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RESEARCH ARTICLE

STUDIES ON MORPHOLOGICAL, ANATOMICAL AND EPIDERMAL LAYERS IN WILD SPECIES OF *CYMOPOGON MARTINII* (ROXB.) FROM SOUTH INDIA.

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Abstract

Cymbopogon martinii (Roxb.) is wildy growing aromatic species belonging to 'Rusae' series under Poaceae. The naturally growing *C. martinii* were collected from varied ecological locations of South India like Ootacamund (T.N.), Shivery hills (Salem, T.N.), Hyderabad (A.P.), Bababudangiri hills (Karnataka), Chamundi Hills, Mysore (Karnataka), Yelwal Reserve Forest (Karnataka), Pykara hills (T.N.), Himavadgopala swamy Hills (Karnataka), Kemmanagundi (Karnataka), Kates point, Mahabaleswar (Maharashtra) and Odakkali (Kerala). The collections were designated as ecological 'Types' (Type 1 to 11) and were maintained as Germplasm in the Department of Biotechnology, Bangalore University, Bangalore under uniform conditions for morphological and anatomical studies. During the present investigation gross morphological features of the plant, anatomical and epidermal layer of the leaf were characterized from the collected specimens and the details were recorded. The study showed that Type 5 of *C. martinii* belonged to 'sofia' variety and rest of the Types belonged to 'motia' variety.

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Introduction:-

The genus *Cymbopogon* belongs to the grass family Poaceae (Gramineae) containing nearly 184 species, sub species, varieties and sub varieties, out of which 54 species are known and accepted worldwide (Bertea & Maffei 2010). The *Cymbopogon* species are known for their aromatic value and majorly used commercial species include *C. citratus* (West Indian lemongrass), *C. martinii* var. motia and sofia (Palmarosa and ginger grass respectively), *C. flexuosus* (East Indian lemongrass), *C. winterianus* (Java citronella) and *C. nardus* (Ceylon citronella). The name *Cymbopogon* is derived from Greek word, "Kymbe" boat and "Pogon" beard, first one referring to boat shaped spatheoles, a conspicuous feature of inflorescence, while the second one is supposed to be descriptive of having many awned inflorescences (Bor 1953; Bor 1960). The Indian *Cymbopogons* are classified under three taxonomic series as Citrati, Rusae and Shoenanthi (Stapf 1906).

Cymbopogon martinii (Roxb.) belongs to Rusae series and found indigenous to South India (Vinutha et al., 2013). It exists in two remarkable similar forms known as "motia and sofia", which gives better oil quality having high

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percentage of geraniol content (Bor 1953). The “motia” variety yield Palmarosa oil and “sofia” variety yield Ginger grass oil, commercially utilized for perfumery and medicinal purposes (Maffei 2002). India was the major producer of oil along with Guatemala, China, Mexico and Bangladesh. The oil finds extensive application in perfumery, cosmetic, flavor and aroma therapy. It is also an effective insect repellent used to store grains, antihelminthic to nematodes, antifungal and exhibit mosquito repellent properties (Olorunnisola *et al.*, 2014). The Palmarosa oil possesses characteristic aroma resembling rose scent and thus added to soaps and cosmetics (Rao *et al.*, 2005). The plant is source of high grade geraniol (75-95%) used as starting material for number of synthetic aromatic chemicals like geranyl esters (Soenarko 1977; Jagadishchandra 1975).

During the present investigation an attempt has been made to collect the wild “ecotypes” of *C.martinii* from different locations of South India and details on plant morphology, leaf anatomy and epidermal layers were investigated.

Materials and Methods:

Collection and maintenance of ecotypes:

The *C.martinii* were collected from wild ecological locations of South India like, Ootacamund (T.N.), Shivery hills (Salem, T.N), Hyderabad (A.P), Bababudangiri hills (Karnataka), Chamundi Hills, Mysore (Karnataka), Yelwal Reserve Forest (Karnataka), Pykara hills (T.N), Himavadgopalswamy Hills (Karnataka), Kemmanagundi (Karnataka), Kates point, Mahabaleswar (Maharashtra) and Odakkali (Kerala). The collections were designated as ‘Types’ (Type 1 to 11) and maintained in Department garden of Biotechnology, Bangalore University, Bangalore under uniform conditions.

Types	Place of collection
Type-1	Bababudangiri hills (Karnataka)
Type-2	Chamundi Hills, Mysore (Karnataka)
Type-3	Yelwal Reserve Forest (Karnataka)
Type-4	Ootacamund (TN)
Type-5	Shivery hills (Salem, T.N)
Type-6	Kemmanagundi (Karnataka)
Type-7	Himavadgopala swami Hills (Karnataka)
Type-8	Pykara hills (TN)
Type-9	Kate’s point, Mahabaleswar (Maharashtra)
Type-10	Odakkali (Kerala)
Type-11	Hyderabad (A.P)

Morphological Characters:

The morphological characters like length and thickness of Culm, length and breadth of leaf, texture and color of the leaf, angle of the leaf with Culm, length of ligule, length of leaf sheath, length of inflorescence, nature of branching, length of spatheole, shape of the bisexual spikelet were studied from the flowering culms.

Leaf Anatomy:

Leaf anatomy was studied by taking transverse section of lamina. The fresh leaf material was treated with FAA (90 ml of 70% ethanol + 5 ml of glacial acetic acid + 5 ml of formaldehyde solution) for 48 hours and washed in water. The mid portion of leaf blade was selected and transferred to 10% hydrofluoric acid for 24 hours, washed in running water for 2 hours and transferred to 70% ethanol. The sections of leaf blade were taken, treated with hypochlorite solution for 25 min, washed and preserved in 70% ethanol.

The sections were stained using a mixture of 94 parts of 1% Saffranin in 70% ethanol and 6 parts of Delafield’s Hematoxylin for 30-120 min. The material was washed in 50% ethanol, dehydrated in alcohol series cleared in xylol and mounted in Canada balsam (Metcalf 1960). For the description of lamina, standard methods were followed (Ellies, 1976).

Epidermal layer:

The technique described by Metcalfe (Metcalf 1960) was followed to study the details of epidermis. The mid portion of leaf blade was cut (half way between the blade apex and the ligule of leaf) and placed on the slide. The material was first washed in laboratory detergent solution and the tissue above the epidermis to be examined was

scraped off using razor blade. The epidermis was washed in water and the adhering cells were carefully removed using soft brush.

Result:-

Totally 11 different Types of wild *C. martinii* were collected from various locations of South India and subjected to (i) morphological, (ii) leaf anatomical and (iii) epidermal characteristics and the described as follows:

Type-1:

- (i) **Plant morphology:** Strongly Aromatic grass with erect culms, 90-120 cm high, tillers 16-21, unbranched; leaf 27-35 x 1.6-1.9 cm, linear lanceolate, coarsely scabrid along margin, cordate at base, amplexicaul, make obtuse angle with culms; ligule membrano-chartaceous, 3-5 mm long; leaf sheath shorter than internode, smooth with all nodes exposed; inflorescence linear-oblong, false decomposed panicle upto 35 cm long, moderately dense; spatheole 18-20 mm long, orange to bright red at maturity, elliptic acute; racemes 15-18 mm long, one sub sessile, other pedicelled, lowest pair of spikelet in the subsessile raceme homogamous male; pedicel of lower most pedicelled spikelet in the sessile raceme swollen and adnate to rachis, sessile spikelet 3-3.5 mm long elliptic oblong excluding wings, lower glume with deep median groove, 2-nerved, broadly winged, awn 16-18 mm long, pedicellate spikelet 4.4-5 mm long elliptic-acute, lower glume with 7-9 nerves (Fig 1a).
- (ii) **Leaf anatomy:** Leaf lamina flat, vascular bundles arranged in abaxial line; midrib not associated with colorless mesophyll cells, median bundle distinct, basic type of vascular bundles with metaxylem present on either side of protoxylem, sclerenchymatous, girder projects abaxially (Fig 1b).
- (iii) **Leaf epidermal characteristics:** Short cells in coastal region alternate with silica cells in long uninterrupted rows, sometimes 3-4 cells fused to form long cells, short cells in intercostal region, solitary; silica bodies cross to dumb-bell shaped, long cells with thin walls, hooks absent, only micro hairs present, 33-40 μm long, distal cell 14-16 μm long; basal cell wider and more inflated than distal cell, distal cell tapering to an acute apex, tip pointing towards the apex of the leaf, stomata in rows, subsidiary cells triangular to low dome-shaped (Fig 1c).

Flowering period: October - November.

Specimen collection: Bababudangiri hills (Karnataka)

Habitat: Hilly region

Type-2:

- (i) **Plant morphology:** Loosely tufted perennial aromatic grass, culms procumbent to erect, 150-350 cm tall, 8-10 mm in diameter, rarely branched at base, radical leaves few, culms often bent at nodes, nodes swollen, often waxy; leaves 40-65 x 2-3 cm, pale green, linear lanceolate, coarsely scabrid along margin, base cordate, nearly amplexicaul, angle on culm obtuse; ligules 2-5 mm long, membrano-chartaceous; leaf sheath upper 2-3 shorter than internodes and rest longer, over-lapping, smooth glabrous, spathe panicle erect, compound upto 60 cm, spatheoles 15-22 mm long, lowermost pedicel of pedicelled spikelet in sessile raceme swollen and adnate to pedicel; sessile spikelet 3.5-4 mm long elliptic-oblong, broad winged, lower glume 0.8-1 mm wide, with deep median groove, 2-nerved and broadly winged, awn 12-16 long; pedicellate spikelet elliptic acute, 3.5-5 mm long, lower glume 1.2 mm wide, glabrous 7-9 nerved (Fig 2a).
- (ii) **Leaf anatomy:** Lamina flat, vascular bundles arranged in abaxial row, keel very prominent and dome like abaxially 25-32 bundles included in the keel, xylem and phloem easily distinguishable, meta xylem comparatively absent, median bundle distinctly large anchor shaped sclerenchymatous girder projecting abaxially colorless cells of keel extends towards lamina, leaf margin with numerous prickles (Fig 2b).
- (iii) **Leaf epidermal characteristics:** Short cells in the inter-coastal regions solitary and those in costal bends alternate with silica bodies in long uninterrupted rows, silica bodies cross to dumb-bell shaped, long cells with thin sinuous walls, both macro hairs and hooks present, hooks with bulbous base, tip short and pointed, microhairs 40-50 μm long, basal cell inflated 20-25 μm long, distal cell narrow and tapering, 20-25 μm long; stomata with triangular to low-dome-shaped subsidiary cells (Fig 2c).

Flowering: October- November

Specimens collected: Chamundi hills (Karnataka)

Habitat: Rocky hill slopes

Type-3:

- (i) **Plant morphology:** Perennial aromatic grasses, culms erect, 180-230 cm long, smooth, glabrous, terete, lower nodes often swollen, radical leaves few, often branched at the base; lamina 30-45 x 1.4-2 cm, dark green, linear lanceolate, scabrid along margin, rounded to cordate at base, forming right angle to obtuse angle with culm;

ligule membrano-chartaceous, 3-4 mm long, leaf sheath-upper few shorter, lower ones longer and overlapping, smooth glabrous, spathate panicle sparsely branched, 15-30 cm long, spatheole 15-22 mm long, bright-red at maturity; racemes 18-20 mm long, the pedicel of lowermost pedicelled spikelet in sessile-raceme swollen and glossy, rachis internodes and pedicel pilose along margin; sessile spikelet up to 3 mm long, glabrous, lower glume chartaceous, 1 mm wide, elliptic ovate with a deep median groove, broadly winged 2-nerved; awn 12-18 mm long, pedicellate spikelet 4 mm long, glabrous, lower glume elliptic-acute (Fig 3a).

- (ii) **Leaf anatomy:** Leaf blade flat, vascular bundles in abaxial rows, median bundle large, keel narrow includes 6-8 bundles, 1-2 bundles possess clear distinguishable xylem and phloem vessels and the rest vascular bundles show indistinguishable xylem and phloem, colorless mesophyll cells do not extend, median bundle projected abaxially by sclerenchymatous girder, leaf margin exhibits many prickles, broad based with sharp tips pointing towards the tip of the leaf (Fig 3b).
- (iii) **Leaf epidermal characteristics:** Short cells in intercostal region mostly solitary, sometimes paired, in costal bands they alternate with silica cells in the long uninterrupted rows, silica bodies dumbbell shaped, long cells with thin sinuous walls, both hooks and micro hairs present, hooks bulbous based with short tip, microhairs 35-40 μm long, basal cell 18-19 μm long, inflated, distal cell 14-18 μm long tapering to pointed apex; stomata in long rows, subsidiary cells dome-shaped (Fig 3c).

Flowering: November - December

Specimen collected: Yelwal reserve forest (Karnataka)

Habitat: Rocky hill slopes.

Type-4:

- (i) **Plant morphology:** Perennial aromatic grass, culm erect, 100-185 cm tall, smooth, glabrous, terete, tiller many, unbranched, radical leaves few, lower nodes often swollen; leaf blades 20-25 X 1.0-1.2 cm, linear lanceolate, pale green, scabrid along margin, cordate to amplexicaul at base, leaf blade forms acute angle with culm; leaf sheath smooth and glabrous, upper 2-3 shorter, lower ones longer and overlapping; panicle 20-30 cm long, erect, sparsely branched; spatheole 18-22 mm long bright red at maturity; racemes 18-20 mm long, pedicel of lowermost pedicelled spikelet in sessile raceme swollen and adnate to rachis, internodes of rachis and pedicel pilose along margin, sessile spikelet 3.5 mm long, glabrous, lower glume chartaceous, 1 mm wide, ovate with deep median groove, broadly winged, 2-nerved; awn 12-18 mm long; pedicellate spikelet 4 mm long, glabrous, lower glume lanceolate, 8-nerved (Fig 4a).
- (ii) **Leaf anatomy:** Lamina flat, vascular bundles in abaxial rows, median bundle associates with colorless mesophyll cells to form narrow keel possessing 10-12 indistinguishable xylem and phloem vascular bundles; median bundle distinct with its sclerenchymatous girder projecting abaxially, leaf margin with many prickles each with pointed end and broad base (Fig 4b).
- (iii) **Leaf epidermal characteristics:** Short cells in intercostal region solitary, in costal bands alternates with silica cells in long uninterrupted rows; silica bodies dumb-bell shaped, long cells with thin sinuous walls; both hooks and micro hair present, hooks bulbous based, tip of the hook short and erect; micro hair 40-45 μm long, basal cells 16-23 μm long inflated, distal cells 14-20 μm long, with pointed apex; stomata with low-dome-shaped subsidiary cells (Fig 4c).

Flowering: October - November.

Specimens collected: Ootacamund (T.N)

Habitat: Rocky hill slopes.

Type-5:

- (i) **Plant morphology:** Perennial aromatic grasses with thick and erect sometimes procumbent culms, 100-185 cm tall, 4-7 mm in diameter, smooth, glabrous, lower nodes swollen culms unbranched, often waxy, tillers 20-30, radical leaves few; leaf blades 25-32 x 2-205 cm, pale yellow, leaf blades thick, lanceolate, the tip tapering into long narrow structure, margin smooth, seldom scabrid, amplexicaul at base, making acute angle with the culms; ligule membrano-chartaceous, 4-7 mm long; leaf sheath glabrous, smooth upper few shorter and lower ones longer and overlapping, spathate panicle 30-60 mm long, branched, dense, spatheoles 20-30 mm long, bright red at maturity; racemes 18-20 mm long, pedicels of lowermost pedicelled spikelet in sessile raceme swollen and glossy; sessile spikelets 3.5-4.5 mm long, lower glume lanceolate acute, wings broad, sometimes with 2 nerves, 1 mm wide with deep median groove; awn 12-18 mm long; pedicellate spikelet 4-4.5 mm long, glabrous, lower glume lanceolate with 8-10 nerves (Fig 5a).

- (ii) **Leaf anatomy:** Lamina flat, thick, keel narrow, median bundle distinct, sclerenchymatous girder projects abaxially; keel with 6-7 indistinguishable xylem and phloem vascular bundles, colorless cells do not extend beyond the keel (Fig 5b).
- (iii) **Leaf epidermal characteristics:** Short cells in intercostal region solitary and in costal bands alternate with silica bodies in long uninterrupted rows, cross-to dumb-bell-shaped silica bodies, long cells with thin sinuous walls; hooks and micro hair present, hooks few, bulbous based, tip short; micro hair 38-42 μ m long, basal cells 18-22 μ m long inflated, distal cell 18-22 μ m long, tapering to pointed apex; stomata in long rows with high-dome-shaped subsidiary cells; leaf margin smooth (Fig 5c).

Flowering: December - January.

Specimens collected: Shivery Hills (Salem, T.N)

Habitat: Rocky Hill slopes.

Type-6:

- (i) **Plant morphology:** Perennial aromatic grasses, culms erect, terete, 100-150 cm tall, unbranched, lower nodes swollen, tillers 20-30; leaf blade 20-32 x 2.0-2.5 cm, linear lanceolate, yellow-green, cordate to rounded at base, forms obtuse angle with culm ligule 3-5 mm long membrano-chartaceous; leaf-sheaths glabrous smooth, the upper are shorter and rest longer and overlapping; spathe inflorescence compound, 45-65 cm long, dense; spatheoles 20-25 mm long, bright red at maturity; racemes 18-20 mm long, lowermost pedicel of pedicelled spikelet in sessile raceme swollen and glossy, rachis internodes and pedicel pilose along margin, sparsely pilose on back; sessile spikelet 3.5-4 mm long, glabrous, lower glume elliptic acute with a broader tip, wings broad, glume with a deep median groove, 2-nerved; awn 12-18 mm long; pedicellate spikelet 4 mm long, glabrous, lower glume lanceolate, 8 nerved (Fig 6a).
- (ii) **Leaf anatomy:** Lamina flat, median bundle distinct, keel narrow with 6-8 indistinguishable xylem and phloem vascular bundles; colorless mesophyll cells extend beyond the keel; median bundle forms smooth dome-shaped arc abaxially without projection (Fig 6b).
- (iii) **Leaf epidermal characteristics:** Short cells in intercostal region solitary, in coastal bands they alternate with silica bodies in long uninterrupted rows; silica bodies dumb-bell shaped, long cells with thin sinuous walls; only micro hairs present, hooks absent, microhairs 40-44 μ m long, basal cell 20-22 μ m long, inflated, distal cell 20-22 μ m long, tapering in to sharp apex; stomata in long rows with high-dome-shaped subsidiary cells; leaf margin almost smooth with very few blunt prickles at tip of leaf (Fig 6c).

Flowering: November - December.

Specimens collected: Kemmanagundi (Karnataka)

Habitat: Rocky hill slopes.

Type-7:

- (i) **Plant morphology:** Perennial aromatic grasses, culms erect, 100-170 cm tall, terete, purple thinned, smooth glabrous, lower nodes often swollen, unbranched, tillers 20-25, radical leaves few; lamina 21-32 x 1.2-1.5 cm, linear lanceolate, dark green with purple tint, tint prominent along margin, cordate at base, forms right angle to obtuse angle with culm; ligule 4-5 mm long, membrano-chartaceous; leaf sheath glabrous, smooth, deep green with purple tint, upper 2-3 shorter than internode, rest longer and overlapping; leaf margin smooth; inflorescence 20-38 cm long, dense, sparsely branched, spatheoles 20-25 mm long, bright red at maturity; racemes 18-22 mm long, pedicel of lowermost pedicelled spikelet in sessile raceme swollen and adnate to rachis, rachis internodes and pedicel pilose along margin, sparsely pilose on back; sessile spikelet 3-3.5 mm long, glabrous, lower glume chartaceous 1 mm wide, ovate with a deep median groove, broadly winged, 2-nerved; awn 15-18 mm long; pedicellate spikelet 4 mm long, glabrous, lower glume lanceolate, 8-nerved (Fig 7a).
- (ii) **Leaf anatomy:** Lamina flat, median bundle associated with colorless mesophyll cells forming dome-shaped keel, median bundle distinct not projected abaxially, forms smooth curve with keel; 8-10 bundles in keel, 2-4 vascular bundles show clear distinguishable xylem and phloem vessels without presence of meta xylem and rest of them possess indistinguishable vascular bundles (Fig 7b).
- (iii) **Leaf epidermal characteristics:** Short cells in intercostal region solitary, in costal bands either solitary or in pairs, alternate with silica bodies in long uninterrupted rows; silica body dumb-bell shaped, long cells with thin sinuous walls, hooks absent, only microhairs present, 40-42 μ m long, basal cell 20-22 μ m long and inflated, distal cell 19-20 μ m long tapering to narrow tip; stomata in long rows, subsidiary cells dome-shaped; leaf margin smooth with very few blunt prickles towards tip of leaf (Fig 7c).

Flowering: October - November
 Specimens collected: Himavadgopalaswamy Hills (Karnataka)
 Habitat: Rocky hill slopes

Type-8:

- (i) **Plant morphology:** Perennial aromatic grass, culms erect, 90-120 cm tall, smooth, terete, often branched from base, stilt roots often present; leaf blades 10-15 x 0.8-1.0 cm, linear lanceolate, pale green smooth, glabrous, rounded to cordate at base, forms obtuse angle with culm; ligule 3-5 mm long, membrano-chartaceous; leaf sheath smooth and green, most nodes exposed, margin of leaf blade coarsely scabrid, spatulate; inflorescence compound, short 15-20 cm long, spatheoles 18-20 mm long, bright red at maturity; racemes 18-20 mm long, pedicel of the lowermost pedicelled spikelet in the sessile raceme swollen and adnate to rachis, sessile spikelet 3-3.5 mm long, glabrous, lower glume chartaceous, 1mm wide, ovate, with deep median groove, broadly winged, 2-nerved; awn 15-18 mm long; pedicelled spikelet upto 4 mm long glabrous, lower glume lanceolate, 8-nerved (Fig 8a).
- (ii) **Leaf anatomy:** Lamina flat, median bundle associated with colorless mesophyll cells forming narrow keel containing 13-16 vascular bundles, 2-4 vascular bundles show clear distinguishable xylem and phloem vessels without presence of meta xylem and rest of them possess indistinguishable vascular bundles; colorless cells do not extend beyond keel; median bundle distinct with sclerenchymatous girder projecting abaxially (Fig 8b).
- (iii) **Leaf epidermal characteristics:** Short cells in intercostal region solitary in costal bands solitary or in pairs, alternates with silica cells in long interrupted rows; silica bodies dumb-bell shaped, long cells with thin sinuous walls, no hooks, only micro hairs present, 40-42 μm long basal cell 20-21 μm long, inflated, distal cell 20-21 μm long tapering to sharp apex; stomata with high-dome-shaped subsidiary cells (Fig 8c).

Flowering: October - November.
 Specimens collected: Pykara hills (T.N)
 Habitat: Rocky hill slopes.

Type-9:

- (i) **Plant morphology:** Perennial and aromatic with short culms, culms erect 60-100 cm tall, branched at lower nodes, radical leaves many; leaf blade 10-18 x 0.8-1.3 cm, lanceolate, pale green, smooth, glabrous coarsely scabrid along margin, amplexicaul at base, forms acute angle with culm; ligule 3-5 mm long, chartaceous; leafsheath smooth, green, upper 2-3 shorter than internodes, lower ones longer and overlapping; inflorescence short, 15-20 cm long, dense, sparsely branched; spatheoles 18-20 mm long, pedicel of lower most pedicelled spikelet in sessile raceme swollen and adnate to rachis; sessile spikelet 3-3.5 mm long, lower glume chartaceous, ovate with deep median groove, broadly winged, 2-nerved; pedicelled spikelet upto 4 mm long, lower glume lanceolate, glabrous, 8-nerved (Fig 9a).
- (ii) **Leaf anatomy:** Lamina flat, median bundle associated with colorless mesophyll cells forming a narrow keel containing 8-10 vascular bundles, 1-2 vascular bundles show clear distinguishable xylem and phloem vessels without presence of meta xylem and rest of them possess indistinguishable vascular bundles; colorless cells do not extend beyond the keel; median bundle distinct with sclerenchymatous girder slightly projecting abaxially (Fig 9b).
- (iii) **Leaf epidermal characteristics:** Short cells in intercostal region solitary, in costal bands solitary or in pairs, alternate with silica cells in long uninterrupted rows; silica bodies dumb-bell shaped; long cells with thin sinuous walls; hooks and microhairs present, hooks with bulbous base and tip elongated into sharp structure; microhairs abundant, 40-42 μm long, basal cell inflated 20-21 μm long, distal cell of same size; stomata in long rows, subsidiary cells dome-shaped, Leaf margin coarsely scarbrid with many pointed prickles (Fig 9c).

Flowering: October - November.
 Specimen collected: Kate's point, Mahabaleswar (Maharashtra).
 Habitat: Rocky hill slopes.

Type-10:

- (i) **Plant morphology:** Perennials aromatic, culms erect, 120-160 cm tall, branched from base, lower nodes swollen; leaf blade 19-26 x 1-1.2 cm, linear lanceolate, dark green, smooth but coarse along margin, cordate at base, often amplexicaul, forms right angle to obtuse angle with culm; ligule 4-6 mm long, chartaceous; leaf sheath smooth green, shorter than internodes, all nodes exposed, straw yellow in color; inflorescence long 25-45 cm long, branched; spatheoles 20 mm long, bright red at maturity; racemes 18-20 mm long, pedicel of lowest pedicelled spikelet in sessile-racemes swollen and adnate to rachis; sessile spikelet 3-3.5 mm long,

glabrous, lower glume elliptic-ovate with deep median groove, broadly winged, 2-4 nerved, pedicelled spikelet upto 4 mm long, lower glume lanceolate, 8-nerved (Fig 10a).

- (ii) **Leaf anatomy:** Lamina flat, median bundle associated with colorless cells forming narrow keel, 10-12 vascular bundles in keel, 2-4 vascular bundles show clear distinguishable xylem and phloem vessels without presence of meta xylem and rest of them possess indistinguishable vascular bundles; median bundle slightly projects abaxially (Fig 10b).
- (iii) **Leaf epidermal characteristics:** Short cells in intercostal region solitary, in costal bands they alternate with silica cells in long uninterrupted rows; silica bodies dumb-bell shaped; long cells with thin sinuous walls; both microhairs many, 40-42 μm long, basal cell 20-21 μm long inflated, distal cell of same dimension tapering to pointed apex; stomata in long rows with dome-shaped subsidiary cells; leaf coarsely scabrid with many prickles (Fig 10c).

Flowering: October - November.

Specimens collected: Odakkali (Kerala)

Habitat: Rocky hill slopes.

Type-11:

- (i) **Plant morphology:** Perennials, aromatic, culms erect, 140-200 cm tall, robust terete, lower nodes often swollen and bent; leaf blades 30-45 x 15-25 cm, linear lanceolate, pale green, base cordate, amplexicaul, forms right angle to obtuse angle with culm; ligule 4-6 mm long, membrano-chartaceous; leaf sheath smooth, shorter than inter node, almost all nodes exposed, leaf margin coarse; inflorescence 30-50 cm long, narrow, sparsely branched; spatheole 20-22 mm long, bright red at maturity; racemes 20-22 mm long; pedicel of lowermost pedicelled spikelet in sessile raceme swollen and adnate to rachis; sessile spikelet 3-3.5 mm long, lower glume chartaceous, elliptic-ovate, with deep median groove, broadly winged, 2-nerved; pedicelled spikelet upto 4 mm long, lower glume lanceolate, 8-nerved (Fig 11a).
- (ii) **Leaf anatomy:** Lamina flat, median bundle associated with colorless mesophyll cells forming short keel, 8-10 bundles with indistinguishable xylem and phloem vessels in keel; colorless cells do not extend beyond keel, median bundle distinct, sclerenchymatous girder projects abaxially (Fig 11b).
- (iii) **Leaf epidermal characteristics:** Short cells on intercostal region solitary, on costal bands in long uninterrupted rows, alternating with silica cells; silica bodies dumb-bell shaped to nodular by fusion of 4-6 silica bodies; long cells with thin sinuous walls; hooks absent, only micro hairs present, 40-44 μm long, basal cell 20-22 μm , long inflated, distal cell 18-20 μm long tapering to narrow pointed apex; stomata in long rows, subsidiary cells low-dome shaped; leaf margin coarsely scabrid with sharp pointed prickles (Fig 11c).

Flowering: October - December.

Specimens collected: Hyderabad (A.P)

Habitat: Rocky hill slopes.

FIGURES:

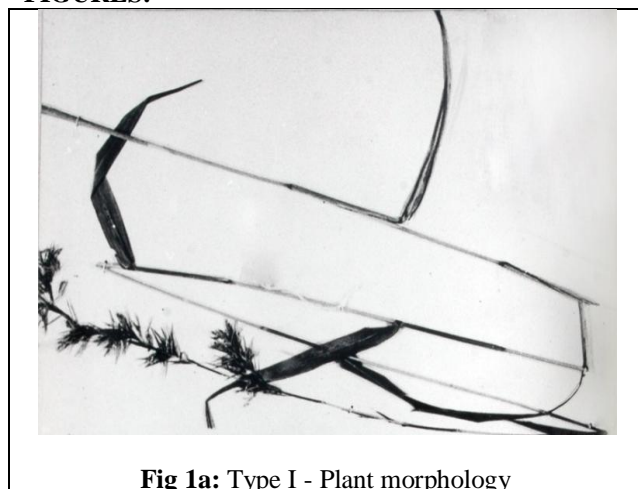


Fig 1a: Type I - Plant morphology



Fig 1b: Type I - Leaf anatomy



Fig 1c: Type I - Leaf epidermis



Fig 2a: Type II - Plant morphology



Fig 2b: Type II - Leaf anatomy

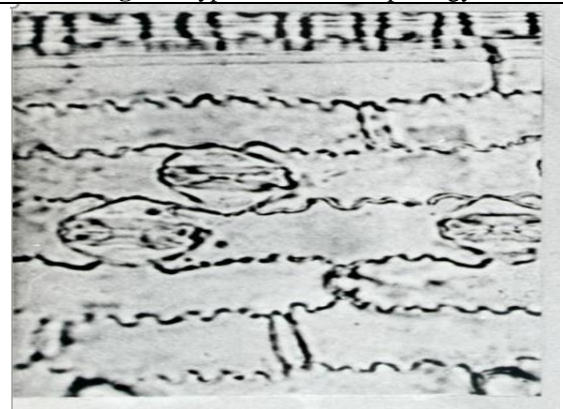


Fig 2c: Type II - Leaf epidermis



Fig 3a: Type III - Plant morphology

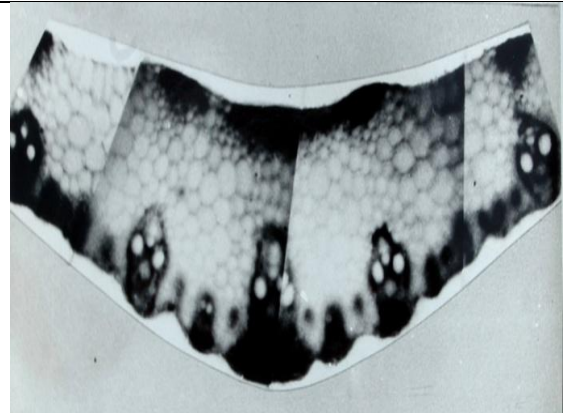


Fig 3b: Type III - Leaf anatomy

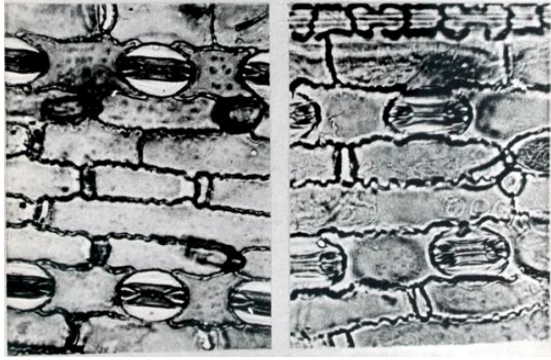


Fig 3c: Type III - Leaf epidermis



Fig 4a: Type IV - Plant morphology



Fig 4b: Type IV - Leaf anatomy

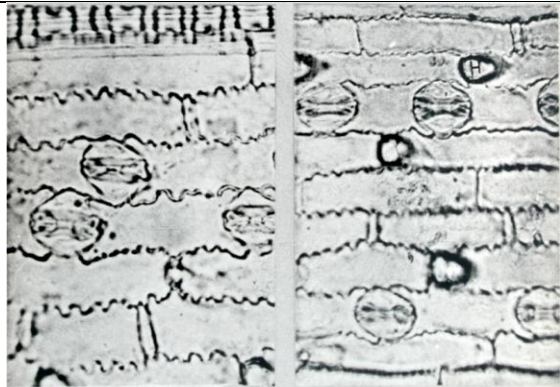


Fig 4c: Type IV - Leaf epidermis



Fig 5a: Type V - Plant morphology

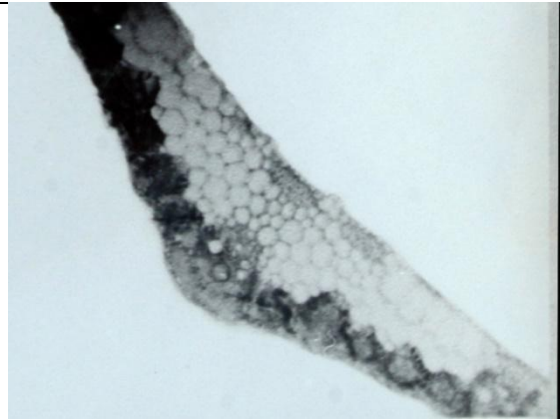


Fig 5b: Type V - Leaf anatomy

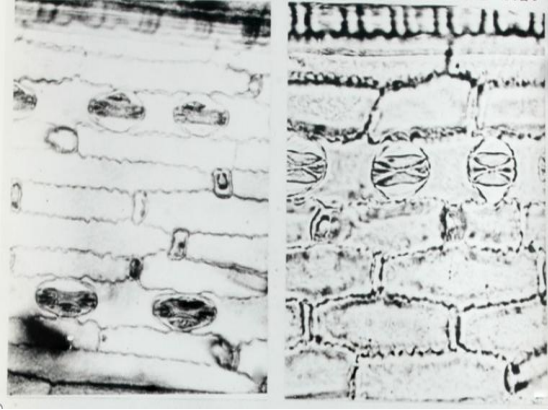


Fig 5c: Type V - Leaf epidermis

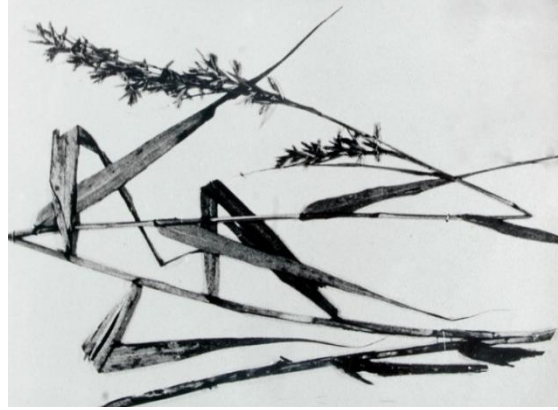


Fig 6a: Type VI- Plant morphology

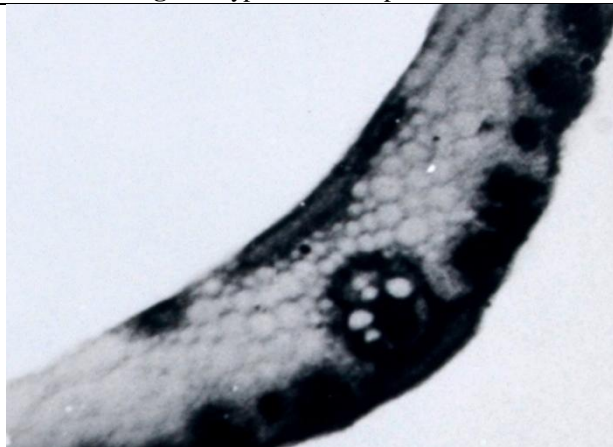


Fig 6b: Type VI - Leaf anatomy



Fig 6c: Type VI - Leaf epidermis



Fig 7a: Type VII - Plant morphology



Fig 7b: Type VII - Leaf anatomy

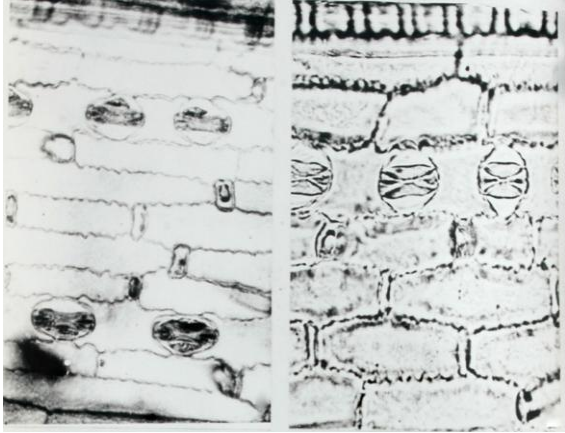


Fig 7c: Type VII - Leaf epidermis



Fig 8a: Type VIII - Plant morphology



Fig 8b: Type VIII - Leaf anatomy



Fig 8c: Type VIII - Leaf epidermis



Fig 9a: Type IX - Plant morphology



Fig 9b: Type IX - Leaf anatomy

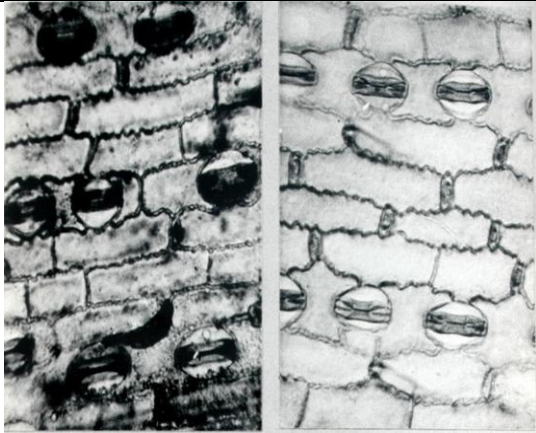


Fig 9c: Type IX - Leaf epidermis



Fig 10a: Type X - Plant morphology

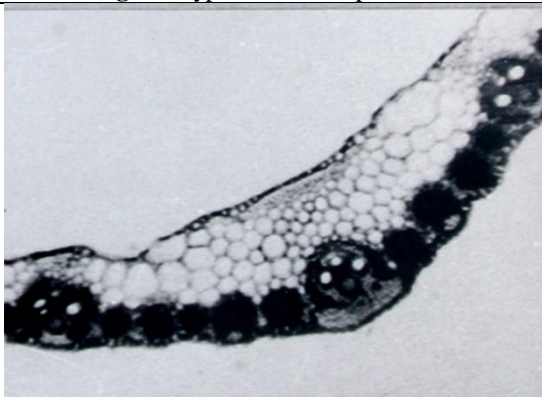


Fig 10b: Type X - Leaf anatomy

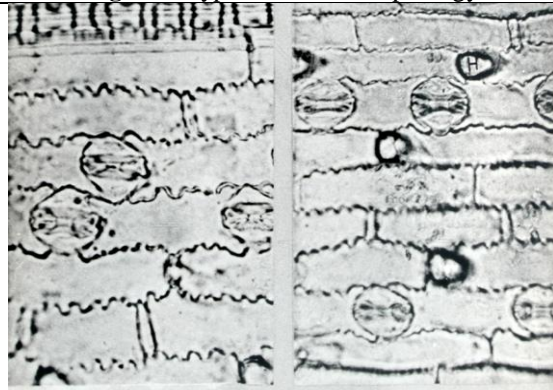


Fig 10c: Type X - Leaf epidermis



Fig 11a: Type XI - Plant morphology



Fig 11b: Type XI - Leaf anatomy

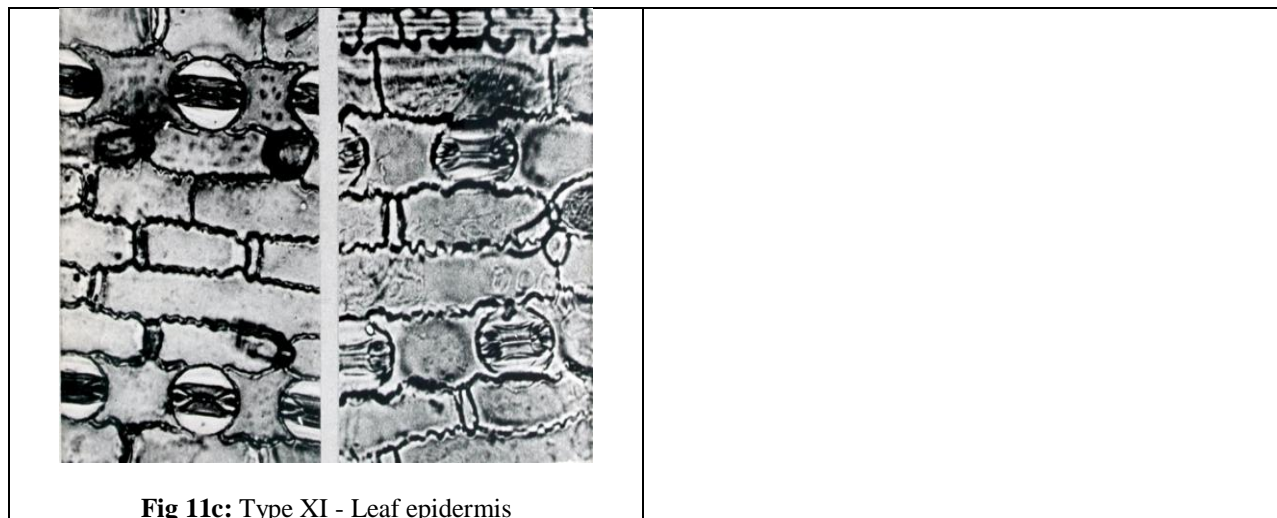


Fig 11c: Type XI - Leaf epidermis

Discussion:

During the study based on distinct morpho-anatomical characters of the plant, eleven types (Type 1 to 11) were recognized in the wild collections of *C. martinii* from South India. The Type-1 of *C. martinii* differs anatomically from rest of the Types by possessing a distinct midrib instead of keel, by possessing marked microhairs on the abaxial surface and by conspicuously absence of hooks. The Type-2 showed unique characteristics and differed from other Types in their morphology having gigantic size and besides, anatomically showed the presence of considerably large keel. Type-3 has a characteristic leaf blade which is coarsely scabrid along the margin and possesses hooks and microhairs and narrow keel. Type-4 to Type-9 differs from the rest in possessing lamina that forms a characteristic acute angle with the culms. The said morphological features seem to be characteristics of the *C. martinii* variety sofia in the species recognized (Gulati *et al.* 1970).

Many other characters of the variety Sofia such as the ploidy, the size and shape of the sessile spikelet, including the habit and habitat were, however, characteristically found only in Type-5. Hence Type-5 is recognized as similar and synonymous to *C. martinii* variety sofia (Gulati *et al.* 1970).

Type-8 and Type-9 resemble each other in habit, in the short stature of plants, and in possessing a lamina of narrow keels, but differ in their leaf angles and trichomes. The leaves of Type-8 form obtuse angle with the culm whereas those of Type-9 form acute angle with culm. Further in Type-8 the hooks were absent from abaxial epidermis whereas hooks in Type-9, Type-6 resembles Type-5 in many respects but differs from it in leaf character forming an obtuse angle with the culm and absence of hooks. Type-7 differs from rest of the Types in having the aerial parts of the plant body suffused with purple color; the leaf margin being smooth and the median bundle not projecting abaxially. These grasses are medium statured and very common in South India, possessing cordate leaves with a narrow keel and median bundle being projecting abaxially, both microhairs and hooks are present. Type-11 differs from others possessing culms with all nodes exposed, narrow short keel and absence of hooks on the abaxial epidermis, the leaf margin being coarse with prickles.

The present studies on the *C. martinii* of Rusae and the types recognized in each species reveal that there is no drastic variation with regard to the structure and morphology of the spikelets, both within and between the species, indicating the floral homogeneity of the members and the series as whole. However, leaf morphology and its anatomy, in addition to the general morphology of the plants; have yielded valuable information of taxonomic importance.

Controversies have existed for many years among different workers as to the number of varieties to be recognized under *C. martinii*, the famous 'Rosha' grass of commerce. However, the two varieties recognized from earlier are sofia and motia (Stapf 1906) and has been validated recently (Gulati *et al.* 1970; Mathela *et al.* 1990).

Collections under the Type-5 are synonymous and equivalent to variety martinii and variety Sofia respectively. The rest of the Types described under *C. martinii* are very distinct in their morpho-anatomical characters deserve varietal

status and will have to be formally described under the respective species in further morphological studies of the wild species.

The leaf anatomy in the wild *C. martinii* revealed the taxonomical differences existing between the Types (Type 1-11). The leaf blades of approximately same age group were used for the present study. The mesophyll showing radiating chlorenchyma, bundle sheath single with large chloroplasts; starch grains in bundle sheath cells (as confirmed by iodine test) indicated Kranz Syndrome leaf anatomy in all the Types. The present investigations were noted to be characteristic and found to be consistent in each of the recognized Types.

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