

PHYTON

ANNALES REI BOTANICAE

VOL. 40, FASC. 2

PAG. 209–328

27. 12. 2000

Phyton (Horn, Austria)	Vol. 40	Fasc. 2	209–222	27. 12. 2000
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Nucleated Xylem Fibres in some Indian Herbaceous Species

By

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With 2 Figures

Received October 27, 1999

Accepted November 16, 1999

Key words: Nucleated xylem fibres, parenchyma cells.

Summary

RAJPUT K. S. & RAO K. S. 2000. Nucleated xylem fibres in some Indian herbaceous species. – *Phyton* (Horn, Austria) 40 (2): 209–222, 2 figures. – English with German summary.

The xylem fibres retained their nucleus even after their secondary walls have been laid down, in sixty species of twenty nine genera belonging to twelve families. In both, libriform and fibre tracheids the nucleus was oval to oblong or fusiform shaped. Nonseptate fibres were uninucleate while septate fibres had two to three compartments, accompanied by a nucleus in each compartment. Accumulation of starch in fibre lumina was a common feature in all the species studied. The xylem fibres in *Pupalia lappacea* has also revealed presence of rhomboidal crystals. Xylem fibres were characterised by thick lignified walls with a narrow lumen and tapering

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ends. Cells which were morphologically transitional between the fibres and axial parenchyma were also noticed in some species. Occurrence of nucleus in xylem fibres and its possible significance is discussed.

Zusammenfassung

RAJPUT K. S. & RAO K. S. 2000. Holzfasern mit Kernen in einigen krautigen Arten Indiens. – *Phyton* (Horn, Austria) 40 (2): 209–222, 2 Abbildungen. – Englisch mit deutscher Zusammenfassung.

Die Holzfasern von 60 Arten, die 29 Gattungen und 12 Familien angehörten, behielten ihren Kern sogar nachdem die Sekundärwände angelagert wurden. Sowohl in Holzfasern als auch Fasertracheiden war der Kern oval bis länglich oder spindelförmig geformt. Nicht septierte Fasern waren einkernig, während septierte Fasern zwei- oder dreigeteilt waren, wobei in jedem Teil ein Kern vorhanden war. Die Anreicherung von Stärke im Lumen der Fasern war charakteristisch für alle untersuchten Arten. Die Holzfasern von *Pupalia lappacea* zeigen überdies rhombische Kristalle. Die Holzfasern waren gekennzeichnet durch dicke, verholzte Zellwände und ein enges Lumen und bandförmige Enden. In einigen Arten konnten auch Zellen beobachtet werden, welche morphologisch einen Übergang zwischen den Fasern und dem axialen Parenchym darstellten. Das Auftreten eines Kernes in den Holzfasern und seine mögliche Bedeutung wird diskutiert.

Introduction

Xylem fibres have commonly been accepted as dead cells but in some instances they may retain their living protoplast even after the secondary walls have been laid down (BAILEY 1953). Since BAILEY'S report, living fibres have been reported in shrubs and subshrubs belonging to different families of Angiosperms (BRAUN 1961, FAHN & ARNON 1963, FAHN & LESHEM 1963, PARAMESWARAN & LIESE 1969, CARLQUIST 1988, RAJPUT & RAO 1999a, b) and in some species of *Ephedra* (ESAU 1965).

Although, development of vascular cambium and xylem structure of some of the genera in the present investigation have been studied earlier (MAHESHWARI 1930, JOSHI 1931, 1934, BHARGAVA 1932, PANT & MEHRA 1961), no mention is made about the presence of nuclei in the xylem fibres. Moreover, it has been suggested that nucleated xylem fibres occur frequently in subshrubs, shrubs and climbers (FAHN & LESHEM 1963). In this connection, we were interested to know whether it is also true in case of herbaceous genera. Therefore, present investigation aims to report the occurrence of nucleated xylem fibres in some herbaceous taxa from few Angiospermic families and to confirm whether occurrence of such living fibres is common feature in herbs.

Materials and Methods

Sixty species belonging to twelve families have been examined (Table 1). Samples were collected from the plants growing in M. S. University Campus at Baroda. Six to eight stem pieces from ten plants for each species were collected and fixed

immediately in FAA (BERLYN & MIKSCH 1976). Tangential and radial longitudinal sections of 12–15 µm thick were prepared using sliding and rotary microtome. These sections were stained either with safranin – fast green (JOHANSEN 1940) or with tannic acid-ferric chloride-lacmoid combination (CHEADLE & al. 1953). Sections were also treated with 4 % acetocarmine and I₂KI for nucleus and starch localisation respectively.

Maceration of xylem of each species was also prepared to study general morphology and size of the fibres. One hundred measurements were chosen randomly to obtain mean and standard deviation.

Results

The structure of xylem fibres is studied in sixty species of twenty nine genera from the twelve different families (Table 1). Although, all the species studied in the present investigation are basically herbaceous in nature but their habit varies. They are either diffuse prostrate, climbing or erect and annual or biannual herbs.

The nuclei in the fibres are more or less similar in shape i.e. oval to oblong or elongated to fusiform shape (Figs. 1A-H, 2A-G) but their size varies in all the species (Table 1). Their length including the sharp points is noticed maximal (29 µm) in *Polygonum glabrum* (Fig. 1A) and minimal in (4 µm) *Amaranthus spinosa* (Fig. 1B) but their width does not show much variation (Table 1). In the species possessing septate fibres, each compartment retains a nucleus. Nuclei of the fibres remain similar in shape to those of axial and ray parenchyma cells of the xylem.

The nucleated xylem fibres are characterised by thick lignified walls with a narrow lumen and tapering ends. Structure of xylem fibres varies greatly among all the species, some of the fibres are straight and spindle shaped while others have undulate walls. Occurrence of branched fibres is a common feature in all the species studied. In most of the species they are nonseptate but septate fibres are observed in *Polygonum* and *Muehlenbeckia*. The septate fibres are divided into two to three compartments with thin transverse septa. Pits on walls are simple and confined to radial walls. Their slit like aperture forms a narrow angle with the fibre axis. Fibre tracheids are also found to possess nuclei in *Trianthema monogyna*, *T. triquetra*, *Arua laneta* and *A. sanguianoleata*. The fibre length varies from species to species and found maximum in *Vicoa indica* (782 µm) and minimum in *Mollugo hirta* (362 µm). Their lumen diameter is relatively more in *Solanum nigrum* (25 µm) and less in *Mollugo hirta* (14 µm). Fibre wall thickness does not show significant variation among the species studied (Table 1). Accumulation of starch in the fibre lumina is a common feature in all the species. Its distribution differs from species to species, in some species e.g. *Boerhaavia diffusa*, *B. rependa*, *B. verticillata*, *Mollugo hirta*, *M. pentaphylla*, *Trianthema monogyna*, *T. triquetra* etc. the starch grains fill the fibre lumina to such extent that they completely mask the

nucleus (Fig. 2E, F), while in some starch remains restricted around the nucleus. Rhomboidal crystals are also observed in the fibre lumina of *Pupalia lappacea* (Fig. 2G).

Parenchyma cells differ from xylem fibres by being broader, shorter and having thinner walls. They also possess more number of large circular simple pits on their lateral walls. In *Boerhaavia rependa*, *B. verticillata*, *Ruellia tuberosa*, *Ruellia prostrata* and *Chrysanthemum*, some of the cells observed have characters which are transitional between those of typical xylem fibres and axial parenchyma (Fig. 2H).

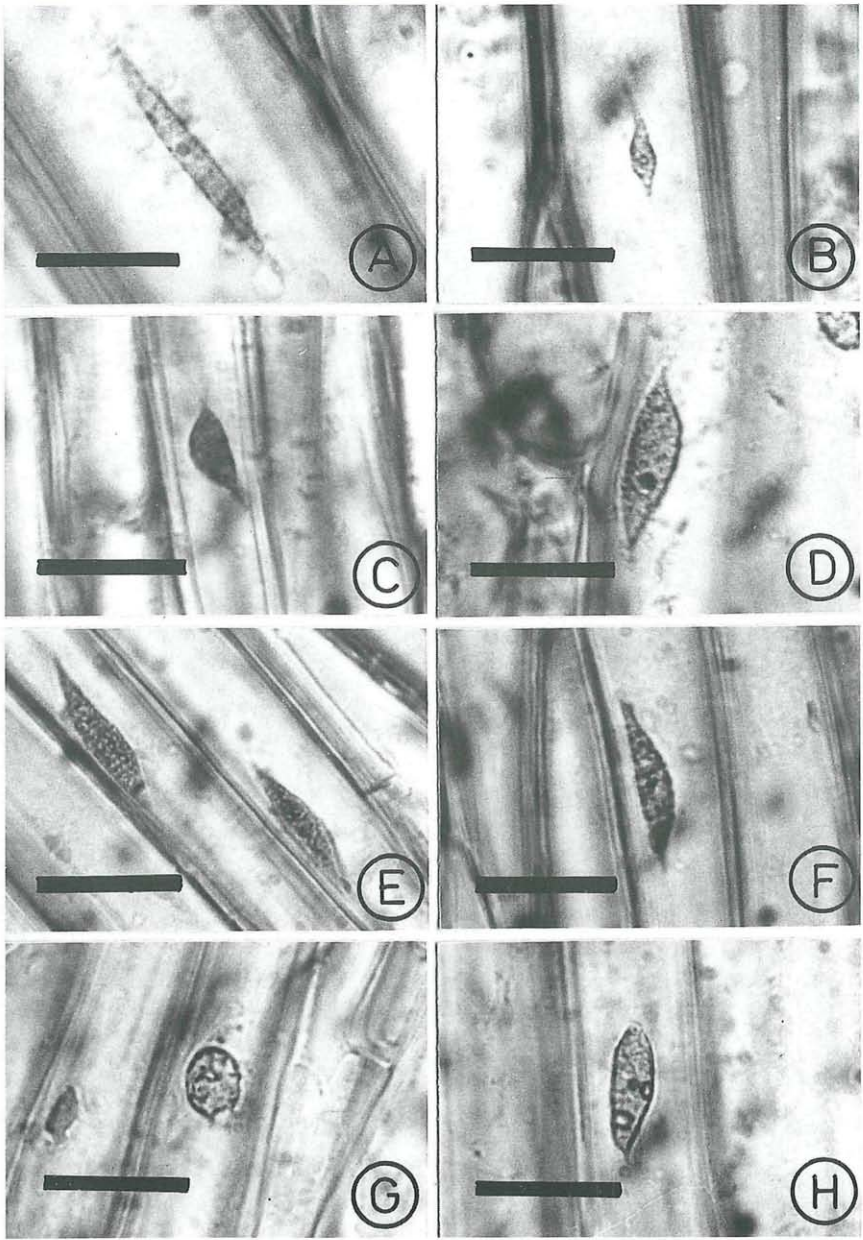
Discussion

Occurrence of nucleated xylem fibres seems not to be an uncommon feature and is reported in several genera belonging to different families of angiosperms (BAILEY 1953, BRAUN 1961, FAHN & SARNET 1960, FAHN & ARNON 1963, RAJPUT & RAO 1999a, b) as well as in some species of *Ephedra* (ESAU 1965). We further add sixty species of different families of angiosperms to this list. According to FAHN & LESHEM 1963 living fibres appear frequently in plants of arid habitats which are generally woody shrubs or subshrubs. It appears that nucleated xylem fibres also occur frequently in herbaceous genera as these life forms generally represent the vegetation of unfavourable habitats. However, the retention of nucleus is not limited to libriform fibres but its presence is also known in fibre tracheids (FAHN & ARNON 1963, ESAU 1965). Nucleated fibre tracheids are also noticed in *Trianthema monogyna*, *T. triquetra*, *Achyranthes aspera* etc. in the present study. Occurrence of nucleus and development of septa in *Ribes* has been studied in detail by PARAMESWARAN & LIESE 1969. In septate fibres, nucleus divides often more than once after the complete formation of secondary wall. A thin transverse septa is formed between the secondary nuclei (PARAMESWARAN & LIESE 1969). Occurrence of nuclei in each compartment and development of septa in all the plants possessing nucleated septate fibres may be similar to *Ribes* as described by PARAMESWARAN & LIESE 1969.

It has been proposed that occurrence of nucleated fibres is associated with their diminishing supporting function, exhibiting transition forms leading towards parenchyma cells prevailing herbaceous plants (FAHN & ARNON 1963). Furthermore, occurrence of cells that are transitional between xylem fibres and axial parenchyma in *Boerhaavia rependa*, *B. verticillata*, *Ruellia tuberosa*, *R. prostrata* and *Chrysanthemum* and accumulation of starch in the fibre lumina of all the species coincided with

Fig. 1. Xylem fibres showing nucleus in tangential longitudinal sections.

A: *Polygonum glabrum*, B: *Amaranthus spinosa*, C: *Gynandropsis pentaphylla*, D: *Tridax procumbens*, E: *Synedrella nodiflora*, F: *Helianthus annuus*, G: *Solanum xanthocarpum*, H: *Capsicum annum*. Bars = 20 µm



the observations made by FAHN & ARNON 1963. From these results it is evident that nucleated xylem fibres is an adaptive feature and in addition to mechanical support it also act as a reservoir of photosynthetic material representing further connection between parenchyma cells and xylem fibres.

Accumulation of starch is observed in both, septate as well as in non-septate fibres. PARAMESWARAN & LIESE 1969 suggested that the ability to store starch in fibres may compensate for a paucity of storage parenchyma. In septate fibres of *Pupalia lappacea* along with starch and nucleus, rhomboidal crystals are also encountered in the same compartment. Such fibres with crystals and nuclei have already been reported in some genera by WOLKINGER 1969.

The main function of living fibres appears to be storage of starch, which can be used at a time of high cambial activity (METCALFE & CHALK 1983, RAJPUT & RAO 1999a, b). But herbaceous plants do not attain much radial growth, therefore, it may be used at the time of sprouting of new shoots and their rapid growth and development with the arrival of favourable conditions.

Acknowledgement

Authors are thankful to Council of Scientific and Industrial Research (CSIR), New Delhi for financial support.

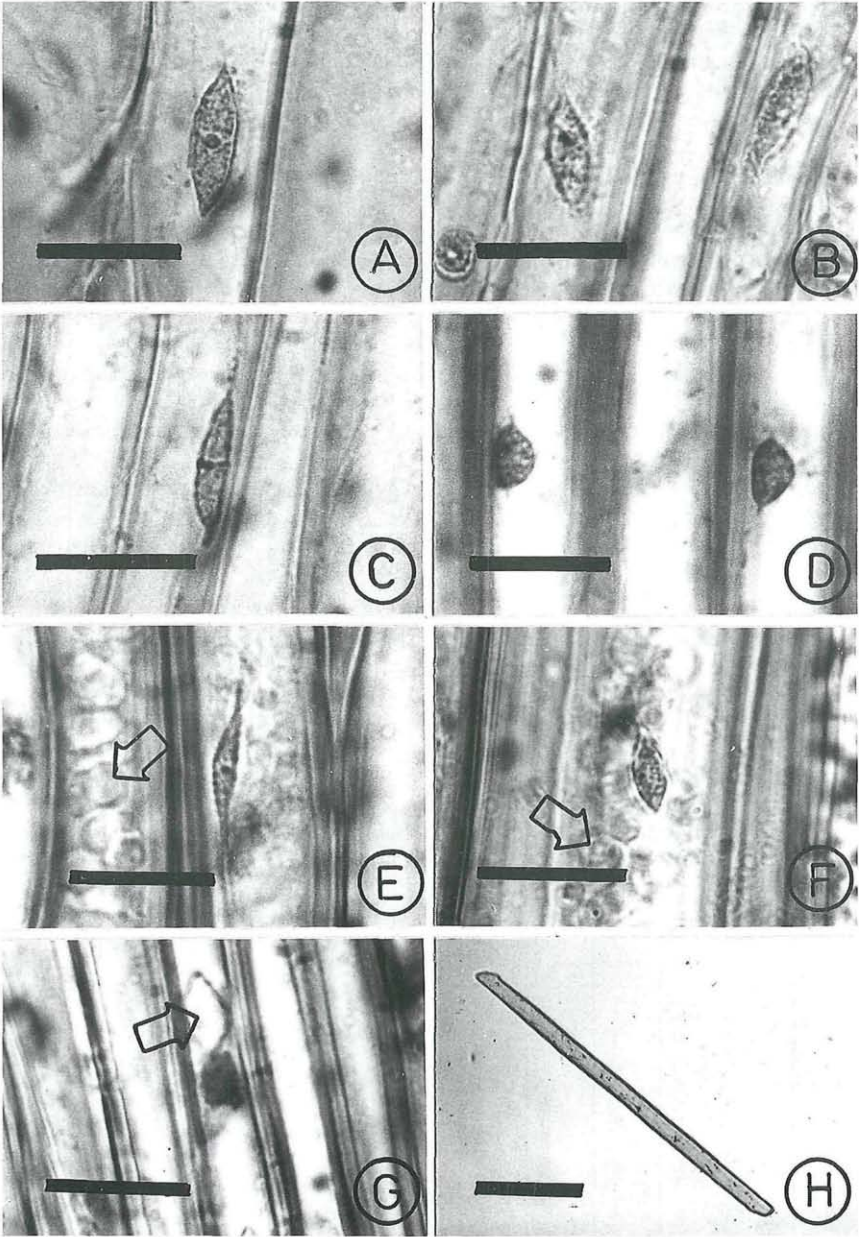
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Fig. 2. A–G Xylem fibres with nucleus in tangential longitudinal section, H: Transitional parenchyma.

A: *Datura fastuosa*, B: *Peristrophe bicaliculata*, C: *Ruellia tuberosa*, D: *Achyranthes aspera*, E: *Boerhaavia diffusa*, F: *Mollugo pentaphylla*, G: *Pupalia lappacea*. Arrow indicates rhomboidal crystal in fibre lumen. H: Transitional cell intermediate to xylem fibres and axial parenchyma in *Chrysanthemum indicum*.

A–G Bars = 20 µm and 2H Bar = 500 µm



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Table 1. Dimensional details of xylem fibres and nuclei.

Sr. No	Plant Name	Family	Fibre length μm	Wall thickness μm	Lumen diameter μm	Nuclei length μm	Nuclei width μm	Nucleated fibres in xylem
1.	<i>Argemone mexicana</i>	<i>Papaveraceae</i>	566 ± 7.85	4 ± 1.83	20 ± 0.49	10 ± 0.96	6 ± 1.18	Many
2.	<i>Gynandropsis pentaphylla</i>	<i>Capparidaceae</i>	404 ± 4.95	4 ± 0.35	22 ± 1.98	9 ± 0.97	4 ± 0.42	Many
3.	<i>Trianthema monogyna</i>	<i>Aizoaceae</i>	460 ± 6.89	4 ± 0.41	18 ± 1.64	16 ± 0.90	3 ± 0.25	Many
4.	<i>Trianthema triquetra</i>	<i>Aizoaceae</i>	585 ± 7.67	4 ± 0.44	20 ± 1.83	15 ± 1.75	3 ± 0.33	Many
5.	<i>Trianthema pentandra</i>	<i>Aizoaceae</i>	490 ± 6.31	3 ± 0.63	16 ± 1.29	8 ± 0.92	4 ± 0.47	Many
6.	<i>Mollugo hirta</i>	<i>Molluginaceae</i>	362 ± 3.94	3 ± 0.27	14 ± 1.53	8 ± 1.21	3 ± 0.44	Many
7.	<i>Mollugo oppositifolia</i>	<i>Molluginaceae</i>	421 ± 8.45	3 ± 0.93	13 ± 1.22	6 ± 0.79	3 ± 0.57	Many
8.	<i>Mollugo pentaphylla</i>	<i>Molluginaceae</i>	391 ± 5.64	3 ± 0.41	16 ± 1.41	7 ± 0.89	4 ± 0.29	Many
9.	<i>Eclipta erecta</i>	<i>Compositae</i>	638 ± 7.98	3 ± 0.61	18 ± 2.33	13 ± 1.42	4 ± 0.34	Many
10.	<i>Eclipta alba</i>	<i>Compositae</i>	652 ± 6.54	3 ± 0.41	20 ± 1.42	10 ± 0.85	3 ± 0.75	Many

Sr. No	Plant Name	Family	Fibre length μm	Wall thickness μm	Lumen diameter μm	Nuclei length μm	Nuclei width μm	Nucleated fibres in xylem
11.	<i>Tridax procumbens</i>	Compositae	713 ± 7.68	4 ± 0.41	24 ± 1.87	18 ± 1.88	5 ± 0.51	Many
12.	<i>Synedrella nodiflora</i>	Compositae	523 ± 6.31	3 ± 0.32	19 ± 2.24	17 ± 1.60	3 ± 0.27	Many
13.	<i>Vicoa indica</i>	Compositae	782 ± 9.99	4 ± 0.37	20 ± 1.48	21 ± 1.76	3 ± 0.27	Many
14.	<i>Vicoa cernua</i>	Compositae	778 ± 7.53	3 ± 0.62	19 ± 1.56	18 ± 1.25	4 ± 0.68	Many
15.	<i>Chrysanthemum indicum</i>	Compositae	711 ± 9.26	4 ± 0.53	19 ± 1.68	15 ± 1.19	5 ± 0.61	Many
16.	<i>Helianthus annuus</i>	Compositae	797 ± 7.95	4 ± 0.24	21 ± 1.57	9 ± 2.11	5 ± 0.60	Few
17.	<i>Helianthus rigidus</i>	Compositae	778 ± 6.91	4 ± 0.32	20 ± 0.73	7 ± 1.11	5 ± 0.74	Few
18.	<i>Tagetes erecta</i>	Compositae	618 ± 6.65	4 ± 0.25	22 ± 1.58	14 ± 1.34	4 ± 0.43	Few
19.	<i>Solanum nigrum</i>	Solanaceae	672 ± 9.65	3 ± 0.33	25 ± 2.45	10 ± 0.51	8 ± 0.58	Many
20.	<i>Solanum melongena</i>	Solanaceae	584 ± 5.90	4 ± 0.46	21 ± 1.73	9 ± 1.06	8 ± 0.98	Few
21.	<i>Solanum xanthocarpum</i>	Solanaceae	832 ± 8.21	4 ± 1.45	22 ± 1.45	17 ± 2.75	7 ± 0.91	Many

Sr. No	Plant Name	Family	Fibre length μm	Wall thickness μm	Lumen diameter μm	Nuclei length μm	Nuclei width μm	Nucleated fibres in xylem
22.	<i>Capsicum annuum</i>	<i>Solanaceae</i>	843 ± 9.06	4 ± 0.49	22 ± 1.42	15 ± 1.61	8 ± 0.89	Many
23.	<i>Datura fastuosa</i>	<i>Solanaceae</i>	837 ± 8.82	4 ± 0.61	25 ± 2.73	21 ± 2.15	7 ± 0.78	Many
24.	<i>Datura metel</i>	<i>Solanaceae</i>	809 ± 7.31	3 ± 0.59	22 ± 1.70	18 ± 1.02	5 ± 0.62	Many
25.	<i>Lindenbergia muraria</i>	<i>Scrophulariaceae</i>	565 ± 6.96	4 ± 1.47	20 ± 0.36	9 ± 1.21	3 ± 0.46	Few
26.	<i>Blepharis maderaspatensis</i>	<i>Acanthaceae</i>	626 ± 9.29	4 ± 0.25	20 ± 1.80	8 ± 0.42	3 ± 0.34	Many
27.	<i>Peristrophe bicalyculata</i>	<i>Acanthaceae</i>	635 ± 9.68	4 ± 0.38	18 ± 1.99	12 ± 1.59	4 ± 0.29	Many
28.	<i>Ruellia tuberosa</i>	<i>Acanthaceae</i>	614 ± 9.96	4 ± 0.41	19 ± 1.44	8 ± 0.93	5 ± 0.75	Many
29.	<i>Ruellia prostrata</i>	<i>Acanthaceae</i>	666 ± 8.74	4 ± 0.48	21 ± 1.35	9 ± 0.74	4 ± 0.40	Many
30.	<i>Boerhaavia diffusa</i>	<i>Nyctaginaceae</i>	465 ± 7.33	3 ± 0.51	17 ± 1.29	11 ± 0.77	4 ± 0.41	Many
31.	<i>Boerhaavia verticillata</i>	<i>Nyctaginaceae</i>	584 ± 6.99	4 ± 0.43	16 ± 1.45	10 ± 1.51	3 ± 0.32	Many
32.	<i>Boerhaavia repanda</i>	<i>Nyctaginaceae</i>	527 ± 8.34	3 ± 0.36	17 ± 1.51	10 ± 1.21	3 ± 0.52	Many

Sr. No	Plant Name	Family	Fibre length μm	Wall thickness μm	Lumen diameter μm	Nuclei length μm	Nuclei width μm	Nucleated fibres in xylem
33.	<i>Achyranthes aspera</i>	<i>Amaranthaceae</i>	507 ± 7.62	3 ± 0.27	22 ± 1.44	8 ± 1.03	3 ± 0.42	Many
34.	<i>Aerva sanguinolenta</i>	<i>Amaranthaceae</i>	476 ± 8.36	4 ± 0.24	21 ± 1.53	7 ± 1.69	3 ± 0.40	Many
35.	<i>Aerva lanata</i>	<i>Amaranthaceae</i>	485 ± 7.51	3 ± 0.31	18 ± 0.98	5 ± 1.01	3 ± 0.41	Many
36.	<i>Alternanthera pungens</i>	<i>Amaranthaceae</i>	472 ± 8.70	3 ± 0.41	16 ± 1.14	6 ± 0.83	3 ± 0.43	Many
37.	<i>Alternanthera triandra</i>	<i>Amaranthaceae</i>	480 ± 7.12	3 ± 0.84	18 ± 1.32	7 ± 0.78	3 ± 0.39	Many
38.	<i>Alternanthera sessilis</i>	<i>Amaranthaceae</i>	490 ± 7.11	3 ± 0.63	18 ± 0.85	9 ± 1.13	4 ± 0.58	Many
39.	<i>Amaranthus spinosus</i>	<i>Amaranthaceae</i>	434 ± 9.75	3 ± 0.25	16 ± 1.67	4 ± 0.64	3 ± 0.32	Few
40.	<i>Amaranthus tricolor</i>	<i>Amaranthaceae</i>	526 ± 6.86	4 ± 0.37	21 ± 1.69	8 ± 1.63	4 ± 0.40	Few
41.	<i>Amaranthus viridis</i>	<i>Amaranthaceae</i>	415 ± 6.43	3 ± 0.23	17 ± 1.87	7 ± 0.79	4 ± 0.57	Few
42.	<i>Amaranthus paniculatus</i>	<i>Amaranthaceae</i>	545 ± 6.00	4 ± 0.41	20 ± 2.05	6 ± 0.61	3 ± 0.39	Few
43.	<i>Amaranthus lividus</i>	<i>Amaranthaceae</i>	480 ± 6.50	4 ± 0.57	19 ± 2.38	7 ± 1.92	4 ± 0.39	Few

Sr. No	Plant Name	Family	Fibre length µm	Wall thickness µm	Lumen diameter µm	Nuclei length µm	Nuclei width µm	Nucleated fibres in xylem
44.	<i>Celosia argentea</i>	<i>Amaranthaceae</i>	675 ±7.76	3 ±0.42	21 ±1.54	8 ±1.03	3 ±0.29	Many
45.	<i>Celosia cristata</i>	<i>Amaranthaceae</i>	655 ±11.32	3 ±0.44	20 ±1.35	6 ±1.21	3 ±0.31	Many
46.	<i>Digera arvensis</i>	<i>Amaranthaceae</i>	598 ±9.64	3 ±0.51	17 ±1.24	6 ±0.89	3 ±0.40	Many
47.	<i>Nothosaerua brachiata</i>	<i>Amaranthaceae</i>	512 ±7.43	3 ±0.53	19 ±1.71	5 ±0.92	3 ±0.41	Many
48.	<i>Pupalia lappacea</i>	<i>Amaranthaceae</i>	655 ±9.87	3 ±0.33	21 ±1.81	10 ±1.35	4 ±0.58	Many
49.	<i>Pupalia atropurpurea</i>	<i>Amaranthaceae</i>	632 ±8.91	3 ±0.62	17 ±0.99	9 ±1.55	4 ±0.32	Many
50.	<i>Chenopodium album</i>	<i>Chenopodiaceae</i>	582 ±8.24	3 ±0.32	22 ±1.96	9 ±1.17	4 ±0.51	Many
51.	<i>Chenopodium murale</i>	<i>Chenopodiaceae</i>	576 ±6.89	3 ±0.49	20 ±1.65	7 ±0.86	3 ±0.67	Many
52.	<i>Rivinia humilis</i>	<i>Phytolaccaceae</i>	535 ±6.89	4 ±0.41	18 ±2.29	12 ±1.32	3 ±0.53	Many
53.	<i>Polygonum glabrum</i>	<i>Polygonaceae</i>	715 ±9.31	3 ±0.50	22 ±0.98	29 ±3.44	3 ±0.48	Many
54.	<i>Polygonum jagopyrum</i>	<i>Polygonaceae</i>	538 ±8.84	3 ±0.61	20 ±2.20	18 ±2.57	3 ±0.32	Many

Sr. No	Plant Name	Family	Fibre length µm	Wall thickness µm	Lumen diameter µm	Nuclei length µm	Nuclei width µm	Nucleated fibres in xylem
55.	<i>Polygonum barbatum</i>	<i>Polygonaceae</i>	569 ±7.32	3 ±1.23	22 ±1.87	20 ±1.83	3 ±0.44	Many
56.	<i>Polygonum plebeium</i>	<i>Polygonaceae</i>	593 ±7.27	4 ±0.39	21 ±1.98	8 ±0.44	3 ±0.50	Many
57.	<i>Muehlenbeckia platyclados</i>	<i>Polygonaceae</i>	580 ±6.31	3 ±0.42	17 ±0.74	8 ±0.89	3 ±0.34	Many
58.	<i>Acalypha ciliata</i>	<i>Euphorbiaceae</i>	630 ±6.42	3 ±0.71	20 ±1.33	7 ±0.51	4 ±0.42	Few
59.	<i>Acalypha indica</i>	<i>Euphorbiaceae</i>	619 ±7.98	3 ±0.37	21 ±1.92	5 ±0.43	4 ±0.37	Few
60.	<i>Phyllanthus niruri</i>	<i>Euphorbiaceae</i>	518 ±9.03	3 ±0.45	17 ±1.28	7 ±0.31	3 ±0.22	Many

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Jahr/Year: 2000

Band/Volume: [40_2](#)

Autor(en)/Author(s): Rao Karumanchi S., Rajput Kishore S.

Artikel/Article: [Nucleated Xylem Fibres in some Indian Herbaceous Species. 209-222](#)