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IDENTIFICATION OF FIBERS OF WOODY AND NON-WOODY PLANT SPECIES IN PULP AND PAPERS

VAHIDREZA SAFDARI[1*], MOHAMMAD REZA NIKSERESHT SIGARODY[1] AND MOINUDDIN AHMED[2]

[1]Agriculture and Natural Resources Faculty, Department of Wood and Paper Science, Islamic Azad University, Karaj Branch, Iran
[2]Laboratory of plant Ecology and Dendrochronology, Department of Botany Federal Urdu University of Arts, Science and Technology Gulshan-e-Iqbal, Campus, Karachi, Pakistan
[*]Corresponding author E-mail: Vahid.safdari@gmail.com

Abstract

Now a days the paper factories, which because of environmental issues and lack of forest sources, use waste papers, need to identify fibers in raw materials to improve quality of recycled papers. In order to evaluate feasibility of fibers identification, papers of 9 Iranian important factories (12 different papers) were sampled and the frequency of identified species in papers was recorded in many micro- slides, prepared from the papers according to ISO 9184-1 (Anon., 1990). The morphological and anatomical characteristics of Iranian hardwoods already been studied and the valuable atlases were used for the identification of exotic fibers. The results showed that identification of paper fibers was feasible. The vessel elements, specially shape, spiral thickness, perforation plates and ray pits on vessels were the important features in the identification of hardwoods. The type of cross field pits on tracheids were the main diagnostic features for softwoods identification and parenchyma, epidermal cells and vessel elements for non-woody plants. The softwoods of *Pinus* spp., *Larix* sp., and *Picea* sp., the hardwoods of *Populs* sp., *Fagus* sp., *Betula* sp., *Alnus* spp., and *Carpinus* sp. and the non-woods of Wheat, Rice, Cotton and Corn were the most plentiful species found in sampled papers. Repetition of recycle, refine and beating in paper production process caused the destruction of fibers and so identification of paper fibers especially of similar fibers species (vessel elements and tracheids) was very difficult. In addition to knowing anatomical characteristics of woody and non-woody plants, this practice is most important in identification of paper components.

Introduction

Wood fiber properties together with pulping process and other mill treatments determine the quality of paper and paper products (Horn, 1974, 1978; Strelis & Kennedy, 1967). To produce quality paper products, in addition to production process (mechanical, chemical, semi-chemical, chemical mechanical), some other treatments such as refining and beating and the kind of raw materials are also important (Britt 1971; Sjostrom & Alen 1999; Drost *et al*., 2004). Consequently, pulp and paper manufacturer should always know specifically what types of fiber they are using. Safdari *et al*., (2008) used hand lens to identify Iranian commercial wood but the fiber identification is very important from the view point of pulp and paper production.

In pulps, the anatomical relationship of the cells to each other no longer exists and thus cannot be used as diagnostic features (Strelis & Kennedy, 1967). Some anatomical characteristics such as transition between eralywood and latewood in softwoods, vessel grouping in hardwoods and vascular bundle in non-woods which are visible in solid form cannot be distinguished in macerated or pulp form.

The macerated anatomical characteristics in addition to paper's component identification can be very helpful in identification of small to large wood samples and various type of composites, which may not provide enough of all the surfaces necessary to reveal diagnostic characteristics (Wheeler and Baas, 1998) as well as sawdust (Tsoumis, 1981), wood fragments (Hoadley,1990), veneers, small pieces of historical and archaeological wood (Jashemski, 1990; Safdari & Devall, 2008;), decayed, stained, and finished wood and wood with preservatives which would not have the original color and natural texture.

Consequently, fiber identification is prerequisite before using in pulp and paper industrials (Strelis & Kennedy, 1967), especially factories which because of environmental issues and lack of forest sources, use waste papers, need to identify fibers in raw materials to improve quality of recycled papers. To determine what materials have been used in any papers, it is necessary to have information about different fibers of woody and non-woody plants.

In this research, we are going to study: 1) which anatomical characteristics of softwoods, hardwoods and non-woods are important in identification of macerated form of woody and non-woody plants? 2) Determining of frequency of plant species used for paper production?

Material and Methods

Identification of iranian important hardwoods by maceration process: In order to make correct identification of used plant species in papers, we needed to be familiar with anatomical properties of species in pulp form (macerated status). In this research, prominent woody species of the Hyrcanian zone of Iran which were used in a previous study (Safdari & Devall, 2008), viz., *Acer insign bois*, *Alnus subcordata*, *Buxus hyrcana, Carpinus betulus, Diospyrus lotus, Fagus orientalis, Fraxinus excelsior, Gleditsia caspica, Parrotia persica, Populus caspica, Pterocarya fraxinifolia, Quercus castaneifolia, Sorbus torminalis, Tilia platyphyllos (rubra), Ulmus glabra* and *Zelkova carpinifolia*) were selected. From above species, at the most 10 splinters were collected and treated with 30% hydrogen peroxide and glacial acetic acid 1:1 at 60°C for 48 h in glass=lidded test tubes (Franklin, 1945). The anatomical properties of wood species were studied carefully and diagnostic features recorded.

Paper collection: In order to identify fibers of papers, we sampled 12 papers from 9 factories in Iran namely Mazandaran Wood and Paper Industries, Latif, Choka,

Afra Kaghaz Sepahan, Farava Cellulose Zagrose, Sagheh Cellulose, Kaghazsazi Yasamin, Sanaye Moghavaye Yazd and Meysam Kagh.

Micro-slide preparation: According to ISO standard (9184-1(1990-12-15) and Parham and Gray, (1990), for each of the papers several micro- slides (25/4×76/2mm) were prepared. At first, 0.25g of sample paper from different parts of each produced paper was placed in small beaker and boiled in distilled water for few minutes (Adamopoulos, 2006). Some paper samples could not be softened by distilled water, so boiled in 1% Sodium hydroxide (NaOH) for 30 minute, and then soft fibers were washed by %2 hydrochloric acid (HCL) or distilled water. The softened papers were rolled with finger into small pellets and were shaken vigorously in a large test tube with the addition of some water until the pellets were thoroughly disintegrated. The suspension was diluted to a consistency of about 0.05% (wt./vol.) and then 1 ml of the suspension was transferred with a pipette and evenly distributed on the size of entire cover glass area on to micro-slide already placed on cleaned table. Using of hot plate for drying of micro-slides caused stitching of fibers together, so for avoiding of this problem, micro-slides were left at room temperature for 24. When the surface color of micro slide got whitish sediments, it was ready for staining. One or two drops of aqueous safranin were added and covered with cover glass. The above procedure produced a count of about 400–600 fibers per slide (Parham & Gray, 1990).

For each produced paper, at least 3 slides were prepared,examined and photographed. For more confidence and to avoid loss of rare fibers (vessels, tracheids and other diagnostic features), some of micro-slide were provided with more concentration (more than 0.05% (wt. /vol.) visually. The micro-slides were observed under a Nikon Microphot (Nikon YS2-T) light microscope equipped with complete optics for bright-field microscopy, cross-hair eyepiece and a 35 mm camera (Sony, Model No SSC-Dc50AP). The entire cover glass area was systematically examined in lines by traversing the slide horizontally. The structural details of fibers were studied to a magnification range of ×100 to ×800. The fibers of each genera were identified by diagnostic features, as described below:

The procedure of fiber identification: In this investigation, identification of hardwoods based on our studies on those native species which their prominent features have previously been recorded and for exotic species help was taken from many valuable Atlases (Strelis & Kennedy (1967), Côté (1980), Parham & Gray (1990), mainly Ilvessalo-Pfäffli (1995) and Husseini (2000).

The identification of woody and non-woody species in pulp is based on the structural features of individual cells. The identification of softwoods was performed mainly on the basis of cross-field pitting of the thin-walled. Differentiation of hardwood species or genera was based on the features of vessel elements (size and shape, type of perforations, presence of spiral or reticulate thickenings, type of inter-vessel pitting, size, shape and arrangement of pits to ray parenchyma and presence of pits on vascular elements. Non-wood fibers used for papermaking are derived from selected tissues of various monocotyledonous or dicotelydonous plants (Parham & Kaustinen, 1974). Differentiation of non-woods fibers was made by the presence of cells other than fibers such as parenchyma, epidermal, vessel elements and rings from annular vessels, by the general shape of fibers including width and length and the shape of fiber ends (Adamopoulos, 2006; Strelis & Kennedy, 1967; Panshin & DeZeeuw, 1980; Ilvessalo-Pfäffli, 1995).

Result and Discussion

Woody and Non-woody species, used in papers of important Iranian factories are given in Table 1. According to Table 1, hardwood, softwood and non-wood fibers were observed in all produced papers.

In hardwoods, vessel elements are very important in identification. Perforation plates, spiral thickenings and ray pits in vessels elements are most prominent key characters for identification (Fig. 1). Fibers of hardwood species are very similar and designation of fiber species is not feasible. In Iranian native species, only *Alnus subcordata*, *Fagus orientalis*, *Platanus orientalis* (only narrow vessels), *Parrotia persica* have scaliform perforation plates. Spiral thickening were found in *Acer insign bois*, *Carpinus betulus* (faint spiral thickness*), Sorbus torminalias, Tilia platyphyllos (rubra)*, *Gleditsia caspica, Ulmus glabra, Zelkova carpinifolia* which in three latest one spiral thickness belongs to latewood vessels. Ray pits in many species like *Carpinus betulus, Populus caspica, Pterocarya fraxinifolia, Quercus castaneifolia, Ulmus glabra, Zelkova carpinifolia* were large and oval. But in other species such as *Acer insign bois*, *Alnus subcordata*, *Buxus hyrcana, Diospyrus lotus, Fraxinus excelsior, Gleditsia caspica, Sorbus torminalias, Tilia platyphyllos (rubra),* being small and tiny. *Gash like or scalifortm ray pits* (Anon., 1989) made identification *of Fagus orientalis, Platanus orientalis and Parrotia persica* easier. Also vessels shapes (barrel, oblong and drum) helped in categorizing of species in two divisions, “ring-porous wood” and “diffuse–porous wood” and was helpful in identification (Fig. 1). Some other anatomical characteristics such as Vasicenteric tracheid in some species like Oak and vascular tracheids in Ash were provided good guidance for identification of species. In softwoods: early-wood tracheids cross-field pits: Windo-like, Pinoid, Picoid, Taxodoid, Cupresoid were most important features in identification (Anon., 2004). In non-woods: epidermal cells, vessel and parenchyma were more useful features in identification.

In softwood groups, species like *Pinus* spp., *Picea* spp. and *Larix* spp., (Table 1 and Fig. 2), and in hardwoods: *Populus* sp., *Fagus* sp., *Betula* sp., *Alnus* sp., *Carpinus* sp., (Table 1 and Fig. 1) and in non-wood species, Wheat, Rice, Corn, belonging to grass fibers and Cotton to fruit fibers had most frequency in collected papers (Table 1 and Fig. 3). Some of identified species such as *Pinus* sp., *Picea* sp., *Larix* sp., *Betula* sp., *Ulmus* sp., *Acacia auriculiformis*, *Eucalyptus* sp., *Magnolia acuminata* and *Nyssa sylvatica*, were not Iranian native species and their existence referred to imported papers (all kind of papers and also packaging papers of goods) and imported pulp too. It is recorded that *Pinus* species had the highest frequency and diversity in comparison to other softwood species (Table 1).

Table 1. Use of different plant genera and species in different paper factories.

Kind of paper / Genera and species	Wood and paper Mazandaran			Latif	Khoka	Afrakaghaz sepahan	Saghe cellulose	Faravr cellulose zagros	Kaghazsazi yasamin	Sanaye moghavay yazd	Meysam Kaghaz	
	N	F	P	T	TL	TL	TL	TL	TL	TL	TL	F
Softwoods (Fig. 1)												
Pinus sylvestris	+++	+++	+++	+++	+++		+++			+++	+++	+++
Pinus resinosa		+++	+++						+++			
Pinus strobes						+++	+++	+++	+++		+++	+++
Pinus halepensis				+++		+++						+++
Pinus ponderosa					+++	+++		+++		+++		+++
Pinus radiata							+++				+++	
Pinus pinaster	+++											
Pinus taeda								+++				
Pinus kesiya					+++	+++			+++	+++		
Picea or Larix	+	+		+	+	+	+				+	+
Abies sp.			+					+				
Hardwoods (Fig. 2)												
Populus sp.	+++	+++	+++	+	+++	+++	+++	++	+++	+++	++	+++
Alnus sp.		++	++		++	++	++	++		++	++	
Betula sp.			++		+++	+++	++	++	++	++	++	
Carpinus betulus	++	++	++		++	++	++	+				+
Fagus sp.	++	++	++		++	++	++	+	++	++	++	++
Tilia sp.		+						+	+			
Acer sp.								+				
Quercus sp.						+	+	+		+		
Nyssa sylvatica								+				
Magnolia acuminata								+				
Ulmus sp.	+	+								+	+	
Fraxinus excelsior								+	+			
Liquidambar styraciflua		+	+									
Acacia auriculiformi		+		+++					+		++	
Eucalyptus						+			+			
Non-woods (Fig. 3)												
Wheat	+	+	+	+	+	++	+	++	++	+	+	
Sugercane						++		++				
Rice	+	+	+		+	++						++
Corn		+				++					+	++
Bast fibers					+					+	+	
Cotton			+	+++	+			+	+		+	

1) N: News paper, F: Fluting, P: Print paper, T: Tissue, TL: Test Liner

2) +: a rare occurrence; ++: a usual occurrence and +++: a frequent occurrence (based on visual estimation of the relative amounts of earlywood tracheids with different morphological characteristics for softwoods, different vessel elements for hardwoods and fibers and associated cells for non-wood components).

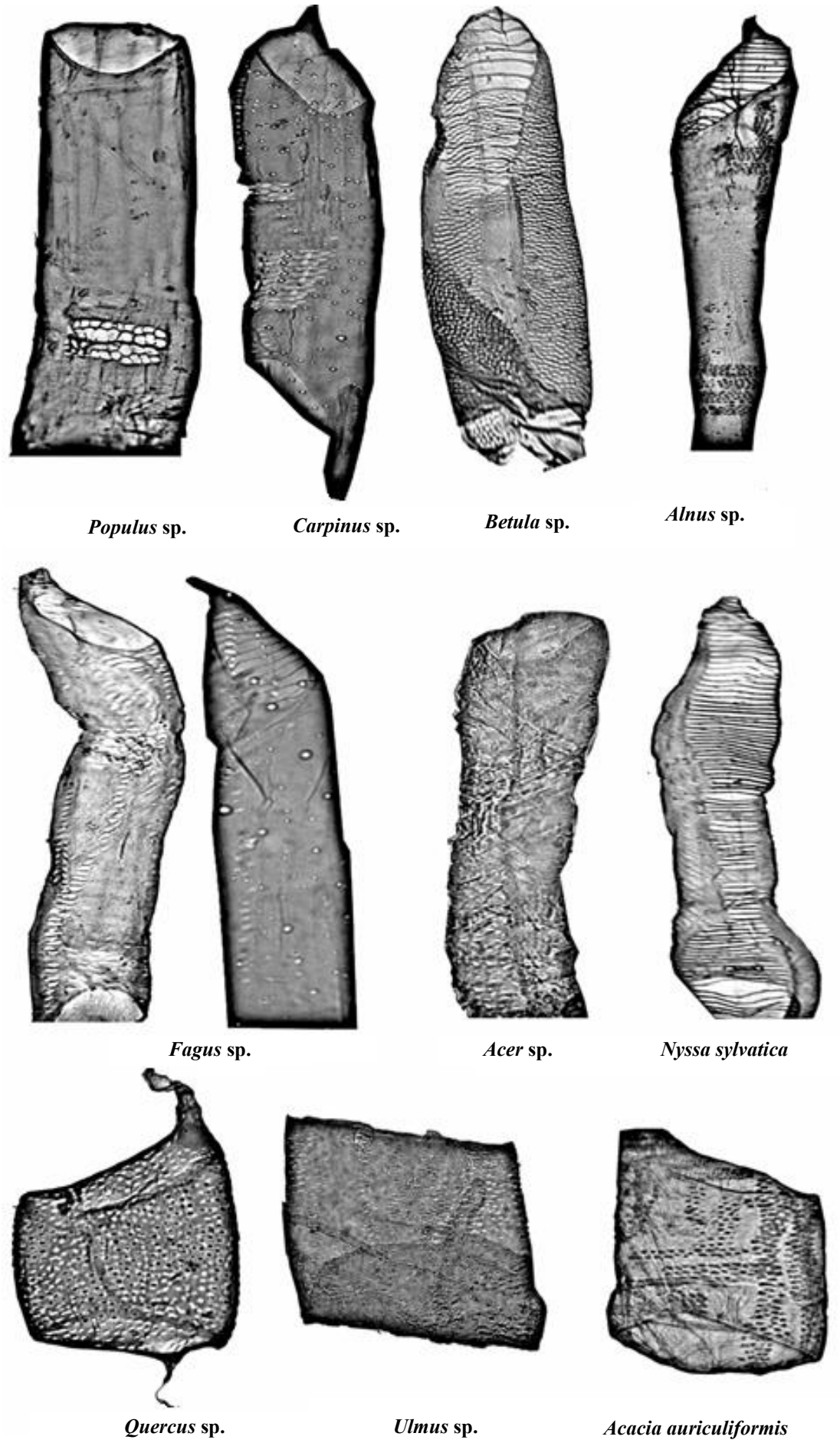

Fig. 1. Identification of hardwoods in different papers on the basis of features of vessels

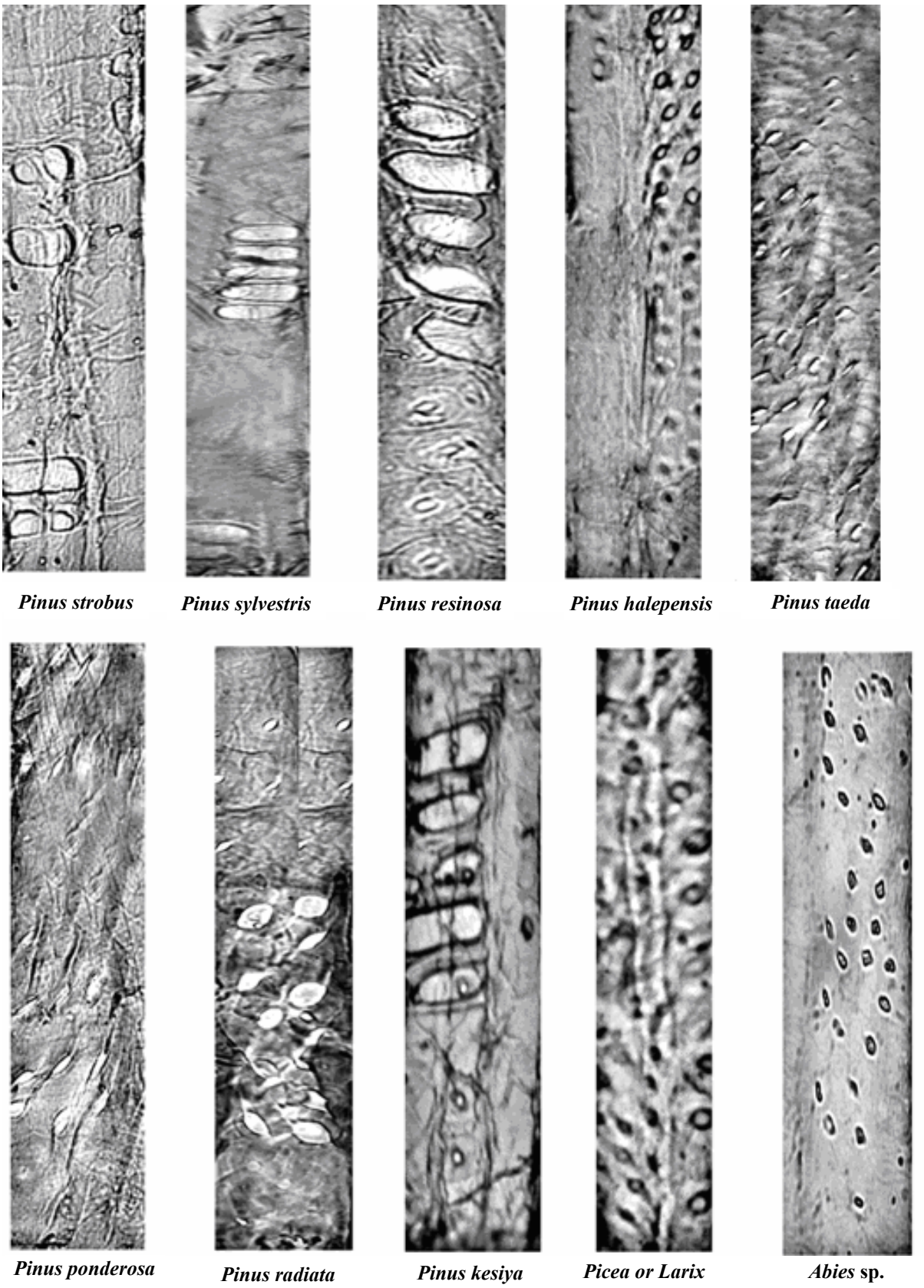

Fig. 2. Identification of softwoods in different papers on the basis of features of cross-field pitting of earlywood tracheids

Some vessels and tracheids on micro-slides were found, fragmented, due to recycling process and some treatments like refining and betting. Identification of these elements sometimes lead to error in similar species such as "*Betula* sp. and *Alnus* sp., *Populus* sp., and *Carpinus* sp. Cross field pits in many tracheid were similar and sometime other researchers categorized these in 5 groups (Parham & Gary,1990, Ilvessalo-Pfaffli, M-S,1994). Specially, when trachids were fragmented, then a portion of tracheid was visible on micro slides, the probability of error in counting of window like or pinoids pits are avoidable. For more confidence in identification, more micro slides and observations are recommended.

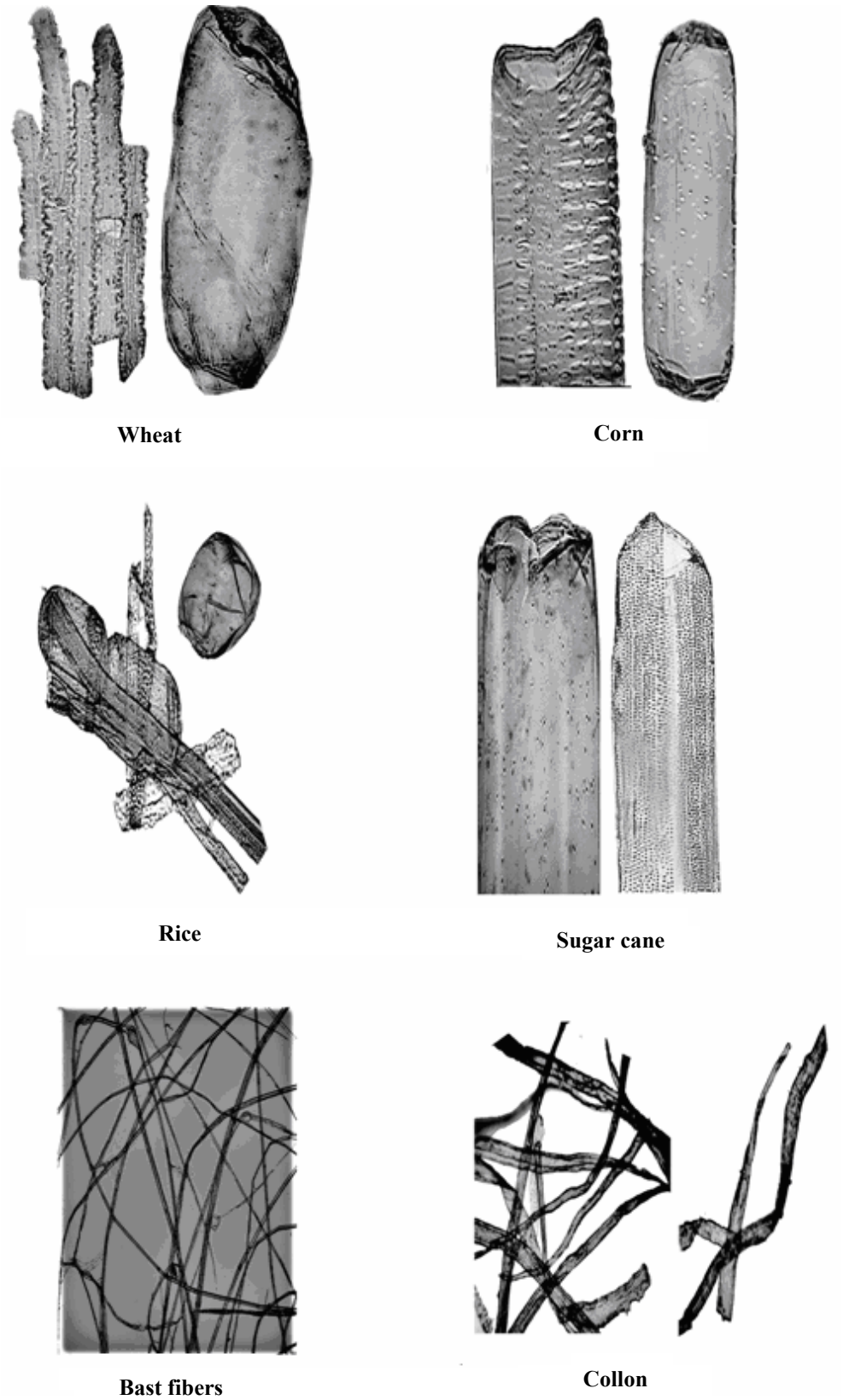

Fig. 3. Identification of non-woods in different papers on the basis of features of parenchyma, epidermal and fiber cells.

According to this study, the identification of plant species in papers and waste papers are feasible and successful. Our finding about important features in fiber identification was similar to others researchers (Strelis & Kennedy 1967; Ilvessalo- Pfaffli, 1995, Adamopoulos, 2006). The identification of hardwood samples was easier than softwoods and even non-woods, due to more anatomical diversity in hardwoods.

In contrast to Ilvessalo-Pfaffli, (1995) who found ray tracheids as one of the useful feature in softwood identification, we could not find ray tracheids helpful in identification. It is because of the fact that the ray tracheids are somehow similar to fragmented longitudinal tracheids and can be mistaken and also the content of ray tracheid in softwoods is low and cannot be seen frequently.

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