FURTHER CONTRIBUTIONS TO OUR KNOWLEDGE OF \textit{MUSOCAULON INDICUM} JAIN

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\textbf{INTRODUCTION}

One of the petrified blocks collected from the Mohgaon Kalan area in the intertrappean beds of Madhya Pradesh has a false erect stem included in it. A detailed study of this stem which forms the subject-matter of this paper showed that this is a pseudostem formed by overlapping leaf-bases comparable to those found in the Musaceae. In fact Jain (1960) has described \textit{Musocaulon} a false stem based upon "leaf-sheaths". Our specimen is comparable to this and is more fully and better preserved than his specimen.

The silicified block (Plate XVI, Photo 1) in transverse section shows part of a pseudostem and several leaves cut transversely with their prominent midribs \((l)\). A transverse section of the entire pseudostem (Text-Fig. 1) shows clearly two sheathing basal parts of leaves one inside the other. In the centre occurs rolled up a third coiled but not fully differentiated leaf. The outer one \((ol)\) shows a thick midrib with plenty of scattered fibrous and fibrovascular bundles and air-spaces \((as)\) disposed in an arc-like manner. A peripheral zone of fibrous tissue is conspicuous. The second leaf-base \((sl)\) is enclosed within the first in a way suggesting a distichous phyllotaxis and has the midrib directed in the opposite direction. The involution of the sheath is of the convolute type and its margin ends in a fine point. The third undifferentiated leaf \((il)\) is narrow, closely coiled and bears a single row of fibrovascular bundles. The specimen measured about 11 cm. in length and 3.6 cm. in its longer diameter and 1.6 cm. in its shorter diameter.

\textbf{ANATOMY}

A transverse section of the outer leaf-base in the midrib region (Text-Fig. 2) shows a thick-walled epidermis (not very clearly seen) underlying which is a row of groups of fibrous tissue \((fbt)\) separated by parenchymatous bands \((pb)\). The entire ground tissue interior to this is filled by small fibrous bundles.
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(fb) and small and big fibrovascular bundles (fvb). The air canals are arranged in a single arc at the abaxial side and are separated by transverse septa (s). This consists of several layers of parenchymatous cells. In the outer edge of the septum the fibrous bundles (fb) occur in an arc with the concavity facing outwards (Text-Fig. 2). In the body of the septum itself the fibrous and fibrovascular bundles are generally alternate. The inner edge of the septum carries a big fibrovascular bundle (fvb). The bundles referred to above generally show the ventral lobe of the sclerenchyma directed towards the adaxial side of the sheath, while the bundles in the central portion (inner portion) of the midrib are not orientated in a definite direction (Text-Fig. 3) but occur scattered amidst the fibrous bundles. The ground tissue has thin-walled rounded parenchymatous cells overlapping each other. Towards the adaxial side there occur a number of tannin cells (tc) (Text-Fig. 4) either singly or in groups, succeeded by smaller cells underlying the epidermis. The ground tissue cells in this region are generally angular and isodiametric (Plate XVII, Photo 2).

The second leaf-base infolded in the first has its rather pronounced midrib directed in the opposite direction and the leaf-sheath is convolute. The midrib is not fully preserved and as far as can be seen does not show the large air-spaces disposed in an arc. The ground tissue is made up of rounded overlapping cells (Text-Fig. 2) and the portion near the adaxial region is as in Text-Fig. 4. The vascular bundles in the midrib portion occur in a scattered manner. But the vascular bundles in the expanded portion of the sheath are arranged in two or three series or arcs as stated by Jain (1960) (Plate XVII, Photos 2&3). The main bundles (forming arc one) are nearer the adaxial side while the smaller ones (forming arcs two and three) are towards the abaxial side (Text-Fig.15). The fibrous bundles occur in both abaxial as well as adaxial sides, but in some portions they number more towards the adaxial side (Plate XVII, Photo 5). The fibrovascular bundles show a large amount of sclerenchyma on the ventral side. The ventral and dorsal sclerenchyma often meet on the sides (Text-Fig. 5). Text-Figure 6 shows a transverse section of a part of the leaf-base with the dorsal fibrous bundles (fb), the general overlapping rounded ground tissue cells and the main oval fibrovascular bundle with its large ventral sclerenchyma (vsc) and lesser dorsal sclerenchyma (dsc) (Plate XVII, Photo 3). The xylem elements (xy) generally number one, often two, the "Commissural connectives" (Tomlinson, 1959) (cc) and crushed phloem (ph) can also be made out. The "Commissural connectives" are found in between the xylem elements and phloem. A few cells of the fibrous bundles and some belonging to the ventral and dorsal sclerenchyma of the fibrovascular bundles also show dark
contents and may well be the beginnings of stegmata which occur regularly in the Musaceae. A few layers of the ground tissue towards the adaxial side have slightly transversely stretched cells. Text-Figures 7 and 8 represent diagrammatically on a large scale a part of the leaf-base cut vertically. They show the prominent fibrous bundles near the abaxial side and the smaller fibrous bundles towards the adaxial side. In the centre are seen a number of bundles of the outer arc and the larger lobed bundles of the main arc (Plate XVII, Photo 5). This lobed bundle (Text-Fig. 8) shows on the right as though a small part is being laterally abstricted. Plate XVII, Photo 4 shows one bundle cut off from the main bundle on the dorsal side (b). It may be that new bundles are abstricted off like this as has been suggested by Jain. But we have not so far come across bundles being abstricted on the ventral side as suggested by Jain. In the second leaf-base also at particular places one can see the distinct sub-epidermal fibrous tissue separated by parenchyma as seen in Text-Fig. 2. The tannin cells occur only on the adaxial side and not on both sides as reported by Jain. Towards the narrower margin the mesophyll of the leaf-base becomes compact and a single row of fibrovascular bundles remain, the bundles themselves being small (Text-Figs. 9 and 10).

The innermost leaf is in six coils with the ends slightly tucked in. The leaf is uniform in breadth and contains a single series of fibrous bundles. Fibrous bundles line both the upper as well as the lower epidermis. Text-Figure 11 shows a diagrammatic view of the transverse section of the outer coil with the fibrous bundles on both sides. The fibrous bundles of the abaxial side are smaller while those of the adaxial side are bigger. The fibrovascular bundles show more adaxial sclerenchyma than abaxial (Text-Figs. 11 and 12). The xylem is reduced to only one or two xylem elements (xy) and generally two or three thick-walled commissural connectives. The phloem is not well preserved. A parenchymatous sheath surrounds the fibrovascular bundle. In the innermost coil (Text-Fig. 13) the fibrous bundles have not yet appeared and the fibrovascular bundles are not only elongated extending from epidermis to epidermis but also are closely packed (Plate XVII, Photo 6). Here too the bundles (Text-Fig. 14) show greater ventral sclerenchyma, just a few xylem elements, thick-walled commissural connectives and badly preserved phloem.

The prepared slides show a number of transversely cut pieces of the leaf where the midrib and the lamina are visible (Text-Figs. 15, 16 and 17). But unfortunately the preservation in the laminar part is not clear probably because of the easy destruction of the soft-walled tissues of the leaf. Yet one can recognise that the mesophyll was differentiated into the palisade and the
spongy parenchyma (Text-Fig. 17). The palisade tissue can be made out with a little difficulty being sometimes closely and sometimes loosely packed (Text-Fig. 16). Its arrangement suggests a certain amount of possible disorder before fossilization. The vascular bundles can just be recognised but the tissues are crushed very much to show their natural disposition. Text-Figure 17 represents a transverse section of the marginal part of the leaf where the palisade seems to extend almost from the upper epidermis to the lower epidermis and also the crushed vascular bundles. The midrib however is slightly better preserved (Text-Fig. 18). It shows almost the same characters as are seen in Text-Figs. 1 and 2. The fibrous and fibrovascular bundles occur scattered and in the latter in some places the dorsal sclerenchyma dominates.

Bits of epidermis obtained from the outermost and innermost coils of the inner leaf show that the stomata occur more or less in rows between upper epidermal cells as in Text-Fig. 19 (Plate XVII, Photo 7). A closer study of the stoma reveals that there are as in *Musa* (Skutch, 1927) two narrow guard cells surrounded by four subsidiary cells, two polar and two lateral (Plate XVII, Photo 8) (Text-Fig. 20). The polar subsidiary cells have one or two more cells placed immediately behind them suggesting a possible derivation by division from a common cell. The stomata as in *Musa* are superficial.

**DISCUSSION**

The specimen described in this paper can, in view of its false stem, only be referred to the Scitamineae and in the light of its erect pseudostem to the Zingiberaceae and Musaceae in particular. In the Zingiberaceae the arc of main bundles in the leaf-sheath is abaxial in position (Tomlinson, 1955) while in the Musaceae it is adaxial. Judged by this important anatomical criterion, our specimen could be placed only in the Musaceae. In the Musaceae there are two genera *Musa* and *Ensete* formerly merged together, but recently separated from each other (Cheesman, 1947 and Lane, 1955). Lane has pointed out the following three important distinguishing characters of *Ensete*: a monocarpic habit, granulose papillose pollen grains (not smooth), T-shaped embryo (not straight). It is of course impossible to read any of these characters in our specimen. The comparison of our specimen to any of these two genera must therefore be purely a matter of conjecture particularly in view of the fact that both the genera are reported from India. Faced with the same difficulty Jain (1960) referred his specimen of a false stem to the Musaceae and placed it under a non-committal name *Musocaulon*. We prefer to refer our specimen also to the same genus and confirm the
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reference of this genus, to the Musaceae on the basis of the following characters observed by us.

A few bits of the epidermis showing the stomata and epidermal cells have been found. Each stoma has two polar subsidiary cells and two lateral subsidiary cells exactly as in the genus Musa (Skutch, 1927). Stomatal pits as in Musa (Tomlinson, 1959) are also found in our specimen although the stomata are not confined to them. The anatomical characters include those of the leaf-sheath and the midrib. In the genus Musa (Tomlinson, 1959) there is a single arc of air canals separated by parenchymatous partitions in the leaf as well as the midrib. This feature is found in our specimen. The main vascular bundles are nearer the adaxial side in Musa a feature also seen in our specimen. Although closely resembling Musa in the above points our specimen shows some variations. Fibrous bundles are distributed both towards the abaxial as well as adaxial side in our specimen. On the abaxial side of the midrib there is a layer of thick-walled cells separated into groups by parenchymatous partitions. This tissue is comparable in a way with a similar tissue figured by Skutch (1927) on the lower side of the midrib in Musa sapientum. But the difference consists in there being no parenchymatous partition in M. sapientum and the absence of radial pits in this tissue in our specimen. Unlike Musa our specimen shows that the air canals are not so big and that the ground tissue is more prominent on the adaxial side of the midrib and the fibrous and fibrovascular bundles in this region are far too many. The preservation in our fossil does not permit our locating the laticifers which are such a distinguishing feature of Musa. It is quite likely that the above variations may be purely of the nature of varietal differences.

In the foregoing comparisons only Musa has been considered because there is enough literature regarding this genus (Solereder and Meyer, 1930; Skutch, 1927; Tomlinson, 1959). We are not in a position to compare our specimen with Ensete as no literature on its anatomy was available although Baker and Simmonds (1953) have given a good account of its systematics. Indeed there does not seem to be much information on the subject. The possibility of a comparison of our specimen with the South American Ensete also should not be overlooked because there are other links with the Deccan intertrappean flora and the living South American flora in Rodeites dakshinai (Sahni, 1943) and Cyclanthodendron sahnii (Sahni and Surange, 1953).

Jain has also described a fossil Musaceous pseudostem collected from the same Deccan intertrappean series. His specimen is only slightly bigger than ours and consists of “a few open concentric leaf-sheaths”. Our speci-
men shows two sheathing leaf bases with their midribs preserved and one, the innermost leaf and of course the youngest, in a region where the midrib has not yet developed. The midrib is 1.6 cm. wide in the middle and narrows towards the margin. There are a number of anatomical similarities between our specimen and his. The arrangement of the vascular bundles, the nature of the ground tissue, the structure of the fibrous and fibrovascular bundles are similar in both the specimens. But there are some differences also. Jain's specimen is characterised by the absence of air canals and intercellular spaces, but our specimen shows air canals in an arc-like manner divided at intervals by septa of thin parenchymatous cells. This is a characteristic feature in *Musa* and *Ensete*. Jain's specimen contains fibrous bundles only on the abaxial side. They are present in both abaxial as well as adaxial surfaces in our specimen. According to Jain, tannin cells are found in both the surfaces but they occur only on the adaxial side in our specimen.

Jain has given the anatomical description of leaf-sheaths only, probably his specimen did not show the midrib portion. But in our specimen the midrib portion is very well preserved. The structures in the midrib portion are thick-walled epidermis, then a layer of fibrous tissue, separated by parenchymatous cells, air canals divided by septa, fibrovascular and fibrous bundles. Jain has not mentioned about the stomata a point in which our specimen has thrown some light.

Our specimen which can evidently be referred only to *M. indicum* adds a few more anatomical details to our knowledge of this petrified pseudostem. The facts collected by Jain and also noticed by us confirm its Musaceous affinity.

It is relevant to point out here that some possibly Musaceous fruits *Musa cardiosperma* (Jain, 1960) and a Musaceous petiole (Mahabale, MS) have been described from the same locality. But we are not in a position to make any comparisons as the latter paper has not yet appeared in print. In view of our findings we would like to slightly emend Jain's generic and specific diagnosis as follows:—

**GENERIC DIAGNOSIS**

*Musocaulon* Jain

Pseudostem of open concentric leaf-sheaths, lamina sheaths thicker in the middle, narrowing towards the margins air canals present, ground tissue parenchymatous, tannin cells present on the adaxial side, vascular and fibrous bundles numerous, arranged in an ill-defined arc, the arc of main vascular
bundles close to the adaxial surface and the arcs of fibrous bundles close to
the abaxial side or on both the abaxial and adaxial side. Vascular bundle
dumbbell-shaped or oval-shaped, typically with a conspicuous solitary meta-
vascular conducting element in the centre, some thick-walled elements between
the latter and the phloem representing the “commissural connectives”,
a fibrous sheath on either pole (xy and ph) and parenchymatous cells complet-
ing it laterally. Midrib with thick-walled epidermis, layer of groups of
sclerenchymatous cells separated by parenchymatous partitions air canals
present in the midrib, fibrous and fibrovascular bundles distributed abundantly
without any special order. Tannin cells mostly on the adaxial side. Stomata
on both surfaces of the leaf lamina arranged with the long axis of the stoma
parallel to the length of the leaf-sheath. Stoma with two lateral and two
polar subsidiary cells.

**Specific Diagnosis**

*M. indicum* Jain

Groups of thick-walled cells separated by parenchymatous partitions. Cells of the ground tissue more or less circular towards the abaxial and middle region and those close to the adaxial side more or less tangentially flattened as seen in cross-section. Tannin cells on the adaxial side mostly angular in cross-section, either singly or in groups. Conducting elements made up of spirally and reticulately thickened elements. Mesophyll differentiated into palisade and spongy. Stomata more or less in rows parallel to the length of the leaf; each stoma is surrounded by two polar and two lateral subsidiary cells.

Locality—Mohgaon Kalan.
Age—Eocene.
Type specimen—M 132. Kept in the Department of Botany, Lucknow University.

**Summary**

A petrified pseudostem from the Deccan intertrappean beds, belonging to the family Musaceae is described in this paper and referred to Jain’s *Musocaulon indicum*. Some of Jain’s observations are confirmed and new facts not recorded by him are figured and described. The anatomy of the midrib and epidermis with stomata has been studied. These facts confirm the Musaceous affinity of the specimen and draw attention to features of resemblance between the living genus *Musa* and the petrified specimen.
REFERENCES


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EXPLANATION TO TEXT-FIGURES

TEXT-FIGS. 1-7

Fig. 1. Transverse section of the entire stem, × 46. as air spaces; ol. outer leaf base; sl, second leaf base, il, inner leaf. Fig. 2. A portion of the midrib showing the detailed structure, × 20. as., air space; fbt., fibrous tissue; fb, fibrous bundles; fvb, fibrovascular bundles; gt, ground tissue; s, septa; pb parenchymatous band. Fig. 3. Middle portion of the midrib showing scattered fibro-vascular (fvb) and fibrous bundles (fb), × 20. Fig. 4. Adaxial portion of the midrib showing the ground tissue and tannin cells, × 20. tc, tannin cells; gt, ground tissue. Fig. 5. Transverse section of the leaf sheath showing different areas of fibrovascular (fvb) and fibrous bundles (fb), × 40. Fig. 6. A portion of the leaf sheath enlarged showing all the structural details, × 78. cc, commissural connectives; dsc, dorsal sclerenchyma; fb, fibrous bundles; pl, phloem (crushed); st, stegmata; vsc, ventral sclerenchyma; xy, xylem element. Fig. 7. A portion of the leaf sheath showing branched fibrovascular bundles, × 40. fb, fibrous and fvb, fibrovascular bundles.
PHOTOS 2-8
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**TEXT-FIGS. 8-20**

Fig. 8. A lobed bundle showing lateral abstriction of bundle, × 40. Figs. 9 and 10. Marginal part of the sheath with a single row of fibrovascular bundles, × 100 and × 40. Fig. 11. Diagrammatic representation of the fibrovascular and fibrous bundles in the outer coil of the inner leaf, × 40. Fig. 12. One fibrovascular bundle of the outer coil showing all the details, × 118. *dsc*, dorsal sclerenchyma; *vsc*, ventral sclerenchyma; *xy*, xylem element. Fig. 13. Diagrammatic representation of the fibrovascular bundles in the inner coil of the inner leaf, × 40. Fig. 14. One fibrovascular bundle of the inner coil with full details, × 118. *ph*, phloem; *sh*, parenchyma sheath; Fig. 15. A transverse section of the leaf with midrib and lamina, × 14. Fig. 16 and 17. Transverse sections of the laminar part. Only palisade cells are prominent, × 40. Fig. 18. A cross-section of a portion of the midrib, × 14. Fig. 19. Distribution of the stomata in the epidermis, × 132. Fig. 20. The detailed structure of a stoma, *ac*, subsidiary and *gc* guard cells, × 264.

**EXPLANATION OF PLATES XVI-XVII**

**PLATE XVI**

*PHOTO 1.* The cross section of the entire pseudostem. Near the arrows can be seen young leaves with lamina attached to midribs. × 5.

**PLATE XVII**

*PHOTO 2.* Cross-section of a part of the leaf sheath. Note the fibrous bundles (*f*) on both the sides, × 41.

*PHOTO 3.* One fibrovascular bundle of the above sheath enlarged, × 215.

*PHOTO 4.* Cross-section of a part of leaf base showing branched bundles. Note the abstriction of bundles laterally and abaxially in the bundles numbered *a* and *b* respectively, × 39.

*PHOTO 5.* Cross-section of a part of the inner coil of the inner leaf enlarged to show the vascular bundles, × 279. (*cc*, commisural connectives, *dsc*, dorsal sclerenchyma; *vsc*, ventral sclerenchyma; *xy*, xylem element.

*PHOTO 6.* Cross-section of a part of the lamina showing palisade cells (*p*) × 157.7.

*PHOTO 7.* The distribution of the stomata on the epidermis, × 180.6.

*PHOTO 8.* A single stoma from the leaf enlarged to show the pore (*po*) and the subsidiary cells (*se*). The outlines of the guard cells can also be made out at the poles of the stoma, × 900.