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Anatomical variations in Indian Mesozoic pentoxylean stems

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ABSTRACT

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Anatomical variations are described in the pentoxylean stems collected from the Rajmahal Hills, Jharkhand. The fossil stem taxa considered here are *Pentoxylon, Nipanioxylon, Guptioxylon* and *Purioxylon*. In all these, stem surface is more or less smooth except for the dwarf shoots of *Pentoxylon* which have elliptical leaf bases in close spirals. The vasculature is polystelic and the secondary wood is pycnoxylic. Patches of sclerotic cells are seen in the ground tissue. In *Pentoxylon,* there are 5-7 endocentric steles surrounding a pentagonal pith. *Nipanioxylon* has 8 concentric or exocentric steles in a ring outside the pith periderm. *Guptioxylon* has 4-6 main concentric steles, endocentric or little irregular in shape; cortical and pith bundles are of various shapes and sizes. In *Purioxylon*, the pith periderm is surrounded by a ring of manoxylic bundles which are collateral, conjoint and endarch. Cortical bundles are of various sizes and have pycnoxylic wood. Phylogenetic importance of this study is also discussed.

Key-words: Anatomy, pentoxylean stems, Mesozoic, Rajmahal Hills, Jharkhand, India.

INTRODUCTION

Srivastava (1944, 1945) instituted two new pentoxylean stems taxa, i.e. *Pentoxylon sahnii* and *Nipanioxylon guptae,* from the petrified cherts from Nipania, Rajmahal Hills, Jharkhand. Sahni (1948) accepted the establishment of *P. sahnii* but was little hesitant for *N. guptae*. Vishnu-Mittre (1957) believed *N. guptae* a distinct taxon but the material he studied was probably a conifer (Bose et al. 1985). Sharma et al. (2010), on the basis of study of better preserved material and slides, described *N. guptae* as a distinct pentoxylean stem different from *Pentoxylon*. Sharma (1969a) published a paper on *P. sahnii* and suggested the manner of origin of the cortical bundles. Sharma (1969b) instituted *Guptioxylon amarjolense*, a new pentoxylean stem. It has, in addition to the four main steles, medullary and cortical steles (bundles) of various shapes and sizes. Sharma (1972a) described another species of *Guptioxylon*, *G. endocentrica*, from Amarjola which has six endocentric main steles resembling that of *P. sahnii* but it has a number of pith bundles in addition to the cortical ones. Sharma (1972b) described one more pentoxylean stem *Purioxylon jurassica* from Amarjola, Rajmahal Hills. It has a pith periderm, manoxylic collateral, conjoint and endarch bundles while the cortical bundles have pycnoxylic woods. Sharma (1973a) showed 6-7 steles in a thin shoot of *Pentoxylon sahnii*. Sharma (1973b) described the anatomy of two kinds of short shoots collected from Amarjola. Sharma (1974a) published a paper on *Pentoxylon* and reported the presence of a distinct periderm layer surrounding the five steles in *P. sahnii*.

This is not a common feature of *P. sahnii*. Sharma (1974b) described the branching pattern of *P. sahnii*. More than two types of branching pattern were suggested. Sharma (1979) published further observations on the anatomy of short shoots of *P. sahnii* and suggested that the traces to leaves and a branch originate in an identical manner and favoured the polystelic vasculature in *P. sahnii*. Sharma (1980) described that in *P. sahnii* vascular supply to a branch originates from 2-3 steles of the stem and a branch base receives a number of bundles similar to that of a leaf base.

Bose et al. (1985) published a review paper on *Pentoxylon* plant and discussed the anatomy of four types of shoots but without proper diagrams. This happened because neither they collected enough material themselves nor prepared slides and the description was based on old slides present at the Birbal Sahni Institute of Palaeobotany, Lucknow. They also treated *Guptioxylon amarjolense* and *G. endocentrica* as synonym of *P. sahnii* without giving proper justification. Bose et al. (1985) did not make any comment on *Purioxylon jurassica* Sharma 1972b. On the other hand, Sharma and associates collected hundreds of specimens and prepared a large number of slides for the publication purpose. Sharma and Bohra (1980) and Sharma et al. (1987) discussed the phylogeny of the Pentoxyleae and derived the pentoxylean anatomy from medullosan pteridosperms through *Guptioxylon* like an intermediate taxon. Suthar et al. (1988) described the anatomy of a new type of branch system identical to that of the peduncle of *Carnoconites compactus* Srivastava (Sahni 1948, figure 35). Srivastava and Banerji (2000) also published a review paper on *Pentoxylon* plant but they did not discuss much on its vasculature. Sharma (1996, 2001) and Sharma et al. (2010) discussed the vasculature of pentoxylean stems on the basis of study of better preserved specimens and good slides prepared from them.

In the present paper, anatomical variations in the pentoxylean stems, collected from Amarjola, Sonajori and Nipania localities, are described. Phylogenetic interpretations are also given.

MATERIAL AND METHOD

Hard and silicified fossiliferous cherts were collected from Nipania and Sonajori localities. Sections of these cherts were cut with a diamond edge wheel. In the Amarjola locality, fossils are found embedded in ferruginous sandy rock and are fragilc. These were cooked in canada-balsam prior to their sectioning with a wire bandsaw. Slides were prepared by the usual techniques of grinding and polishing methods and mounted in dilute canada balsam.

DESCRIPTION

Pentoxylon sahnii Srivastava 1945

More than one hundred petrified specimens of this taxon were collected by the authors from Amarjola. These range in size from 7 to 50 mm in diameter and 15 to 100 mm in length. Stem surface is smooth to transversely wrinkled. Similarly, a number of short shoots with elliptical leaf bases in close spirals could also be collected from Amarjola (Sharma et al. 2001). These range in size from 6-20 mm in diameter and 25 to 30 mm in length (Text-figure 6). At Nipania and Sonajori, the stems and short shoots are found embedded in silicified cherts and are visible only in thin sections. However, casts of the short shoots are visible in some of the cherts collected from Nipania.

Cross section through a thick shoot shows a typical periderm layer in the outer portion of cortex. Cortex has patches of sclerotic cells. Normally, 5 endocentric steles are present surrounding a pentagonal pith (Text-figures 2, 5). Patches of sclerotic cells are also present in pith. Mucilage canals are absent in the ground tissue. Each stele has a crushed primary xylem and well developed centripetal secondary xylem (Text-figure 1). Secondary xylem of the centrifuged side is either absent or comparatively poorly developed (Text-figures 1, 4-5). Growth rings are present in the secondary xylem. Secondary phloem is nicely preserved in many sections (Text-figure 14) and consists of tangentially arranged sieve cells and the fibers (Sharma & Bohra 1977). A tangential longisection shows 1-8 cells high uniseriate wood rays (Sharma 1969a). Radial longisection shows presence of uniseriate contiguous bordered pits on radial walls of tracheids (Sharma 1969a). Biseriate pits

are rare (Srivastava 1945, pl. 5, figure 42). Pits in cross field 1 or 2, large, circular with a narrow border.

Sharma (1973a, 1974a, b, 1980) observed many variations in the stelar system of the stem of *P. sahnii*. There is no relation between thickness of stem and number of main steles. A thin shoot may have 6-7 steles (Text-figure 3). In some of the sections through the stem an internal periderm (Sharma 1974a, b) surrounding the steles is present (Text-figure 5). The cortical bundles originate as a result of fission of the centrifugal secondary xylem of steles (Text-figure 1). These detached portions either act as leaf traces or traces to a branch. Sometimes, a portion of the centripetal secondary xylem also passes to the base of the branch (Sharma 1974b).

In short shoots, collected from Amarjola (Sharma et al. 2001), 5 or 6, circular steles are present surrounding the pentagonal pith. Centripetal and centrifugal xylems are more or less equally developed. Primary xylem is also preserved but protoxylem position remained unclear, i.e. not mesarch (Text-figures 7-9). Leaf traces, originate from either side of the primary xylem plate (Text-figure 7). The ground tissue has patches of sclerotic cells (Text-figure 8). The second type of short shoots (thin shoots) have distantly placed leaf bases (Text-figure 10) (Sharma 1973b). Centrifugal xylem is poorly developed while ceritripetal one has comparatively much developed xylem with growth rings. Leaf traces originate from centrifugal xylem (Text-figure 11). Srivastava (1945), Sahni (1948) and Vishnu-Mittre (1957) figured cross sections of short shoots from Nipania bearing 5 plates of xylem surrounding a wide pith. We also have similar slides (Text-figure 12).

Bose et al. (1985) described breaking down of the five steles into a number of vascular pieces in the terminal portion of the shoot (Bose et al. 1985, figure 3C). Such a condition has not been observed in any specimen by us. Suthar et al. (1988) described a new type of shoot system (Text-figure 13) in *P. sahnii* which resembles the peduncle of *Carnoconites compactus* (Sahni 1948, figures 42-43). The vascular system has 5-7, narrow curved vascular arms (Text-figure 13) made up of 2-5 cells thick xylem. Endarch leaf (bract) traces originate frequently and in the leaf (bract) base the bundles become diploxylic and are arranged in an arc or row.

Nipanioxylon guptae Srivastava 1945

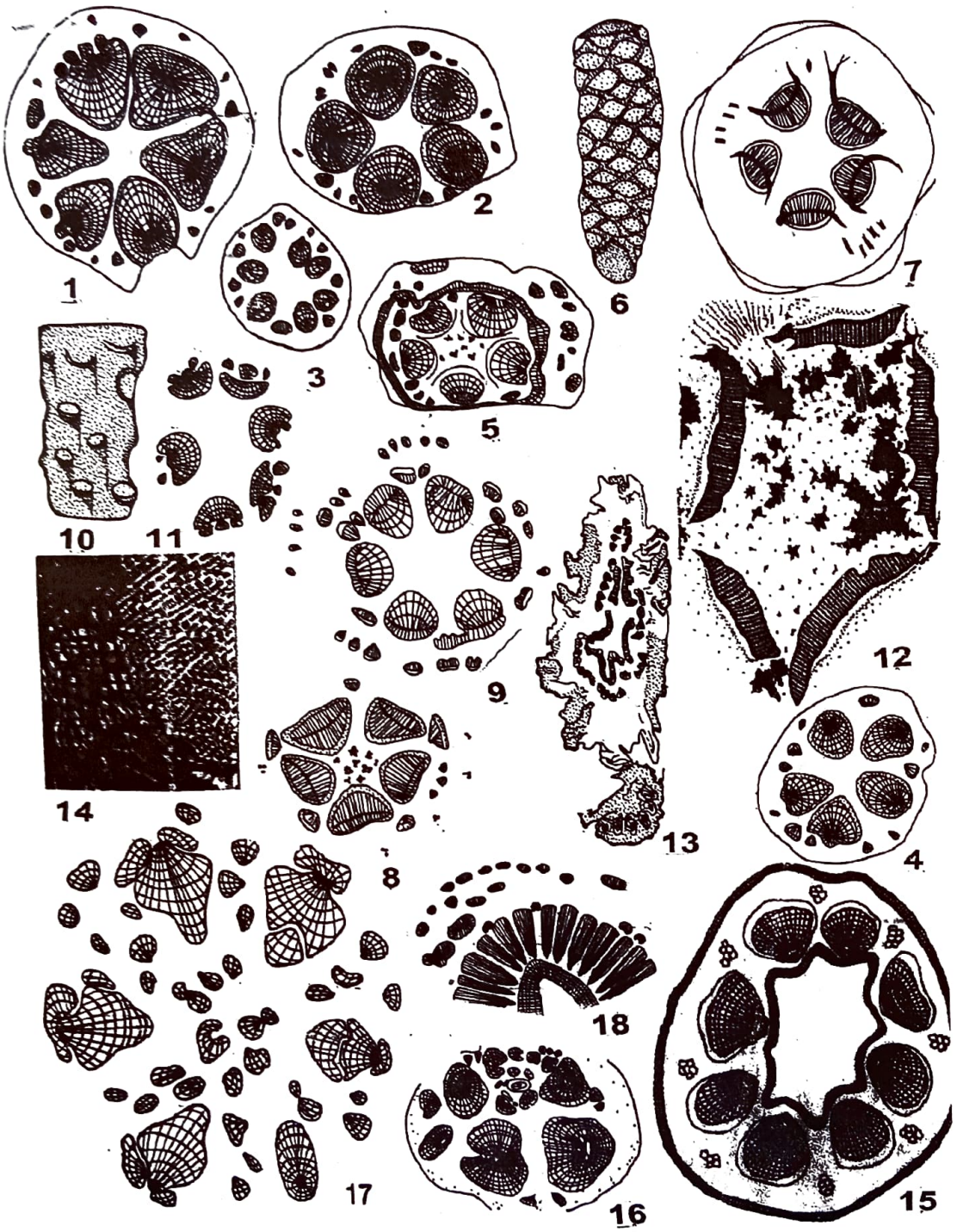
While preparing thin sections through the Nipania cherts, we observed four cross sections through the stem of *N. guptae*. The periphery is bound by a periderm layer. Cortex has patches of sclerotic cells. There are 8 exocentric steles outside the pith periderm (Text-figure 15). Wood is compact with growth rings. Primary xylem is poorly preserved. Centripetal xylem is much less in amount than that of the centrifugal side. In an oblique section, uniseriate contiguous bordered pits could be seen on radial walls of the tracheids. Anatomy suggests distinction of *N. guptae* from *Pentoxylon sahnii*. More investigations are needed on this controversial taxon.

Guptioxylon amarjolense Sharma 1969b

Two petrified specimens were collected from Amarjola and from the type specimen No. BIG/Raj. A. five serial sections were prepared. Stem surface is smooth, 8-19 mm in diameter and approximately 80 mm in length. There are 4 large concentric or little endocentric steles of unequal sizes. Primary xylem is crushed, secondary xylem is compact and differentiated into growth rings. Pith has smaller sized steles (bundles) of various shapes and sizes. Cortex also has many steles of various sizes and shapes and are exarch, mesarch and endarch (Text-figure 16). Sharma (1974a) identified two more variations, i.e. *Guptioxylon* A and *Guptioxylon* B. Further investigations are needed on this taxon.

Guptioxylon endocentrica Sharma 1972a

Stem thick, 50 mm in diameter with six endocentric steles of variable sizes which are arranged in a ring surrounding a large pith (Text-figure 17). Primary xylem is crushed; secondary xylem compact and differentiated into growth rings. Centrifugal xylem is much reduced. Medullary bundles many exarch, endarch or mesarch. Cortical bundles endarch and originate from the centrifugal xylem of the main steles (Text-figure 17). It resembles *P. sahnii* but differs in the presence of medullary bundles. Sclerotic nests are present in the ground tissue.



Text-figures 1-18. 1. *Pentoxylon sahnii* C.S. stem–six endocentric steles, cortical bundles originate from centrifugal xylem x6. 2. Same. More or less concentric steles x6. 3. Same. A thin shoot with 7 endocentric steles x6. 4. Same shoot with 5 steles x 6. 5. Same. An internal periderm surrounds the 5 steles x6. 6. Same. A short shoot with elliptical leaf bases in close spirals x3. 7. Same. C.S. short-shoot with 5 steles each having centripetal and centrifugal secondary xylems, primary xylem gives rise leaf traces from either ends x12. 8. Same. C.S. 5 steles without growth rings. Sclerotic cells present in the ground tissue x12. 9. Same. Short shoot C.S. 5 steles with growth rings and leaf traces x12. 10. Same. Thin shoot with distantly placed leaf bases x3. 11. Same. C.S. thin shoot, 6 steles with poorly developed centrifugal xylem. Centripetal xylem has growth rings x6. 12. Same C.S. short shoot from Nipania. 5 arc shaped stele having only centripetal xylem Patches of sclerotic cells common x24. 13. Same. Short shoot resembling in anatomy to the peduncle of *Carnoconites compactus* x8. 14. Thick stem C.S. with well developed secondary phloem outside secondary xylem of stele x72. 15. *Nipanioxylon guptae*. C.S. stem with two periderm and 8 exocentric steles. Secondary xylem compact with growth rings x12. 16. *Guptioxylon amarjolense* C.S. stem with 4 unequal steles, medullary and cortical bundles many x6. 17. *G. endocentrica* C.S. stem with 6 endocentric steles and many medullary and cortical bundles present x8. 18. *Purioxylon jurassica* C.S. stem with pith periderm, manoxylic vascular ring and cortical bundles of various sizes x8.

Purioxylon jurassica Sharma 1972b

The type specimen No. B VI/Raj A has longitudinal wrinkles and an axillary bud. Four serial sections were prepared through the type specimen. Pith fistular and parenchymatous with a periderm layer. Outside it are present loosely arranged collateral, conjoint and endarch bundles (Text-figure 18). Cortex has many steles (bundles) of various sizes and shapes and all have compact secondary xylem with exarch, mesarch and endarch protoxylem resembling those of *Guptioxylon*. Outer portion of cortex has mucilage canals, a character different from other pentoxylean stems. Sharma (1972b, 1974a) considered the anatomy of *Purioxylon* an intermediate type between *Pentoxylon* and the cycads.

DISCUSSION

A new group 'the Pentoxyleae' of Jurassic gymnosperms was established on the basis of study of petrified plants which showed peculiarities in anatomical characters (Sahni 1948). For example, in *Pentoxylon* five endocentric steles made the vascular system. Wood was compact and differentiated into growth rings, wood rays were small and uniseriate, tracheids had uniseriate contiguous bordered pits on radial walls (Srivastava 1945). Leaf midrib had a row or an arc of 5-8 diploxylic bundles. In a seed cone, ovules were orthotropus and attached directly to the cone axis. Microsporophylls radial with balloon shaped microsporangia (Vishnu-Mittre 1953). Anatomical variations are noticed in pentoxylean stems collected from Amarjola, Nipania and Sonajori localities of the Rajmahal Hills. Sharma et al. (2010) have included four stem genera, i.e. *Pentoxylon*, *Nipanioxylon*, *Guptioxylon* and *Purioxylon* in the Pentoxyleae. Anatomical variations are also noticed in the vegetative and fertile short shoots. The former produce leaves (*Nipaniophyllum*) whereas the latter give rise origin separately to seed bearing cones and the microsporophylls. Bose et al. (1985) though divided the stem and its branches into four types yet the description remained unclear for want of proper diagrams. On the other hand, Sharma (1973a, b, 1974a, b, 1979, 1980, 1996, 2001), Sharma et al. (2010) and Suthar et al. (1988) explained the anatomical variations and their phylogenetic importance with the help of suitable photographs and drawings. Vascular supply to leaf and a branch originate in an identical manner and as such this has been related to those of *Cycadeoidea* (Delevoryas 1968) and *Gnetum* (Maheshwari & Vasil 1961). Srivastava (1945) considered *Nipanioxylon guptae* a distinct taxon different from *Pentoxylon* in number and orientation (exocentric, opposite to endocentric of *Pentoxylon*) of steles and presence of pith periderm. However, the wood is identical in being compact and presence of growth rings. Ground tissue has patches of sclerotic cells. Sahni (1948) though considered the investigation incomplete yet he assigned the material to the Pentoxyleae. Bose et al. (1985) studied some of the old slides of Srivastava present at the Birbal Sahni Institute of Palaeobotany, Lucknow and, on the basis of photographs published in Srivastava (1945), considered *Nipanioxylon* related to conifers. Bose et al. (1985) did not make any mention of Plate 9, figure 91 and its enlargement (Plate 10, figure 95) of Srivastava (1945). These are not collateral bundles of a conifer stem. No conifer stem has pith periderm, exocentric steles and patches of sclerotic cells in the ground tissue. Sharma et al. (2010) described *N. guptae*, a distinct pentoxylean stem and different from *Pentoxylon*. Their observations are based on 4 slides prepared through Nipania cherts. However, further investigations are required on this taxon and related organs.

Guptioxylon endocentrica Sharma (1972a) has stelar system more or less identical to that of *Pentoxylon sahnii*. But the presence of medullary bundles separate it from *P. sahnii*. *G. amarjolense* is quite distinct from *P. sahnii* in the number and morphology of steles. Medullary and cortical bundles are many and of various shapes and sizes. Sharma (1973a, 1974a) derived the vasculature of *G. amarjolense* from a medullosan stem and traced the evolution of *Pentoxylon sahnii* through *G. endocentrica* by disappearance of medullary bundles.

Purioxylon jurassica Sharma (1972b) is peculiar in having characters of cycads and pentoxylean stems. Presence of manoxylic vascular ring and mucilage canals in outer portion of cortex relate *Purioxylon* with cycads

while the compact wood of cortical bundles associates it with the pentoxylean taxa. Further investigations are needed on this taxon.

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