or the cylinder may be traversed at intervals by sclerenchyma of the next region extending up to the epidermis. Chlorenchyma cells are arranged in a single row, radially around the small vascular bundles in all the species of *Glyphochloa* as noted by Metcalfe (l.c.) in panicoid grasses, a character frequently seen in leaf (Characteristic Kranz anatomy, Plates 1-8). The bundle sheath cells contain chloroplast as seen in the leaf.

Vascular bundles:

Vascular bundles are scattered but spaced towards the center than towards the periphery of the culm. Vascular bundles towards the center of the culm are much larger than those that are next to the epidermis. The outermost vascular bundles are embedded in the peripheral sclerenchyma. The individual vascular bundles are circular, angular, or 7-9 sided. The bundles are collateral with the phloem at the pole of the bundle towards the periphery of the culm, where it is usually embedded in a fibrous tissue. In small vascular bundles the metaxylem vessels are neither

conspicuously larger in diameter nor properly developed. In most of the other larger vascular bundles the metaxylem is usually characterized by two (or occasionally more) vessels with greater diameter. The protoxylem lying at the opposite pole of the bundle usually has a solitary vessel or a short radial row of vessels with lesser diameter than other vessels. The protoxylem elements usually breakdown and are usually replaced by longitudinal intercellular cavities (lacunae). Phloem lies between the metaxylem elements. Vascular bundles are similar in most of the grasses and all the species of *Glyphochloa*.

It is seen that the sclerenchyma cells (hypodermal) are 3 or 4-layered in all the species of *Glyphochloa* with single awn as compared to those of two awned species of *Glyphochloa* wherein it is 2-layered. Probably these extra layers protect single awned species from mechanical stress as they grow up to 50 cm high. The culm of the related genera growing in the drier region show many layered, thickened hypodermis in the outer region with small amount of mesophyll & bundles rarely with Kranz anatomy as seen in *Glyphochloa*.

Surface ribs & grooves:

All the species of *Glyphochloa* and its related genera show the presence of shallow ridges and furrows which increase in number from base to apex of the culm. There is usually one prominent curvature only on one side.

Leaf:

In grasses midrib may be prominent or not, and the midrib is seen from the abaxial than from the adaxial surface forming keel. Midrib is usually not very distinct in single awned species of *Glyphochloa* but prominent and U or V shaped or flattened in two awned species as in *G. mysorensis* and *G. forficulata* (Plate 2&5). The vascular bundles are well supported by sclerenchymatous patches and the two halves of the lamina are more or less symmetrical on either side of the midrib.

Epidermal Cells are barrel shaped in all the species of *Glyphochloa*, few cells may be inflated as in *G. henryi* and rarely in *G. acuminata* var. *acuminata*, cells arranged end to end interrupted by stomata at few places, lined by cuticle of about 2.3-5.06 μm thickness.

Mesophyll - Ground tissue is seen between the adaxial and abaxial epidermis and is made up of chlorenchymatous cells radiating around small and large vascular bundles.

Vascular bundles:

Vascular bundles are generally arranged in a single row and embedded more or less in the middle of the mesophyll, more closer to the abaxial (lower) surface. They are in an arc as observed by Metcalfe (l.c.) in *Saccharum bengalense* and *Euchlaena perennis* or they correspond to the shape of the leaf in transverse section. Vascular bundles are of different sizes and different orders, the biggest being the midrib bundle. The individual vascular bundles are more or less circular or elliptical in outline or angular specially the smaller vascular bundles.

Bundle Sheaths:

Nearly every vascular bundle is surrounded either completely or partly by one bundle sheath, consisting of a single layer of cells. It consists of parenchymatous cells with thin or slightly thickened walls. The transverse section shows that the cells are inflated and conspicuous (sheath cells more inflated in pancoid grasses), contain chlorophyll, the granules are of larger size and darker in

colour. Chloroplast is centripetal or centrifugal in arrangement. *Glyphochloa* is C4 grass with NADP-ME sub type (Dayanandan 1983). Single layered bundle sheath as seen in *Glyphochloa* is characteristic of panicoid grasses (Metcalfe l.c.).

Sclerenchyma:

Support is provided by fibrous and other types of thick walled cells that collectively constitute the sclerenchyma. It is in the form of subepidermal longitudinal strands or girders which follow the course of vascular bundles. Sclerenchyma are seen as small patches along with vascular bundles called as strands. They may also go deeper linking or connecting the vascular bundle with the epidermis on one or on both the adaxial and abaxial epidermis to form girders. In *Glyphochloa* the species with single awn normally show sclerenchyma strands following the course of both small and big vascular bundles while in two awned species the sclerenchyma strands as well as girders are seen at constriction of the leaf on either side (for additional support) Plate 2,5&6. According to Metcalfe (l.c.) grasses from dry or arid localities show well developed sclerenchyma e.g *Arundo donax* where the bundles are accompanied by wide adaxial and abaxial girders of

sclerenchyma (Metcalfe l.c.). The present observations show that though *Glyphochloa* species grow during monsoons, they developed these adaptation to the harsh waterless rocky habitats which provides temporary dryness during monsoonal gaps.

Bulliform and colourless cells:

Transverse section of the lamina always show certain cells that are translucent and colourless. They form part of the epidermis, cells are larger and more inflated and occur on the adaxial surface of the leaf. They form a band of parallel long cells parallel with the long axis of the leaf and are arranged regularly in single awned species of *Glyphochloa* or irregularly as in divergent awned species. They were considered as hinge cells or motor cells and believed to help in inflation and deflation due to changes of turgor, and in rolling or folding of the leaves in which they occur. Though their property is not fully understood, in *Glyphochloa* they appear to function as water storage tissue, and this feature is characteristic of *Glyphochloa* species along with *Ophiuros bombaiensis* which grows in a similar habitat and shows a similar structure. Some more colourless and translucent cells that occur in the mesophyll of some grass leaves are also occasionally seen

in *G. acuminata* var. *acuminata, G. henryi, G. veldkampii, G. acuminata* var. *stocksii etc.*

Epidermis in surface view:

The lamina is divided into longitudinal zones or strips in surface view which distinguishes the intercostal zones (between the veins) from the costal zones.

Orientation of cells:

Horizontal zones or files of cells lie parallel to the long axis of the leaf. The long cells are elongated horizontally (parallel to the long axis of the leaf) and relatively narrow. The short cells occur in horizontal rows either solitary or in pairs. The short cells in the costal and intercostal zones are usually differently arranged and distributed. Short cells are generally classified into silica-cells, when each of them is more or less completely filled with a single silica-body, or cork cells when their cell walls give the reactions of cork Metcalfe (l.c.). Cork cells are commonly silicified more as compared to silica cells. The silica bodies in the silica cells assume very characteristic forms such as, dumb-bell shaped (abundant), tall, narrow and crenate-horizontal (infrequent), crenate vertical, and cross shaped (common).

Costal region shows dumb - bell shaped (abundant), crenate -horizontal (infrequent), and cross shaped (common) silica cells. The intercostal region shows dumb - bell shaped, cross shaped and crenate vertical between the long cells. The long cells vary in length in the costal region. They are long and narrow or short and broad in the intercostal region and both show sinuous walls. Stomata are confined to the intercostal zones, in horizontal bands. The guard cells are dumb-bell shaped and over lapping, while the subsidiary cells are triangular, a characteristic of panicoid leaf, sometimes dome shape subsidiaries are seen in few species. Inter-stomatal cells are those that lie in the same horizontal longitudinal files as stomata and serve to separate the individual stomata in an individual file from one another, the end walls of these are concave where they fit round the stomata.

In *Glyphochloa* the dermal appendages may conveniently be classified as (a) Macro-hairs and (b) Micro-hairs.

Macro-hairs:

Macro-hairs have been so designated because they are nearly always much longer than the micro-hairs. Very often they form an indumentum on a grass leaf which can easily be seen

with the naked eye or simple hand lens. Macro-hairs are unicellular, they vary in length from 700-750 μm, the basal portion is swollen and constricted and has tapering end. The bases of the hair are sunken and surrounded by epidermal cells that are more inflated and raised above the epidermis (leaf surface). They are also referred to as cushion hairs and they occur in inter-costal region. They are seen in *G. forficulata, G. mysorensis, G. ratnagirica & G. divergens* (Plate 2).

Micro-hairs:

They are generally much smaller than macro-hairs and are commonly two-celled. They are found in all the species of *Glyphochloa*. They are very often not very distinct or absent in section because the distal cell is very thin-walled and, is easily damaged and hence commonly missing. They do not take up the stains very readily either. It is being suggested that the hairs serve for the secretion of some undetermined substances (Metcalfe l.c.). Micro-hairs commonly occur either in the stomatal bands or in the interstomatal region near the ends of the cells (Plate 9).

The contribution of taxonomy in general and grass taxonomy is enormous Renvoize (1982) surveyed the leaf

blade anatomy in Andropogoneae and showed its taxonomic significance. Peterson (1989) showed its importance within the genus *Muhlenbergia*. The shape and anatomy of the basal leaves was used to distinguish ecotypes in *Poa pratensis* L.and *Poa angustifolia* L.(Papp 1999). The present study shows that in *Glyphochloa* the leaf anatomical details can be very well used for distinguishing not only species but also varieties.

KEY BASED ON ANATOMY

1. Leaf in transverse section constricted (always):

    2. Leaf sheath with lateral cavities in transverse section:

        3. Midrib prominent, 'U' shaped in leaf transverse section . . ***G. mysorensis***

        3. Midrib prominent, 'V' shaped in leaf transverse Section . ***G. forficulata***

    2. Leaf sheath without lateral cavities in transverse section:

        4. Silica cells present in the inter-costal region of leaf peeling . . . . . ***G. divergens***

        4. Silica and cork cells present in the inter-costal region of leaf peeling . . . . . ***G.ratnagirica***

1. Leaf in transverse section not constricted or rarely constricted:

    5. Lateral main veins in transverse Section shifted upwards:

        6. Epidermal cells in leaf inflated at few places . . . ***G. henryi***

        6. Epidermal cells in leaf not inflated . . . . ***G. veldkampii***

    5. Lateral main veins in transverse section not shifted upwards:

7. Lateral region in leaf sheath with cavities:

8. Leaf midrib distinct as compared to the rest of the lamina:

9. Mesophyll in midrib present;cortex in root five to six layered; endodermis in root with thin fibrous bands . . . ***G. acuminata*** var.***acuminata***

9. Mesophyll in midrib Region present or absent; cortex in root four or five layered;endodermis in root thickly fibrou. .***G. acuminata*** var.***woodrowii***

8. Leaf Midrib not distinct as Compared to the rest of the lamina:

10. Colourless mesophyll in midrib region absent . . . ***G. santapaui***

10. Colourless mesophyll in midrib region present . . . ***G.acuminata*** var. ***stocksii***

7. Lateral region in leaf sheath without cavities:

11. Mesophyll in leaf absent; root cortex more than 5 layered . . . . . .***G. goaensis***

11. Mesophyll in leaf rarely present; cortex in root four or five layered . . . . . ***G. talboti***

* ***G.hirsuta*** **is not included due to want of fresh materials.**

1(a) Glyphochloa acuminata (Hack.) Clayton var. ***acuminata***

T.S of root:

Piliferous layer single, thick walled, cells hexagonal; exodermis 1-2 layered, cells thick walled; cortex 5-6 layered, thin, circular, in radial rows, disintegrating to form radial plates; stele large, endodermis single layered, cells rectangular with fibrous bands on inner and radial walls occuping ¼-½ part of the cell; pericycle single layered, not prominent; metaxylem with 8 to 9 large vessels; protoxylem with few smaller vessels, phloem not prominent; pith with thin or thick walled rounded cells depending on the age (Plate 1G).

T.S. of Culm:

Circular to ovate in outline, with a curvature on one side and small ridges and furrows on all sides; epidermis single layered, cells rounded to rectangular, interrupted by sunken stomata at few places; cuticle thick *ca* 3.79 µm; macro-hairs absent; vascular bundles in the outer region small, with Kranz anatomy, bundle sheath cells 4-6 in number; hypodermis 3-4 layered, sclerenchymatous, embedding number of large vascular bundles beginning at furrow; cortex parenchymatous, thin walled, cells hexagonal to

circular in shape, with intercellular spaces; central region with larger and loosely arranged cells; vascular bundles 7-8 sided, scattered towards the periphery in cortex, with prominent metaxylem and few protoxylem (2-3) elements with lacunae; phloem forming a prominent patch between the metaxylem elements.

T. S. of Leaf:

Leaf succulent, 5-veined, leaf transverse section crescent shaped in outline, rarely constricted; midrib prominent, 'U' shaped; water tissue or bulliform cells on adaxial part, regular, covering ½-¾th portion of the leaf, cells rectangular, colourless with rounded ends (in surface view compactly arranged and hexagonal), each up to 105 x 45 μm; mesophyll cells colourless, 1-4 layered along the midrib, absent in lateral lamina, hexagonal to rounded; vascular bundles arranged in the form of an arc towards abaxial side, lateral main bundles rarely shifted upwards; girders or strands present below the large bundles and few small bundles, each with Kranz anatomy, bundle sheath cells in small vascular bundles rounded, 4-6 in number. Lower epidermis (abaxial surface) with barrel to circular shaped cells and at few places with inflated cells; cuticle of abaxial surface *ca* 5.06 μm, stomata sunken; macro-hairs

absent; micro-hairs up to 38 x 13 μm, two celled. (Plate 1A)

Leaf Sheath:

Adaxial epidermis single layered, cells barrel to rectangular shaped, bulbous in the median region; cuticle *ca* 3.23 μm thick, interrupted by sunken stomata at few places; mesophyll in median region, 4-5 layered, cells hexagonal to circular, compactly arranged; vascular bundles as in lamina; central region solid, lateral part with loose cells, some cells in the median region near the epidermis becomes thicker; abaxial epidermis single layered, cells elongated to barrel shaped (bigger in the median region), lined by cuticle; keel single layered.

Leaf Peeling:

Costal/intercostal zonation conspicuous. Papillae absent. Costal long cells long and narrow, up to 152 x 8 μm; intercostal long cells 75-182 x 30-3 μm, cells rectangular with conspicuous, sinuous walls with rounded ends, short cells with cork/silica pairs, silica bodies cross, dumb-bell to crenate-vertical shaped; stomata common 46-25 μm; subsidaries slightly dome shaped to triangular, guard cells

overlapping to flash with the interstomatals; interstomatal cells rectangular with sinuous wall and concave ends; prickles and macro-hairs absent, costal cells conspicuous in long, single rows in silica/cork pairs, alternating with each other (dumb-bell, cross and nodular to crenate). Micro-hairs present, 33-38 x 13 μm, two celled.

Note: *G. acuminata* var. *acuminata* differs from *G. acuminata* var. *stocksii* & *G. acuminata* var. *woodrowii* in its anatomy as shown in the table 7.

1(b). *G. acuminata* (Hack.) Clayton var. ***stocksii*** (Hook. f.) Clayton

T.S of root:

Piliferous layer single, slightly thick walled, cells hexagonal; exodermis 3-layered, with thick walled cells 2-layered and thin walled cells 1-layered; cortex 4-5 layered, thin, circular, in radial rows, disintegrating to form radial plates; stele large; endodermis single layered, with thickened inner walls (¼-½ portion of cell); pericycle single layered, not prominent; metaxylem with 8-9 large vessels; protoxylem with few smaller vessels, phloem in few patches, not prominent; pith with thin or thick walled rounded cells depending on the age.

T.S. of Culm:

Circular to ovate in outline, with a curvature on one side and small ridges and furrows on all sides; epidermis single layered, cells rounded to rectangular, interrupted by sunken stomata at few places; cuticle *ca* 5.06 µm thick; macro-hairs absent; vascular bundles in the outer region small, with Kranz anatomy, bundle sheath cells 4-6 in number; hypodermis 3-4 layered, sclerenchymatous, embedding number of large vascular bundles beginning at furrow;

cortex parenchymatous, thin walled, cells hexagonal to circular in shape, with intercellular spaces; central region with larger and loosely arranged cells; vascular bundles 7-8 sided, scattered towards the periphery in cortex, with prominent metaxylem and few protoxylem (2-3) elements with lacunae; phloem forming a prominent patch between the metaxylem elements (Plate 1C).

T. S. of leaf:

Leaf succulent, 5-veined, leaf transverse section crescent shaped in outline, not constricted; midrib not very prominent; water tissue or bulliform cells on adaxial part, regular, covering ½-¾th portion of the leaf, cells rectangular, colourless with rounded ends (in surface view compactly arranged and hexagonal), up to 189.25 x 126.50 μm; mesophyll cells colourless, 1-2 layered along the midrib, absent in lateral lamina, hexagonal to rounded; vascular bundles arranged in the form of an arc towards abaxial side; girders or strands present below the large bundles and few small bundles, each with Kranz anatomy, bundle sheath cells in small vascular bundles rounded, 4-6 in number. Lower epidermis (abaxial surface) with barrel to circular shaped cells; cuticle of abaxial surface 3.79-5.06

μm, stomata sunken; macro-hairs absent; micro-hairs up to 38 x 10 μm, two celled.

Leaf Sheath:

Adaxial epidermis single layered, cells barrel to rectangular shaped, bulbous in the median region; cuticle *ca* 5.06 μm thick, interrupted by sunken stomata at few places; mesophyll in median region 4-5 layered, cells hexagonal to circular, compactly arranged; vascular bundles as in lamina; central region solid, lateral lamina with loose cells; some cells in the median region near the epidermis becomes thicker; abaxial epidermis single layered, cells elongated to barrel shaped (bigger in the median region), lined by cuticle (*ca* 3.25 μm), keel single layered (Plate 1B).

Leaf Peeling:

Costal/intercostal zonation conspicuous. Papillae absent. Costal long cells long and narrow, up to 182 x 30 μm; intercostal long cells shorter, 75-164 x 38 μm, cells rectangular, sinuous with rounded ends; short cells with cork/silica pairs; silica bodies cross, dumb-bell to crenate-vertical shaped; stomata common *ca* 47 x 29 μm;

subsidiaries triangular, guard cells overlapping to flash with the interstomatals. Interstomatal cells rectangular with sinuous wall and concave ends; prickles and macro-hairs absent, costal cells conspicuous in long single rows in silica/cork pairs, alternating with each other, sometimes 2 cork cells alternating with 2 silica cells, silica bodies panicoid type dumb-bell, cross and nodular to crenate shaped. Micro-hairs small and elongated, *ca* 37.95 x 10.12 µm, two celled.

Note: *G.acuminata* var. *stocksii* can be differentiated anatomically from its varieties *G. acuminata* var. *acuminata* and *G. acuminata* var. *woodrowii* as seen in table 7.

1(c). ***G. acuminata*** (Hack.) Clayton var. **woodrowii** (Bor) Clayton

T.S of root:

Piliferous layer two layered, thick walled, cells hexagonal; exodermis 1-2 layered, thick walled cells rarely seen; cortex 4-5 layered, thin, circular, in radial rows disintegrating to form radial plates; stele large, endodermis single layered, cells showing fibrous bands occupying ¾th to whole cell; pericycle single layered, not prominent; metaxylem with 6-14 large vessels; protoxylem not prominent; phloem not prominent; pith with thin or thick walled rounded cells depending on the age.

T.S. of Culm:

Circular to ovate in outline, with a curvature on one side and small ridges and furrows on all sides; epidermis single layered, cells rounded to rectangular, interrupted by sunken stomata at few places; cuticle *ca* 3.79 µm thick; macro-hairs absent; vascular bundles in the outer region small, with Kranz anatomy, bundle sheath cells 4-6 in number; hypodermis 3-4 layered, sclerenchymatous, embedding number of large vascular bundles beginning at furrow; cortex parenchymatous, thin walled, cells hexagonal to

circular in shape, with intercellular spaces; central region with larger and loosely arranged cells; vascular bundles 7-8 sided, scattered towards the periphery in cortex, with prominent metaxylem and few protoxylem (2-3) elements with lacunae; phloem forming a prominent patch between the metaxylem elements. (Plate 1F).

T.S. of Leaf:

Leaf succulent, 5-veined, transverse section crescent shaped in outline, rarely constricted; midrib prominent, 'U' shaped; water tissue or bulliform cells on adaxial part, regular, covering ½-¾th portion of the leaf, cells rectangular, colourless with rounded ends (in surface view compactly arranged and hexagonal), each up to 105 x 45 μm; mesophyll cells colourless, 1-2 layered (few cells) along the midrib, absent in lateral lamina, hexagonal to rounded; vascular bundles arranged in the form of arc in the abaxial surface; girders or strands present below the large bundles and few small bundles, each with Kranz anatomy, bundle sheath cells in small vascular bundles rounded, 4-6 in number. Lower epidermis (abaxial surface) with barrel to circular shaped cells; cuticle of abaxial surface *ca* 5.06 μm thick, stomata sunken; macro-hairs absent; micro-hairs up to 48 x 13 μm, two celled.

Leaf Sheath:

Adaxial epidermis single layered, cells barrel to rectangular shaped, bulbous in the median region; cuticle *ca* 5.06 µm thick, interrupted by sunken stomata at few places; mesophyll in median region 4-5 layered, cells hexagonal to circular, compactly arranged; vascular bundles as in lamina; central region solid, lateral lamina with loose cells or with cavities; some cells in the median region near the epidermis becomes thicker; abaxial epidermis single layered, cells elongated to barrel shaped (bigger in the median region), cuticle *ca* 3.25 µm thick. Keel single layered (Plate 1E).

Leaf Peeling:

Costal/intercostal zonation conspicuous. Papillae absent. Costal long cells long and narrow up to 177 x 30-55 µm, intercostal long cells 156.86 x 20.24 µm, cells rectangular with conspicuous sinuous walls with rounded ends; short cells with cork/silica pairs; silica bodies cross, dumb-bell to crenate-vertical shaped; stomata common *ca* 44 x 24 µm; subsidiaries dome shaped to triangular, guard cells overlapping to flash with the interstomatals. Interstomatal cells rectangular with

sinuous wall and concave ends; short cells between long cells dumb-bell to cross shaped or crenate, costal short cells in one or two rows, silica/cork alternatively or 2 cork cell alternating with 1 silica body; silica bodies dumb-bell common, nodular-crenate abundant and cross shaped rare. No prickles and no macro-hairs present. Micro-hairs, small, 45.54 x 10.12-12.65 µm, two celled.

Note: *G. acuminata* var. *acuminata* differs from *G. acuminata* var. *stocksii* and *G. acuminata* var. *acuminata* on the basis of root and leaf anatomy as given in the table 7.

Table 7: Comparison of anatomical characters between varieties of *G. acuminata*

Characters	*G. acuminata* var. *acuminata*	*G. acuminata* var. *stocksii*	*G. acuminata* var. *woodrowii*
Root exodermis	1-2 layered	more than 2 layered	1-2 layered
Root cortex	5-6 layered	4-5 layered	4-5 layered
Root endodermis fibrous bands	Covering 1/4 to 1/2 cell	Covering 1/4 to 1/2 cell	Covering 3/4 to entire cell
T.S of leaf	lateral VB rarely shifted	Not shifted	Not shifted
Leaf midrib	Distinct	Not distinct	Distinct
Mesophyll in leaf midrib	Present	Present	Present or absent
Average stomatal size	46 x 25 µm	47 x 29 µm	44 x 24 µm
Stomatal frequency	13	14	14

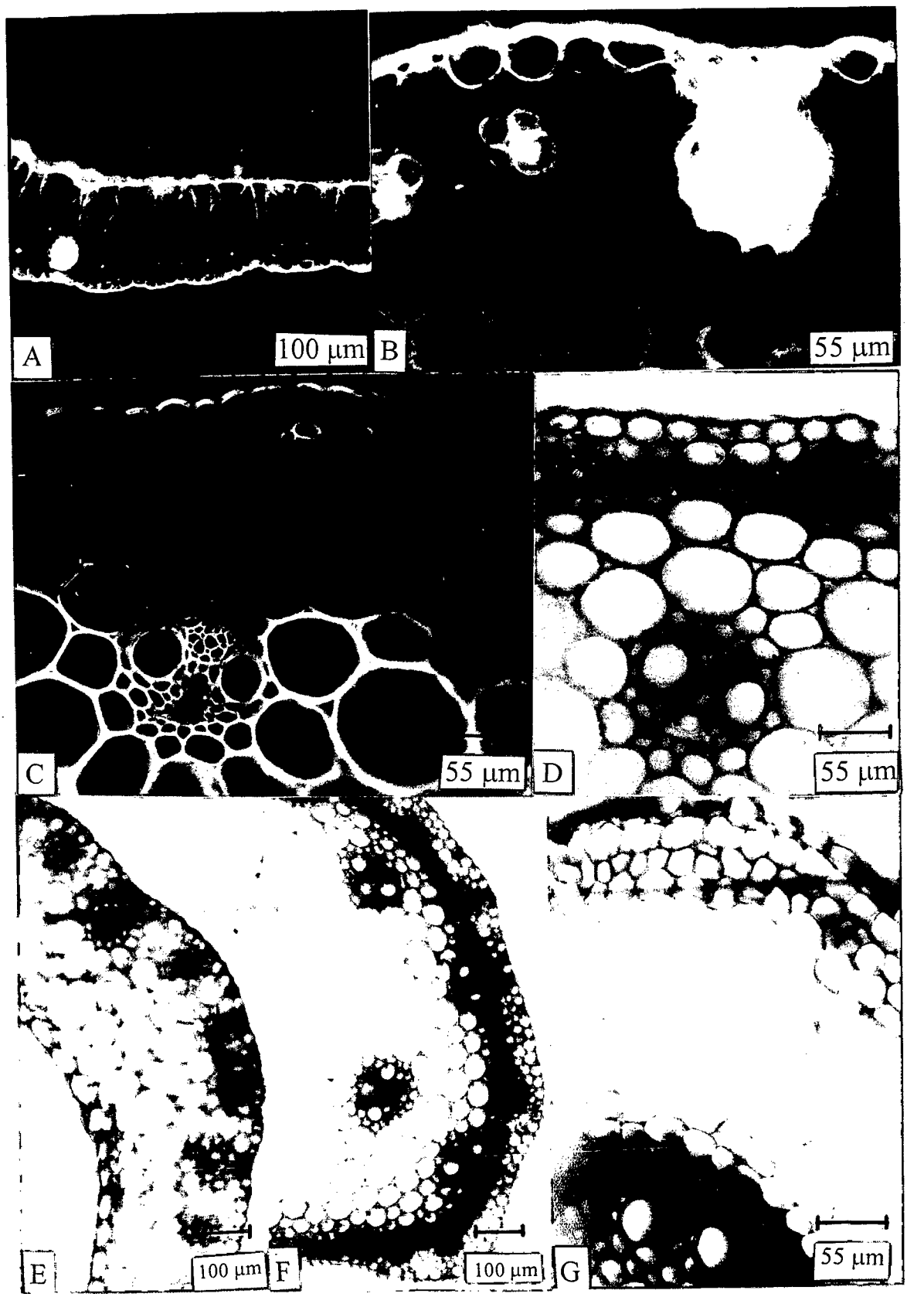


Plate 1: ***G. acuminata*** **(Hack.) Clayton var.** ***acuminata*** (A&G): (A) T.S. of leaf showing regularly arranged bulliform cells; (G) T.S. of root. ***G. acuminata*** **(Hack.) Clayton var.** ***stocksii*** **(Hook.f.) Clayton** (B, C & D): (B) T.S. of leaf sheath with main vascular bundle; (C) T.S. of culm; (D) T.S. of culm showing 3-layered thick walled hypodermis. ***G. acuminata*** **(Hack.) clayton var.** ***woodrowii*** **(Bor) Clayton** (E & F) : (E) T.S. of leaf sheath showing midrib region; (F) T.S. of culm with 3 – 4 layered thick walled hypodermis.

2. G. divergens (Hack.)Clayton

T.S of root:

Piliferous layer single, thin walled, cells hexagonal; exodermis 1-2 layered, thick walled cells; cortex 4-5 layered, thin, circular, in radial rows, disintegrating to form radial plates, stele large; endodermis single layered, with ¾ th part of the wall showing fibrous bands; pericycle single layered, not prominent; metaxylem 4-7 large vessels; protoxylem small patches towards periphery, not prominent; phloem, not prominent; pith with thin or thick walled rounded cells.

T. S. of culm:

Circular to ovate in outline, with a curvature on one side and small ridges and furrows on all sides; epidermis single layered, cells rounded to rectangular, interrupted by sunken stomata at few places; cuticle *ca* 2.53 µm thick; macro-hairs present, *ca* 30 x 10.12 µm long; vascular bundles in the outer region, small, with Kranz anatomy; bundle sheath cells 4-6 in numbers; hypodermis 1-3 layered, sclerenchymatous, embedding number of large vascular bundles beginning at furrow; cortex parenchymatous, thin walled, cells hexagonal to circular, with intercellular

spaces; central region with larger and loosely arranged cells; vascular bundles, angular, 6-7 sided, scattered towards the periphery in cortex, with prominent metaxylem and few protoxylem elements with lacunae; phloem forming a prominent patch between the metaxylem elements (Plate 2D).

T.S of Leaf:

Leaf slightly succulent, 4-5 veined, leaf transverse section with wavy margin, constricted at lateral main veins; midrib prominent, U-flattened shaped; water tissue or bulliform cells irregular, covering ½-¾th -portion of leaf, cells rectangular to triangular, colourless, with rounded ends, (In surface view compactly arranged and hexagonal), each 38-188 x 25-127 µm; cuticle 3.98-5.06 µm thick; mesophyll cells colourless, hexagonal to rounded, 1-2 layered along the midrib, absent in lateral lamina; vascular bundles arranged in the form of arc on the abaxial surface; girders or strands below the large bundles and few small bundles, each with Kranz anatomy; bundle sheath in small vascular bundle rounded, 4-5 in number, with poorly developed vascular tissue. Along lateral main veins sclerenchyma girders present on adaxial and abaxial surface. Abaxial epidermis with barrel to circular shaped cells; cuticle *ca* 3.8 µm thick; stomata sunken, after

regular intervals; macro-hairs present, one celled with constricted base, lined by raised epidermal cells.

Leaf sheath:

Adaxial epidermis single layered, cells barrel to rectangular shaped, bulbous in the median region; cuticle *ca* 5.06 µm thick, interrupted by sunken stomata at few places; mesophyll in median region 3-4 layered, cells hexagonal to circular, compactly arranged; vascular bundles as in lamina; bundle sheath cells rounded, 4-5 in number with main vascular bundles and smaller lateral bundles with sclerenchyma girders or strands; lateral veins constricted at few places, with sclerenchyma strands on adaxial and abaxial side of the leaf; central and lateral region solid. Abaxial epidermis single layered, cells elongated to barrel shaped (bigger in the median region; some cells in the median region near the epidermis becomes thicker), lined by 2.53-3.8 µm thick cuticle. Keel single layered.

Leaf Peeling:

Costal/intercostal zonation conspicuous. Papillae absent. Long cells in the costal region long and narrow, up to 114-164 x 23-28 µm long; intercoastal cells 63-114 x 23 -

25 µm, cells rectangular with sinuous wall and rounded ends, between the long cells are short cells in cork/silica pairs or only cork cells in many places; silica bodies dumb-bell to cross shaped. Interstomatal cells rectangular, sinuous with concave ends up to 114 x 56 µm; stomata common, 46 x 26 µm, subsidiaries triangular; short cells in rows of 1 or 2, silica/cork cells alternating or 2-4 silica cells alternating with 1 cork cells. Silica cells are dumb-bell shaped with broad or narrow center, no prickles. Micro-hairs present, *ca* 30 x 10.12 µm, 2 celled, basal cell smaller, apical with pointed apex. (Table 8).

Note: *G. divergens* can be compared in anatomy with other divergent awned species like *G. forficulata*, *G. mysorensis* and *G. ratnagirica* as seen in table 8.

3.*G. forficulata* (C. E. C. Fisch.) W. D. Clayton

T.S of root:

Piliferous layer single, slightly thickened, cells hexagonal; exodermis 1-2 layered, thick walled cells; cortex 6-7 layered, thin, circular in radial rows disintegrating to form radial plates, stele large, endodermis single layered, inner wall fibrous; pericycle single layered, not prominent; metaxylem with 5-8 large vessels; protoxylem with few smaller vessels, not prominent; phloem not prominent; pith with thin or thick walled rounded cells depending on the age.

T.S of culm:

Circular to ovate in outline, with a curvature on one side and small ridges and furrows on all sides; epidermis single layered, cells rounded to rectangular, interrupted by sunken stomata at few places; cuticle 3.8-5 μm thick; macro-hairs present, *ca* 750 μm long; vascular bundles in the outer region small, with Kranz anatomy, bundle sheath cells 4-6 in number; hypodermis 2-3 layered, sclerenchymatous, embedding number of large vascular bundles beginning at furrow; cortex parenchymatous thin walled, hexagonal to circular in shape, with intercellular spaces; central

region with larger and loosely arranged cells; vascular bundles scattered towards periphery in cortex, with two prominent metaxylem and few protoxylem elements with lacunae; phloem forming a prominent patch between the metaxylem elements(Plate 2C).

T.S of Leaf:

Leaf slightly succulent, 3-5 veined, leaf transverse section with wavy outline, constricted at lateral main veins; midrib prominent, V-shaped; water tissue or bulliform cells on adaxial part, irregular, covering ½-¾th portion of leaf, cells rectangular to triangular, colourless, with rounded ends (in surface view compactly arranged and hexagonal), each 101-127 x 56 µm in length; mesophyll cells colourless, 1-2 layered along the midrib, absent in lateral lamina, hexagonal to rounded; vascular bundles arranged in the form of arc on the abaxial surface; girders or strands present below the large bundles and few small bundles, each with Kranz anatomy; bundle sheath cells in small vascular bundles rounded, 4-6 in number; lower epidermis with barrel to circular shaped cells; cuticle of abaxial surface 2.5-3.8 µm thick; stomata sunken, after every 3-4 cells; macro-hairs present, 700-750 µm long, one

celled with constricted base; lined by raised epidermal cells.

Leaf sheath:

Adaxial epidermis single layered, cells barrel to rectangular shaped, bulbous in the median region; cuticle *ca* 5.06 µm thick, interrupted by sunken stomata at few places; mesophyll region in median region 4-5 layered, cells hexagonal to circular, compactly arranged; vascular bundles as in lamina; lateral main veins constricted at few places, with sclerenchyma strands on adaxial and abaxial side; central mid region and lateral region with cavities, some cells in the median region near the epidermis becomes thicker; abaxial epidermis single layered, cells elongated to barrel shaped (bigger in the median region), lined by cuticle; keel single layered(Plate 2E).

Leaf peeling:

Costal/intercostal zonation conspicuous. Papillae absent. Long cells in the costal region long and narrow, up to 177 x 18 µm; intercostal long cells shorter and stouter, long cells rectangular, with rounded ends and have conspicuous sinuous walls, sinuosity fine; stomata common *ca* 57 x 33 µm, subsidiaries triangular, guard cells over

lapping to flash the interstomatals. Interstomatal cells rectangular, sinuous with concave ends, interstomatal short cells cross shaped, *ca* 17.71 x 15.18 μm or crenate vertical silica bodies *ca* 126.5 x 4.34 μm, costal short cells in single rows often seen. Silica body dumb-bell crenate horizontal, few nodular and cross shaped (mostly crenate), cork cell rectangular to irregularly shaped, *ca* 30.36 x 7.59 μm, silica/cork cells alternating, sometimes two silica bodies alternate with one cork cell; prickles absent; macro-hairs present, elongated, sometimes branched, bulbous with constricted base and long and tapering body; micro-hairs present, *ca* 45.54 x 12.65 μm, two celled. (Table 8)

Note: Midrib region in transverse section of leaf is V shaped which differentiates *G. forficulata* from other divergent species, other characters of distinctions is given in table 8.

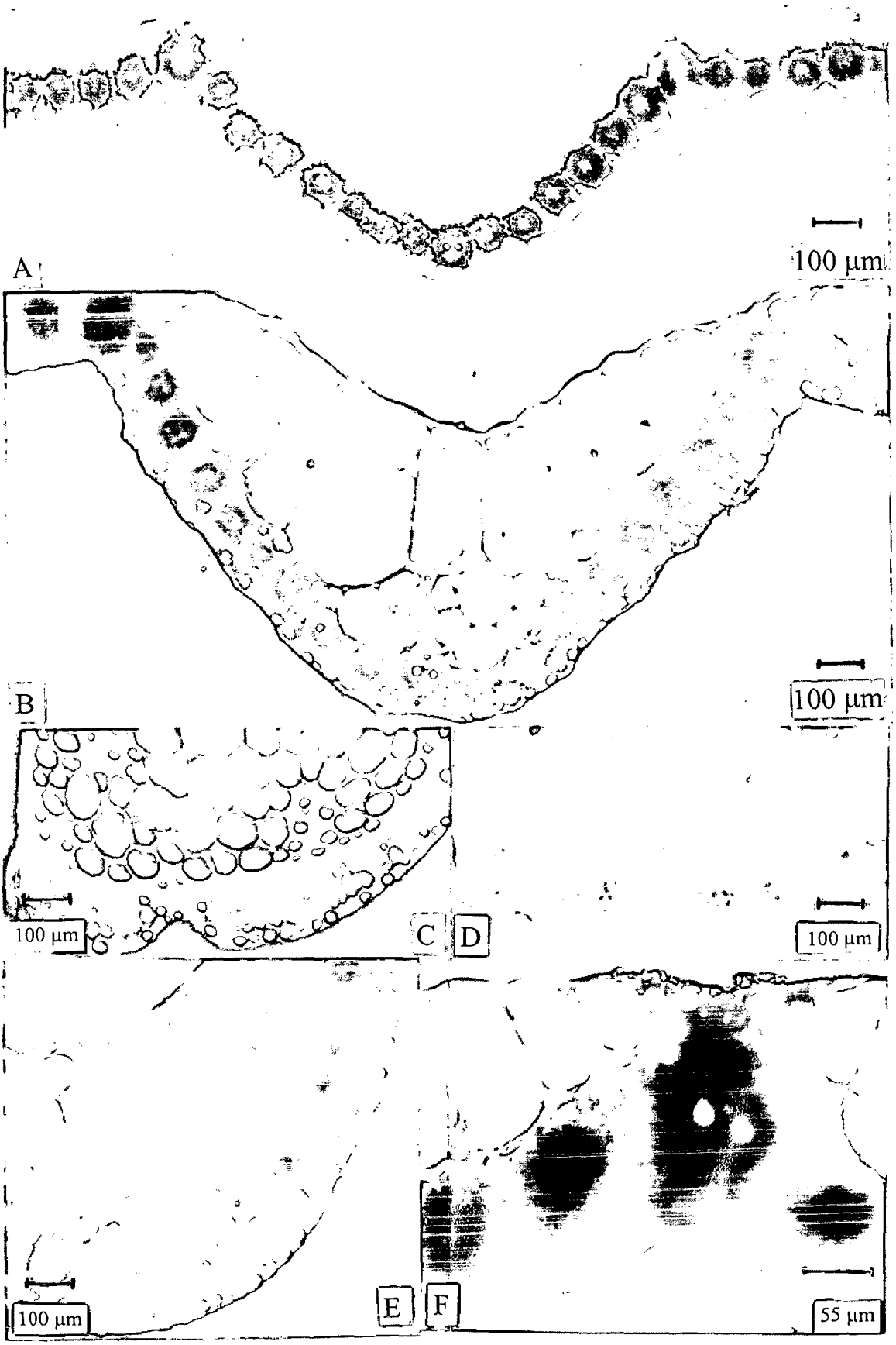


Plate 2: ***Glyphochloa divergens*** **(Hack.) Clayton** (A&D): (A) T.S. of leaf showing irregular arrangement of bulliform cells with hair; (D) T.S. of culm showing vascular bundles with Kranz anatomy. ***Glyphochloa forficulata*** **(C. E. C. Fischer) Clayton** (B, C, E&F): (B) T.S. of leaf showing small 'V' shaped midrib region & colourless mesophyll cells; (C) T.S. of culm showing ridges & thickened hypodermis; (E) T.S. of leaf sheath showing mid region; (F) T.S. of leaf with constriction at lateral main veins, along with girdles.

4. *G. goaensis* (Rao & Hemadri) Clayton

T.S of root:

Piliferous layer single, walls slightly thickened, cells hexagonal thick walled; exodermis 1-2 layered; cortex 4-6 layered, thin, cells circular, in radial rows, disintegrating to form radial plates; stele large; endodermis single layered, ¼th to entire inner walls thickened, in few cases whole cell thickened; pericycle single layered, not prominent; metaxylem 9 to 10 large vessels; protoxylem small patches towards periphery, not prominent; phloem not prominent; pith with thin or thick walled rounded cells depending on the age.

T.S of culm:

Circular to ovate in outline, with a curvature on one side and small ridges and furrows on all sides; epidermis single layered, cells rounded to rectangular, interrupted by sunken stomata at few places; cuticle *ca* 5.06 µm thick; macro-hairs absent; vascular bundles in the outer region small, with Kranz anatomy; bundle sheath cells 4-6 in numbers; hypodermis 3-4 layered, sclerenchymatous, embedding number of large vascular bundles beginning at furrow; cortex parenchymatous, thin walled, cells hexagonal

to circular in shape, with intercellular spaces; central region with larger and loosely arranged cells; vascular bundles 7-8 sided, scattered towards the periphery in cortex, with prominent metaxylem and few protoxylem elements (2-3) with lacunae; phloem forming a prominent patch between the metaxylem elements(Plate 3F & G).

T.S. of Leaf:

Leaf succulent, 7-9 veined, leaf transverse section crescent shaped in outline, no constriction at lateral main veins; midrib not prominent; water tissue or bulliform cells (adaxial surface) regular, covering *ca* ¾th portion of leaf, cells long, rectangular, colourless, with rounded ends, (in surface view compactly arranged and hexagonal), each *ca* 63 x 30 µm, smaller at lateral veins; mesophyll cells rarely present, colourless, hexagonal to rounded, single layered along the midrib, absent in lateral lamina; vascular bundles arranged in the form of arc on the abaxial surface, small and big, each with Kranz anatomy; girders or strands present below big bundles and few small bundles; bundle sheath cells in small vascular bundles rounded, 4-7 in number, with poorly developed vascular tissue. Lower epidermis with barrel to circular shaped cells; cuticle *ca*

5.06 µm thick; stomata sunken at regular intervals. Macro-hairs absent (Plate 3B & C).

Leaf sheath:

Adaxial epidermis single layered, cells barrel to rectangular shaped, bulbous in the median region; cuticle *ca* 5.06 µm thick; interrupted by sunken stomata at few places; mesophyll in median region, 4-5 layered, cells hexagonal to circular shaped, compactly arranged; vascular bundles as in lamina; bundle sheath cells rounded, 4-5 in number, big vascular bundles and few small vascular bundles with sclerenchyma girders or strands; central & lateral region solid; lower epidermis single layered, cells elongated to barrel shaped (bigger in the median region), lined by cuticle; (some cells in the median region near the epidermis becomes thicker); Keel single layered (Plate 3A).

Leaf peeling:

Costal/intercostal zonation conspicuous. Papillae absent; long cells in the costal region long and narrow, up to 164 x 25 µm; intercostal long cells shorter and stouter, *ca* 158 x 40 µm; cells rectangular with rounded ends, with conspicuous sinuous walls, sinuosity fine; stomata common

ca 45 x 28 µm, subsidiaries triangular, guard cells overlapping to flash the interstomatals; interstomatal short cells cross, dumb-bell or crenate-vertical (silica cells), coastal short cells in single rows; silica cells dumb-bell, few nodular and butterfly shaped; cork cell rectangular to irregularly shaped, silica/cork cells alternating. Prickles absent. Micro-hairs present, *ca* 37.95 x 10.12 µm, two celled (Plate 3D & E).

Note: *G. goaensis* is closer to *G. talbotii* and *G. santapaui* in its anatomy but differs from them as per the table 9.

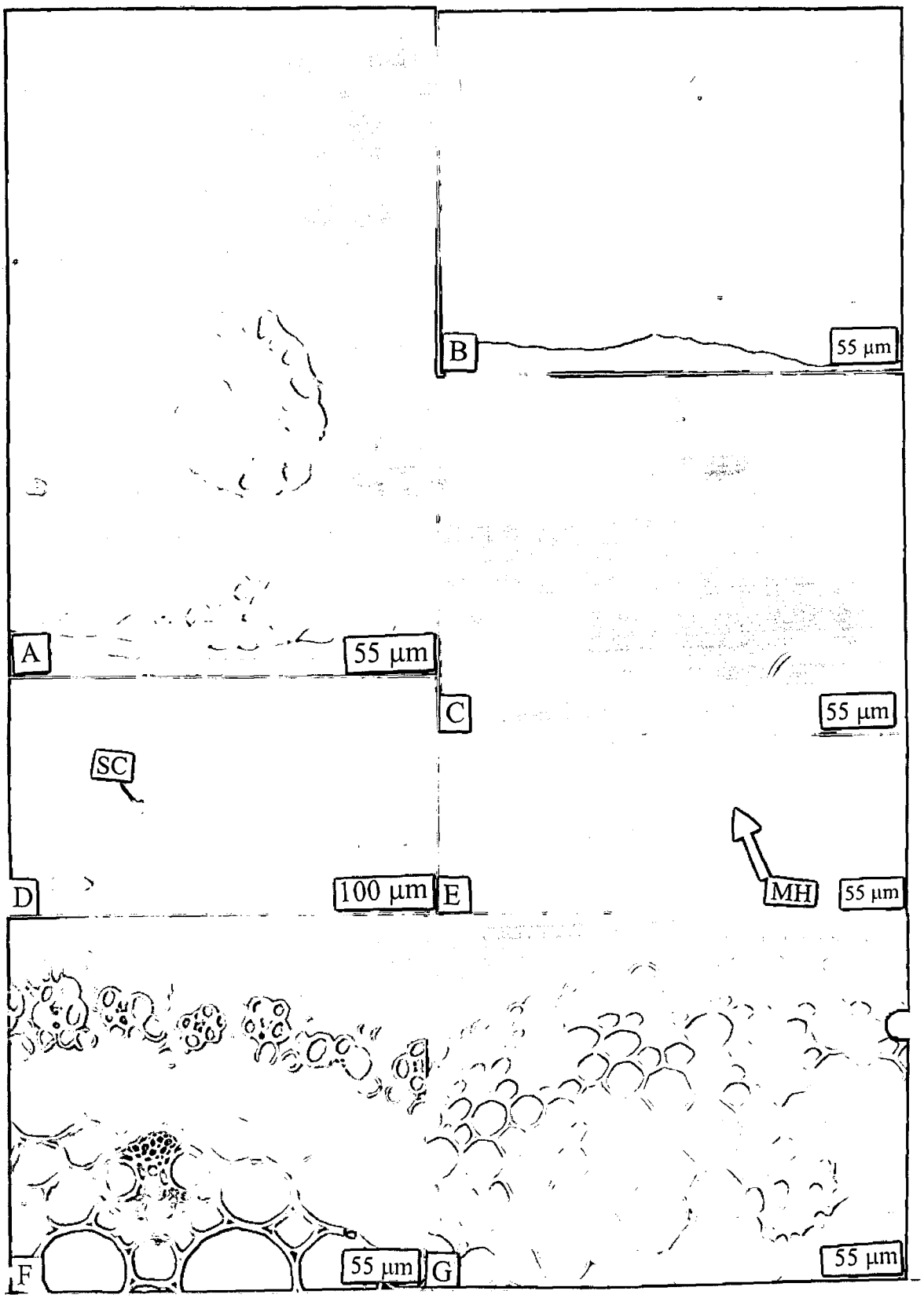


Plate 3: ***Glyphochloa goaensis*** **(Rao & Hemadri) Clayton:** (A) T.S. of leaf sheath with vascular bundle and sclerenchymatous strand; (B) T.S. of leaf showing regularly arranged bulliform cells & bundle sheath cells; (C) T.S. of leaf showing sunken stomata; (D) Leaf peeling showing silica cells & stomata; (E) Leaf peeling with stomata & microhairs; (F) T.S. of culm showing small vascular bundles with large bundle sheath cells.(G) T.S. of culm with thick walled, 3 – 4 layered hypodermis; MH = Microhair SC = Silica cell

5. ***G. henryi*** Janarth. et. al.

T.S of root:

Piliferous layer single, cells hexagonal walls slightly thickened; exodermis one layered, thin walled cells and 3-4 layered, thick walled cells; cortex 5-7 layered, circular, in radial rows, disintegrating to form radial plates; stele large; endodermis single layered, inner walls fibrous; pericycle single layered, not prominent; metaxylem 8 large vessels; protoxylem in small patches towards periphery, not prominent; pith with thin or thick walled rounded cells depending on age.

T.S of culm:

Circular to ovate in outline, with a curvature on one side and small ridges and furrows on all sides; epidermis single layered, cells rounded to rectangular, interrupted by sunken stomata at few places; cuticle 5.06-7.59 μm thick; macro-hairs absent; vascular bundles in the outer region small, with Kranz anatomy, bundle sheath cells 4-6 in numbers; hypodermis 3-4 layered, sclerenchymatous, embedding number of large vascular bundles beginning at furrow. Cortex parenchymatous, thin walled, hexagonal to circular in shape, with intercellular spaces; central

region with larger and loosely arranged cells; vascular bundles 7-8 sided, scattered towards the periphery in cortex, with prominent metaxylem and few protoxylem (2-3) elements with lacunae; phloem forming a prominent patch between the metaxylem elements (Plate 4G).

T.S of Leaf:

Leaf succulent, 7-9 veined, leaf transerve section crescent shaped in outline, constriction absent at lateral main veins; midrib not prominent, slightly U-shaped or flattened; water tissue or bulliform cells regular, covering *ca* ½-¾th portion of leaf, cells long, rectangular, colourless, with rounded ends (in surface view compactly arranged and hexagonal), each *ca* 50 x 25 µm, smaller at lateral veins; mesophyll cells colourless, 1-2 layered along the midrib, absent in lateral lamina, hexagonal to rounded; vascular bundles arranged in the form of arc towards abaxial side; girders below midrib and lateral main bundles, sclerenchyma patches or strands below few small bundles, each with Kranz anatomy; bundle sheath cells in small vascular bundles rounded, 4-6 in number, with poorly developed vascular tissue; lateral main bundles shifted upwards; abaxial epidermis with inflated cells at few

places, cuticle of abaxial surface 5.06 μm thick. Stomata sunken. Macro-hairs absent (Plate 4A & B).

Leaf sheath:

Adaxial epidermis single layered, cells barrel-rectangular shaped, bulbous in the median region; cuticle 5.06-7.59 μm thick interrupted by sunken stomata at few places; mesophyll in median region 4-5 layered, cells hexagonal-circular, compactly arranged; vascular bundles as seen in the lamina, each with Kranz anatomy; bundle sheath cells rounded, 4-5 in number; main vascular bundles shifted upwards, few small vascular bundles and main bundles with sclerenchyma girders or strands; median region with cavities; lower epidermis single layered, cells elongated to barrel shaped (bigger in the median region), lined by cuticle. (some cells in the median region near the epidermis becomes thicker), (Plate 4E).

Leaf peeling:

Costal/intercostal zonation conspicuous; papillae absent; long cells in the costal region long and narrow up to 228 x 15 μm, intercostal long cells shorter and broader, 202 x 38μm-63 x 43 μm; long cells in the costal/ intercostal region rectangular, finely sinuous, with

rounded ends; silica/cork pair (common) between long cells; stomata common, *ca* 42 x 27 μm, subsidiaries triangular, guard cells overlapping to flash the interstomatals; interstomatal cells rectangular, sinuous with concave ends (big & small); costal long cells in single, long, continuous rows under the vein in silica/cork pair alternating, rarely 2 to 3 silica cells alternating with one cork cell. Silica bodies mostly dumb-bell and nodular to crenate-horizontal (rare); cork cell *ca* 25.3 x 12.65 μm, silica bodies *ca* 15.18 x 7.59 μm; prickles absent; macro-hairs absent; micro-hairs small, two celled *ca* 30.36 x 12.65 μm (Table 10).

Note: *G. henryi* is closely related to *G. veldkampii* with its epidermal cells (adaxial surface) showing few inflated cells (Table 10).

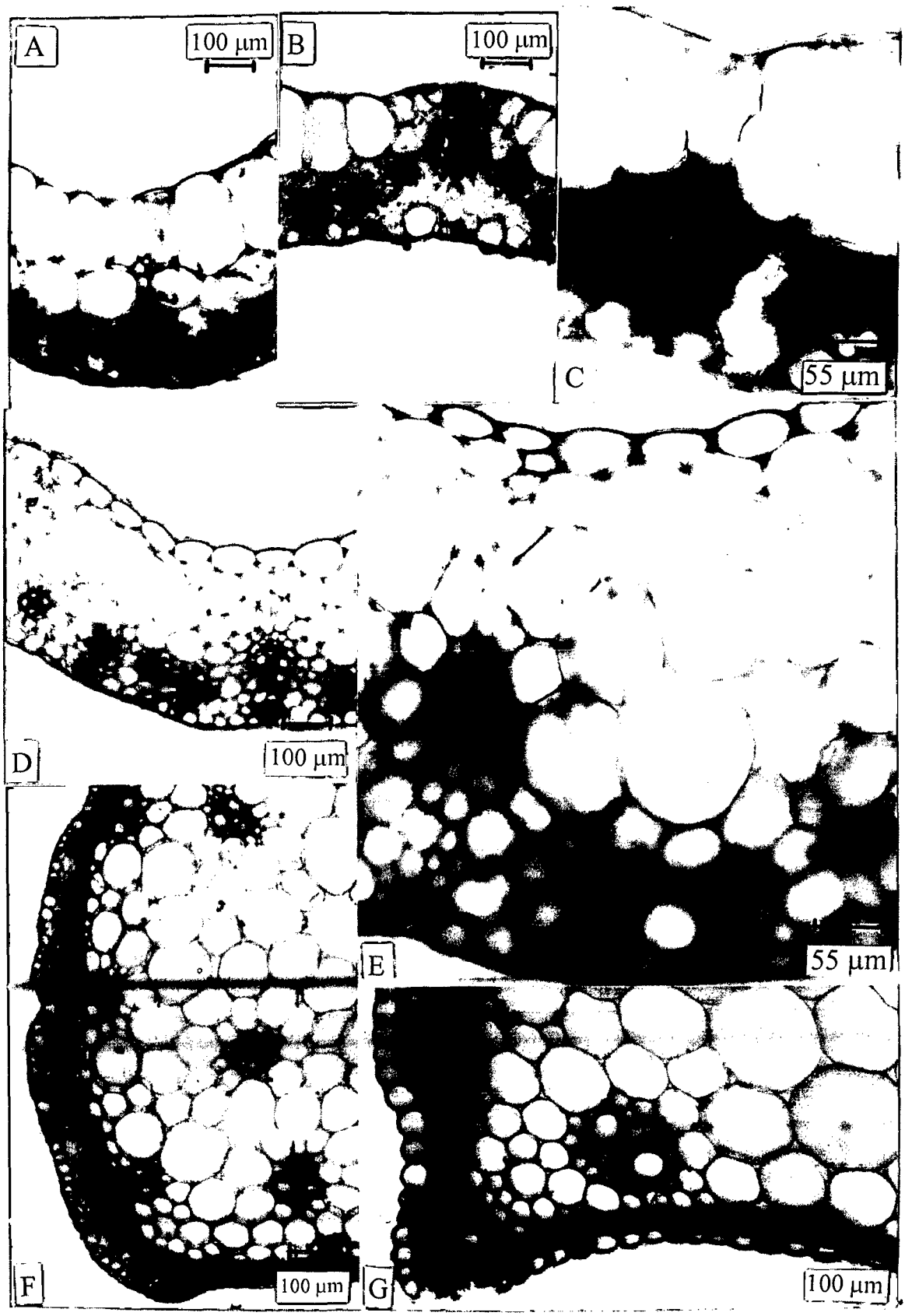


Plate 4: ***Glyphochloa henryi*** **Janarth. et. al.** (A,B,E&G) : (A) T.S. of leaf showing midrib region; (B) T.S. of leaf with lateral main vein shifted upwards; (E) T.S. of leaf sheath showing loosely arranged cells in mid region; (G) T.S. of culm with 3 – 4 layered, thick walled hypodermis. ***Glyphochloa veldkampii M A Fonseca*** (C, D & F): (C) T.S. of leaf showing bulliform cells in mid region; (D) T.S. of leaf sheath with loose cells in midrib region; (F) T.S. of culm showing 3 – 4 layered, thick walled hypodermis.

6. ***G. mysorensis*** (Jain & Hemadri) Clayton

T.S of root:

Piliferous layer single, cells hexagonal wall slightly thickened; exodermis one layered, 1-2 rarely single, thick walled cells; cortex 4-5 layered, thin, circular, in radial rows, disintegrating to form radial plates; stele large; endodermis single layered, inner wall thickened; pericycle single layered, not prominent; metaxylem with 4 large vessels; protoxylem in small patches towards periphery, not prominent; phloem, not prominent; pith with thin or thick walled rounded cells depending on the age (Plate 5E).

T.S of culm:

Circular to ovate in outline, with a curvature on one side and small ridges and furrows on all sides; epidermis single layered, cells rounded to rectangular, interrupted by sunken stomata at few places; cuticle *ca* 3.585 µm thick; macro-hairs present, *ca* 750 µm long; vascular bundles in the outer region small, with Kranz anatomy; bundle sheath 4-6 in number; hypodermis 2-3 layered, sclerenchymatous, embedding number of large vascular bundles begining at furrow; cortex parenchymatous, cells thin walled, hexagonal to circular in shape, with intercellular spaces; central

region with larger and loosely arranged cells; vascular bundles scattered towards periphery in cortex, 7 to 8 sided with two prominent metaxylem and few protoxylem elements with lacunae; phloem forming a prominent patch between the metaxylem elements (Plate 5B).

T.S of Leaf:

Leaf slightly succulent, 3-5 veined, leaf U-shaped; water tissue or bulliform cells irregular, covering *ca* ½-¾th portion of leaf, rectangular to triangular, colourless, with rounded ends (in surface view compactly arranged and hexagonal), each 127-139 x 51 µm in length; mesophyll cells colourless, 1-3 layered along the midrib, absent in lateral region, hexagonal to rounded; vascular bundles arranged in the form of arc towards abaxial surface, small and big; girders or strands present below the big bundles and few small bundles, each with Kranz anatomy; bundle sheath in small vascular bundles rounded, 4-6 in number, with poorly developed vascular tissue; lower epidermis with barrel to circular shaped cells; cuticle of abaxial surface *ca* 3.585 µm thick; stomata sunken, after every 3-4 cells; macro-hairs present, 700 µm long, one celled with constricted base, lined by raised epidermal cells (Plate 5C).

Leaf sheath:

Adaxial epidermis single layered, cells barrel to rectangular shaped, bulbous in the median region; cuticle *ca* 5.06 µm thick, interrupted by sunken stomata at few places; mesophyll region in median region 4-6 layered, cells hexagonal to circular, compactly arranged; central region solid and lateral region with cavities; vascular bundles as in lamina of leaf; bundle sheath cells rounded, 4-5 in number; larger vascular bundles and few small vascular bundles with sclerenchyma girders or strands; lateral veins constricted at few places, with sclerenchyma strands on adaxial and abaxial side; abaxial epidermis single layered, cells elongated to barrel shaped (bigger in the median region), lined by cuticle. (some cells in the median region near the epidermis becomes thicker).

Leaf peeling:

Costal/intercostal zonation conspicuous. Papillae absent. Long cells in the costal region long and narrow, up to 117 x 13 µm and 152 x 28 - 68 x 30 µm in the intercostal region. They are short and broader, long cells rectangular with rounded ends, conspicuous, sinuous wall finely sinuous, ovate-oblong; stomata common *ca* 52 x 33 µm; interstomatals cells rectangular, sinuous with concave

ends, short cells in interstomatal region present in few rows, in silica/cork pairs; rarely absent, silica bodies cross shaped or dumb-bell shaped; costal short cells in single rows, alternating in silica/cork pairs; silica body *ca* 20.24 x 10.12 μm, cork cells irregular to rectangular to squarish; *ca* 10.12 x 12.65 μm; silica cells range from dumb-bell, abundant to cross shaped, prickles absent; macro-hairs present, constricted with raised cells around the base, body elongated with tapering end; micro-hairs present, two celled, 35.42-37.95 x 10.12-12.65 μm (Plate 5A).

Note: *G. mysorensis* is similar to the other divergent awned species, but differs from them as given in table 8.

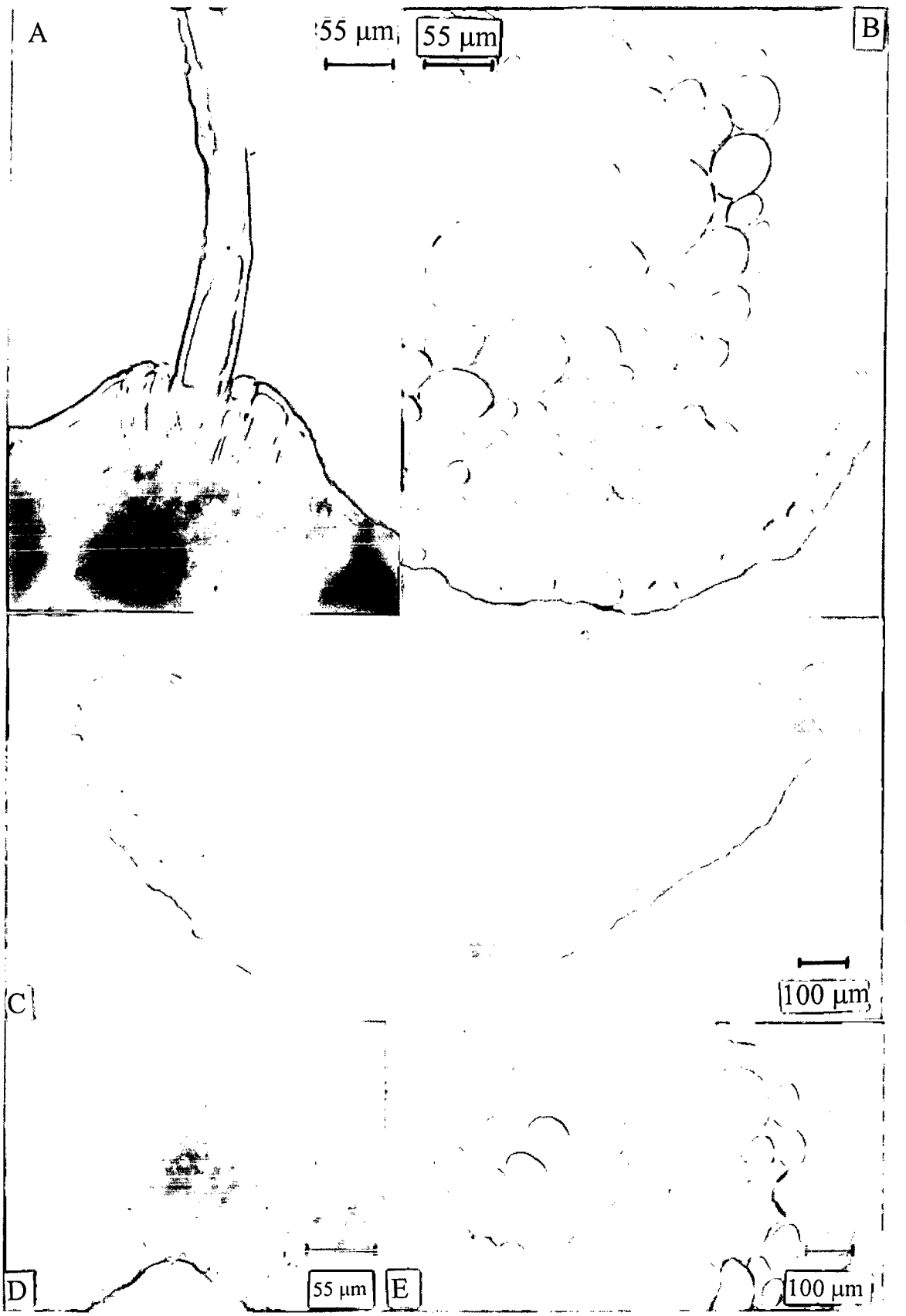


Plate 5: ***Glyphochloa mysorensis*** **(Jain & Hemadri) Clayton:** (A) T.S. of leaf showing a single hair with constricted base and raised cells; (B) T.S. of culm showing small vascular bundles with bundle sheath cells and thickened hypodermis (2 – 3 layered); (C) T.S. of leaf with 'U' to flattened shaped midrib region & irregular bulliform cells; (D) T.S. of leaf with constriction at lateral main bundle and sclerenchyma strand; (E) T.S. of root.

7. ***G. ratnagirica*** (Kulk. & Hem.) Clayton

T.S of root:

Piliferous layer single, cells hexagonal thick walled; exodermis 2-3 layered, cells thick walled; cortex 6 layered, thin, circular, in radial rows, disintegrating to form radial plates; stele large; endodermis single layered, occuping ½-¾th part of the cell, thickened; pericycle single layered, not prominent; metaxylem 5 to 6 large vessels; protoxylem small patches towards periphery, not prominent; phloem not prominent; pith with thin or thick walled rounded cells depending on the age (Plate 6D).

T.S of culm:

Circular to ovate in outline, with a curvature on one side and small ridges and furrows on all sides; epidermis single layered, cells rounded to rectangular, interrupted by sunken stomata at few places; cuticle *ca* 3.8 µm thick; macro-hairs present, *ca* 750 µm long; vascular bundles in the outer region small, with Kranz anatomy; bundle sheath 4-6 in numbers; hypodermis 1-3 layered, sclerenchymatous, embedding number of large vascular bundles beginning at furrow; cortex parenchymatous, thin walled; cells hexagonal to circular, with intercellular spaces; central region with

larger and loosely arranged cells; vascular bundles scattered towards the periphery in cortex, with prominent metaxylem and few protoxylem elements with lacunae; phloem forming a prominent patch between the metaxylem elements (Plate 6B & C).

T.S of Leaf:

Leaf slightly succulent, 4-5 veined, leaf transverse section with wavy margin, constricted at lateral main veins; midrib prominent, U-shaped; water tissue or bulliform cells irregular, covering ¼-½ portion of leaf, cells rectangular to triangular, colourless, with rounded ends (in surface view compactly arranged and hexagonal), 101-127 x 56 µm; mesophyll cells colourless, hexagonal to rounded, 1-2 layered along the midrib, absent in lateral lamina; vascular bundles arranged in the form of arc on the abaxial surface; girders or strands below the large bundles and few small bundles, each with Kranz anatomy; bundle sheath in small vascular bundle rounded, 4-6 in number, with poorly developed vascular tissue. Abaxial epidermis with barrel to circular shaped cells; cuticle *ca* 2.5 µm; stomata sunken after regular intervals; macro-hairs

present, *ca* 700 µm long, one celled with constricted base, lined by raised epidermal cells (Plate 6A & E).

Leaf sheath:

Adaxial epidermis single layered, cells barrel to rectangular shaped, bulbous in the median region; cuticle *ca* 5.06 µm thick interrupted by sunken stomata at few places; mesophyll in median region, 4-5 layered, cells hexagonal to circular, compactly arranged; vascular bundles as in lamina; bundle sheath cells rounded, 4-5 in number with bigger vascular bundles and few small vascular bundles with sclerenchyma girders or strands; lateral veins constricted at few places, with sclerenchyma strands on adaxial and abaxial side of the leaf; central and lateral region solid; abaxial epidermis single layered, cells elongated to barrel shaped (bigger in the median region), lined by cuticle (some cells in the median region near the epidermis becomes thicker); keel single layered.

Leaf Peeling:

Costal/intercostal zonation conspicuous. Papillae absent. Long cells in costal region long and narrow, up to 132 x 30 µm with short cells in silica/cork pairs;

intercoastal long cells shorter and broader, *ca* 114 x 40 µm, cells rectangular with rounded ends and sinuous wall, sinuousity fine, stomata common *ca* 45 x 26 µm, subsidiaries triangular, guard cells overlapping to flush the interstomatals; interstomatals cells rectangular, sinuous with concave ends, interstomatal short cells common in cork/silica pairs, silica cells dumb-bell to cross shaped, *ca* 22.77 x 10.12 µm; cork cells compressed vertically, *ca* 45.54 x 7.59 µm; costal short cells in single continuous rows in silica/cork pairs alternating, sometimes one cork cell alternating with two silica bodies; the costal silica bodies are dumb-bell shaped (most abundant); macro-hairs present, with raised crown of cells at base; micro-hairs present, *ca* 25.3 x 12.65 µm, two celled.

Note: *G. ratnagirica* is similar to *G. mysorensis*, *G. forficulata*, and *G. divergens* differing in few characters as shown in Table 8.

Table 8: Comparision of Anatomical features in divergent awned species.

Characters	*G.forficulata*	*G.mysorensis*	*G.ratnagirica*	*G.divergens*
Root exodermis	1-2 layered	1-2 layered	more than 2 layered	1-2 layered
Root cortex	more than 5 layered	4-5 layered	more than 5 layered	4-5 layered
Leaf midrib region in T.S.	V-shaped	U - shaped	U-shaped	U-flattened
Leaf sheath lateral region	Cavities	Cavities	Solid	Solid
Stomatal size	57 x 33 μm	52 x 33 μm	45 x 26 μm	46 x 26 μm
Stomatal frequency	8	12	10	14

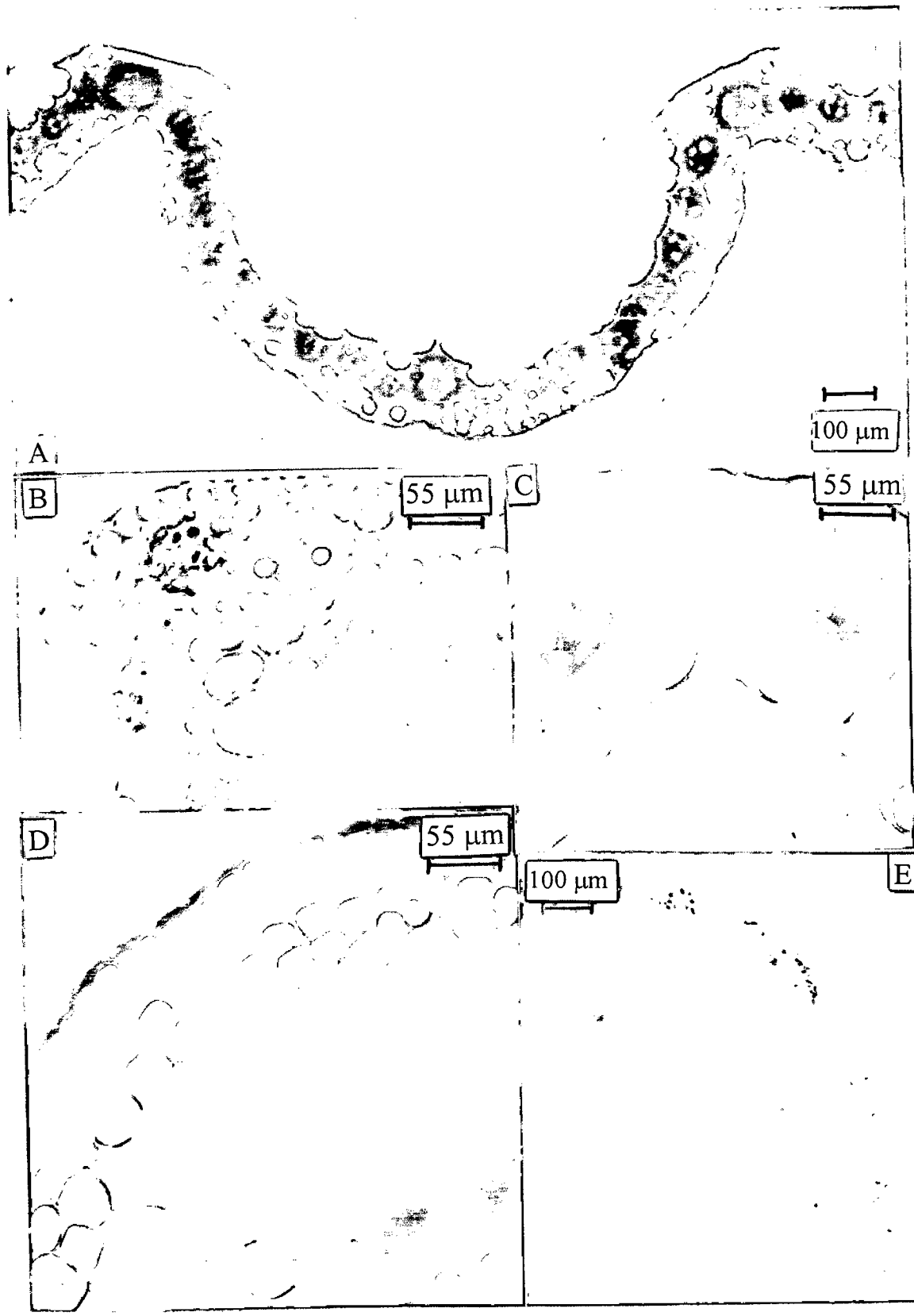


Plate 6: *Glyphochloa ratnagirica* (Kulk. & Hem.) Clayton: (A) T.S. of leaf showing 'U' shaped midrib and lateral constriction; (B) T.S. of culm with 1 – 2 layered thick wall hypodermis; (C) T.S. of leaf showing constriction at lateral main vein & sclerenchyma girdle; (D) T.S. of root; (E) T.S. of culm with central loose cells and thick walled hypodermis.

8. ***G. santapaui*** (Jain & Desh.) Clayton

T.S of root:

Piliferous one to two layered, cells hexagonal thick walled, exodermis two to three layered, cells thick walled; cortex 6 layered, thin, circular, in radial rows, disintegrating to form radial plates; stele large; endodermis single layered, whole cell with fibrous bands; pericycle single layered, not prominent; metaxylem 7 to 10 large vessels; protoxylem in small patches towards periphery, not prominent; phloem not prominent; pith thin/thick walled rounded cells.

T.S of culm:

Circular to ovate in outline, with a curvature or groove on one side and small ridges and furrows on all sides; epidermis single layered, cells rounded to rectangular, interrupted by sunken stomata at few places; cuticle *ca* 3.8 µm thick; macro-hairs absent; vascular bundles in the outer region small, with Kranz anatomy, bundle sheath cells 4-6 in numbers; hypodermis 3-4 layered, sclerenchymatous, embedding number of large vascular bundles begining at furrow; cortex parenchymatous, thin walled, cells hexagonal to circular in shape, with

intercellular spaces; central region with larger and loosely arranged cells; vascular bundles 7-8 sided, scattered towards the periphery in cortex, with prominent metaxylem and few protoxylem elements with lacunae; phloem forming a prominent patch between the metaxylem elements (Plate 7F).

T.S of Leaf:

Leaf succulent, 3-4 veined, leaf transverse section crescent shaped in outline, no constriction at lateral main veins; midrib not prominent; water tissue or bulliform cells regular, covering *ca* ¾th portion of leaf, cells long, rectangular, colourless, with rounded ends (in surface view compactly arranged and hexagonal), each *ca* 63 x 76 µm, smaller at lateral veins; mesophyll cells absent; vascular bundles arranged in the form of arc on the abaxial surface, small and big, each with Kranz anatomy. Girders or strands present below the big and small bundles; bundle sheath cells rounded, 4-6 in number, with poorly developed vascular tissue; vascular bundles not shifted upwards; lower or abaxial epidermis with barrel to circular shaped cells; cuticle *ca* 5.04 µm thick; stomata sunken; macro-hairs absent (Plate 7D).

Leaf sheath:

Adaxial epidermis single layered, cells barrel to rectangular shaped, bulbous in the median region; cuticle *ca* 5.06 µm thick interrupted by sunken stomata at few places; mesophyll in median region, 4-6 layered, cells hexagonal to circular, compactly arranged; vascular bundles as in lamina; bundle sheath cells rounded, 4-5 in number, larger vascular bundles and smaller vascular bundles with sclerenchyma girders or strands; central region as well as lateral lamina with loose cells or cavities; lower epidermis single layered, cells elongated to barrel shaped (bigger in the median region), lined by cuticle (some cells in the median region near the epidermis becomes thicker); keel single layered (Plate 7A).

Leaf Peeling:

Costal/intercostal zonation conspicuous; papillae absent or present at few places; long cells in the costal region long and narrow, up to 177 x 25 µm; costal long cells shorter and broader, *ca* 164 x 43 µm, rectangular with rounded ends and finely sinuous; stomata common, *ca* 51 x 34 µm, subsidiaries triangular, guard cells overlapping to flash the interstomatals; interstomatals cells rectangular,

sinuous with concave ends; intercostal short cells cross shaped, irregular to dumb-bell shaped, *ca* 16.12 x 10.12 µm; cork cell is about *ca* 12 x 25.30 µm; costal short cells in single rows in silica/cork pairs or two cork cells alternating with one silica cell or two silica cells with one cork cell; silica bodies dumb-bell (abundant) and crenate-horizontal shape (rare). Silica cell *ca* 25.3 x 10.12 µm and cork cell *ca* 17.71 x 12.65 µm, rectangular to irregularly shaped; prickles absent; macro-hairs absent; micro-hairs 55.66 x 12.65-15.16 µm, two celled.

Note: *G. santapaui* is similar in anatomical features to *G. talbotii* and *G. goaensis*, Table 9 shows the differences between these species.

9. G. talbotii (Hook. f.) Clayton

T.S of root:

Piliferous layer single, cells hexagonal thick walled; exodermis more than 2 layered, thin walled cells and one to three layered thick walled cells; cortex 4-5 layered, circular, in radial rows, disintegrating to form radial plates; stele large; endodermis single layered, cells rectangular with fibrous bands on inner and radial walls occuping ½-¾th part of the cell; pericycle single layered, not prominent; metaxylem 8 or more large vessels; protoxylem small patches towards periphery, not prominent; pith with thin or thick walled rounded cells depending on age (Plate 7G).

T.S of culm:

Circular to ovate in outline, with a curvature on one side and small ridges and furrows on all sides; epidermis single layered, cells rounded to rectangular, interrupted by sunken stomata at few places; cuticle *ca* 5.06 µm thick; macro-hairs absent; vascular bundles in the outer region small, with Kranz anatomy, bundle sheath 4-6 in numbers; hypodermis 2-3 layered, sclerenchymatous, embedding number of large vascular bundles beginning at furrow; cortex

parenchymatous, thin walled, cells hexagonal to circular in shape, with intercellular spaces; central region with larger and loosely arranged cells; vascular bundles 7-8 sided, scattered towards the periphery in cortex, with prominent metaxylem and few protoxylem (2-3) elements with lacunae; phloem forming a prominent patch between the metaxylem elements (Plate 7B).

T.S of Leaf:

Leaf succulent, 3-5 veined, leaf transverse section crescent shaped in outline, constriction absent at lateral main veins; midrib not prominent; water tissue or bulliform cells regular, covering *ca* ¾ th portion of leaf, cells long, rectangular, colourless, with rounded ends (in surface view compactly arranged and hexagonal), each 89 x 63-56 µm in length, smaller at lateral veins; mesophyll cells rarely present colourless, single layered along the midrib, absent in lateral lamina, cells hexagonal to rounded; vascular bundles in the form of arc towards abaxial side; girders present below midrib and lateral main bundles, sclerenchyma patches or strands present below few small bundles, rarely over lateral bundles, each with Kranz anatomy; bundle sheath cells in small vascular bundle rounded, 4-7 in number, with poorly developed vascular tissue; abaxial

epidermis with barrel to circular shaped cells; cuticle 5.06 µm thick; stomata sunken; macro-hairs absent (Plate 7C).

Leaf sheath:

Adaxial epidermis single layered, cells barrel to rectangular shaped, bulbous in the median region; cuticle *ca* 5.06 µm thick interrupted by sunken stomata at few places; mesophyll in median region, 4-6 layered, cells hexagonal to circular, compactly arranged; vascular bundles as seen in lamina; bundle sheath cells rounded 4-5 in number, bigger vascular bundles and few small vascular bundles with sclerenchyma girders or strands; central and lateral region solid; abaxial epidermis single layered, cells elongated to barrel shaped (bigger in the median region), lined by cuticle (Some cells in the median region near the epidermis becomes thicker); keel single layered (Plate 7E).

Leaf Peeling:

Costal/Intercostal zonation conspicuous; papillae absent; intercostal long cells long and narrow up to 202 x 15 µm; costal long cells shorter and broader, up to 197 x 15

µm; long cells rectangular with rounded ends and finely sinuous; stomata common in costal region 55 x 31 µm, subsidaries triangular, guard cells overlapping to flash the interstomatals; interstomatal cells rectangular, sinuous with concave ends; intercostal short cells cross shaped, irregular to dumb-bell shaped *ca* 16.12 x 10.12 µm; costal short cells in 1 to 2 rows, continuously arranged in alternating silica/cork pairs; silica bodies dumb-bell (abundant) and butterfly (rare) shaped, *ca* 25.3 x 10.12 µm and cork cell *ca* 17.71 x 12.65 µm, cells rectangular to irregular; prickles absent; macro-hairs absent; micro-hairs *ca* 43.01 x 12.65 µm long, two celled, basal cell small.

Note: *G. talbotii, G. goaensis, G. santapaui* are close to each other in most of the anatomical features. Table 9 brings out the differences between these single awned species.

Table 9: Anatomical differentation in *G. talbotii*, *G. goaensis*, and *G. santapaui*

Characters	G.talbotii	G.goaensis	G.santapaui
Root exodermis	more than 2 layered	1-2 layered	more than 2 layered
Root cortex	4-5 layered	more than 5 layered	more than 5 layered
Root endodermis fibrous bands	1/2 to 3/4 Cell	1/4 to entire cell	3/4 to entire cell
Mesophyll in leaf	Rarely present or absent	Absent or rarely present	Absent
Leaf sheath midrib region	Solid	Solid	Cavities
Leaf sheath lateral region	Solid	Solid	Cavities
Stomatal size	55 x 31 μm	45 x 28 μm	51 x 34 μm
Stomatal frequency	11	8	9

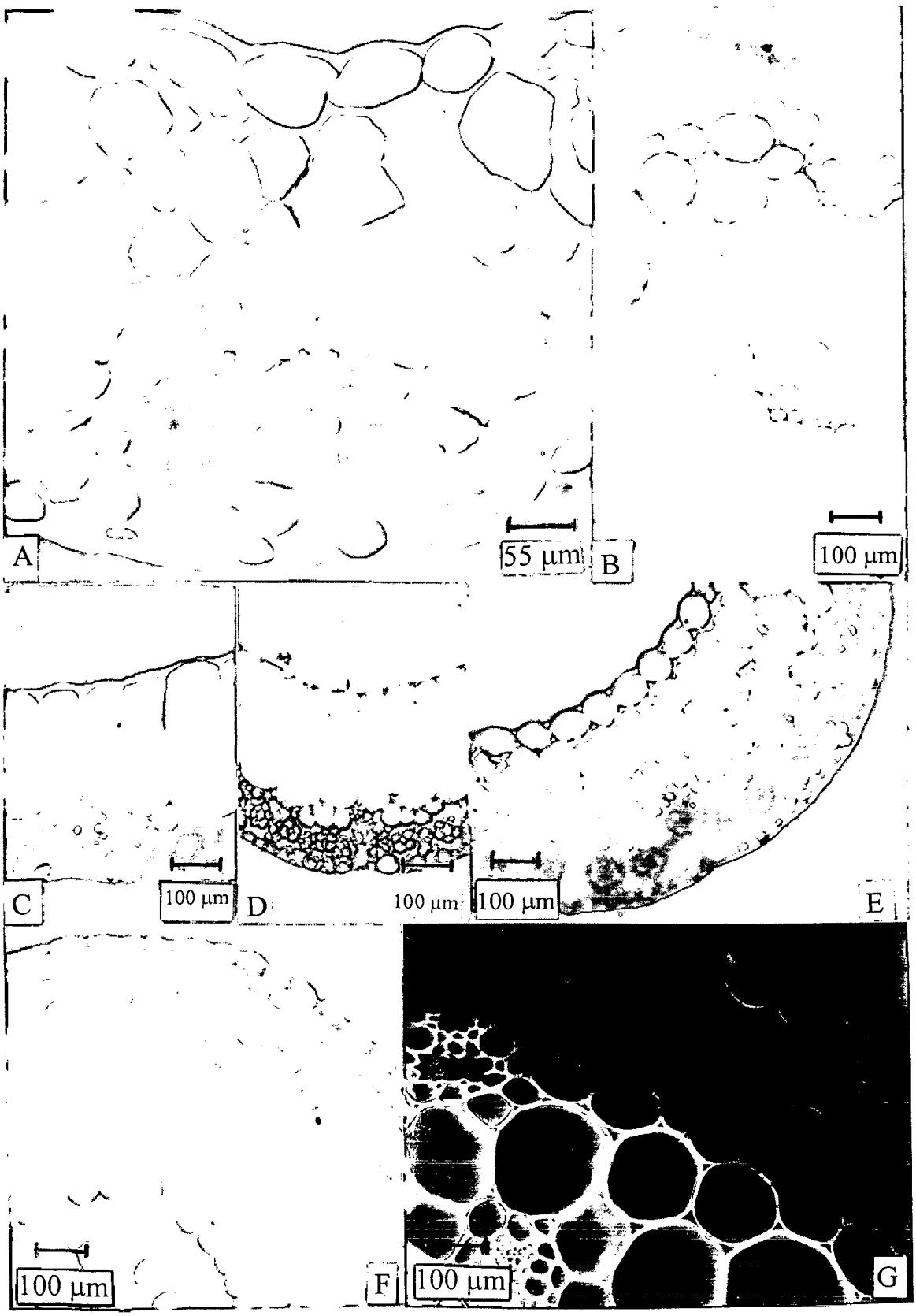


Plate 7: ***Glyphochloa talbotii*** **(Hook.f.) Clayton** (B, C, E&G)**:** (B) T.S. of culm showing thick walled 2 – 3 layered hypodermis; (C) T.S. of leaf with regularly arranged large bulliform cells; (E) T.S. of leaf sheath showing central mid region (without cavities); (G) T.S. of root. ***Glyphochloa sanatapaui*** **(Jain & Desh.) Clayton** (A, D & F)**:** (A) T.S. of leaf sheath with cavities in central mid region; (D) T.S. of leaf with large, regularly arranged bulliform cells; (F) T.S. of culm with thickened hypodermis.

10. *G. veldkampii* M. A. Fonseca & M. K. Janarthanam

T.S of root:

Piliferous layer single, cells hexagonal thick walled, exodermis 1-2 layered, cells thick walled; cortex 6-7 layered, cells thin, circular, in radial rows, disintegrating to form radial plates; stele large; endodermis single layered, inner walls fibrous; pericycle single layered, not prominent; metaxylem 4 to 7 large vessels; protoxylem in small patches towards periphery, not prominent; phloem not prominent; pith with thin or thick walled rounded cells.

T.S of culm:

Circular to ovate in outline, with a curvature on one side and small ridges and furrows on all sides; epidermis single layered, cells rounded to rectangular, interrupted by sunken stomata at few places; cuticle *ca* 5.06 µm thick; macro-hairs absent; vascular bundles in the outer region small, with Kranz anatomy, bundle sheath cells 4-6 in numbers; hypodermis 3-4 layered, sclerenchymatous, embedding number of large vascular bundles beginning at furrow; cortex parenchymatous, thin walled, cells hexagonal to circular in shape with intercellular spaces; central

region with larger and loosely arranged cells; vascular bundles 7-8 sided, scattered towards the periphery in cortex, with prominent metaxylem and few protoxylem elements (2-3) with lacunae; phloem forming a prominent patch between the metaxylem elements (Plate 4F).

T.S of Leaf:

Leaf succulent, 6-7 veined, leaf transverse section with slightly wavy margin, no constriction at lateral main veins; midrib not prominent or flattened; water tissue or bulliform cells regular, covering ½-¾th portion of leaf, cells long, rectangular, colourless, with rounded ends, (in surface view compactly arranged and hexagonal), up to 189 x 91 µm, smaller a lateral veins; mesophyll cells colourless, hexagonal to rounded, 1-2 layered along the midrib or rarely present, absent in lateral lamina; vascular bundles arranged in the form of arc on the abaxial surface; girders or strands below large and few small vascular bundles, each with Kranz anatomy; bundle sheath cells in small vascular bundles rounded, 4-6 in number, with poorly developed vascular tissue. Lateral main bundles shifted upwards with few mesophyll cells below the bundles; abaxial epidermis with barrel to circular shaped cells; cuticle *ca*

5.06 µm thick; stomata sunken; macro-hairs absent (Plate 4C).

Leaf sheath:

Adaxial epidermis single layered, cells barrel to rectangular shaped, bulbous in the median region; cuticle *ca* 5.06 µm thick interrupted by sunken stomata at few places; mesophyll in median region 4-5 layered, cells hexagonal to circular, compactly arranged; vascular bundles as in lamina; bundle sheath cells rounded, 4-5 in number; main vascular bundles shifted upwards; Mid rib solid lateral region with loose cells, few small vascular bundles and main bundles with sclerenchyma girders or strands. Lower epidermis single layered, cells elongated to barrel shaped (bigger in the median region), lined by cuticle (some cells in the median region near the epidermis becomes thicker); keel single layered (Plate 4D).

Leaf peeling:

Costal/intercostal zonation conspicuous; papillae absent; long cells in the coastal region long, narrow and rectangular, up to 185 x 15 µm; intercoastal long cells rectangular, short and long with sinuous walls, sinuosity

fine, the cells are about *ca* 164 x 33 µm; stomata common *ca* 51 x 24 µm, subsidiaries triangular, guard cells overlapping to flash the interstomatals; interstomatal cells rectangular, sinuous with concave ends, intercostal short cells in silica/cork pairs or only cork cells; silica bodies *ca* 12.65 x 15.18 µm and cork cells *ca* 7.59 x 35.42 µm; coastal short cells in silica/cork pair alternating with each other or two silica alternating with single cork cell; prickles absent; macro-hairs absent; micro-hairs *ca* 43.01 x 10.12 µm, two celled.

Note: *G. veldkampii* is more closer to *G. henryi* but differs anatomically as given in Table 10.

Table 10: Anatomical features to differentiate *G. henryi* & *G. veldkampii*

Characters	*G.henyri*	*G.veldkampii*
Root exodermis	More than 2 layered	1-2 layered
T.S of leaf	VB shifted upward	VB not shifted upward
Epidermis in leaf	Epidermis with inflated cells	Epidermis without inflated cells
Leaf sheath midrib	Cavities	Solid
Stomatal size	42 x 27 μm	51 x 24 μm
Stomatal frequency	13	10
T.S of culm hypodermal Layer	3-4 layered	3-4 layered

Table 11: Anatomical features of *Glyphochloa* and closely related genera

Sr.No.	Characters	*Glyphochloa*	*Manisuris*	*Mnesithea*	*Ophiuros*	*Rottboellia*
1	Exodermis in root	1-2 layers thick or additional 1 layer of thin walled cells	Absent	1 - 2 layers thick walled	1 layer thick walled	2 - 3 layers thick walled
2	Cortex in root	4 - 5 or more than 5-layers	4 - layers	4 - layers	5 - 6 layers	6 - layers
3	Fibrous bands in endodermis of root	1/2 - Entire	1/4 portion	1/4 - 1/2	1/4 - 3/4	1/4 portion
4	Bulliform cells / water tissue in leaf : proportion and shape	1/2 - 3/4 portion Regular to irregular	1/4 Regular	1/4 - 1/2 portion Irregular	1/4 - 3/4 portion Regular to irregular	1/4 - 1/2 portion Irregular
5	Size of water cell	63.25 - 265 X 15.80 - 50.60 µm	37.95 - 96.14 X 25.30 - 63.25 µm	37.95 - 70.84 X 25.30 - 50.6 µm	50.60 - 17.70 X 25.30 - 113.85 µm	50.60 X 35.42 µm
6	Veins in leaf	3 - 9 veined	4 - 5 veined	3 - 4 veined	3 - 7 veined	3 - 4 veined
7	Leaf constrictions at lateral main veins	Present or absent	Absent	Absent	Present or absent	Absent
8	Colourless mesophyll	1 - 3 layers	3 - 4 layers	3 - 4 layers	1 - 5 layers	6 layers
9	Epidermal cells on abaxial surface	Few inflated	Equal size	Equal size	Equal & few inflated cells	Equal size
10	Vascular bundle of lateral main veins in leaf	Shifted to not shifted	Not shifted	Not shifted	Shifted to not shifted	Not shifted
11	Macrohairs on leaf	Present or absent	Absent	Present	Absent	Absent
12	Midrib in leaf transverse section	U - V to flattened shaped	U - shaped	V - shaped	U - flattened	U - shaped
13	Size of cuticle on adaxial surface	2.53 - 7.59 µm	3.78 µm	5.06 µm	2.53 µm	2.53 - 3.78 µm
14	No. of rows of short cells in coastal region	1 - 5 cells	1 - 15 cells	1 - 4 cells	1 cell	1 - 2 cells
15	Shape of silica bodies	Dumb-bell, nodular, cross butterfly, crenate-elongated	Dumb-bell with broad in middle	Dumb-bell, cross, butterfly	Dumb-bell, nodular, cross, butterfly	Dumb-bell
16	Size of long cell in costal region	132 - 228 X 12 - 30 µm	50.6-126.5 X 30.36 - 32.89 µm	165 X 27.83 µm	15 - 190 X 38 - 46 µm	63.25 - 129.03 X 10 - 12.15 µm
17	Papillae	Absent	Absent	Absent	Absent	Present
18	Size of stomata	42 - 56 X 24 - 34 µm	40 X 29 µm	43 X 29 µm	49 - 51 X 27 - 35 µm	36 X 20 µm
19	Size of microhairs	25 - 55 X 10.12 - 15.18 µm	50 X 10.12 µm	46 X 10.12 µm	43-45 X 12.65-15.18 µm	43 X 7.59 µm
20	Culm hypodermis (T.S)	2 - 4 layered	3 - 4 layered	3 - 5 layered	2 - 4 layered	more than 4 layered
21	Leaf sheath in transverse section	Midrib - solid/ cavities Lateral - solid/cavities	Midrib - solid Lateral - solid	Midrib - solid Lateral - solid	Midrib - solid/cavities Lateral - solid/cavities	Midrib - cavities Lateral - cavities

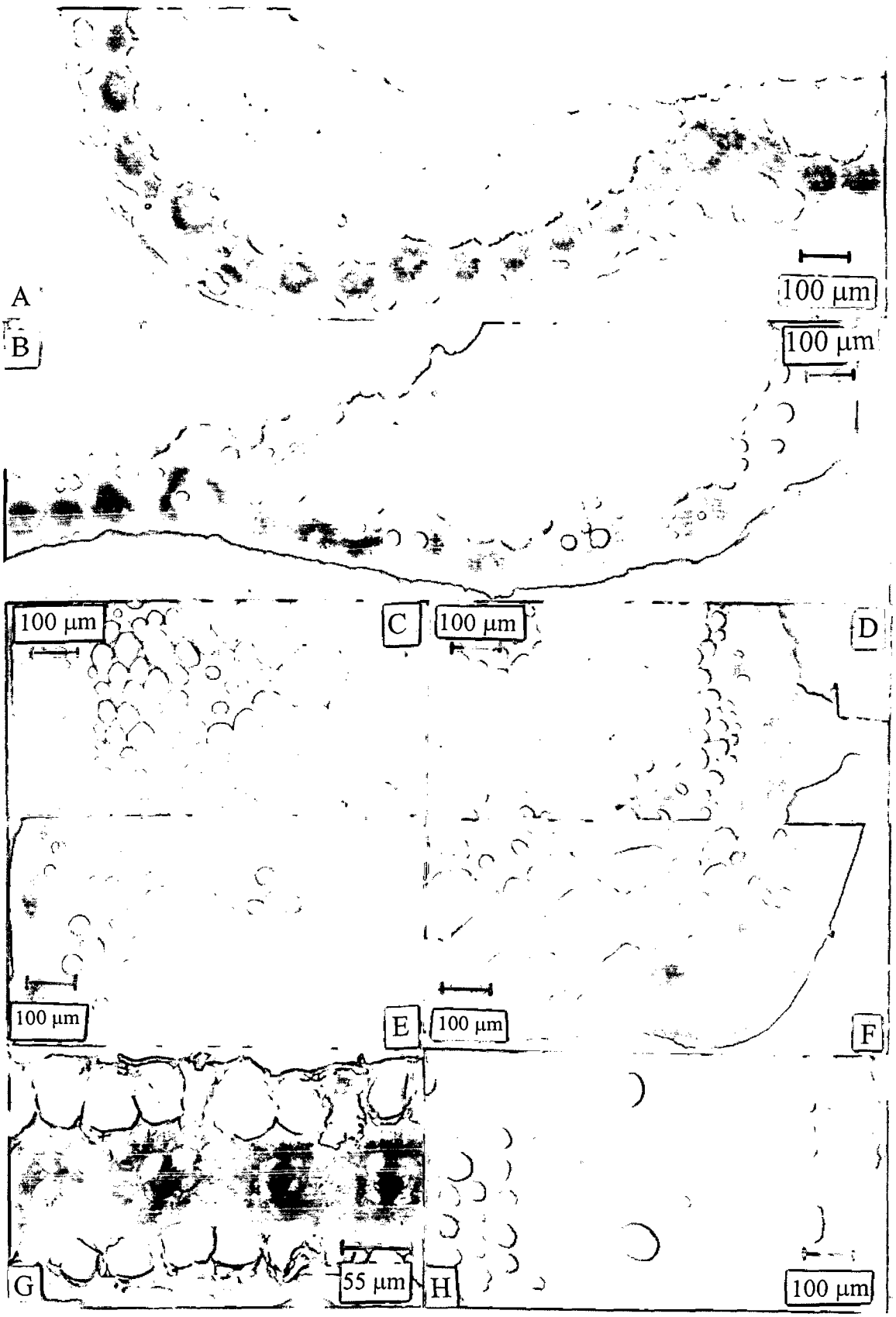


Plate 8: ***Manisuris myuros*** **Linn.** (C&H): (C) T.S. of culm with small vascular bundles & thickened hypodermis; (H) T.S. of root with broad stele & central pith. ***Mnesithea granularis*** **(L.) Koning & Sosef** (D&G): (D) T.S. of culm showing hair & thickened hypodermis; (G) T.S. of leaf with bulliform cells. ***Ophiuros bombaiensis*** **Bor** (A & F): (A) T.S of leaf with shifted lateral main vascular bundle; (F) T.S. of culm with 2 – 3 layered thick walled hypodermis. ***Rottboellia exaltata*** **L.f.** (B&E): (B) T.S. of leaf showing mid region with vascular bundle supported by sclerenchyma girdles; (E) T.S. of culm.

(C) POLLEN

The pollen is stenopalynous throughout *Glyphochloa* and its related genera. In *Glyphochloa* they are circular/ rounded in outline ranging from 20μm- 31μm, mono-porate, operculate. Exine being generally granulose.

(D) STOMATA

Epidermis is interrupted by stomata. They are sunken in the abaxial surface of leaf and occur in the intercostal region of the leaf between the interstomatal cells. The guard cells are dumb-bell, with subsidiaries dome or triangular in shape (Plate 9E).

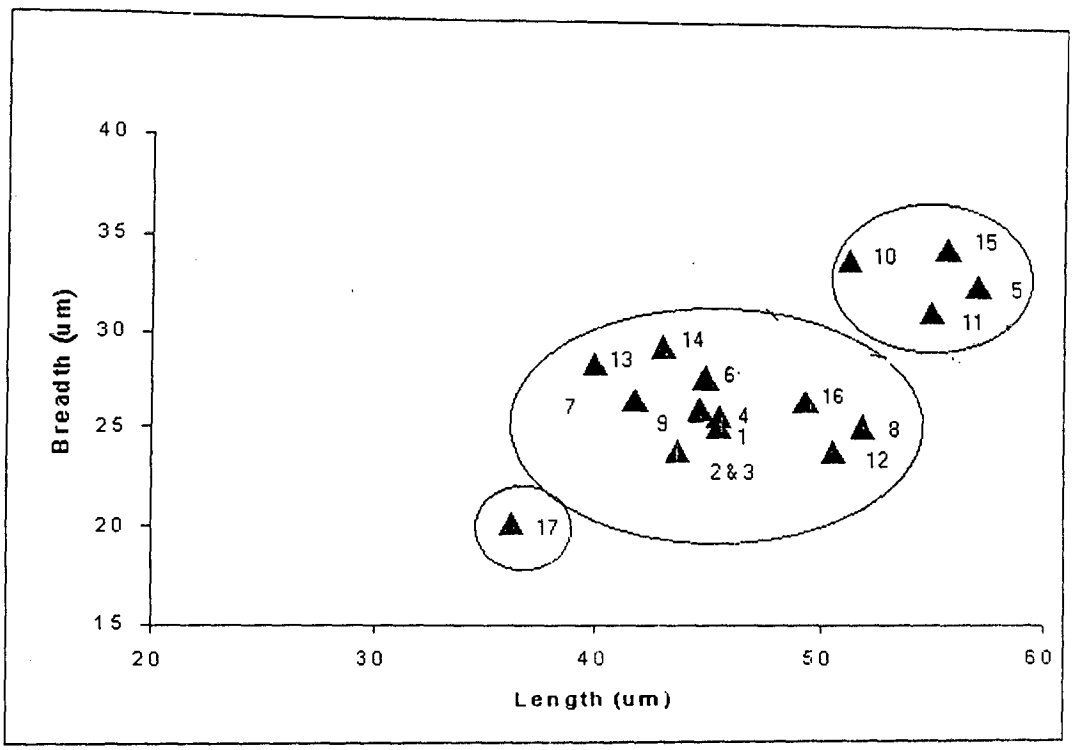
The data (Table 12) on dimensions and frequency of stomata does not show any significant taxonomic relationship. However, the scatter diagram (Fig.16) based on the stomatal length vs breadth brings out three groups. The smallest group comprising the related genus *Rottboellia exaltata* which differ completely from the *Glyphochloa* species and other related genera as shown by morphological and anatomical characters. The second largest group comprises of 3 species of *Glyphochloa* and one species of *Ophiuros*. Among the *Glyphochloa, G. santapaui, G. talbotii* are single awned and *G. forficulata* a two awned species. *Ophiuros bombaiensis* shows smiliarities to single awned group. The third group includes all the remaining species of *Glyphochloa* and its related genera.

Though the stomata have been used extensively for broader groupings or for critical groupings elsewhere, it is of limited use in *Glyphochloa* and its related genera as it appears to be the function of ecological condition.

Table 12 : Stomata in different species of *Glyphochloa* and its related genera

	Average		Range		Frequency	
Species	Length (μm)	Width (μm)	Length (μm)	Width (μm)	Range	Average
G. acuminata var.acuminata	45.54	25.3	43.00 - 48.07	25.3	9 - 17	12.5
G. acuminata var.stocksii	43.64	24.03	40.48 - 48.07	22.77 - 25.30	12 - 15	13.5
G. acuminata var.woodrowii	43.64	24.03	40.48 - 48.07	22.77 - 25.30	12 - 15	13.5
G. divergens	45.54	25.80	43.51	22.70 - 27.83	12 - 15	13.6
G. forficulata	56.92	32.89	50.60 - 58.19	27.83 - 35.42	7 - 10	8.25
G. goaensis	44.9	27.83	43.01 - 45.54	25.30 - 32.89	7 - 10	8.25
G. henyri	41.74	26.56	32.89 - 45.54	22.77 - 30.36	11 - 15	12.5
G. mysorensis	51.86	25.3	43.01 - 58.19	22.77 - 27.83	11 - 12	11.5
G. ratnagirica	44.67	26.13	43.01 - 45.54	25.30 - 27.83	10	10
G. santapaui	51.23	34.15	48.07 - 55.66	32.89 - 35.42	8 - 10	9
G. talbotii	54.92	31.44	48.07 - 58.19	27.83 - 35.42	8 -16	11.28
G. veldkampii	50.6	24.03	48.07 - 53.13	20.24 - 27.83	9 - 11	9.75
Manisuris myuros	39.94	28.56	37.95 - 40.48	22.77 - 35.42	10 - 16	14
Mnesithea granularis	43.01	29.49	40.48 - 45.54	25.30 - 32.89	6 - 12	8
Ophiuros bombaiensis	55.66	34.76	43.01 - 63.25	32.89 - 37.95	7 - 9	8
Ophiuros exaltatus	49.33	26.56	48.07 - 53.13	25.30 - 30.36	8 - 10	8.75
Rottboellia exaltata	36.25	20.24	35.42 - 37.95	17.71 - 22.77	7 - 22	15

Fig. 16: Scatter diagram for *Glyphochloa* species and related genera based on stomata length vs breadth



LEGEND

1. *Glyphochloa acuminata var. acuminata*
2. *G.acuminata var. stocksii*
3. *G.acuminata var. woodrowii*
4. *G.divergens*
5. *G.forficulata*
6. *G.goaensis*
7. *G.henryi*
8. *G. mysorensis*
9. *G.ratnagirica*
10. *G.santapaui*
11. *G.talbotii*
12. *G.veldkampii*
13. *Manisuris myuros*
14. *Mnesithea granularis*
15. *Ophiuros bombaiensis*
16. *O.excaltatus*
17. *Rottboellia exaltata*

(E) SILICA CELLS

Silica cells are made up of amorphous silicon dioxide/ silicon oxide (SiO_2nH_2O), while the Cork cells are with suberised walls containing organic materials. Shapes of the silica bodies in silica cells are important for taxonomic purposes. The size and shape of silica bodies can be used to identify grasses up to their generic level. Krishnan et al (2000) studied Phytoliths (silica cells) of several genera in the family with one or more representative species. They have then provided a key based on silica cells. Presence of excessive silica bodies is a physical deterrent to feeding (as in *Glyphochloa)* Dayanandan (1994).

The species and the related genera of *Glyphochloa* show abundant dumb-bell shaped to butterfly, nodular, elongated and crenate silica bodies which can be seen in the costal region, where they are found in rows, normally alternating with cork cells (Table 13).

The results show that all of the species of *Glyphochloa* are dominated by dumb-bell shaped silica bodies followed by cross, nodular, butterfly and crenate shaped. No grouping could be made within the genus based on these characters as they are much variable within the genus.

Table 13 : Silica bodies in different species of *Glyphochloa*

Species	Silica cells costal alternate or rows	Silica bodies (Shape) Intercostal zone	Silica bodies (Shape) Costal zone
G.acuminata var.acuminata	S/C alt. (1 row)	Cross, dumb-bell to crenate	Dumb-bell (abundant) elongated, crenate cross
G.acuminata var.stocksii	S/C alt. (1 row) 1 / 2 cells	Cross, dumb-bell to crenate	Dumb-bell, elongated, crenate, cross
G.acuminata var.woodrowii	S/C alt. (1-2 rows) rarely	Dumb-bell	Dumb-bell, elongated, (abundant) crenate, cross
G. divergens	S/C alt. (1 row) 4 - 2 cells few case	Dumb-bell	Dumb-bell, butterfly, cross
G. forficulata	S/C alt. (4-5 rows) 1 / 2 cells	Cross,dumb-bell, irregular	Dumb-bell, elongated, crenate
G. goaensis	S/C alt. (1 row)	Cross (few)	Dumb-bell & butterfly
G. henryi	S/C alt. (1 row)	Cross,dumb-bell, irregular	Dumb-bell (abundant) elongated
G. mysorensis	S/C alt. (1 row)	Cross,dumb-bell, irregular	Dumb-bell (abundant) elongated, cross
G. ratnagirica	S/C alt. (1 row) 1 / 2 cells	Cross,dumb-bell, irregular	Dumb-bell
G. santapaui	S/C alt. (1-2 rows) 1 / 2 cells	Cross,dumb-bell, irregular	Dumb-bell, elongated,
G.talbotii	S/C alt. (1-2 rows) 1 / 2 cells	Cross,dumb-bell, to crenate	Dumb-bell (abundant) elongated, cross
G. veldkampii	S/C alt. (1 row) 2 / 3 cells	Cross,dumb-bell, irregular	Dumb-bell (abundant) elongated

C = Cork cell

S = Silica cell

Alt. = Alternate

1/2 = 1 silica alternating 2 cork cells

(F) MICRO-HAIRS

Microhairs are two celled structures in *Glyphochloa*, a characteristic of Panicoidae, with normally basal cell smaller than the apical cell (Plate 9C). They arise in the intercostal region. The data is presented on table 14. The micro-hair characters can be easily used for the construction of identification key.

KEY BASED ON SIZE OF BASAL CELL AND APICAL CELL

1. Micro-hair total size from 40-56 µm:
   2. Basal cell <15 µm in length:
      3. Breadth of the basal cell <10 µm . . ***G. acuminata*** var. ***woodrowii***
      3. Breadth of the basal cell >10 µm . . ***G. forficulata***
   2. Basal cell >15 in length:
      4. Apical cell >30 µm long. . . . . ***G. talbotii***
      4. Apical cell < 30 µm long . . . . . ***G.veldkampii***

1. Micro-hair total size 20-39 µm :
   5. Apical cell width >12 µm . . . . . ***G. acuminata*** var. ***acuminata***
   5. Apical cell width <12 µm:
      6. Length of basal cell >12 µm . . ***.G. mysorensis*** (15.18 µm)
      6. Length of basal cell <12:
         7. Apical cell with length Of 12.65 µm. . . . . ***G. goaensis***

7. Apical cell with length of 25.30 µm. . . . . ***G. acuminata*** var. ***stocksii***

5. Total length from 25-36 µm:

8. Apical cell breadth 7.59 µm . . ***G.ratnagirica***

8. Apical cell breadth 10.12 µm:

9. Apical cell with length of 13.89 µm. . . . . ***G. santapaui***

9. Apical cell with length of 17.71 µm:

10. Basal cell with breadth 10.12 µm: . . . . . ***G. divergens***

10. Basal cell with breadth of 12.65 µm . . . . . ***G. henryi***

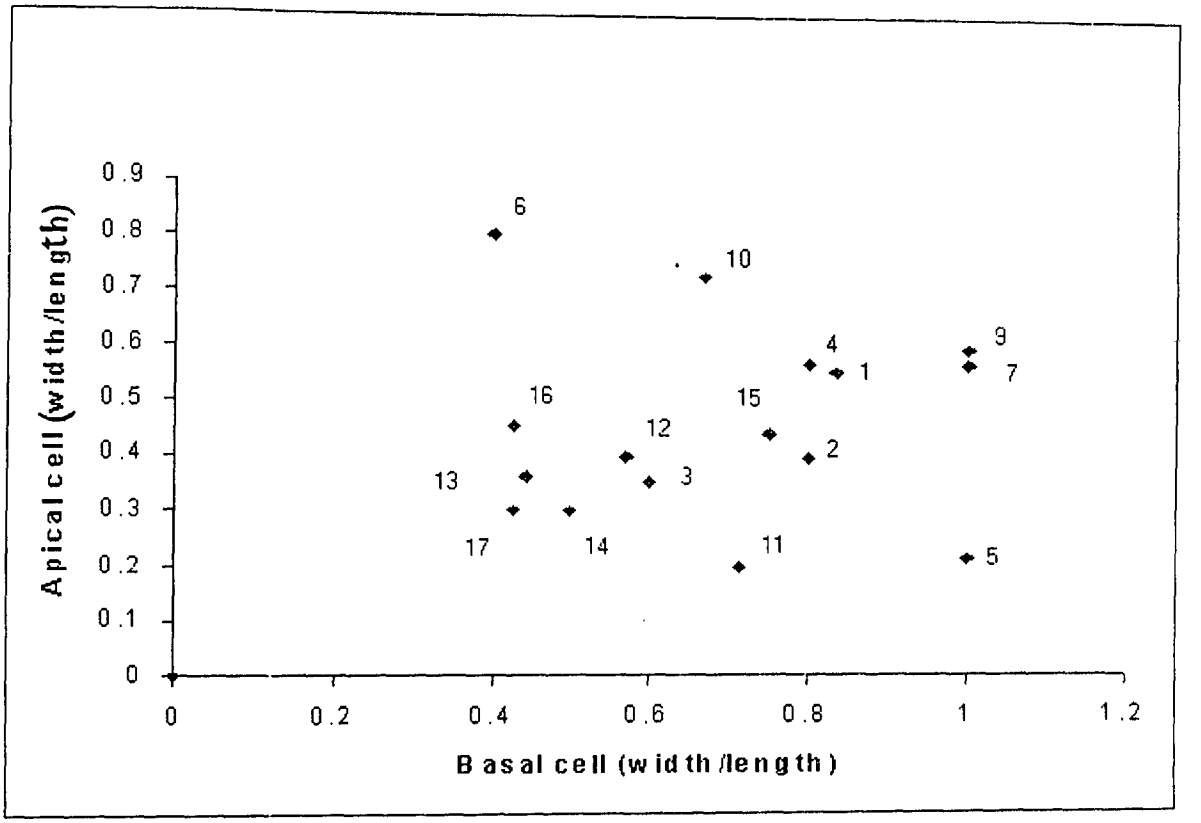
There is a positive correlation between basal cell and apical cells based on the proportion of width/length (Fig. 17). The related genera of *Glyphochloa* appear together in the scatter diagram but for these, there appears to be no taxonomic/ecological correlation within the genus with respect to microhairs.

Microhairs in grasses vary in their ultrastructure (Amarsinghe, 1988). In the present study the morphological characters of microhairs including their length and breadth could be effectively used for the identification of species.

Table 14 : Size of the Microhairs in species of *Glyphochloa* and related genera

Species	Basal cell(µm)		Apical cell(µm)	
	Length	Breadth	Length	Breadth
G. acuminata var.acuminata	15.18	12.65	22.77	12.65
G. acuminata var.stocksii	12.65	10.12	25.3	10.12
G. acuminata var.woodrowii	12.65	7.59	35.42	12.65
G. divergens	12.65	10.12	17.71	10.12
G. forficulata	12.65	12.65	35.42	7.59
G. goaensis	25.3	10.12	12.65	10.12
G. henryi	12.65	12.65	17.71	10.12
G. mysorensis	15.18	12.65	22.77	10.12
G. ratnagirica	12.65	12.65	12.65	7.59
G. santapaui	22.71	15.18	13.89	10.12
G. talbotii	17.71	12.65	37.95	7.59
G. veldkampii	17.71	10.12	25.3	10.12
Manisuris myuros	22.77	10.12	27.83	10.12
Mnesithea granularis	20.24	10.12	25.3	7.59
Ophiuros bombaiensis	20.24	15.18	22.77	10.12
Ophiuros exaltatus	17.71	7.59	27.83	12.65
Rottboellia exaltata	17.71	7.59	25.3	7.59

Fig. 17: Scatter diagram for *Glyphochloa* species and related genera based on proportion of width and length of basal vs apical cells of microhairs



LEGEND

1. *Glyphochloa acuminata var. acuminata*
2. *G.acuminata var. stocksii*
3. *G.acuminata var. woodrowii*
4. *G.divergens*
5. *G.forficulata*
6. *G.goaensis*
7. *G.henryi*
8. *G. mysorensis*
9. *G.ratnagirica*
10. *G.santapaui*
11. *G.talbotii*
12. *G.veldkampii*
13. *Manisuris myuros*
14. *Mnesithea granularis*
15. *Ophiuros bombaiensis*
16. *O.excaltatus*
17. *Rottboellia exaltata*

STARCH

Starch, a reserve carbohydrate exist in the form of grains in the cells. There is a great variation in the size of starch grains in different plant organs as well as a range of size within a single seed or plant organ. There is also a considerable range in shape of starch grains like ovoid, polygonal, spherical, etc. Starch consists of two essentially different constituents amylose and amylopectin. Starch grains are useful in the classification and identification of grasses. Smith (1968) classified several native North American grasses on the basis of starch grains. Starch grains are generally considered to be uniform in Panicoideae. But the present study shows that in genus *Glyphochloa* they are very variable. The caryopsis in different species of *Glyphochloa* was tested for starch grains. Table 15 shows the shapes of starch grains in different species of *Glyphochloa*. However due to enormous variations in their shape and size in species, starch grains could not be used in taxonomic interpretations.

Table 15 : Shape of starch grains in different species of *Glyphochloa* and related genera

Starch Grains	Shape
G.acuminata var.acuminata	Small, rounded to irregular
G.acuminata var.stocksii	Circular,angular & irregular
G.acuminata var.woodrowii	Very small, rounded to irregular
G.divergens	Minute, rounded to regular
G.forficulata	Minute, rounded & angular
G.goaensis	Minute, rounded, elongated or rod shaped
G.henryi	Small, minute, rounded ovoid, rod shaped or curved
G.mysorensis	Small, rounded, elongated, mostly ovoid & angular
G.ratnagirica	Small to medium triangular, rounded to irregular
G.santapaui	Circular
G.talbotii	Circular, angular & irregular
G.veldkampii	Rounded, irregular & angular
Manisuris myuros	Small & rounded
Mnesithea granularis	Rounded
Ophiuros bombaiensis	Rounded & irregular
Ophiuros exaltatus	Rounded & irregular
Rottboellia exaltata	Circular, triangular & angular

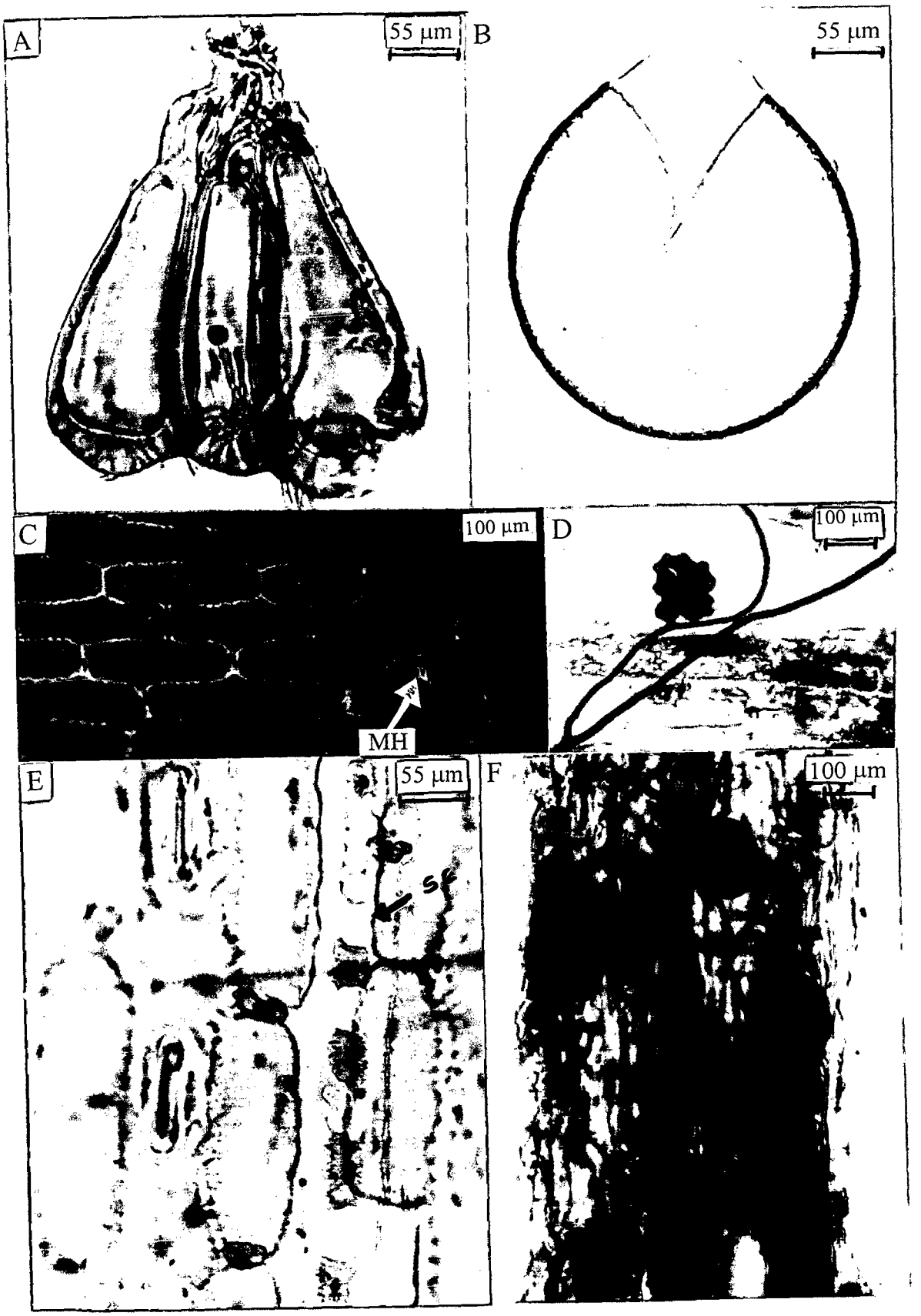


Plate 9: Mycorrhizal Infection and spores (A, B, D & F): A & B Spore of *Glomus* & *Acaulospora*; D Soil borne vesicles; F Vesicles in root. **Leaf peelings** (C & E): C Stomata, Long cells and microhairs; E Stomata, long cells and short cells in rows (silica and cork).

MH = Microhair; SC = Silica cell.

FLAVONOIDS

The flavonoid studies for the species of *Glyphochloa* and its related genera were carried out. The extract was chromatographed using paper and thin layer chromatography in different solvents as described under materials and methods. The results were not significant as only one or two spots could be resolved. Therefore a new method was devised.

According to Harborne (1984) the principal maxima of absorption range from 250-270 nm indicate the presence of flavonols and from 390-430 nm the aurones. He also showed that flavonols are distributed in both cyanic and acyanic flowers and widespread in leaves and these are normally seen in the spectral maxima of 350-386 nm. While aurones are yellow flower pigments occasionally present in other tissues, they give red colour with ammonium and their visible maxima from 370-410 nm. Hence, the extract after diluting with ethanol was scanned for as described under materials and methods for absorption using spectrophotometer. The result showed that the species of *Glyphochloa* and its related genera showed that the species

of *Glyphochloa* and its related genera showed unique patterns of absorbance.

The results, both graph and peak absorptions as picked by spectrophotometer are given in Fig. 18 - Fig. 26.

Using the absorption peaks a key has been constructed to identify the species.

KEY FOR SPECIES OF *GLYPHOCHLOA* BASED ON PEAKS OF ABSORPTION AT DIFFERENT WAVELENGTHS BY FLAVONOIDS

1. Peaks two or more between 300 & 400 nm:

2. Absorption peak below 300 nm absent:

3. Peaks three above 400 nm . . . . . ***G. talboti***

3. Peaks only one above 400 nm . . . . . ***G. henryi***

2. Absorption peaks below 300 nm present:

4. Two peaks between 300 & 400 nm at 332 and 360 nm . . . . . ***G. acuminata*** var. ***woodrowii***

4. Two peaks between 300 & 400 nm at 300 and 315 nm . . . . . ***G. acuminata*** var. ***acuminata***

1. Peak only one between 300 & 400 nm:

5. Peaks absent between 200 & 300 nm:

6. Absorption peak present between 300 & 400 nm

only at 309.60 nm . . . . . ***G. goaensis***

6. Absorption peak present between 300 & 400 nm only at 312.60 nm . . . . . .***G. divergens***

5. Peaks present between 200 & 300 nm:

7. Number of peaks between 245 & 260 nm are three:

8. Peak between 300 & 325 nm is at 314 nm . . ***G. acuminata*** var. ***stocksii***

8. Peak between 300 & 325 nm is above 315nm:

9. Absorption peak between 300 & 325 nm is at 316.80 . . ***G. mysorensis***

9. Absorption peak between 300 & 325 nm is at 319.60 . . ***G. ratnagirica***

7. Number of peaks between 245 & 260 nm are one or two:

10. Peak between 245 & 260 nm is one at 253 nm . . . . ***G.veldkampii***

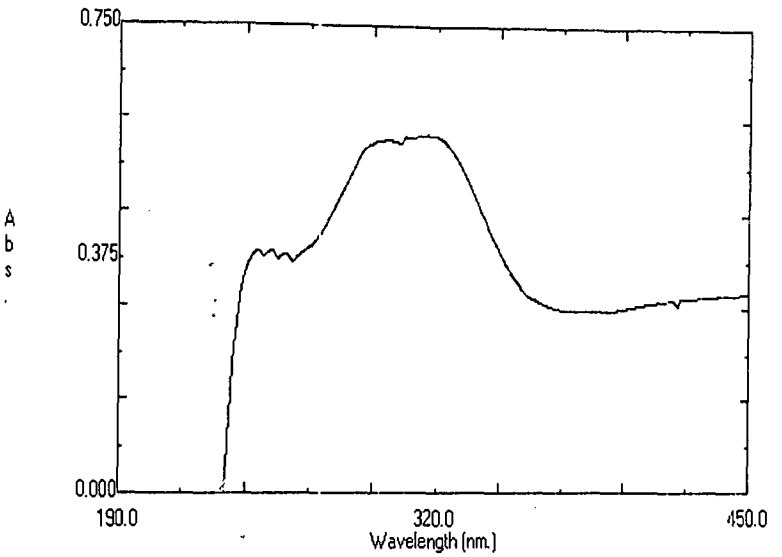
10. Peak between 245 & 260 nm are two:

11. Between 300 & 320 nm peak is at 314.40 .***G.forficulata***

11. Between 300 & 320 nm peak is at 308.40 . .***G. santapauii***

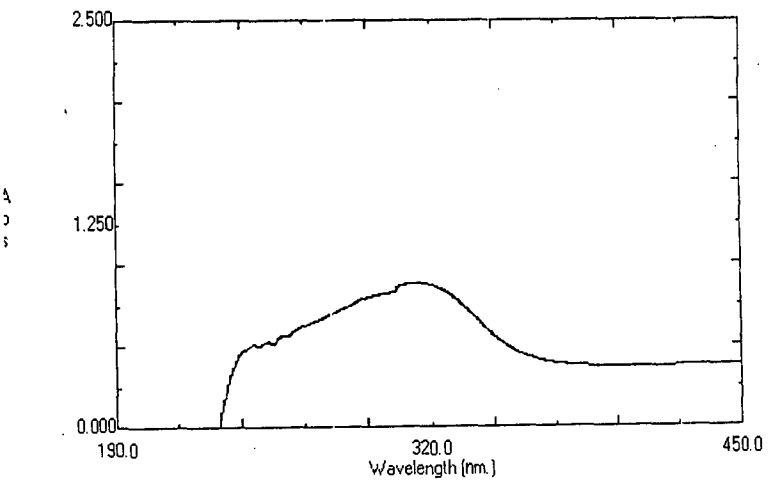
Note: *G. hirsuta* not included due to paucity of material.

(A) *Glyphochloa acuminata* var. *acuminata*



λ (ηm)	Abs
418.40	0.312
315.80	0.574
300.00	0.566
257.40	0.382
252.00	0.389
246.60	0.390

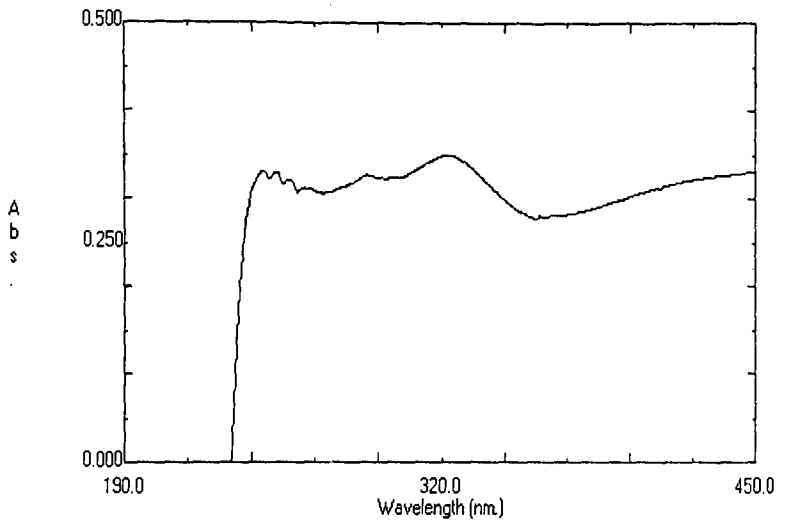
(B) *Glyphochloa acuminata* var. *stocksii*



λ (ηm)	Abs.
415	0.372
314	0.888
259	0.562
252	0.527
246	0.509

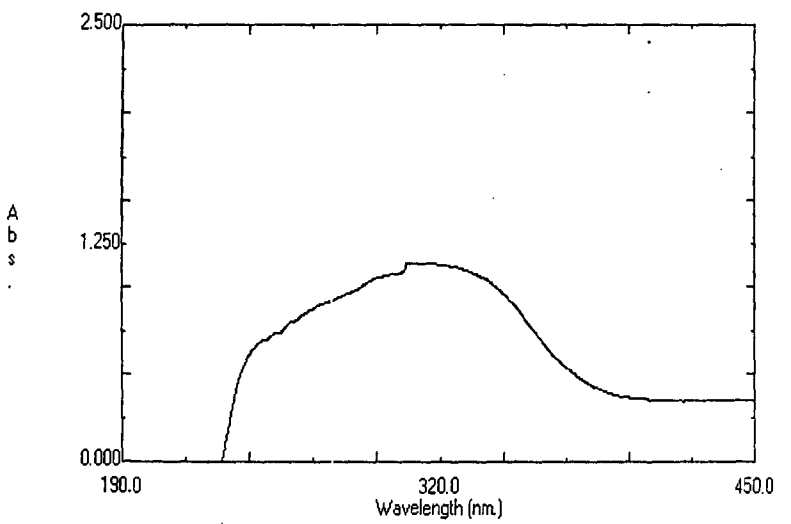
Fig.18: Absorption spectra for flavonoids of different Species of *Glyphochloa*.
(Adjacent tables show peak absorptions as picked up by spectrophotometer).

(A) *Glyphochloa acuminata var. woodrowii*



λ (ηm)	Abs
409.40	0.312
360.60	0.279
322.20	0.347
289.00	0.326
263.40	0.311
256.80	0.321
252.20	0.329
246.40	0.332

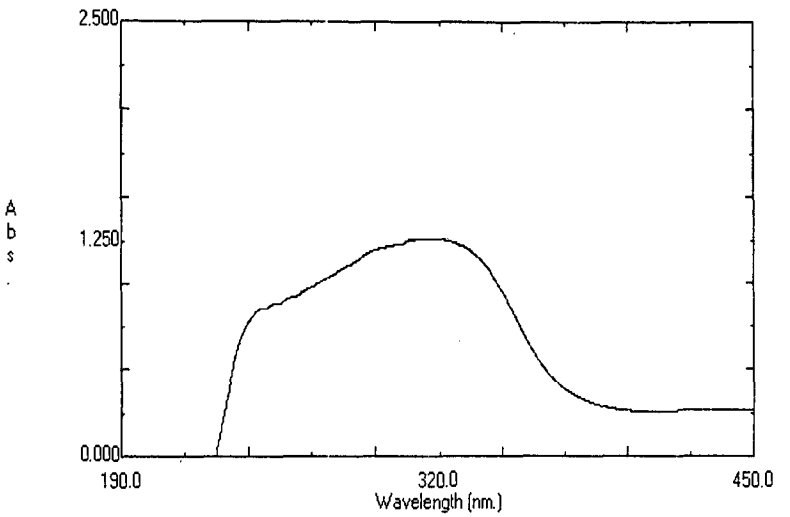
(B) *Glyphochloa divergens*



λ (ηm)	Abs
411.80	0.350
312.60	1.134

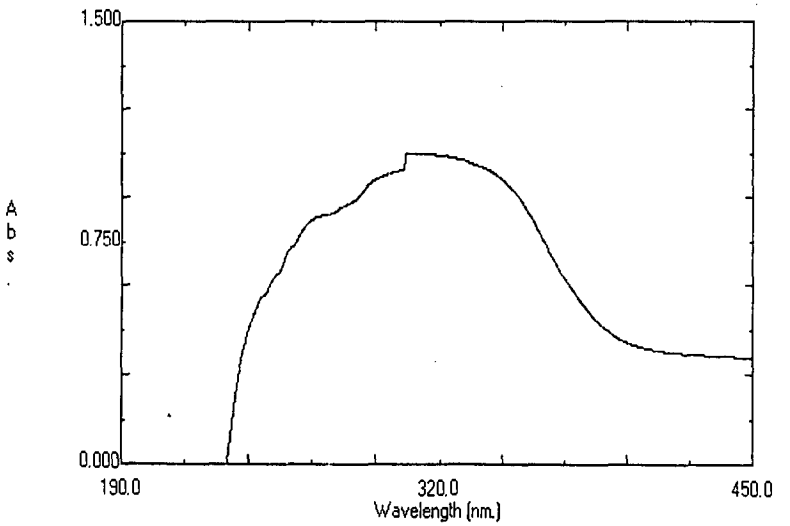
Fig.19: Absorption spectra for flavonoids of different Species of *Glyphochloa*.
(Adjacent tables show peak absorptions as picked up by spectrophotometer).

(A) *Glyphochloa forficulata*



λ (ηm)	Abs
420.40	0.261
314.40	1.260
252.80	0.878
248.20	0.849
216.60	0.508

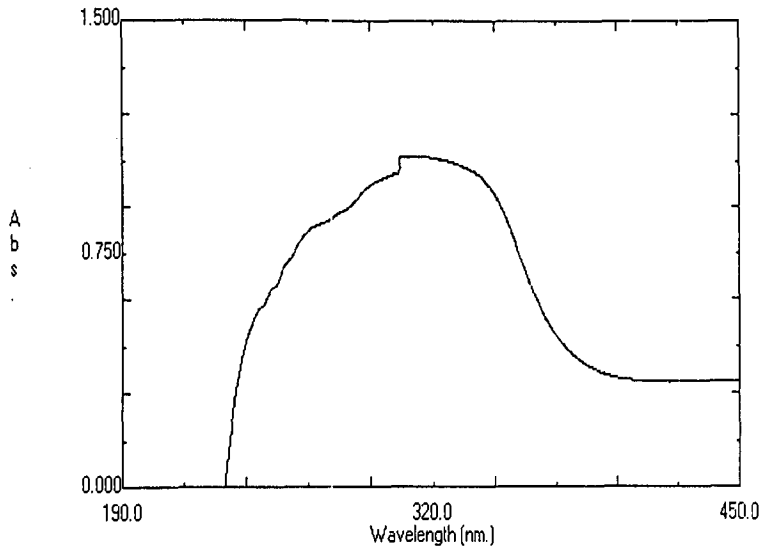
(B) *Glyphochloa goaensis*



λ (ηm)	Abs
411.80	0.379
309.60	1.049

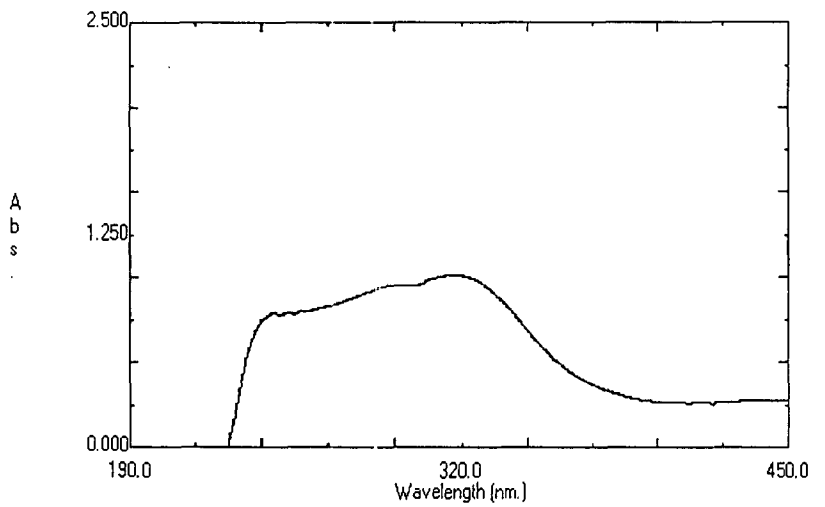
Fig.20: Absorption spectra for flavonoids of different Species of *Glyphochloa*.
(Adjacent tables show peak absorptions as picked up by spectrophotometer).

(A) *Glyphochloa henryi*



λ (ηm)	Abs
416.60	0.337
323.60	1.051
310.40	1.060

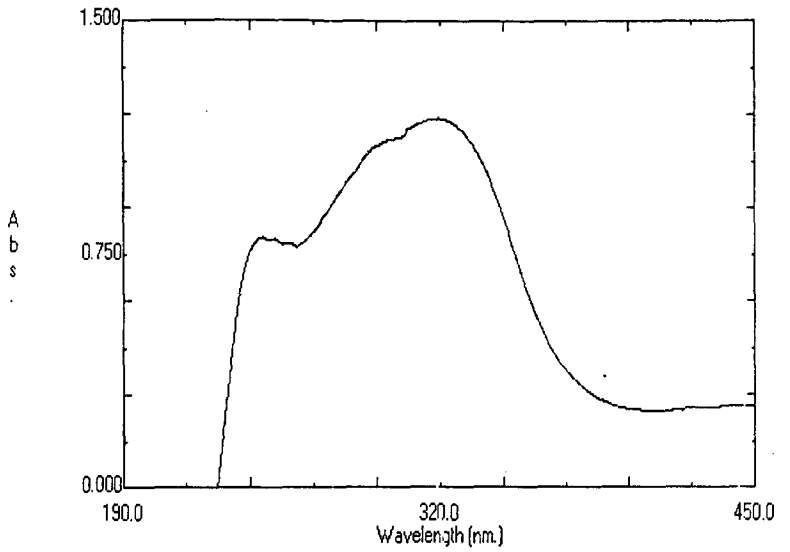
(B) *Glyphochloa mysorensis*



λ (ηm)	Abs
417.20	0.266
316.80	1.010
258.60	0.801
252.60	0.789
247.00	0.785

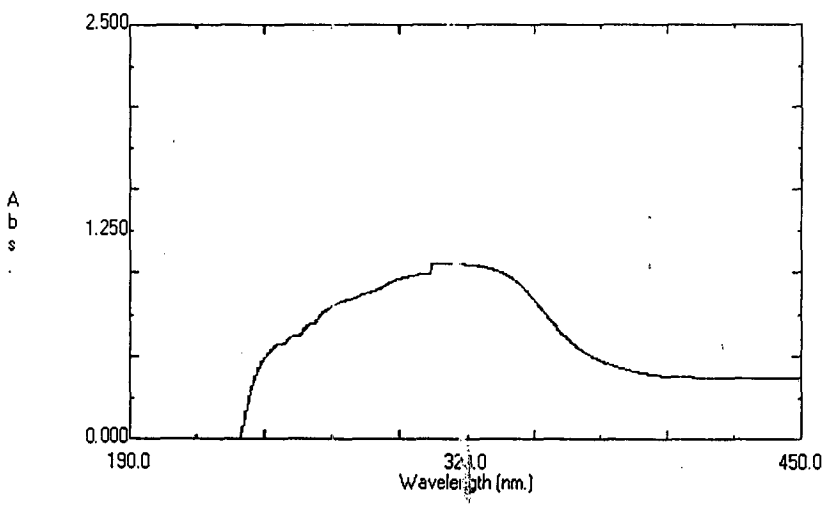
Fig.21. Absorption spectra for flavonoids of different Species of *Glyphochloa*.
(Adjacent tables show peak absorptions as picked up by spectrophotometer).

(A) *Glyphochloa ratnagirica*



λ (ηm)	Abs
418.60	0.254
319.60	1.186
257.20	0.786
252.00	0.799
247.00	0.805

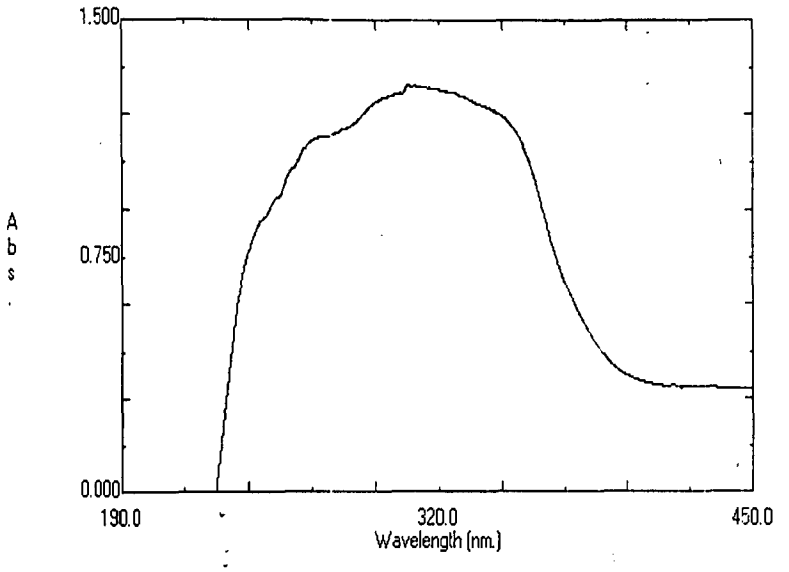
(B) *Glyphochloa santapaui*



λ (ηm)	Abs
419.80	0.372
308.40	1.054
253.20	0.623
247.40	0.576
191.00	0.346

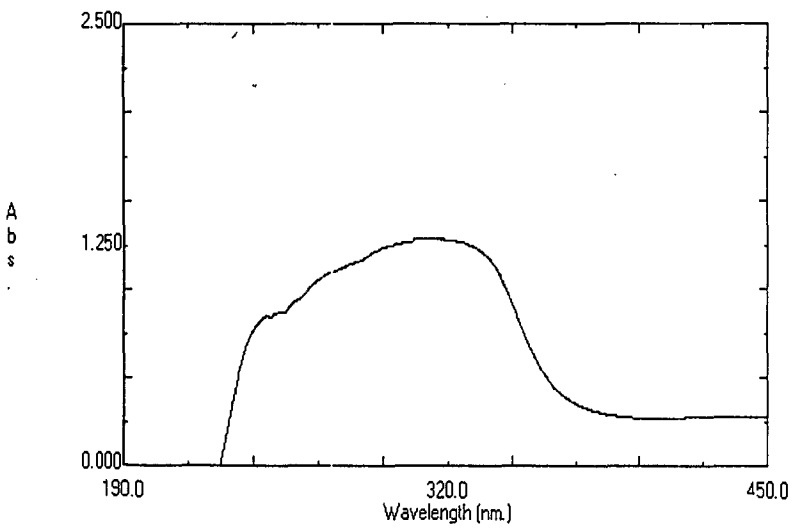
Fig.22: Absorption spectra for flavonoids of different Species of *Glyphochloa*.
(Adjacent tables show peak absorptions as picked up by spectrophotometer).

(A) *Glyphochloa talbotii*



λ (ηm)	Abs
421.40	0.338
416.60	0.341
411.80	0.341
316.00	1.283
307.40	1.292

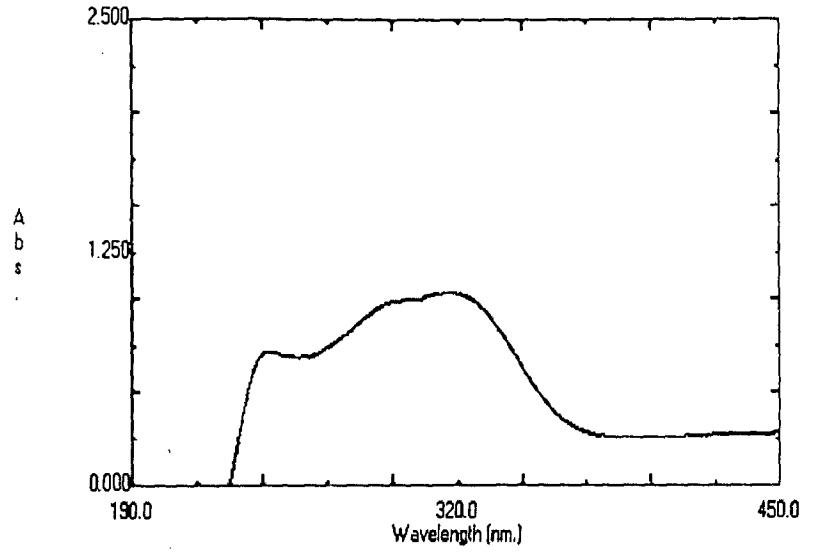
(B) *Glyphochloa veldkampii*



λ (ηm)	Abs
420.60	0.274
312.00	1.291
253.00	0.872

Fig.23: Absorption spectra for flavonoids of different Species of *Glyphochloa*.
(Adjacent tables show peak absorptions as picked up by spectrophotometer).

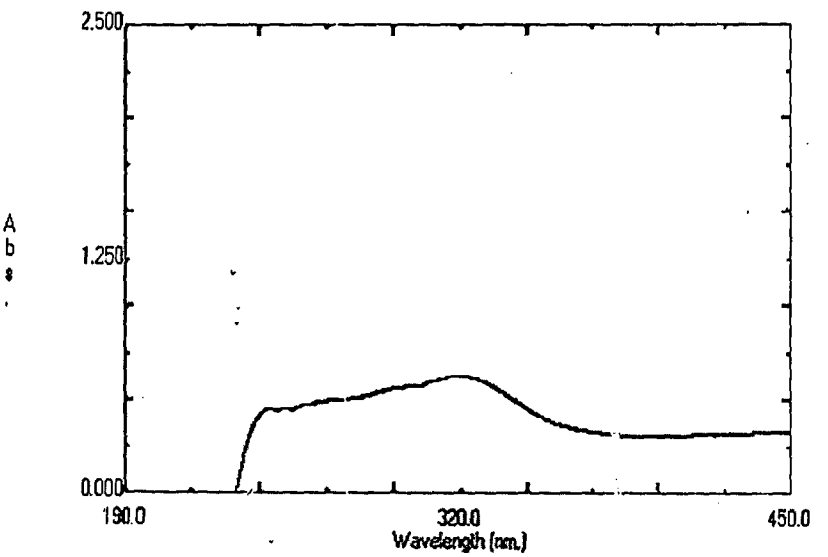
(A) *Manisuris myuros*



λ (ηm)	Abs
418.4	0.268
317.6	1.030
298.8	0.988
258.4	0.691
250.8	0.698
245.6	0.719

I

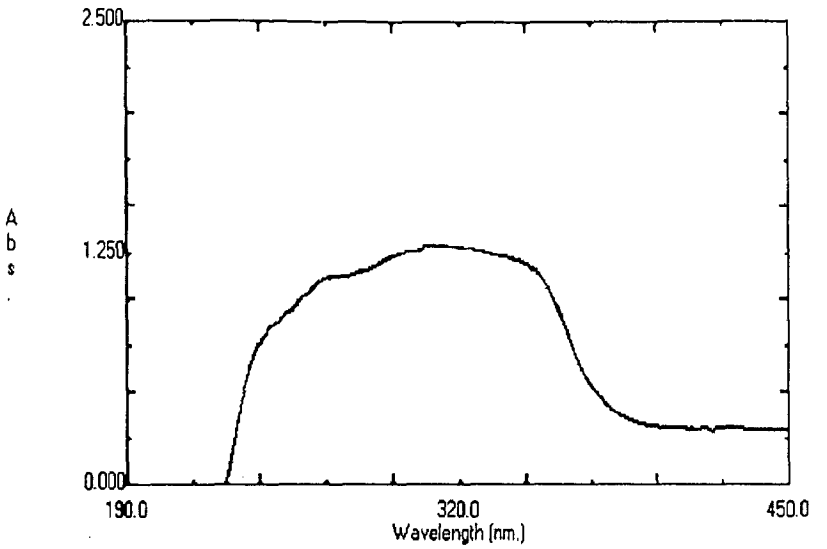
(B) *Mnesithea granularis*



λ (ηm)	Abs
418.8	0.316
360.6	0.360
319.0	0.624
258.8	0.467
252.2	0.450
246.2	0.451

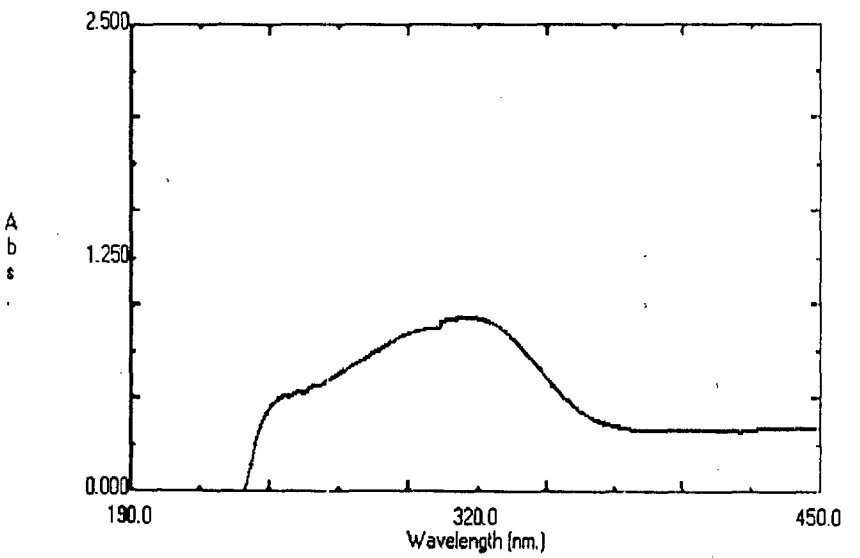
Fig.24: Absorption spectra for flavonoids of related genera of *Glyphochloa*.
(Adjacent tables show peak absorptions as picked up by spectrophotometer).

(A) *Ophiuros bombaiensis*



λ (ηm)	Abs
416.6	0.304
321.0	1.271
313.8	1.283
309.0	1.284

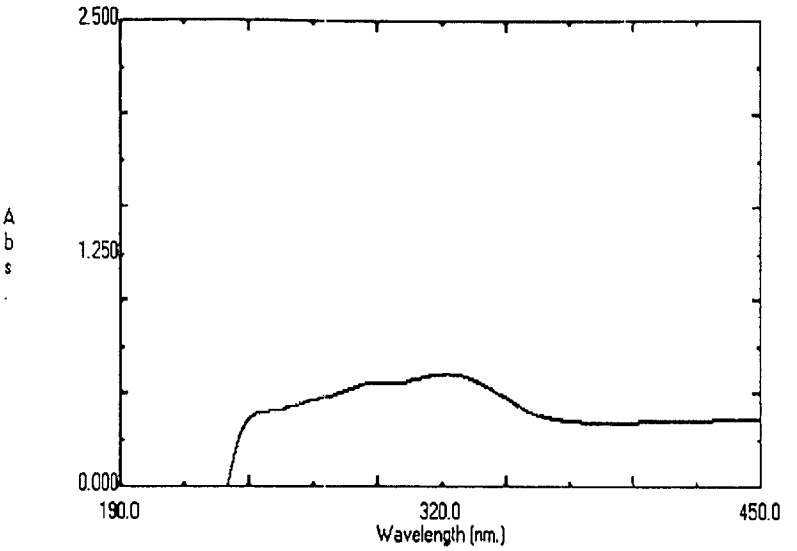
(B) *Ophiuros exaltatus*



λ (ηm)	Abs
417.60	0.330
315.60	0.928
253.00	0.528
247.20	0.507

Fig.25: Absorption spectra for flavonoids of related genera of *Glyphochloa*.
(Adjacent tables show peak absorptions as picked up by spectrophotometer).

Rottboellia exaltata



λ (ηm)	Abs
409.40	0.346
321.80	0.597
291.80	0.551
258.80	0.429
252.20	0.411
246.80	0.401

Fig.26: Absorption spectra for flavonoids of related genera of *Glyphochloa*.

(Adjacent tables show peak absorptions as picked up by spectrophotometer).

The spectral pattern shows similarities between *G. goaensis* and *G. henryi* along with *G. talbotii*, these species are single awned and taxonomically related. *Ophiuros bombaiensis* the related genera is closer to this group which is also anatomically similar.

G. acuminata var. *acuminata* and *G. acuminata* var. *woodrowii* are closer in spectral pattern while *G. santapaui* and *G. divergens* although belonging to different groups of *Glyphochloa* show similar patterns.

Although *G. veldkampii* and *G. acuminata* var. *stocksii*, are single awned species they are found to have similar spectral patterns with *G. mysorensis* and *G. forficulata* the divergent awned species. The related genera *Manisuris myuros* and *Ophiuros exaltatus* is also closer to this group.

G. ratnagirica the divergent awned species stand with an unique pattern and is also distinct in few characters viz. lower glume of the sessile spikelet smooth on back with marginal tubercles and peculiar branching pattern.

The related genera *Rottboellia exaltata* and *Mnesithea granularis* are almost closer to and are distinct from all the other groups.

Spectral patterns shows that the wavelengths of peak absorption are unique for most of the species, the combinations of which can be used for the identification of the species. Though it was not possible to use the absorption peaks for grouping of species at broader level, it was observed that two or three related species were showing certain common peaks apart from their unique ones.

RAPD

RAPD studies were carried out for five species of *Glyphochloa* viz. *G. acuminata* var. *acuminata*, *G. acuminata* var. *woodrowii*, *G. henryi*, *G. ratnagirica*, *G. talbotii* and *Ophiuros bombaiensis*. The results are shown in the photographs of Agarose Gel electrophoresis (plate 10a & b). The Nei and Li's similarity coefficient calculated from the bands are provided in the table 16. Dendrogram constructed based on Nei and Li's similarity index is given in Fig. 27.

The highest genetic similarity was found between *G. acuminata* var. *woodrowii* and *G. talbotii* forming one cluster and *G. ratnagirica* and *Ophiuros bombaiensis* forming another cluster. *G. acuminata* var. *acuminata* is found to be more closer in similarity to the above four species than *G. henryi*. Anatomically *Ophiuros* resembles more with *G. henryi*. However, it is showing some similarities with Cladogram (Fig.35) constructed with morphological and anatomical characters using *Ophiuros* as an outgroup. The over all differences in similarities may be due to the character variation brought in by ecological conditions on one hand and need to study RAPD with wide array of primers on the other.

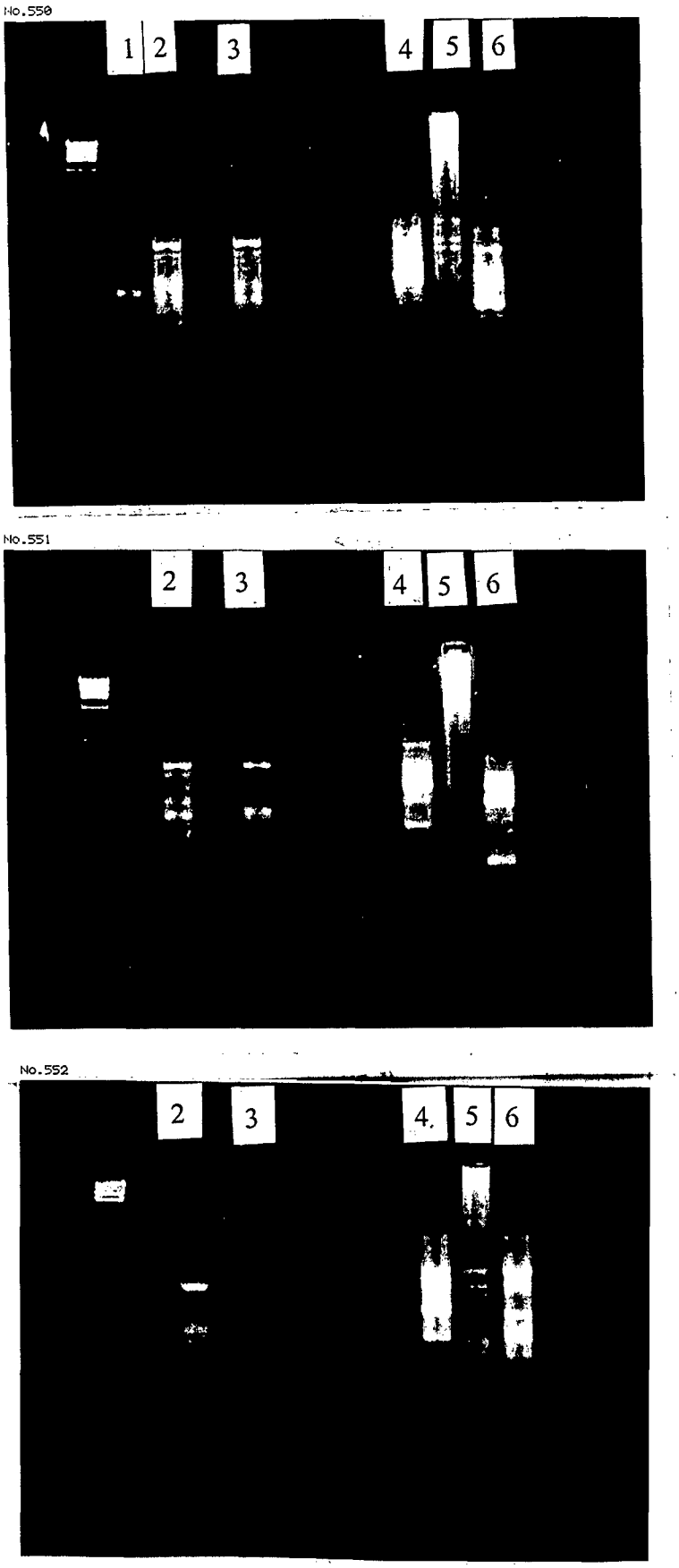


Plate 10a: RAPD profile of *Glyphochloa* species and *Ophiuros bombaiensis* with primers (a) OPE –05, (b) OPE-9, (c) OPE-10, left most lane indicates DNA marker (λ Eco RI-Hind III digest) the species are 1. *G. acuminata* var. *acuminata*; 2. *G. acuminata* var. *woodrowii*; 3. *G. talbotii*; 4. *G. ratnagirica*; 5. *G.henryi*; 6. *Ophiuros bombaiensis*

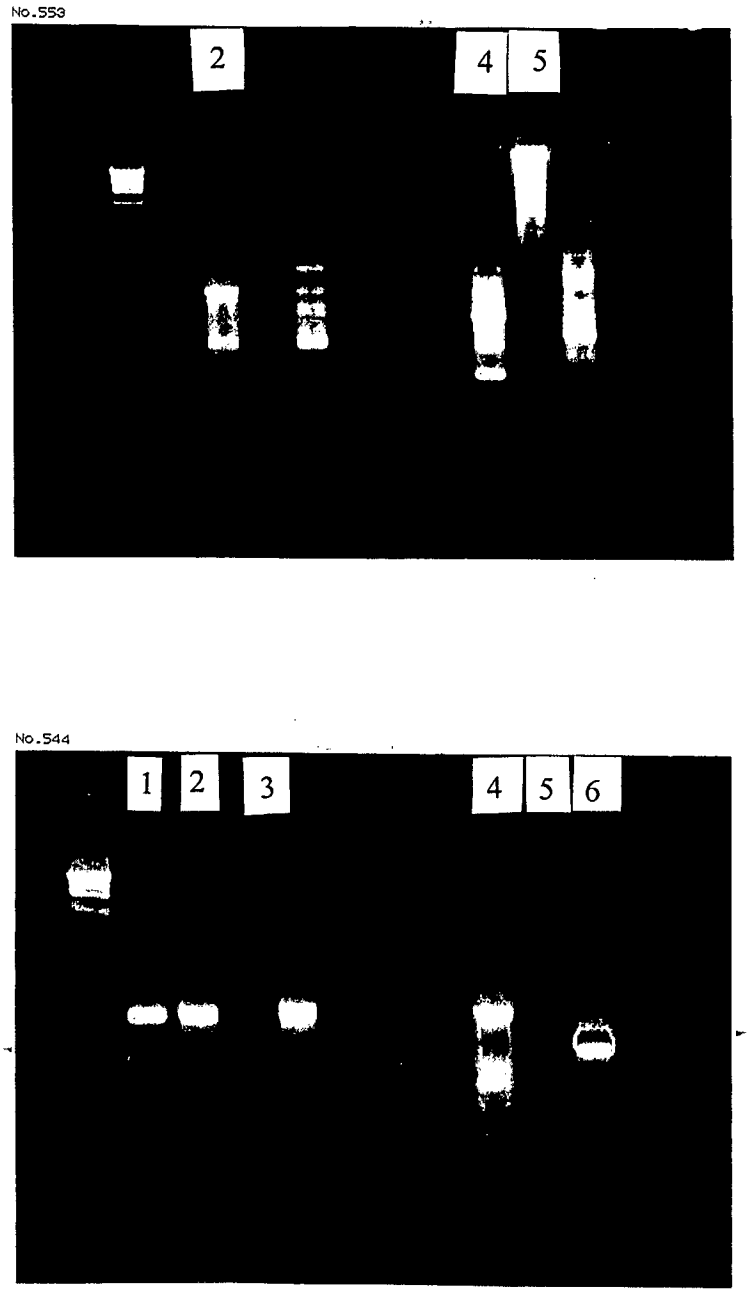


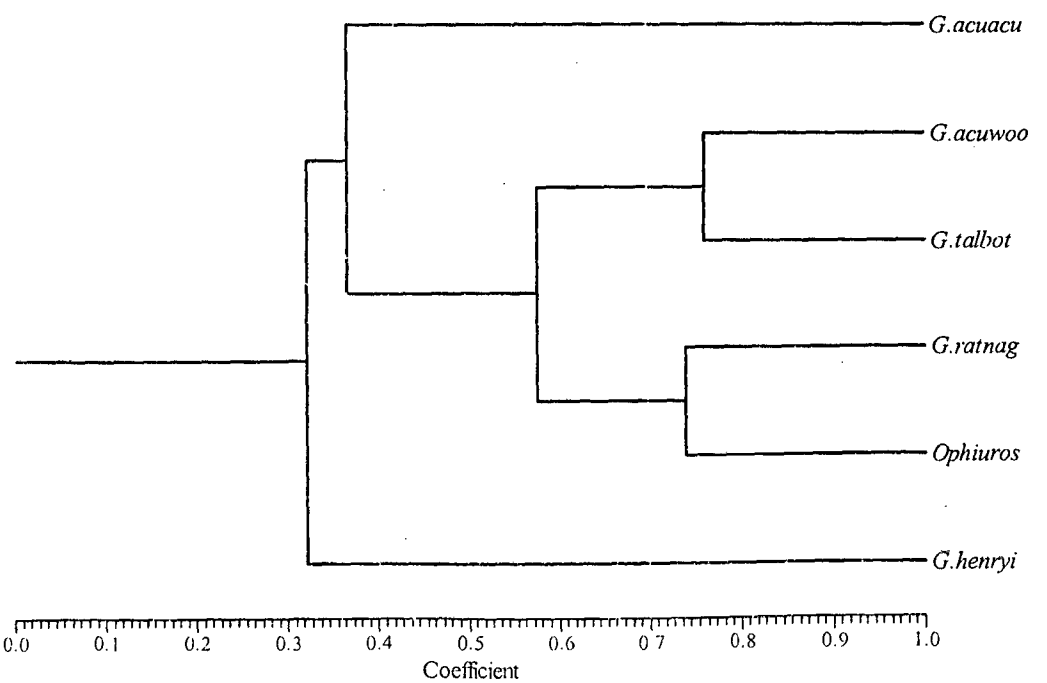
Plate 10b: RAPD profile of Glyphochloa species and Ophiuros bombaiensis with primers (d) OPE –14 and (e) OPE-16, left most lane indicates DNA marker (λ Eco RI-Hind III digest) the species are 1. G. acuminata var. acuminata; 2. G. acuminata var. woodrowii; 3. G. talbotii; 4. G. ratnagirica; 5. G.henryi; 6. Ophiuros bombaiensis

TABLE 16 : **Similarity matrix for Nei and Li's coefficient of *Glyphochloa* species and *Ophiuros bombaiensis***

	G.acuacu 1	Gacuwoo	talboti	Gratnag	Ghenryi	Ophiuros
Gacuacu						
Gacuwoo	0.482	1				
Gtalboti	0.512	0.76	1			
Gratnag	0.254	0.67	0.528	1		
Ghenryi	0.256	0.372	0.352	0.36	1	
Ophiuros	0.212	0.598	0.507	0.739	0.264	1

FIG. 27: **RAPD Similarity between species of *Glyphochloa***

Dendrogram based on similarity index of Nei & Li's constructed using UPGMA option in NTSYSpc



ECOLOGY AND PHYTOGEOGRAPHY

The genus *Glyphochloa* is endemic to Peninsular India. Northern most distribution goes up to Pachmarhi region (Hoshangabad District) of Madhya Pradesh. Remaining species are mostly distributed along the Western Ghats belt. These species show clear split in their distribution pattern which is congruent with their morphological character distribution.

Based on morphology two groups can be recognized in the genus *Glyphochloa*. The first group comprises of *G. acuminata* var *acuminata*, *G. acuminata* var *woodrowii*, *G. acuminata* var *stocksii*, *G. henryi*, *G. veldkampii*, *G. talbotii*, *G. santapaui* and *G. goaensis*. These are characterized by the presence of single awn on the lower glume of sessile spikelet. It was also observed that all these species are comparatively tall, glabrous, showing succulent nature, lower glume of sessile spikelet long and single awned (except *G. acuminata* var. *woodrowii*), back of the glume with ridges (smooth in *G. santapaui*) and margins with tubercles or with tufts of hairs. All these species are found to be located along the Western slopes and coastal plains of Western Ghats, especially concentrating

along Konkan belt. The area is generally low altitude rocky plateaus with thin or no soil cover except *G. acuminata* var. *acuminata* which may be found along the bushes and moist soil.

The second group is characteristic with its divergent awn. All these species, viz. *G. forficulata, G. mysorensis, G. ratnagirica, G. divergens,* and *G. hirsuta* are usually short, and hairy, not succulent, located at higher altitudes on lateritic plateaus or table lands which are normally covered with sufficient amount of soil. The lower glume of sessile spikelet is characterized by the presence of divergent long awn and back of the glume with tubercles, pits and hooks. Margins may also show hooks pointing upwards with tufts of hairs at its end.

The Sindhudurg district in South-West Maharashtra shows about eight species and two varieties of *Glyphochloa*. Therefore, their origin and diversification must have taken place here. Adjacent areas such as Goa and Karnataka with five species each and Kerala with four species, Tamil Nadu with two species and Madhya Pradesh with one (Fig.29 & 30).

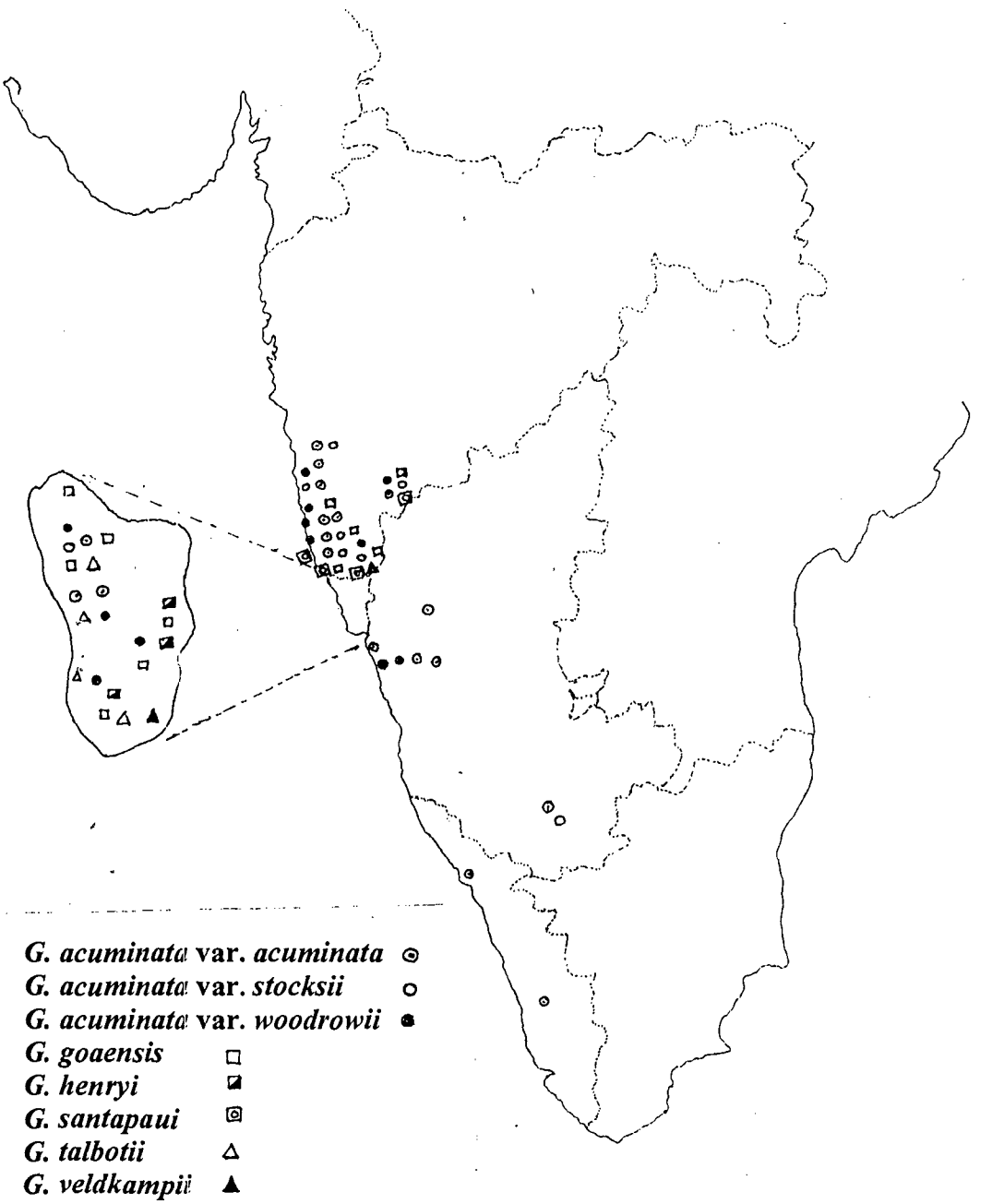


Fig 29: Distribution of single awned species of *Glyphochloa* W. D. Clayton

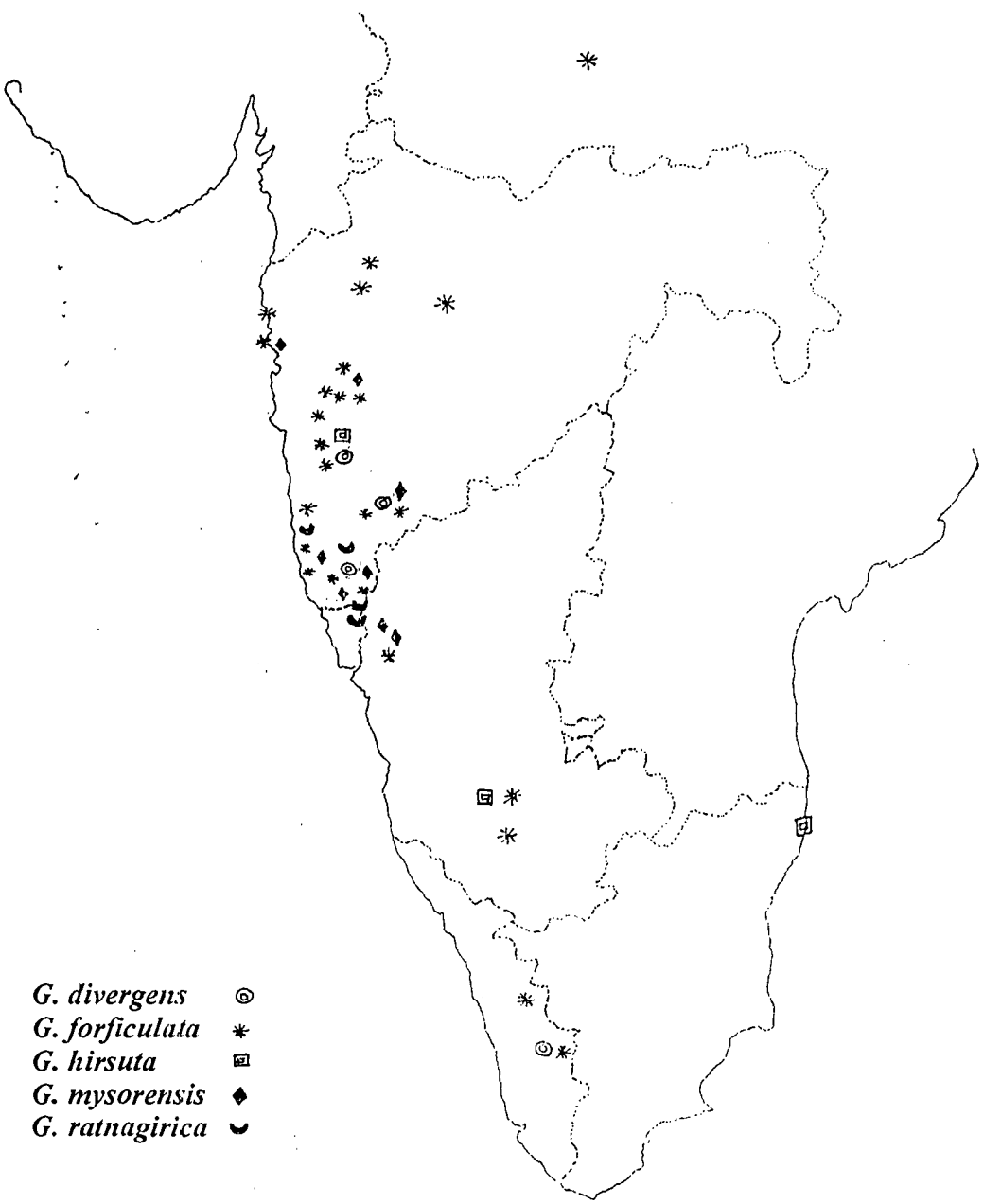
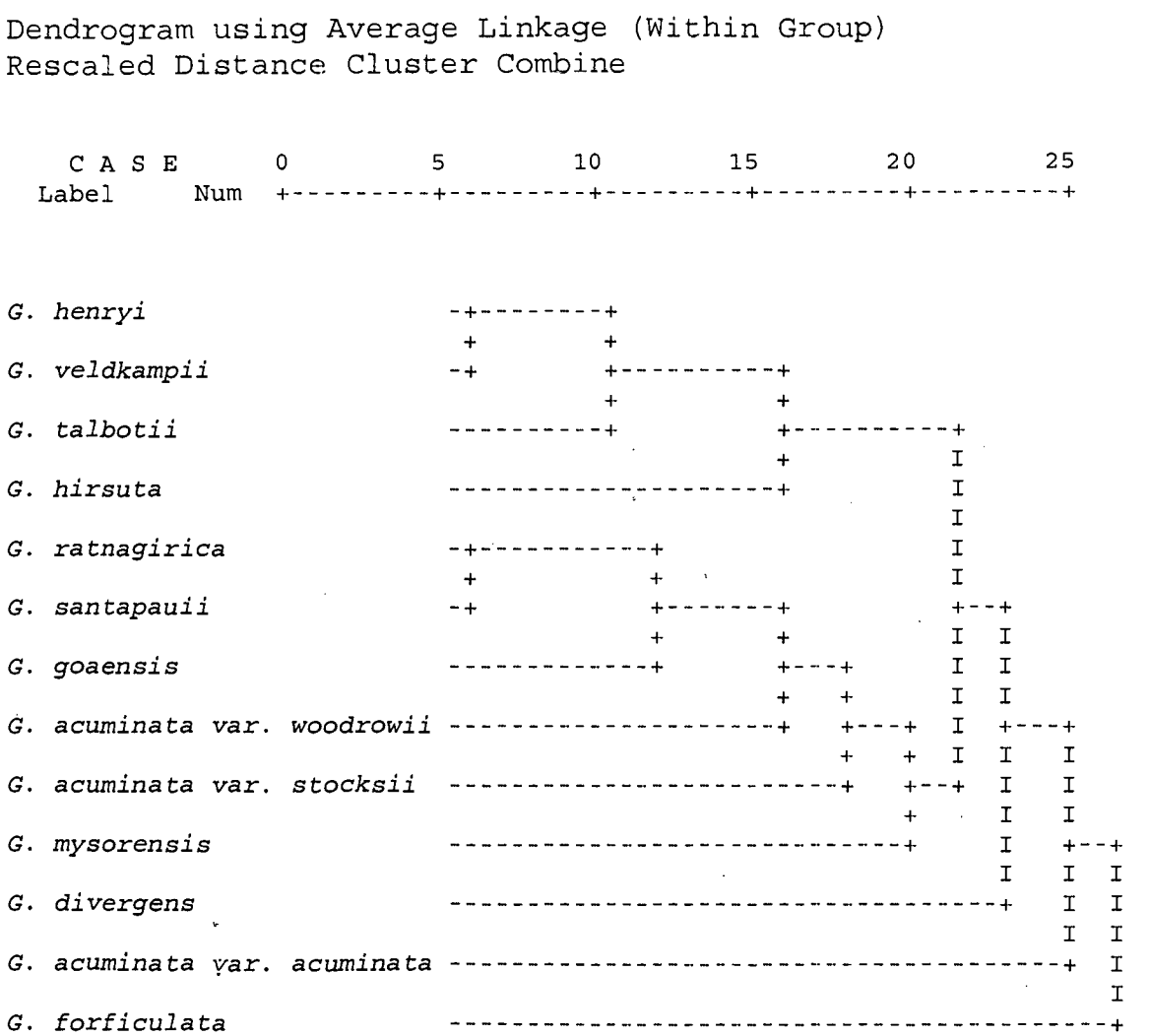


Fig 30: Distribution of two awned species of *Glyphochloa* W. D. Clayton

Table 17: Distribution of the species of *Glyphochloa* in Peninsular India

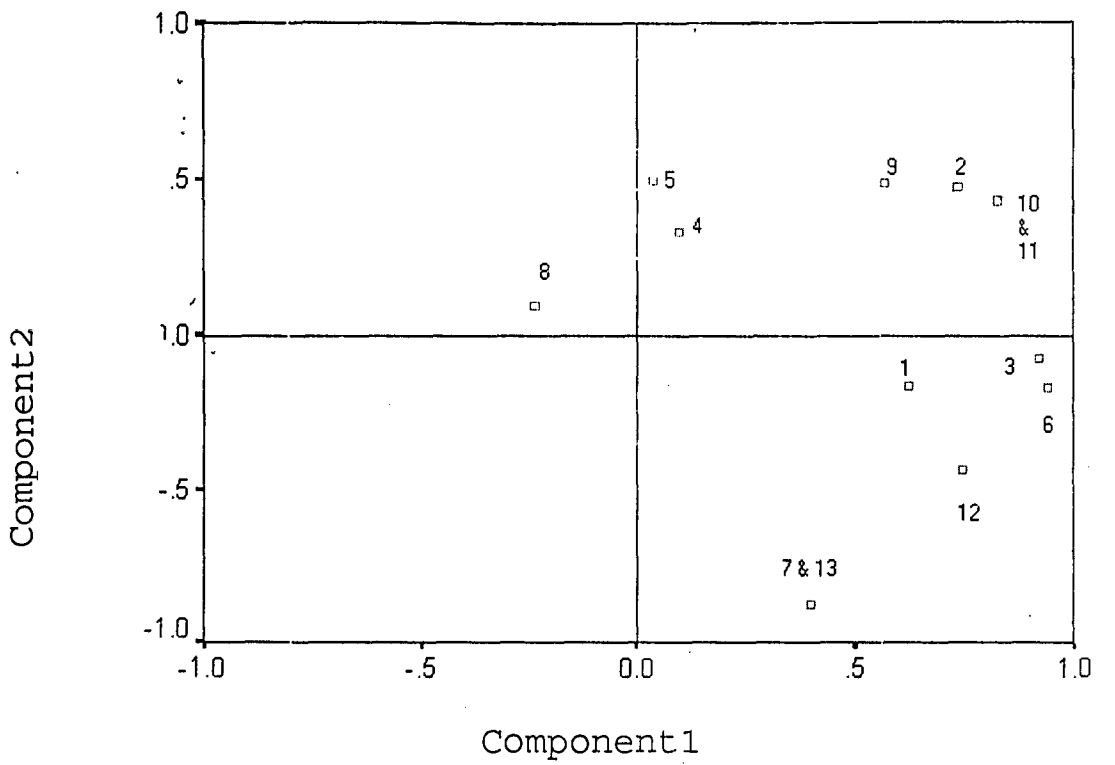
States (in capitals) / Districts	*G.acuminata var. acuminata*	*G. acuminata var. stocksii*	*G. acuminata var. woodrowii*	*G. divergens*	*G. forficulata*	*G. goaensis*	*G. henryi*	*G. hirsuta*	*G. Mysorensis*	*G. santapaui*	*G. ratnagirica*	*G. talbotii*	*G. veldkampii*
MADHYA PRADESH	0	0	0	0	1	0	0	0	0	0	0	0	0
MAHARASHTRA													
Nasik	0	0	0	0	1	0	0	0	0	0	0	0	0
Pune	0	0	0	0	1	0	0	0	0	0	0	0	0
Satara	0	0	0	0	1	0	0	1	0	0	0	0	0
Ratnagiri	1	1	1	0	1	1	0	0	1	1	1	0	0
Kolhapur	0	0	0	1	1	0	0	0	1	0	0	0	0
Shindhudurg	1	1	1	1	1	1	0	0	1	1	1	1	0
GOA	1	0	1	0	0	1	1	0	0	0	0	1	1
KARNATAKA													
Belgaum	0	0	0	0	0	0	0	0	1	0	0	0	0
Dharwar	1	0	0	0	0	0	0	0	0	0	0	0	0
N.Kannara	1	1	1	0	1	0	0	0	1	0	0	0	0
Shimoga	1	0	0	0	0	0	0	0	0	0	0	0	0
Chickmagalur	0	0	0	1	1	0	0	1	0	0	0	0	0
Coorg	0	0	0	1	0	0	0	0	0	0	0	0	0
Hassan	0	0	0	0	1	0	0	0	0	0	0	0	0
Mysore	1	1	0	1	0	0	0	0	1	0	0	0	0
KERALA													
Kasargod	1	0	0	0	0	0	0	0	0	0	0	0	0
Cannanore	1	0	0	0	0	0	0	0	0	0	0	0	0
Palghat	0	0	0	0	1	0	0	0	0	0	0	0	0
Idukki	0	0	0	1	1	0	0	0	0	0	0	0	0

Fig:31 Dendogram constructed using distribution data of *Glyphochloa* species to show the similarities



G = Glyphochloa

Fig 32: Principal component plot based on the distribution data of *Glyphochloa*



1. *G. acuminata* var. *acuminata*
2. *G. acuminata* var. *stocksii*
3. *G. acuminata* var. *woodrowii*
4. *G. divergens*
5. *G. forficulata*
6. *G. goaensis*
7. *G. henryi*
8. *G. hirsuta*
9. *G. mysorensis*
10. *G. ratnagirica*
11. *G. santapauii*
12. *G. talbotii*
13. *G. veldkampii*

G. forficulata is the most widely distributed species found in Maharashtra, Karnataka, Kerala, Tamil Nadu and Madhya Pradesh followed by *G. acuminata var. acuminata* distributed in Goa, Maharashtra, Karnataka, Kerala and Tamil Nadu. (Fig. 30)

There are species which show very narrow distribution. *G. Santapaui* is found only in Sindhudurg and Ratnagiri district of Maharasthra. *G. hirsuta* is so far recorded from bababudan hills of Karnataka, *G. henryi and G. veldkampii* are so far recorded only from Goa the former from two locations and latter from one. G. *talbotii* and *G. goaensis* are recorded both from Goa and Maharashtra.

The table 17 shows that the altitudal difference combine with substrate has influenced the character distribution completely.

Using distributional data table 17 a dendogram (Fig. 31) and principal component analysis (PCA) plot (Fig. 32) were constructed. The dendogram shows that very narrowly distributed species, viz. *G. henryi, G. veldkampii, G. talbotii* and *G. hirsuta* show a single cluster of which the former two show similar distribution. Similarly *G.*

ratnagiri and *G. santapaui* show almost same distribution, though one is two awned and another a single awned species. The overall similarity is not reflecting their taxonomic relationship except in the case of *G. henryi* and *G. veldkampii*. The most widely distributed species, viz. *G. forficulata* and *G. acuminata var. acuminata* are at base. However the component plot (Fig. 32) shows much more clarity as related species are generally segregating together. For example *G. hirsuta, G. forficulata, G. divergens, G. mysorensis* almost form a single cluster without any species appearing in between. Similar case is seen with *G.henryi* and *G.veldkampii*. Hence component plot can be used for interpreting phytogeography and drawing some indications to their relationship.

The ecological conditions and phytogeographical pattern is also reflected in their anatomy. Based on the arrangement of bulliform cells (Plate 1-8) in the transverse section of leaf, all the species can be divided into two groups. One group with regular arrangement of bulliform cells are also characterized by single awn and succulent nature. They all grow on hard lateritic plateaus with little or thin layer of soil. Probably water tissue helps to tide over the dry breaks in monsoons as all these

plants are located in low altitudes. The lateritic rocks dry up during dry breaks of monsoons.

The other group shows irregular arrangement (fan shaped) of bulliform cells (Plate 2, 5 & 6). This is associated with constriction of leaves along lateral main veins. This is seen in all divergent awned species which occur on lateritic plateaus or table lands of higher altitude with sufficient amount of soil. The size of the water tissue is also smaller in these species as compared to the single awned species. This can be easily correlated to the availability of moisture in the soil even during dry spells.

The transverse section of culm shows the characters which are congruent with their ecology, distribution, morphology and leaf anatomy. The single awned group shows the sclerenchymatous hypodermis usually in 3-4 layers. The divergent awned species show the sclerenchymatous hypodermis which is 2-layered. The sclerenchymatous layer forms a support in the culm during stress and strain. It is noted that the plants with 2-layered sclerenchymatous hypodermis are generally short in their habit and grow on high altitudes with high wind velocity.

The anatomical characters seen in the species of *Glyphochloa* are generally xerophytic in nature, for example,

1. The leaf epidermis, the culm and the leaf sheath show thick cuticle (1.25-2.5 μm) to prevent transpiration.
2. The stomata are sunken leading to less transpirational loss.
3. Number of sclerenchyma patches and girders below the vascular bundles in leaf and leaf sheath reduce transpiration and provide support.
4. Bulliform cells or water tissue present for storage of water, which protects leaf in dry weather.
5. Sclerenchymatous hypodermis in culm provides support during stress and checks transpiration in dry weather.

These characters can be seen due to their growth in extreme conditions with little soil around their roots.

Thus phytogeographic considerations in relation to ecology, morphology and anatomy can be tabulated as follows:

Table 18: Ecology related characters variations in genus *Glyphochloa*

Characters	Species at low Altitude and Western slope of Western Ghats	Species at high altitude and eastern side of Western Ghats
Ecology	Barren rocks or thin soil	Good amount of Soil
Height of the plant	Tall to medium in height up to 50 cm	Short, less than 30 cm
Texture of the plant	Glabrous & succulent to touch	Hairy & coarse to touch
Lower glume of sessile Spikelet	Single awned	Two awned
Bulliform cells in transverse Section	Regularly arranged & large	Irregular & Small
Constriction in leaf transverse Section	Usually absent at lateral main veins	Constriction prominent at lateral main veins
Midrib in leaf Transverse Section	Not prominent	Prominent U,V or intermediate shaped
Hypodermis Transverse Section of culm	3-4 layered	2 layered

Mycorrhizae:

Mycorrhizal infection for comparative and ecological studies showed the species of *Glyphochloa* with lot of Vesicular Arbuscular Infection, with most of the species with more than 50% infection (Plate 9F). The most infected species are *G.veldkampii* and *G.henryi* with 86% infection

(Table 19) and least infection was noted in *G.divergens* var.*divergens* with about 22%. VAM (Vesicular Arbuscular mycorrhiza) increases the absorption of diffusion of limited nutrients such as phosphorous, copper, zinc. The nutrients enhance drought resistance by stomatal regulation. Arbuscular mycorrhizal fungi also helps the plants in disease resistance by depressing root penetration and larval developments of nematodes (Sikora, 1978). They also help in tolerance to toxic metals, high soil temperature, adverse pH etc. and also stimulate rooting in plants (Barrow et al. 1977). Apart from the presence of number of vesicles, hyphal coils, soil borne vesicles and sporocarp were seen in these species. Ecologically it was seen that the single awned species show more infection probably helping them to grow in adverse condition on hard lateratic rocky plateaus with very thin layer of soil. Schultz et al (2001) have demonstrated that adaptation of *Andropogon genardii* (Poaceae) to the nutrient levels of their local soils was at least in part due to their dependence on mycorrhizal fungi. Mc Gee (1985) and Grime et al (1997) demonstrated that many plants are unable to grow without AMF (Arbuscular Mycorrhizal Fungi) association. The soil analyzed for the spores/sporocarp (Plate 9A, B & D) shows mostly the spores of genus Scutellospora, Glomus

Table 19 : Mycorrhizal Infection in different Species and related genera of *Glyphochloa*

\+ - Poor; + + - Good; + + + - V. Good

Species	Hyphae	Vesicles	Arbuscles	Percentage of infection	other
G.acuminata var. acuminata	+ +	+ +	+	47	Hyphal coils
G.acuminata var. stocksii	+ + +	+ +	+	65	
G.acuminata var. woodrowii	+ +	+ +	+	46	H.coils,Soil borne vesicle
G.divergens	+ +	+	---	22	
G.forficulata	+ + +	+ +	+ +	51	H.coils Soil borne vesicle
G.goaensis	+ +	+ +	+	58	soil born vesciles
G.henryi	+ + +	+ +	+	86	
G mysorensis	+ +	+ +	---	50	Hyphal coils
G ratnagirica	+ + +	+ + +	---	82	
G santapaui	+ +	+ +	---	34	
G talbotii	+ + +	+ +	+	54	Sporocarp
G veldkampii	+ + +	+ +	+	86	
Manisuris myuros	+ + +	+ +	+	90	Hartig net (best seen)
Mnesithea granularis	+	+	---	32	
Ophiuros bombaiensis	+ +	+	---	30	Hartig net
Ophiuros exaltatus	+ +	+	---	50	Hartig net
Rottbollia exaltata	---	---	---	---	

Table 20: Mycorrhizal spores in species of *Glyphochloa*

Species	No. of spore / 25gms of soil	Genus of fungi found
G. acuminata var. acuminata	166	*Glomus* *Acaulospora*
G. acuminata var. woodrowii	25	*Acaulospora* *Glomus* *Scutellospora*
G.forficulata	235	*Scutellospora* *Glomus* *Acaulospora*
G henryi	324	*Glomus* *Scutellospora*
G.ratnagirica	243	*Glomus* *Acaulospora*
G talbotii	70	*Acaulospora* *Glomus* *Scutellospora*

and Acaulospora, with the number of spores ranging from 25 to 324 per 25 gm of soil. (Table 18)

Among the related genera, *Manisuris myuros* which grows in drier areas showed the maximum infection of 90%. While, in general the related genera showed little infection of VA but there were ectomycorrhizal infection in these plants forming Hartig net in the outer region of the root (Table 17).

NUMERICAL TAXONOMY

Numerical taxonomy was worked out using morphological and anatomical characters separately. The list of morphological and anatomical characters and their their states are given below seperately:

Morphological Characters used in numerical taxonomy:

1. Height of plant:< 25 cm (1), > 25 cm (0)
2. Branching: basal (1), apical (0)
3. Culm: 3 - 5 noded (1), 6 or more noded (0)
4. Size of Internode: 2 - 15 cm (0),20 - 24(1), 30 - 40(2)
5. Leaf blade base: broad truncate (1), narrow (0)
6. Size of leaf blade: 3 - 20 cm(0),21 - 28(1), 58 - 60(2)
7. Number of nerves: $\leq$ 5 (1), > 5 (0)
8. Leaf: hairy (1), glabrous (0)
9. Leaf sheath occupying: < ½ portion (1), > ½ portion (0)
10. Ligule size: < 1.5 mm (1), > 1.5 mm (0)
11. Raceme size: upto 5 cm (1), more than 5 cm (0)
12. Joint and pedicel: (fused) equal (1), unequal (0)
13. Lower glume of sessile spikelet: one awned(1),two awned (0)
14. Back of lower glume: smooth (1), ornamental (0)
15. Margins of lower glume with: hooks/spines (1), No hooks (0)
16. Back of lower glume with: ridges (1), No ridges (0), hooks (2)
17. Vertical furrows at back of lower glume:present (1), absent(0)
18. Lower glume:hairy (1), Not hairy (0)
19. Wing on upper glume of pedicelled spikelet:throughout (1), only on apical part (0), ¾ part (2)
20. Upper glume of pedicelled spikelet present (1), absent (0), sometimes (2)
21. Wing of upper glume of pedicelled spikelet broad (1), narrow (0)

Anatomical Characters used in numerical taxonomy:

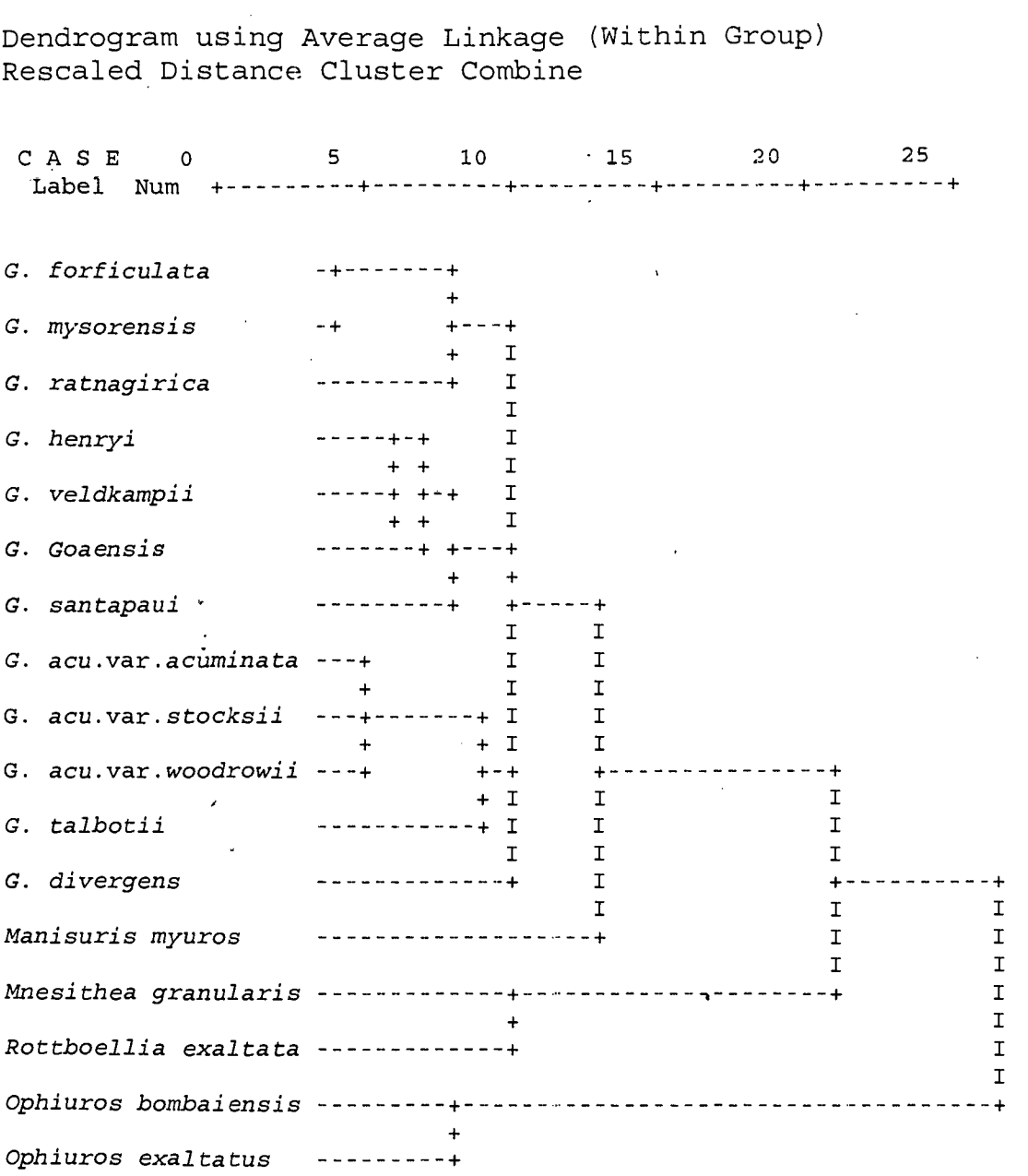
1. Layer between piliferous & endodermis (root):absent (1), Present (0)
2. Exodermis (root): present (1), absent (0)
3. Thick walled exodermis (hypodermis root): 1-2 layered(1), more (0), absent (2)
4. Cortex (root): 4 - 5 layered (1), more layered (0)
5. Thickness in endodermis (root): radial & inner walls (1), whole cell (0)
6. Cuticle size (culm): 2 - 4 um (1), 5 um or more (0)
7. Sclerenchyma tissue(culm):2 layered (1), more than 2 layered (0)
8. Number of grooves in culm: 5 (1), more than 5 (0)
9. Leaf Sheath: solid in mid region (1), with cavities (0)
10. Leaf sheath lateral region: with cavities(0),solid or loose tissue (1)
11. Midrib region of leaf blade: conspicious (1), not conspicious (0)
12. Constrictions in leaf T.S: present(1), absent(0), sometimes (2)
13. Water tissue (leaf): regular (1),irregular 0), sometimes (2)
14. Water tissue occupancy (leaf): ¾ portion (1), ¼ - ½ portion (0)
15. Colourless mesophyll parenchyma in midrib region: present (1), absent (0), rarely present (2)
16. Lateral main veins in leaf: shifted upwards (1), not shifted (0), rarely shifted (2)
17. Inflated cells in lower epidermis below the VB (leaf): present (1), absent (0), sometimes (2)
18. Girders of the lateral veins: adaxial (1), abaxial (0), both (2)
19. Lamina midzone: 'V' shaped (1), 'U' shaped (0), U to flat (2)
20. Macrohairs: present (1), absent (0)
21. Size of stomata: 24 - 33 µm (0), 38 - 46 µm (1), 51 µm (2), 56 - 60 µm (3)
22. Subsidiary cells: triangular (1), dome + triangular (0)
23. Intercostal short cells: cork (0), silica cells (1), both (2)
24. Costal short cells: silica - cork (1), silica - silica - cork (2), cork - cork - silica (0)
25. Costal short bodies (silica) predominently: dumbell(1), nodular (2), mix (0)

Table 21: Morphological character scoring for numerical taxonomy

Species	Morphological Characters																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
G. acuminata var. acuminata	0	1	1	0	0	1	0	0	0	0	1	1	1	0	0	1	1	0	0	2	0
G. acuminata var. stocksii	0	1	1	0	0	0	0	0	0	0	0	1	1	0	0	1	1	0	0	2	0
G. acuminata var. woodrowii	0	0	1	0	0	1	0	1	0	0	0	1	1	0	0	1	1	0	0	2	0
G. divergens	1	1	1	1	0	1	0	1	0	1	1	1	0	0	1	1	1	1	2	1	0
G. forficulata	1	1	1	1	0	0	0	1	0	0	1	1	0	0	1	2	0	0	0	1	1
G. goaensis	0	1	1	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0	0
G. henryi	0	1	0	0	1	0	0	0	1	0	0	1	1	0	1	1	0	0	1	0	1
G. mysorensis	1	1	1	1	0	0	0	1	0	0	1	0	0	0	1	2	0	0	0	1	1
G. ratnagirica	0	0	1	0	0	0	0	1	1	0	1	1	0	1	1	0	0	0	0	0	1
G. santapaui	0	1	1	0	0	0	1	0	0	0	0	1	1	1	0	0	0	1	2	0	1
G. talbotii	0	1	1	1	0	0	1	0	0	0	1	1	1	0	0	1	0	0	0	0	0
G. veldkampii	0	0	1	0	1	0	1	0	1	0	0	1	1	0	1	1	0	0	1	0	1
Manisuris myuros	0	1	0	0	0	0	0	0	1	1	0	1	9	0	0	0	1	0	0	0	0
Mnesithea granularis	0	0	0	0	1	1	0	1	1	1	0	1	9	0	0	0	1	0	9	0	9
Ophiuros bombaiensis	0	0	1	0	0	0	1	0	0	1	0	9	9	0	0	1	0	0	9	9	9
Ophiuros exaltatus	0	0	1	2	0	0	0	0	1	1	0	9	9	0	0	1	0	0	9	9	9
Rottboellia exaltata	0	1	0	1	0	2	0	0	1	0	0	0	9	1	0	0	0	0	9	0	9

G = Glyphochloa

Fig. 33: Dendrogram based on morphological characters for *Glyphochloa* and its related genera.



G = Glyphochloa

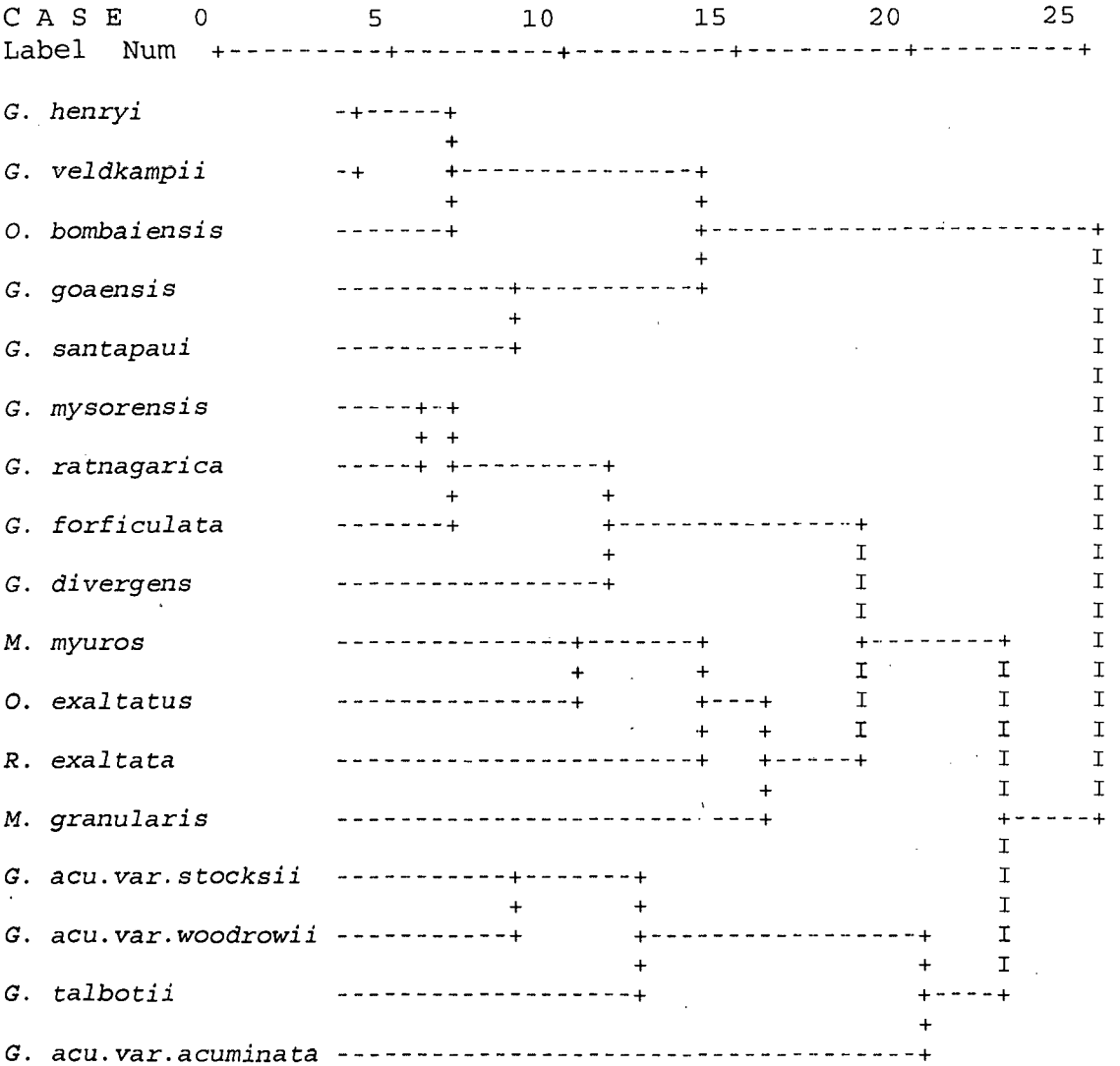
Table 22 : Anatomical character matrix for *Glyphochloa* and related genera

Species	Anatomical Characters																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
G. acuminata var. acuminata	0	1	1	0	1	0	0	0	1	0	1	2	2	1	1	2	2	2	0	0	1	2	1	1	1
G. acuminata var. stocksii	1	1	0	1	1	0	0	0	1	0	0	2	2	1	1	0	0	2	2	0	1	1	1	2	1
G. acuminata var. woodrowii	0	1	1	1	0	0	0	0	1	0	1	2	2	1	2	0	0	2	2	0	1	2	1	2	1
G. divergens	0	0	1	1	1	0	1	1	1	1	1	1	0	1	0	0	0	2	0	1	0	1	2	1	1
G. forficulata	1	1	1	0	1	0	1	1	1	0	1	1	0	1	1	0	0	2	1	1	2	1	1	0	2
G. goaensis	1	1	1	0	1	0	0	0	1	1	0	0	1	1	0	0	0	0	2	0	3	1	1	1	1
G. henryi	1	1	0	0	1	0	0	0	0	0	0	0	0	1	1	1	1	1	2	0	1	1	0	1	1
G. mysorensis	1	1	1	1	1	0	1	1	1	0	1	1	0	1	1	0	0	2	0	1	1	1	1	1	1
G. ratnagirica	1	1	0	0	1	0	1	1	1	1	1	1	0	1	2	0	0	2	0	1	1	1	1	0	1
G. santapaui	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	2	0	3	1	1	2	1
G. talbotii	1	1	0	1	1	0	0	0	1	1	0	2	1	1	2	0	0	2	2	0	1	1	1	0	1
G. veldkampii	1	1	1	0	1	0	0	0	1	0	0	0	0	1	1	1	0	1	2	0	1	1	0	0	1
Manisuris myuros	1	1	1	0	1	0	0	1	1	1	1	0	1	0	1	0	0	2	1	0	1	1	2	1	1
Mnesithea granularis	1	1	1	1	1	0	0	1	1	1	1	0	1	0	0	0	0	0	1	1	0	1	2	1	1
Ophiuros bombaiensis	1	1	1	0	1	0	0	0	1	0	0	0	0	1	1	1	0	1	2	0	3	1	0	1	1
Ophiuros exaltatus	0	1	1	0	1	0	0	1	0	0	1	0	2	0	1	0	0	2	2	1	0	1	2	1	1
Rottboellia exaltata	0	0	2	0	1	0	0	1	0	0	1	0	0	0	1	0	0	2	0	0	0	1	2	1	1

G = Glyphochloa

Fig. 34: Dendrogram constructed using anatomical characters.

Dendrogram using Average Linkage (Within Group)
Rescaled Distance Cluster Combine



G = Glyphochloa, acu = acuminata
M.myuros = Manisuris myuros
M. granularis = Mnesithea granularis
O.= Ophiuros
R.= Rottboellia

Note: *Ophiuros bombaiensis* shows anatomical characters which are similar to *Glyphochloa* and from other genera including other species of *Ophiuros (O. exaltatus)*

The taxa vs. character matrix is given in the table 21 & Table 22 for morphology and anatomy respectively. Using average linkage (within group) method the dendrograms were constructed (Fig. 33 & 34).

The dendrogram constructed using morphological characters (Fig. 33) shows that all the related genera are showing maximum dissimilarity and hence form basal groups in the dendrogram. *Manisuris* is morphologically closer to *Ghyphpchloa* than other genera. *Mnesithea* and *Rottboellia* form a distinct cluster and both the species of *Ophiuros* form another cluster. The species of *Glyphochloa* form three distinct clusters. The first cluster is of *G. mysorensis, G. forficulata* and *G. ratnagirica* all these are divergent awned species. The second cluster consists of *G. henryi, G. veldkampii, G. goaensis* and *G. santapauii*. All these are single awned species and confined to Goa and Maharashtra. Next cluster is formed by varieties of *G. acuminata*, which show much character variation morphologically. However *G. divergens* and *G. talbotii*, the former two awned and the later single awned are found closer to *G. acuminata* group. Relationship between *G. talbotii* and divergent awned species was also recorded in phylogenetic analysis (Fig. 35 & 36).

The dendrogram (Fig. 34) constructed using anatomical characters show three major clusters. One of the clusters comprises of *G. goaensis* and *G. santapaui* in a subcluster and *G. henryi, G. veldkampii* and *Ophiuros bombaiensis* in another subcluster. As discussed under anatomy *O. bombaiensis* is anatomically similar to *Glyphochloa* then *O. exaltatus* or other related genera. All these *Glyphochloa* species are single awned and confined to lower altitude of Maharashtra and Goa along the west coast. Second major cluster consists of varieties of *G. acuminata* and *G. talbotii*. Incidently both the species show lot of morphological variation. The third major cluster consists of two awned species of *Glyphochloa* in one subcluster and related genera (excluding *Ophiuros bombaiensis*) in next subcluster. The two awned species of *Glyphochloa* are distributed in higher altitudes along the Western Ghats and related genera mostly on the eastern side of the ghats in drier areas though they are not rare along the western side of Western Ghats. Hence, it is seen that anatomy is related more to their ecology and geography. Dendrograms constructed using morphology and anatomy separately are not showing same level of similarities between species of *Glyphochloa* and related genera.

PHYLOGENY

The Phylogeny of the genus *Glyphochloa* and its related genera has been studied based on morphological and anatomical characters using *Manisuris myuros* and *Ophiuros bombaiensis* as an outgroup separately. The characters used for the study are given below and the character matrix is given in Table 23. The resulting cladogram (Fig. 35) shows *G. santapaui* as the basal clade when *Manisuris* is used as an outgroup which is very distinct from all the species in having smooth, non-ornamented back of the lower glume of sessile spikelet, with tufts of hairs at base. It is also seen that it is endemic only to two districts, viz. Ratnagiri and Sindhudurg in Maharashtra.

The next clade from the common node of *G. santapaui* leads to two distinct clades. One of the clades terminate in *G. veldkampii*, *G. henryi* and *G. goaensis* which are similar and close in most of the respects as discussed under anatomy, morphology and phytogeography. Among these three *G. veldkampii* and *G. henryi* form terminal taxa and incidentally these are the recently founded species. Their type localities are within 10 km from each other. *G. goaensis* though distributed in the neighbouring districts

Characters used for Cladistics

1. Internode size up to: 15 (0), < 20 (1)
2. Leaf blade base: narrow (0), truncate (1)
3. Number of veins: ≤ 5 (0), > 5 (1)
4. Leaf surface: glabrous (0), hairy (1)
5. Leaf sheath to culm: ≥ ½ (0), < ½ (1)
6. Ligule : ≤ 1.5 mm (0), > 1.5 mm (1)
7. Inflorescence: ≥ 5 cm (0), < 5 cm (1)
8. Joint & pedicel: free (0), fused (1)
9. Sessile spikelet lower glume: one awned (0), divergent (1)
10. Back of glume : ornamental (0), smooth (1)
11. Vertical furrows on back of glume : absent (0), present (1)
12. Glume : glabrous (0), hairy (1)
13. Layer between piliferous & exodermis : present (0), absent (1)
14. Leaf sheath mid region : cavities (0), solid (1)
15. Midrib of blade: inconspicuous (0), Conspicuous (1)
16. Constriction in leaf transverse section: absent (0), present (1)
17. Water tissue on adaxial side: irregular (0), always regular (1)
18. Lateral veins : not shifted upwards (0), in few at least (1)
19. Girdles of lateral veins : one side (0), both sides (1)
20. Macrohairs : absent (0), present (1)
21. Subsidiary cells : triangular (0), dome + triangular (1)
22. Coastal short cells: in pairs (0), in 3's (1)
23. Coastal short cells: dumb-bell (0), nodular (1)

Table 23: Character state values for species of *Glyphochloa* and its related genera used in cladistic analysis

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
G. acuminata var. *acuminata*	0	0	1	0	0	1	1	1	0	0	1	0	0	1	1	1	0	1	1	0	1	0	0
G. acuminata var. *stocksii*	0	0	1	0	0	1	0	1	0	0	1	0	1	1	0	1	1	0	1	0	0	1	0
G. acuminata var. *woodrowii*	0	0	1	0	0	1	0	1	0	0	1	0	0	1	1	1	0	0	1	0	1	1	0
G. divergens	1	0	1	1	0	0	1	1	1	0	1	1	0	1	1	1	0	0	1	1	0	0	0
G. forficulata	1	0	1	1	1	1	1	1	1	0	0	0	1	1	1	1	0	0	-	1	0	1	1
G. goaensis	0	0	1	0	0	1	0	1	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0
G. henryi	0	1	1	0	0	1	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
G. mysorensis	1	0	1	1	1	1	1	1	1	0	0	0	1	1	1	1	0	0	1	1	0	0	0
G. ratnagirica	0	0	1	1	1	1	1	1	1	1	0	0	1	1	1	1	0	0	1	1	0	1	0
G. santapaui	0	0	0	0	0	1	0	1	0	1	0	1	0	0	0	1	0	0	0	0	0	1	0
G. talbotii	1	0	0	0	0	1	1	1	0	0	0	0	1	1	0	1	1	0	1	0	0	1	0
G. veldkampii	0	1	0	0	0	1	0	1	0	0	0	0	1	1	0	0	0	1	0	0	0	1	0
Ophiuros bombaiensis	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0
Manisuris myuros	0	0	1	0	1	0	0	1	-	1	0	0	1	1	1	1	1	0	0	0	1	0	0

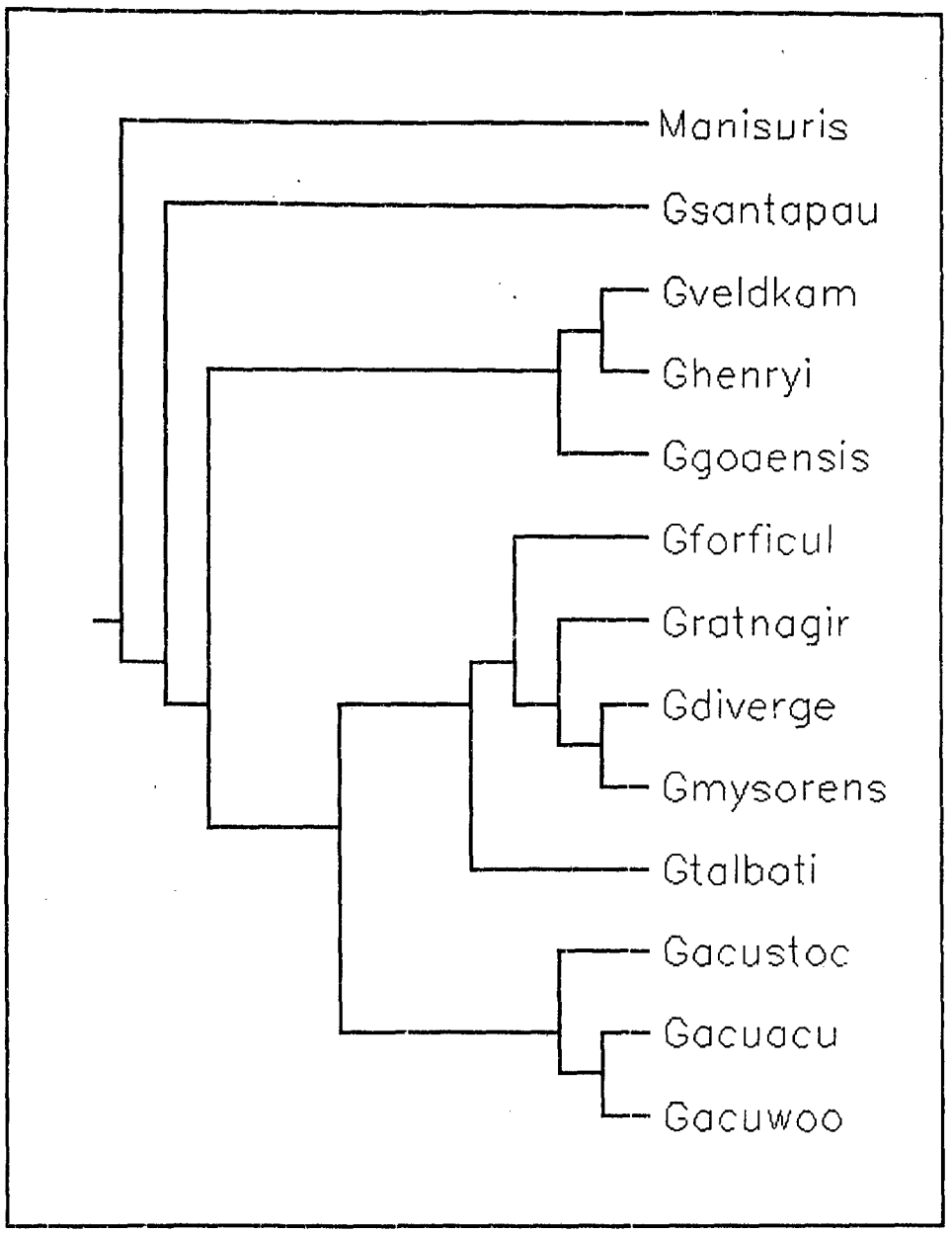


Fig. 35: Cladogram of different species of Glyphochloa when Manisuris is an outgroup.

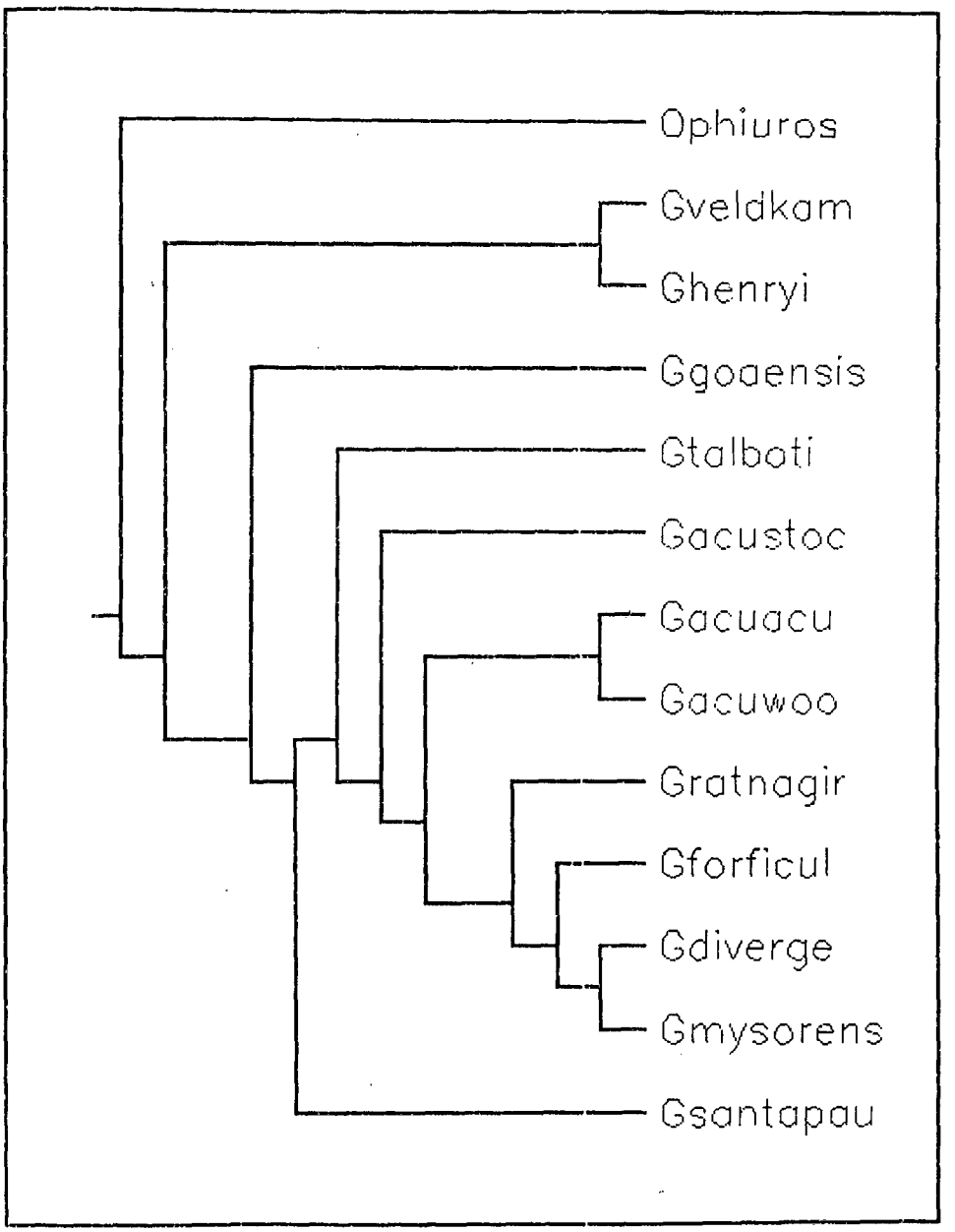


Fig. 36: Cladogram of different species of Glyphochloa when Ophiuros bombaiensis is an outgroup.

of Maharashtra is abundant in Goa. This suggest to their close relationship which is very well reflected in their morphological characters.

Next clade leads to *G. acuminata* with all its three varieties as terminal taxa. They are polymorphic and they differ in their anatomical characters forming a complex. The terminal clade end with *G. ratnagirica, G. forficulata, G. divergens* and *G. mysorensis*. All these species are two awned. *G. talbotii* is related to two awned species at base linking single awned and two awned species. The morphological character, especially the ridges at the back of lower glume of sessile spikelet varying in number and often breaking into smaller units gives a clear indication to its relationship with these species.

When *Ophiuros bombaiensis* was used as an outgroup a similar relationships were obtained (Fig. 36). Divergent awns formed a terminal group, varieties of *G. acuminata* were related to each other and so also *G. veldkampii, G. henryi* and *G. goaensis* as basal clades. However, as compared to *Manisuris* as an outgroup in this case the position of *G. santapaui* and *G. talbotii* were slightly shifted. This may be due to enormous similarities between

Ophiuros bombaiensis and *Glyphochloa* especially anatomically, which are not shared by *O. exaltatus*. This is also reflected in numerical taxonomic studies (Fig. 34).

Thus the phylogenetic analysis shows that two awned species (synapomorphous) forming a terminal group showing different distribution (higher altitudes) are connected to rest of the group through ancestors of G. talbotii, a single awned species. *G. santapaui* forms the basal clade by sharing smooth back of lower glume (a plesiomorphous character) with the outgroups (either *Manisuris* or *Ophiuros*). The remaining single awned species forming two distinct clades. Polymorphic nature in some clades and close similarities (not isolated taxonomically) in some clades indicate to their active speciation.

Chapter 5

CONCLUSION

It is concluded that *Glyphochloa,* as far as the evidences from the present work suggest, is a distinct genus justifying its separation from *Manisuris*. The anatomical similarities of *Ophiuros bombaiensis* to *Glyphochloa* also suggest to their close relationship. The species of *Glyphochloa* are also distinct and can be identified using morphological, anatomical, microhair and flavonoid characters. However, few species exhibit considerable variations between and within the populations. The characters that distinguish the species into broad groups can also be correlated to their ecology and phytogeography. The cladistic analysis suggests those two awned species of *Glyphochloa* evolving as a distinct clade from single awned species.

Chapter 6

SUMMARY

The genus *Glyphochloa* W. D. Clayton of subtribe Rottboelliinae, tribe Andropogoneae and sub family Panicoideae (Watson & Dallwitz 1994.) the genus is restricted to Peninsular India. All the species of the genus *Glyphochloa* were earlier recognised under *Manisuris* L., Clayton (1981) reduced this to a single species and transferred the others to the genus *Glyphochloa*. Though Jain 1970 attempted to understand the taxonomy of this group. (under genus *Manisuris*), further attempt has been made to understand its systematics in a comprehensive manner and the details of its phylogeny. The anatomy of this group has been studied for the first time as the anatomical data was wanting (Watson & Dallwitz l.c.)

Morphology and Systematic treatment:

The related genera of *Glyphochloa* distributed in Peninsular India are *Manisuris*, L. *Mnesithea* Kunth, *Ophiuros* Gaertn. f., *Rottboellia* L.f. of which *Manisuris* is monotypic and is also endemic to Peninsular India. Morphologically the genus is distinguished from all the related genera by the presence of sessile spikelet callus

turbinate or opaque with central knob, lower glume ovate or oblong, crustaceous, smooth or more often, elaborately sculptured with ridges, spines, flaps or columns, with broad membranous wings above, 1-2 awned, with pedicelled spikelet as large as sessile spikelet, pedicel fused to internode.

Morphology of the species of *Glyphochloa* and available species of related genera were studied. It is confirmed that morphologically *Glyphochloa* forms a distinct entity. During the course of study a distinct entity was collected and it is being described in this work as *Glyphochloa veldkampii*, a new species which is related to *G. talbotii* and *G. henryi* (a species described recently by Janarthanam et. al. l.c.). Based on critical study *G. divergens* var. *hirsuta* has been elevated to the rank of a species, viz. *G. hirsuta*. Totally eleven species [viz. *Glyphochloa acuminata* (Hack.) Clayton var. *acuminata*, *G. acuminata* (Hack.) Clayton var. *stockii* (Hook. f.) Clayton, *G. acuminata* (Hack.) Clayton var. *woodrowii* (Bor) Clayton, *G. divergens* (Hack.) Clayton, *G. hirsuta* (C.E.C. Fisch) M. A. Fonseca stat. et. comb. nov. *G. forficulata* (C.E.C. Fisch.) Clayton, *G. goaensis* (Rao & Hemadri) Clayton, *G. henryi*. Janarth. et. al., *G. mysorensis* (Jain & Hemadri) Clayton,

G. ratnagirica (Kulk. & Hem.) Clayton, *G. santapaui* (Jain & Desh.) Clayton, *G. talbotii* (Hook. f.) Clayton, *G. veldkampii* M. A. Fonseca sp. nov.] have been recognized in this work.

This genus can be divided into two groups based on simple and divergent awns. The latter characterises *G. divergens*, *G. forficulata*, *G. hirsuta*, *G. mysorensis* and *G. ratnagirica* into a distinct group. Generally species are very distinct in the genus without any overlapping morphological characters. However few species such as *G. acuminata* show continous variation.

Based on the analysis of these characters, taxonomic decisions have been taken. The systematic treatment part of the thesis provides key for identification, nomenclature, description, notes with morphological and ecological observations, IUCN threat status, distinguishing characters, illustrations and list of specimens examined.

Anatomy:

According to Watson and Dallwitz (l.c.) the anatomical data are wanting, therefore in the present work, anatomical studies of the genus have been undertaken for the first

time. The species of this genus are specially distributed along hard lateritic rocks in low and high altitude and hence the study was undertaken to find out the anatomical pecularities of these species in relation to their habitats. The present study shows that *Glyphochloa* was found to be closely related to *Ophiuros bombaiensis* showing similar anatomical characters (bulliform/water tissue large, small patches of sclerenchyma in leaf, culm with few layered thickened hypodermis and root with small vascular tissue) as compared to other related genera. All these related genera are distributed throughout Peninsular and Central India on open grounds, in damp woodlands or grasslands. Anatomically the species of *Glyphochloa* can be divided into two groups based on the thickness of water tissue (broad or narrow) in the leaf, number of sclerenchymatous hypodermal layers in culm and the presence of hairs in the epidermal peelings of leaf.

These two groups could be correlated to the morphological groupings based on awns and ecological groupings based on altitude. Group with simple awn is distributed in low lying lateritic plateaus and these species are relatively tall, glabrous, succulent with broad and regular water tissue, sclerenchymatous hypodermis more

layered in culm as compared to the divergent awned group. Most of the species can be identified based on their anatomical features. The anatomical descriptions of leaf, leaf sheath, root and leaf peeling along with few photographs are also provided in the thesis.

Pollen:

The pollen is stenopalynous throughout *Glyphochloa* and its related genera. In *Glyphochloa* they are circular/ rounded in outline ranging from 20µm-31µm, mono-porate, operculate. Exine being generally granulose.

Ecology and Phytogeography:

In Peninsular India, *Glyphochloa* forms the second largest endemic genus. *Manisuris*, one of the related genera is also endemic to Peninsular India and grows in dry habitats. The genus *Glyphochloa* is restricted to Peninsular India with distribution of one species extending up to Madhya Pradesh (Central India). The species are mostly concentrated in Goa and Maharasthra with only three species distributed each in Kerala and Tamil Nadu. The lateritic belt along the Konkan coast (Goa and Maharasthra) forms the major habitat of *Glyphochloa* species and almost all the species distributed in this belt are single awned ones. At

slightly higher altitude of Western Ghats, the species with divergent awns are distributed. Though *Glyphochloa* and related genera thrive during monsoons, their habitat specially the laterites fail to retain moisture during the dry spells in monsoon forcing them to adapt to xerophytic conditions. Their habitat also shows that they survive on very thin soil on lateritic rocks. The anatomical studies have shown that the species occupying Konkan belt show regular, large and broad water tissue, culm hypodermis more layered and leaf without constrictions, showing ecological adaptation.

Sindhudurg district of Southwestern Maharasthra shows the maximum number of *Glyphochloa* species (eight species and two varieties) followed by Goa, which harbours five species. Concentrated distribution in Sindhudurg and Goa suggest their possible origin and diversification here. Morphological variations between the populations are generally seen in species with wide areas of distribution (eg. *G. acuminata* and *G. forficulata*), though the variations are also recorded in locally restricted species such as *G. talbotii* and *G. goaensis*.

In the present study it is found that the genus *Glyphochloa* shows very good infection with VAM to the extent of 86% in *G. henryi* and *G. veldkampii*. However the species growing on higher ghats in good soil conditions are showing poor infection with VAM (22% in *G. divergens*). The related genera *Ophiuros, Manisuris, Mnesithea* and *Rottboellia* show maximum of hyphal infection (hartig net) and less vesicular infection, except *Manisuris myuros* which shows 90% VAM infection (growing in drier areas). Thus mycorrhizal infection could be broadly correlated with the ecology of *Glyphochloa* species.

Flavonoids:

Spectral pattern shows that the wavelengths of peak absorption are unique for most of the species, the combinations of which can be used for the identification of the species. Though it was not possible to use the absorption peaks for grouping of species at broader level, it was observed that two or three related species were showing certain common peaks apart from their unique ones, for example small groups comprising of *G. acuminata, G. forficulata* and *G. mysorensis, Manisuris myuros* and *Mnesithea granularis, Rottboellia exaltata* and *Ophiuros exaltatus* have common absorption peaks.

RAPD:

RAPD studies carried out for few *Glyphochloa* species and *Ophiuros bombaiensis* have shown that *G. henryi* is showing more RAPD distance than other species. *G. talbotii* and *G. acuminata* var. *woodrowii* show less distance among themselves as compared to others. Similarly *Ophiuros* is showing close relationship with *G. ratnagirica* among the analyzed species.

Numerical taxonomy:

Dendrogram constructed using morphological characters shows that *Glyphochloa* is distinct from its related genera. The species of *Glyphochloa* found in distict clusters one formed by two awned species another one formed by single awned species confined to Goa and Maharastra and third one by varieties of G. acuminata. It is also noticed that *G. divergens* and *G. talbotii* show similarity to *G. acuminata* group which was also noticed in phylogenetic analysis.

Dendrogram used for anatomy show three major clusters. One of the cluster shows the species which are generally confined to Goa and Maharashtra along with *Ophiuros bombaiensis* and the next cluster show all the varieties of *G. acuminata* and *G. talbotii*. The third cluster shows all

the two awned species in one sub cluster and related genera in another sub cluster.

Phylogeny:

Phylogeny of the genus *Glyphochloa* and its related genera has been studied based on morphological and anatomical characters using *Manisuris myuros* and *Ophiuros bombaiensis* as outgroups seperately. When *Manisuris* was used as an outgroup G. santapaui formed the basal clade. The remaining taxa got divided into three clades, one terminating with the varieties of *G. acuminata* another terminating in *G. goaensis, G. henryi & G. veldkampii* and the third one terminating in two awned speicies. *G. talbotii* formed the basal clade for two awned taxa. When Ophiuros was as an outproup more or less a similar trend was noticed, except for the patern of clades and position of *G. santapaui*.

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