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ON THE ANATOMY OF DWARF SHOOTS OF *PENTOXYLON SAHNII* SRIVASTAVA COLLECTED FROM AMARJOLA IN THE RAJMAHAL HILLS, INDIA

Anatomia krótkopędów *Pentoxylon sahnii* Srivastava z Amarjola w Rajmahal Hills, Indie

ABSTRACT

Anatomy is described of petrified dwarf shoots of *Pentoxylon sahnii* collected from the Jurassic locality of Amarjola in the Rajmahal Hills, India. Anatomy of the long shoots having leaf bases was also studied and it was found that these two types of branches are not only different in their external characters but also in internal structure. In long shoots cortical bundles (leaf traces) are accompanied by secondary xylem and they originate from the centrifugal portion of the main bundles, while in the dwarf shoots leaf traces originate from the primary xylem and do not have the pycnoxylic secondary wood. Similarly, there are differences in the distribution of sclerotic cells in the ground tissues of these branches. The present paper also discusses relationships of *Pentoxylon sahnii* in the light of recent researches.

INTRODUCTION

Srivastava (1946) described the occurrence of branches of dimorphic nature in the stem of *Pentoxylon sahnii*. His observation was later on confirmed by Sahni (1948) and Mittre (1953, 1957). Their findings were based on the study of embedded fossil materials in the silicified cherts collected from the fossiliferous locality of Nipania in the Rajmahal Hills. The present study is based on isolated petrified dwarf shoots found in the characteristic sandy rocks of Amarjola. Earlier authors also studied the anatomy of the dwarf shoots and showed the presence of five curved primary xylem plates facing their concavities on the outer

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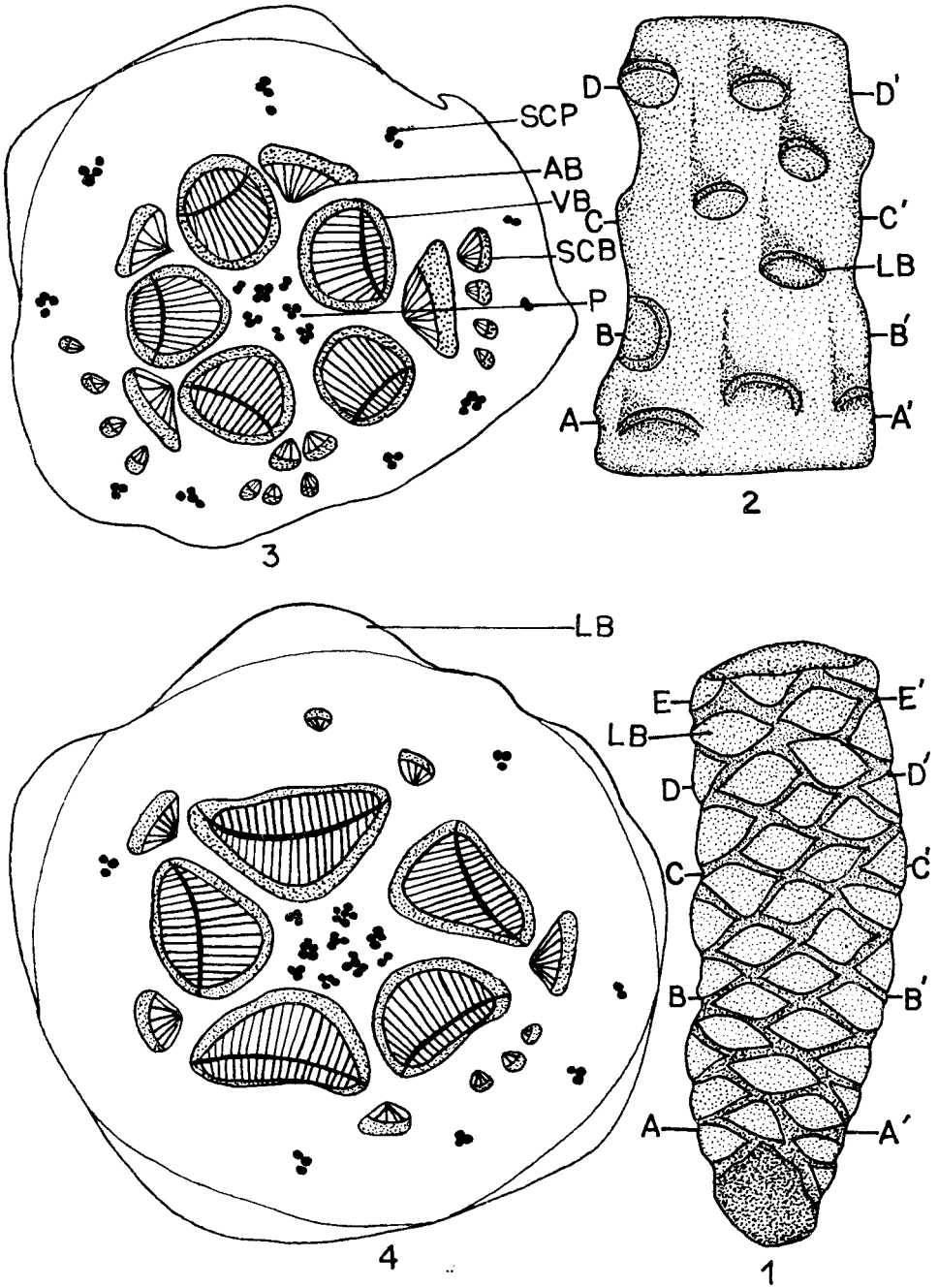


Text-figs. 1—4. *Pentoxylon sahnii* Srivastava

Fig. 1. Dwarf shoot showing external morphology and different levels of sectioning (A—A' to E—E'), × 4

sides surrounding a broad pith. Mittre (1957) described the presence of protoxylem points at the endarch positions in these xylem plates. Secondary xylem of both centripetal as well as centrifugal sides was absent in their specimens. They described the formation of leaf traces from the sides of the xylem plates of the dwarf shoots and a number of such traces are supplied to a leaf base. In the present paper, in addition of giving a detailed account of the internal structure of the dwarf shoots of *Pentoxylon sahnii*, anatomy of the long shoots having leaf bases is also described and compared with the former. On the basis of the present study relationships of *Pentoxylon sahnii* with allied fossil woods have been reconsidered.

DESCRIPTION

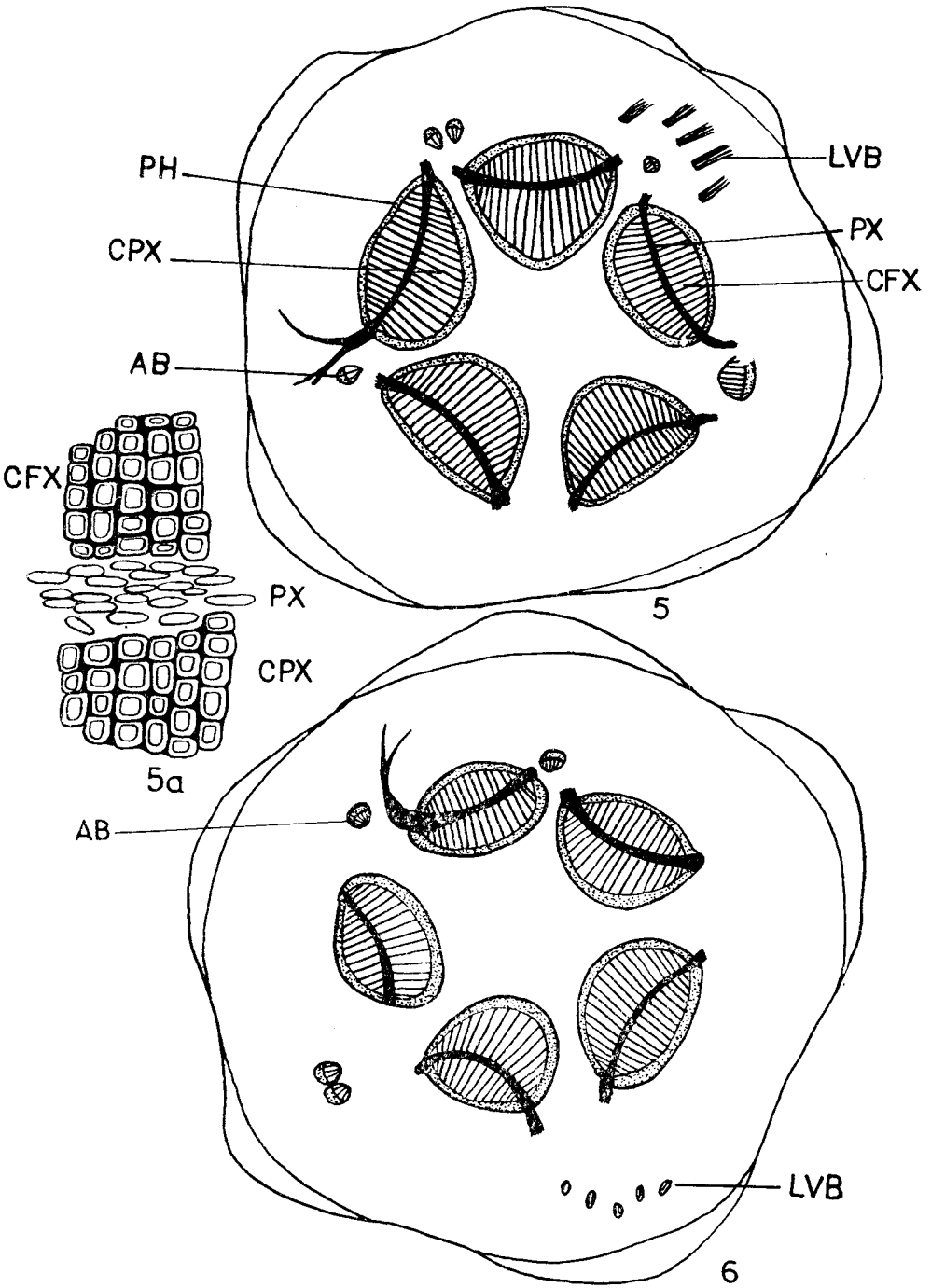
Dwarf shoot. There are a number of specimens of the dwarf shoots of *Pentoxylon sahnii* in author's collection, of which specimen No. B. PD. 1/Raj. A (Plate, fig. 1, Text-fig. 1) is the best preserved. It is a cylindrical, 2·5 cm long, petrified portion of the shoot with a diameter of 6—8 mm. Its outer surface is covered with closely placed and spirally arranged, rhomboid leaf bases. Each leaf base is 3·5×1·2 mm in size. A series of transverse sections A—A' to E—E' (Text-fig. 1) have been cut to study the changes taking place in the anatomy from base to the apex of the shoot.

A—A' (Text-fig. 3). This is a transverse section through the basal part of the shoot. It shows anatomy more or less similar to that found in the old stem of *Pentoxylon sahnii* (Sharma 1969, 1972). Pith and cortex are wide, parenchymatous, and are provided with a number of patches of sclerotic cells. Besides the five concentric bundles forming the main stele of the shoot, there are also five large and endarch bundles alternating with the main bundles and a number of smaller cortical bundles of different sizes in the inner portion of the cortex (Plate, fig. 6, Text-fig. 3). The main bundles are more or less circular, 600×800 μ in size and each is provided with its own secondary xylem without disturbing others. The secondary xylem is rather more on the centripetal than the

Fig. 2. Long shoot showing sparsely placed elliptical leaf bases on its outer surface and different levels of sectioning, × 4

Fig. 3. Dwarf shoot at level A—A', showing presence of sclerotic nests in the ground tissues and numerous cortical bundles in addition to the main bundles of the stele, × 24

Fig. 4. Dwarf shoot at level B—B' showing reduction in number and size of cortical bundles in comparison to Fig. 3, × 24. (LB — leaf base, SCP — sclerotic nest, AB — alternating cortical bundle, VB — main vascular bundle, SCB — smaller cortical bundles, P — pith; all drawings are Camera lucida sketches)



Text-figs. 5—6. *Pentoxylon sahnii* Srivastava

Figs. 5 and 6. Dwarf shoot at levels C—C' and D—D' respectively, showing absence of sclerotic nests in the ground tissues, reduction in cortical bundles and origin of leaf traces from the primary xylem of the main bundles, × 24

centrifugal side. The secondary xylem is pycnoxylic made up of rectangular tracheids arranged in rows. In between the secondary xylem of either side is the primary xylem which is two to three layers thick. Protoxylem elements are undifferentiated. Outside the secondary xylem there are 4—5 layers of secondary phloem both on the centripetal as well as centrifugal sides. Medullary rays present in between the main bundles are parenchymatous and 5—6 cells wide.

Leaf bases are seen outside the cortex, but cellular structures are not clear in any of these. A layer of periderm is also seen in the outer portion of cortex and which is 3—4 cells thick.

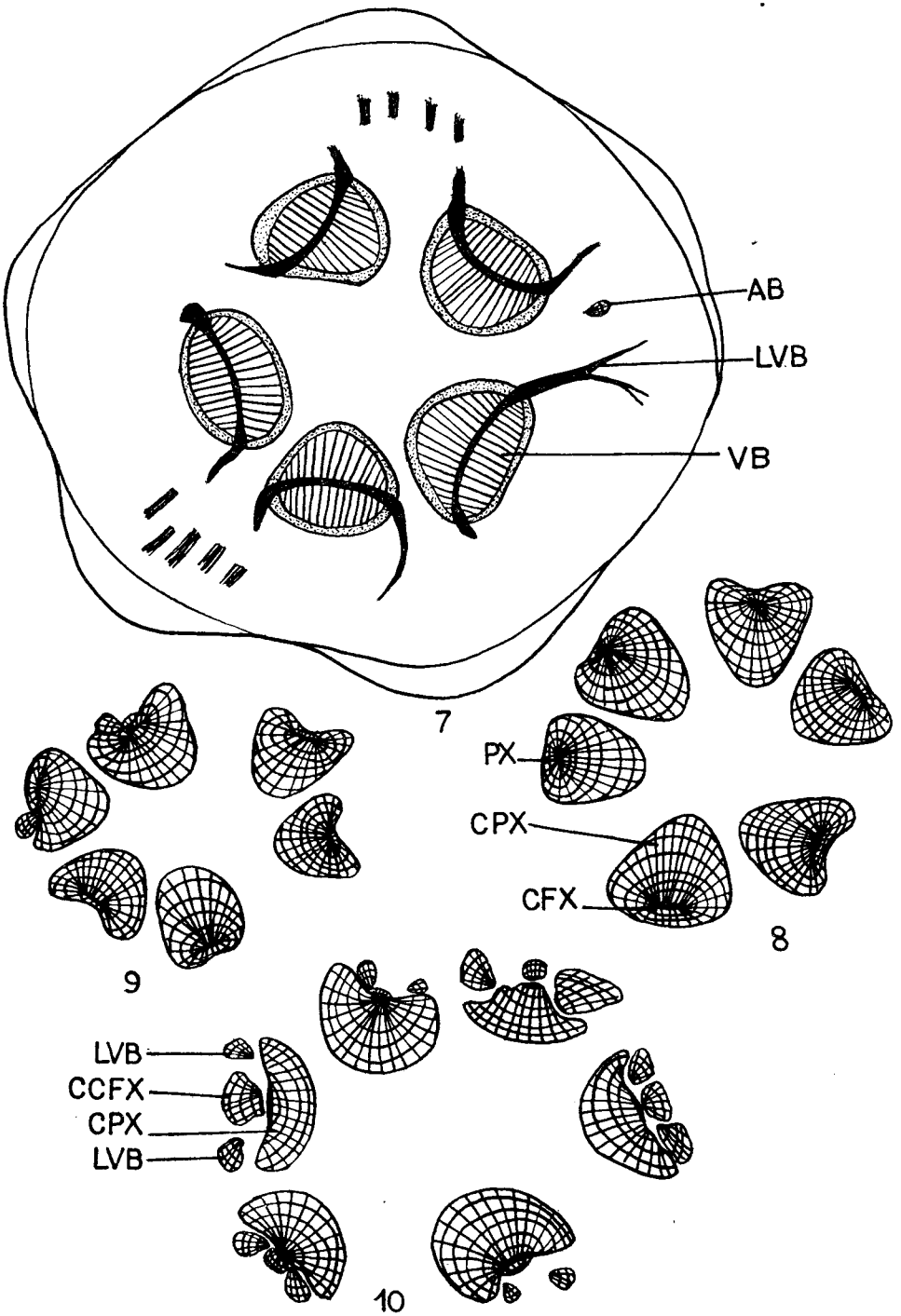
B—B' (Text-fig. 4). This slide shows more or less the same anatomy as seen in the previous section, except that the size of cortical bundles has reduced and the number of patches of sclerotic nests in the cortex is smaller. Pith is still provided with a number of irregularly placed sclerotic nests (Plate, fig. 4).

C—C' (Text-fig. 5). This transverse section is almost through the middle part of the specimen of the dwarf shoot. Five concentric bundles form the major part of the vascular system of the shoot. The size of the alternating endarch bundles is further reduced and some of these are divided into two (Plate, fig. 8). Smaller sized cortical bundles which were present in the basal part of the shoot are not seen at this level. Leaf traces running radially are seen and a number of these are supplied to a leaf base. (Plate, fig. 7, Text-fig. 5). Sclerotic nests are absent in the pith as well in the cortex (Plate, fig. 3). Each vascular bundle of the main stele consisted of a narrow layer of primary xylem which is made up of laterally extending rectangular cells and well developed secondary xylem on its either side. The centripetal xylem is comparatively more developed than that of the centrifugal side. Secondary xylem is pycnoxylic and is made up of squarish cells (Text-fig. 5a). The primary xylem extends out on either side beyond the secondary xylem and produces leaf traces which are devoid of secondary xylem.

D—D' (Text-fig. 6). The transverse section at this level of the shoot shows the same anatomy as seen in the previous slide. Cortical bundles are still smaller in size and leaf traces are seen arising from the sides of the primary xylem of the main bundles.

E—E' (Text-fig. 7). This section shows the anatomy of the upper part of the specimen. „Alternating cortical bundles" are either absent (Plate, fig. 7) or represented as rudimentary bundles (Text-fig. 7). Sclerotic cells are not seen in the ground tissues at this level of the shoot. Leaf bases

Fig. 5a. Dwarf shoot at level C—C', a portion of main bundle showing compactly arranged, squarish cells of secondary xylem on either side of primary xylem, × 120. (LVB — leaf-trace bundle, PX — primary xylem, CFX — centrifugal xylem, PH — secondary phloem, CPX — centripetal xylem, AB — alternating cortical bundle. All drawings are Camera lucida sketches)



Text-figs. 7—10. *Pentoxylon sahnii*. Srivastava

Fig. 7. Dwarf shoot at level E—E', showing absence of sclerotic nests and cortical bundles in the upper part of the shoot. Leaf traces originate from the primary xylem, × 24

are 3·5—4×1·5—2 mm in size and each is provided with a well developed hypodermis, both on the adaxial as well as abaxial sides. Ground tissue of leaf base is parenchymatous having 5—7 bundles. Unfortunately, structure of bundles is not clearly visible.

L o n g s h o o t. Long shoots are of different diameters varying from 5—9 mm. Their outer surface is provided with sparsely placed and spirally arranged, more or less elliptical leaf bases (Plate, fig. 2, Text-fig. 2). Leaf bases are 3×5 mm in size and appear as depressed areas unlike those found in the dwarf shoots, which are seen as raised rhomboid structures. A series of transverse sections have been cut from specimen No. B. Pl 10/Raj. A. (Plate, fig. 2, Text-fig. 2), to study the changes taking place in the anatomy at the different levels in the shoot.

A—A' (Text-fig. 8). This transverse section shows the anatomy of the basal part of the shoot. There are six, sharply endocentric bundles forming the main stele of the shoot. Vascular bundles are of different sizes ranging from 500×600 μ to 550×700 μ. All are provided with pycnoxylic secondary xylem both on the centripetal as well as centrifugal sides. The former is more developed than the latter. The secondary xylem is provided with distinct growth rings. Primary xylem is seen in the form of a crushed tissue in between the secondary xylems of the two sides. Pith is hexagonal, 1·5×1·8 mm in size, parenchymatous, and it is provided with a number of patches of sclerotic cells. The cortex is 1·1—1·3 mm wide, parenchymatous, and it is also provided with sclerotic patches similar to those found in the pith. In the peripheral portion of cortex there is a thick layer of periderm. In the cortex there are also a number of endarch and collateral cortical bundles of different shapes and sizes having secondary xylem. Some of these bundles alternate with the bundles of the main stele.

B—B' (Text fig. 9). There is hardly any change in the general anatomy at this level of the shoot as compared with the one described above. The number of sclerotic nests, however, is smaller both in the pith and in the cortex. In the bundles of the main stele, sides of centrifugal xylem have protruded out and are in the process of detachment from the main bundles.

Fig. 8. Long shoot at level A—A' (cf. Text-fig. 2), showing six, sharply endocentric bundles of the main stele, × 24

Fig. 9. Long shoot at the level B—B', showing extansions of the sides of centrifugal xylems of the main bundles, × 24

Fig. 10. Long shoot at level D—D', showing detachment and divisions of centrifugal xylems of the main bundles forming endarch cortical bundles with secondary xylem, × 24. (AB — alternating cortical bundle; LVB — leaf trace bundle; VB — main vascular bundle; PX — primary xylem; CCFX — central portion of centrifugal xylem; CPX — centripetal xylem; CFX — centrifugal xylem; all drawings are Camera lucida sketches)

C—C'. Transverse section at this level of the shoot shows more or less the same anatomy as given in the earlier slide, except that the sides of centrifugal xylems of the main bundles have become almost detached. Sclerotic nests are seen in the ground tissues of this section.

D—D' (Text-fig. 10). This section shows the anatomy of the upper part of the shoot. In all the bundles of the main stele the secondary xylem of the centripetal side only is left, while that of the centrifugal side has become detached and its parts, lateral and central, are seen running away from the parent bundle forming the collateral and endarch bundles of the cortex. These newly produced cortical bundles are provided with secondary xylem. They become smaller in size and lose their secondary xylem on their way through the cortex and a number of such bundles are supplied to a leaf base. The anatomy of the leaf base is not clear in any of the slides prepared for the present paper.

COMPARISON

Dwarf shoots and long shoots of *Pentoxylon sahnii* are different, not only in the external morphological features but also in anatomy. In the former, leaf bases are close, spiral and rhomboidal in shape, while in the latter they are sparsely placed and elliptical in shape. In the dwarf shoots secondary xylem of both the centripetal as well as centrifugal sides is well developed but it is undifferentiated into growth rings. Primary xylem is a laterally extending, 2—3 cell thick layer, which cut off leaf traces on either side. Leaf traces are devoid of secondary xylem. On the other hand in the long shoots, vascular bundles are sharply endocentric, secondary xylem is differentiated into growth rings, and cortical bundles are produced as a result of detachment of the centrifugal xylem from the main bundles. These newly produced bundles are endarch and provided with secondary xylem. Primary xylem is seen in the form of a small path of a crushed tissue in between the compact secondary xylems of centrifugal and centripetal sides.

The anatomy of the dwarf shoot described in the present paper coincides in certain respects with the descriptions given by Srivastava (1946), Sahni (1948) and Mittre (1957), as in the case of the above descriptions there are five bundles forming the main stele of the shoot. Leaf traces are produced from the sides of the primary xylem plates and a number of such traces are supplied to a leaf base. But in the present specimen, sclerotic nests are not found throughout the entire length of the shoot but are restricted only to the basal part of the specimen. In the earlier descriptions, no mention was made of the presence of secondary xylem in the main bundles of the shoot, which is clearly visible in the present specimen.

DISCUSSION

The majority of earlier authors like Sahni (1948), Delevoryas (1955), Stewart and Delevoryas (1956) and Mittre (1957), compared the anatomy of *Pentoxylon sahnii* with that of the pteridospermous stem genus *Medullosa*, while Archangelsky and Brett (1961) compared its anatomy with the Triassic wood *Rhexoxylon* Bancroft. The present study on the dwarf shoot of *Pentoxylon sahnii* favours the latter view. The manner of origin of leaf traces in the dwarf shoots closely resembles that described in *Rhexoxylon piatnitzkyi* by Archangelsky and Brett (1961). As in the latter case leaf traces originate from the sides of the primary xylem of the main bundles of the stele. Leaf traces divide in the cortex and a number of such traces are supplied to a leaf base. In *R. piatnitzkyi* leaf traces are devoid of secondary xylem like the present specimen of the dwarf shoot of *Pentoxylon sahnii*.

From the present study it may be concluded that in *Pentoxylon sahnii* there were two ways of leaf trace origin. In the main stem and long shoots, leaf traces originated as a result of detachment of the centrifugal part of the main bundles of the stele and these were provided with secondary xylem in the beginning. In this respect *Pentoxylon* resembles *Guptioxylon* (Sharma 1969). In the dwarf shoots leaf traces originated from the sides of primary xylem of the main bundles and they were devoid of secondary xylem, resembling *Rhexoxylon piatnitzkyi*. A leaf trace accompanied by secondary xylem is considered as primitive, while its absence in the trace indicates an advanced feature (Stewart and Delevoryas 1956). Thus the stem of *Pentoxylon sahnii* has a mixture of advanced as well as primitive features.

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STRESZCZENIE

ANATOMIA KRÓTKOPĘDÓW *PENTOXYLON SAHNII* SRIVASTAVA Z AMARJOLA W RAJMAHAL HILLS, INDIE

W pracy omówiono anatomię skamieniałych pędów *Pentoxylon sahnii* pochodzących z jury w miejscowości Amarjola (Rajmahal Hills, Indie). Stwierdzono, że w pędach długich liściośląd y biorą początek z odśrodkowej części wiązek głównych i mają ksylem wtórny, podczas gdy w krótkopędach wychodzą od ksylemu pierwotnego i ksylemu wtórnego nie mają. Pierwszy typ liściośladów przypomina *Guptioxylon amarjolense*, drugi — *Rhexoxylon piatnitzkyi* z triasu Argentyny. Obecność ksylemu wtórnego w pędach długich *Pentoxylon sahnii* uważa autor za cechę pierwotną, brak zaś ksylemu wtórnego w krótkopędach — za cechę ewolucyjnie zaawansowaną.

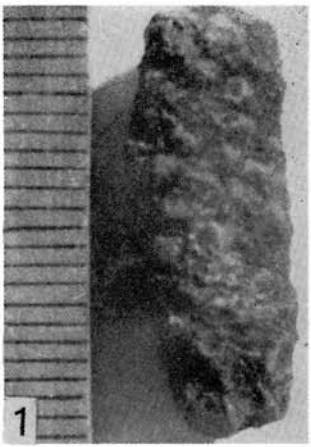
Autor znalazł też różnice w występowaniu komórek sklerenchymatycznych w tkance miękiszowej krótkopędów *Pentoxylon sahnii* w stosunku do dotychczasowych danych w tym względzie.

TABLICA

Plate

Pentoxylon sahnii Srivastava

1. Dwarf shoot, specimen No. B. PD 1/Raj. A. possessing close, spiral and rhomboid leaf bases on its outer surface, × 2
2. Long shoot, specimen No. B. PL 10/Raj. A. showing sparse, spiral and elliptical leaf bases on its outer surface, × 2
3. Dwarf shoot at level C—C' (cf. Text-fig. 1) showing a pentagonal pith without sclerotic nests and surrounding bundles, × 24
4. Dwarf shoot at level B—B' showing a number of irregularly scattered sclerotic nests in the pith and the surrounding unpreserved areas representing main bundles, × 24
5. Dwarf shoot at level D—D' showing absence of sclerotic cells in the ground tissues and circular, poorly preserved bundles of the main stele, × 24
6. Dwarf shoot at level A—A' showing a portion of cortex with collateral cortical bundles and sclerotic nests, × 48
7. Dwarf shoot at level C—C', showing outgoing leaf traces and two poorly represented cortical bundles, × 48
8. Dwarf shoot at the level D—D', showing a cortical bundle divided into two poorly represented bundles, × 48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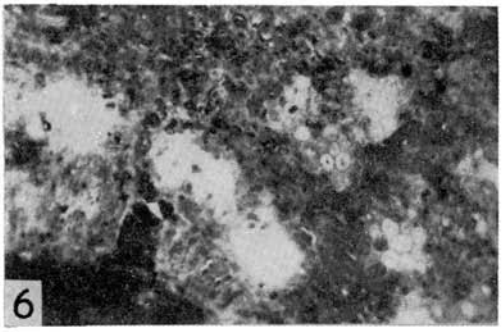
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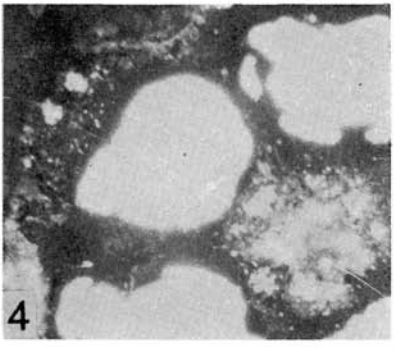
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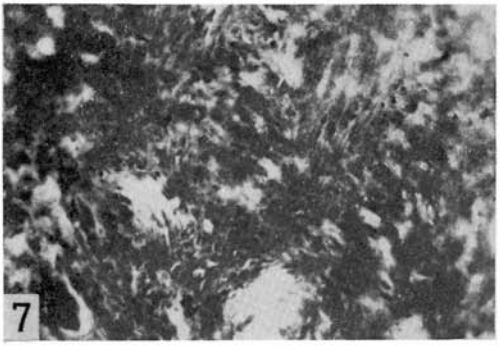
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