CELL STRUCTURES IN THE TRUNK OF OIL PALM AS EXAMINED THROUGH THE OPTICAL MICROSCOPE

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Oil palm (*Elaeis guineensis*) cultivation has been a major agriculture-based industry since the 1960s in Malaysia. The main purpose of cultivating oil palm is for the extraction of palm oil used in the manufacture of edible fats, soap, candles, greases, lubricants and many others (Moll 1987). Related to the large production of palm oil in Malaysia is the abundance of by-products such as the large oil palm trunks. In 1990, about 1.3 million t of dry oil palm trunks were generated through the process of replanting. This is equivalent to about 7% of the total timber export of Malaysia. It is projected that by the year 2000, more than half a million hectare of the area currently under oil palm will be replanted, which means that felled dry trunks equivalent to 7 million t of palmwood will be available (Lim 1991). This vast lignocellulosic material would be wasted if it is not utilised. For the efficient use of this waste material, a good knowledge of the oil palm trunk anatomy is essential.

The structure of the "wood" in palms has been described by many researchers, particularly Tomlinson (1961) on palms in general, Weiner & Liese (1989) on rattan and Sudo (1980) on coconut. Since the 1980s, Killmann & Lim (1985), Lim & Khoo (1986), Mohd. Zin & Imamura (1989) and Lim & Fujii (1997) have variously described the anatomical features of oil palm. However, it is felt that more features regarding the structures of oil palm trunks need to be described, particularly as oil palm trunks and the other by-products of the oil palm have been regarded as a potential source of lignocellulosic material in the future. For example, the potential in utilising oil palm fibres for composite panel products is enormous, provided that information on oil palm wood and the technologies related to its utilisation is available.

The observation of the anatomical features in the trunk of oil palm is often difficult, as a good microscopic slide is difficult to prepare. The "wood" of oil palm, unlike most timbers, is not homogeneous. Apart from the fact that it contains hard vascular bundles scattered in a soft ground tissue, usually there is a very hard peripheral rind surrounding the soft central region (Tomlinson 1961). Sectioning of the wood by using the normal sliding microtome is difficult due to the highly contrasting hard vascular bundles to the soft, thin-walled parenchyma ground tissue. It is virtually impossible to obtain a good microtome section for observation.

Observation of the microscopic structures of oil palm trunk may be done by using scanning electron microscope (Lim & Fujii 1997). However, scanning electron microscope is expensive, and therefore is not always available in a small laboratory. An alternatively thin-sectioning method coupled with the epoxy-embedding method has been adapted for the optical microscopic observation of structures in the oil palm trunk. This method of sample treatment, sectioning and staining is described.

Small blocks of approximately 3 × 3 mm in cross-section and 5 mm long were cut from various parts of an oil palm trunk. They were soaked and swollen well with distilled water in a low-pressure chamber using a rotary pump. The samples were dehydrated with an alcohol series of concentrations 30, 50, 85 and 95%. The dehydrated samples were thoroughly washed with propylene oxide before leaving them in a mixture of epoxy resin and propylene oxide

for half a day. This mixture was drained away, replaced with a fresh epoxy mixture and left overnight. The samples were removed and put in a plastic capsule with epoxy resin and subjected to vacuum for about 1 h to expel air. The plastic capsules with samples and epoxy resin were placed in an oven at 40 °C (1 day), 50 °C (1 day) and 60 °C (2 days). After removing the plastic capsules, the hardened epoxy resin with samples was ready for sectioning. The sectioning was carried out by using a rotary microtome equipped with a glass knife so that thin sections of oil palm trunk could be obtained and picked up on slide glasses. The sections, which were approximately 0.1 to 3 μm thick, were double-stained with 1% safranin and 0.5% gentian violet and mounted with Canada balsam after oven-drying. The slides were observed through a light microscope. Polarised light micrographs and ordinary light micrographs were taken without an analyser using the same microscope and field of view.

For the maceration of fibres, small splinters of oil palm trunk were placed in a mixture of glacial acetic acid and hydrogen peroxide (30 volume at ratio 1:1) in an oven at 60 to 90 °C for a day. They were rinsed with warm water and dehydrated with a graded ethanol series and then mounted with Canada balsam. Observation was carried out using an optical microscope with a dark field and phase contrast.

Figure 1 shows a cross-section from the centre of an oil palm trunk. Vascular bundles are embedded in thin-walled parenchymatous tissue. Most vascular bundles consist of one or two metaxylem cells; a single-strand phloem is located between the metaxylem and the fibre sheath. Occasionally, more than two metaxylem cells may be present, in addition to the presence of protoxylem cells (Lim & Fujii 1997). Generally, the structure of vascular bundles is fairly similar to other types of palms. For example, in rattan, a typical vascular bundle consists of vascular tissues, viz. xylem, phloem and a fibrous sheath (Bhat 1991). However, the xylem characteristically consists of a solitary or often two wide metaxylem vessels and narrow protoxylem vessels, ranging from two to six or rarely eight and more in number on one side of the metaxylem. Thin-walled parenchyma cells are present, interspersing with the xylem vessels. There are usually two phloem strands distributed on two sides of solitary metaxylem vessels except in some genera like *Myrialepis, Plectocomia* and *Plectocomiopsis*. The fibrous sheath is located at the opposite end of the xylem like a cap (Bhat 1991). A study on several erect palms in the Philippines by Espiloy *et al.* (1989) showed similar composition of structural elements in the vascular bundles except that the number of xylem vessels may vary from each other.

Figures 2 and 3 show the fibres of an oil palm trunk as seen from the cross-section and the longitudinal sections respectively. Both these figures were taken by using polarised light. They show a very distinct poly-lamellate structure in the fibre cell walls due to cellulose microfibrils being microcrystaline with natural birefringence. The polarising microscopic observations show that the fibre cell walls are composed of alternative layers of thick layers with longitudinal microfibrillar orientation and of thinner layers with transverse microfibrillar orientation. This feature is not only unique to the fibres of oil palm trunk. Other types of palms also have poly-lamellate fibre wall structures, e.g. rattan (Bhat 1991) and coconut (*Cocos nucifera*) (Sudo 1980). The anatomical structure of bamboo is very closely related to palms. They also have poly-lamellate cell walls in the fibres (Parameswaran & Liese 1976, Fujii 1985).

Figure 4 shows the metaxylem with pit openings leading to the thin-walled parenchyma cells, as viewed from the longitudinal section. Figures 5 and 6 show the parenchyma tissues in the cross-section and longitudinal section respectively. The parenchyma cells have very thin cell walls and are arranged in such a way that there are numerous wide intercellular spaces between them. A similar feature was observed by Lim & Fujii (1997) using scanning electron microscope. This loose form of cell structures may contribute to the weakness of the tissues.

Figure 7 shows a complete vascular bundle with two metaxylem vessels, phloem and fibre "cap". The vascular bundle strand is usually harder than the surrounding thin-walled parenchyma cells and due to drying, the vascular bundle can easily break away, resulting in

the creation of a zone of weakness and poor drying properties.

Figures 8 and 9 show the macerated fibre strands from an oil palm trunk. The fibre length in oil palm is comparatively longer than that of many tropical timbers, ranging from 1.5 to 2.6 mm. The fibres from the peripheral region are shorter than those from the intermediate and central regions of the trunk (Lim & Khoo 1986).

Figure 10 shows silica grains embedded in the outer layer of the bundle sheath. Again, this particular phenomenon is not only confined to the oil palm but also in other palms such as *Areca catechu, Arenga westerhoutii, Oncosperma horridum, O. tigillarium, Livistona rotundifolia* and *Mauritia flexuosa* (Killmann & Hong 1989). The presence of these silica bodies in the wood of oil palm results in rapid dulling of the saw teeth.

Based on the anatomical features explained above, it is not difficult to envisage that several problems will arise during the sawing and processing of the trunk into timber. During sawing, special care has to be taken. The use of tungsten-carbide insertions is recommended to reduce the blunting effect on saw teeth. During drying, uneven shrinkage of the hard vascular bundles and the soft and weak parenchyma cells may lead to severe drying defects.

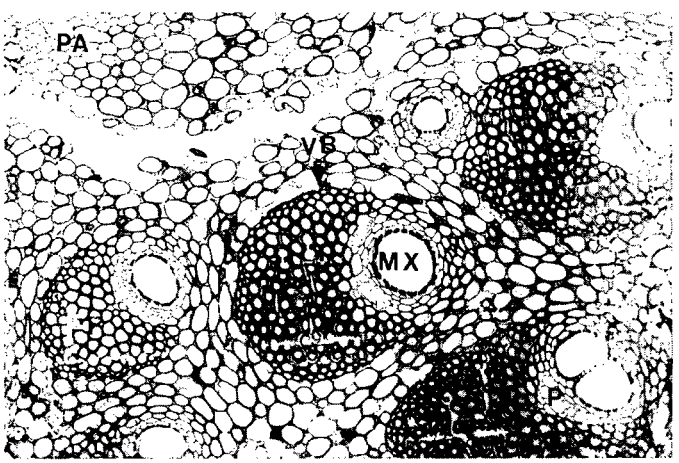

Figure 1. Cross-section showing vascular bundle (VB), metaxylem (MX), fibre (F), parenchyma (PA) and phloem (P) (× 90)

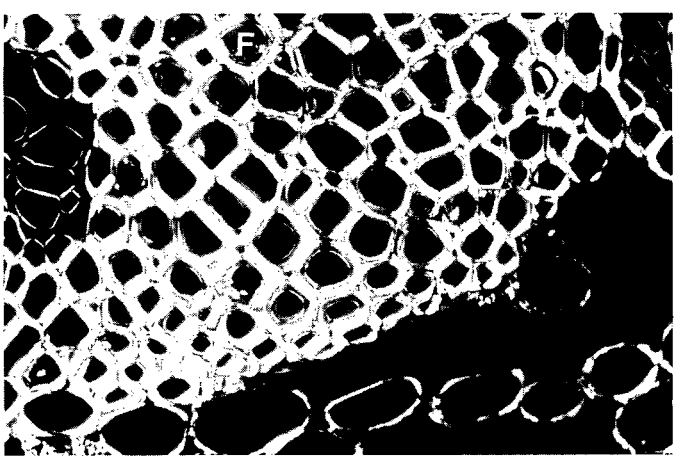

Figure 2. Cross-section showing poly-lamellate walls of fibres (F) (× 350)

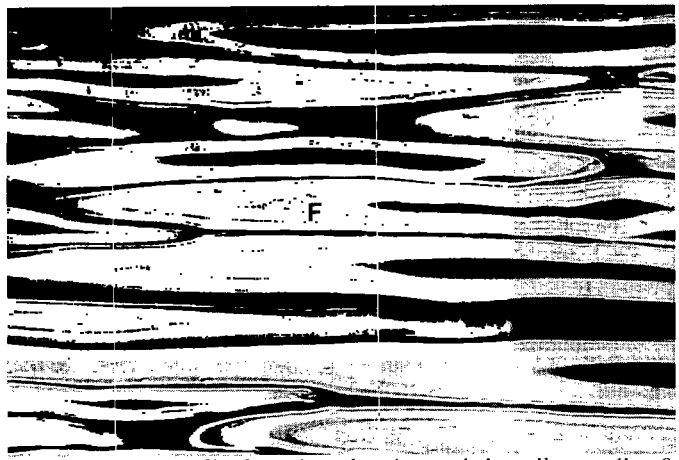

Figure 3. Longitudinal section showing poly-lamellate walls of fibres (F) (× 350)

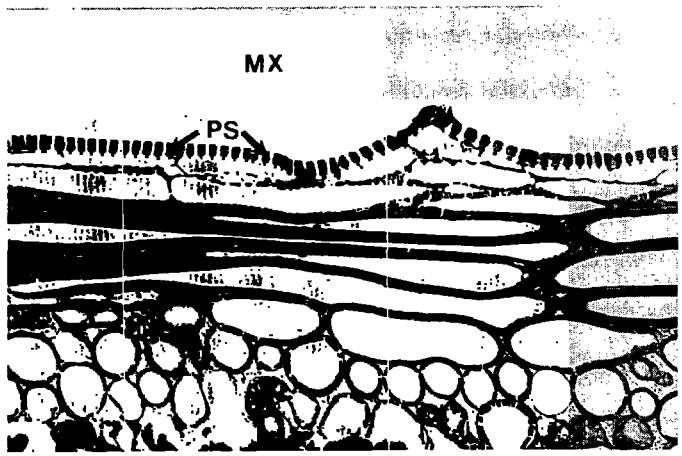

Figure 4. Longitudinal section showing metaxylem (MX) with pits (PS) connecting the vessels to the surrounding parenchyma (× 350)

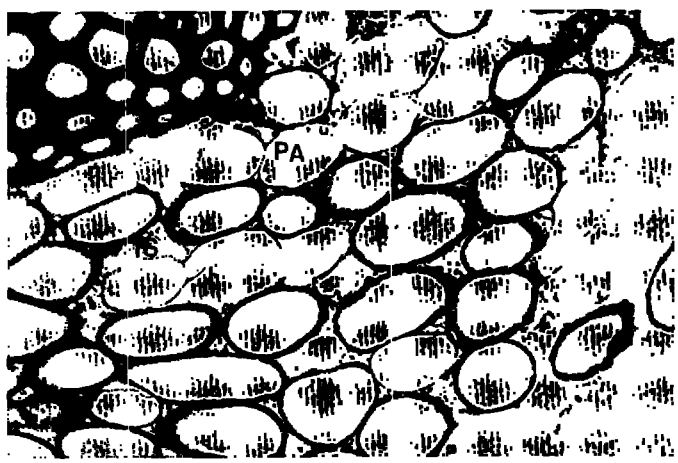

Figure 5. Cross-section of parenchyma region (PA) showing large intercellular spaces (IS) (× 350)

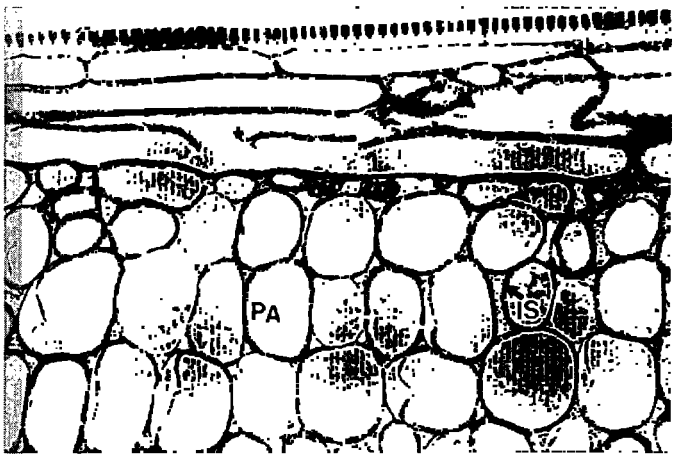

Figure 6. Longitudinal section showing parenchyma cells (PA) with intercellular spaces (IS) (× 350)

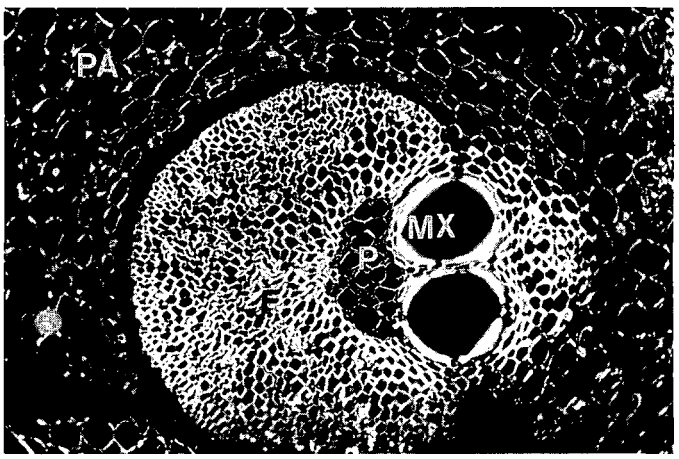

Figure 7. A single vascular bundle strand consisting of two metaxylem cells (MX), phloem (P) and surrounded by fibres (F). The vascular bundle is embedded in parenchyma tissue (PA) (polarised light, × 90)

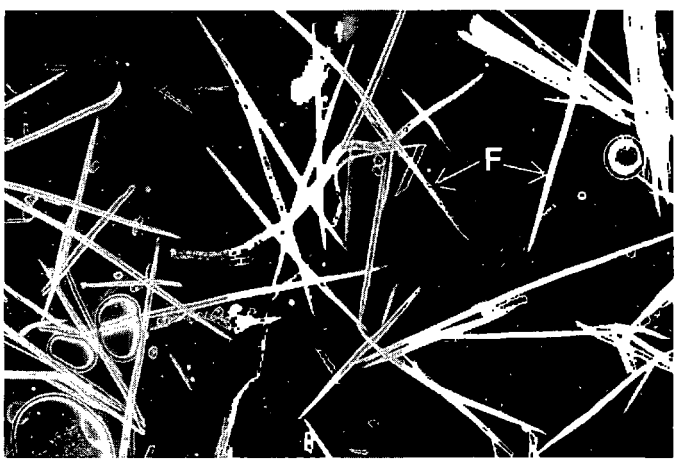

Figure 8. Macerated sample showing fibres (F) (× 35)

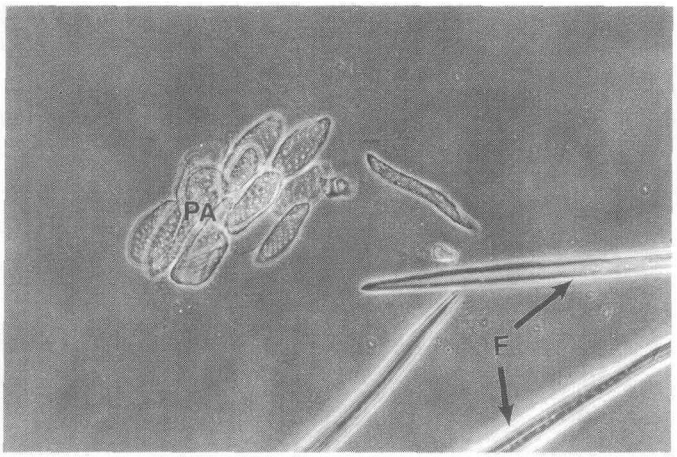

Figure 9. Macerated sample showing parenchyma cells (PA) and fibre strands (F) (× 90)

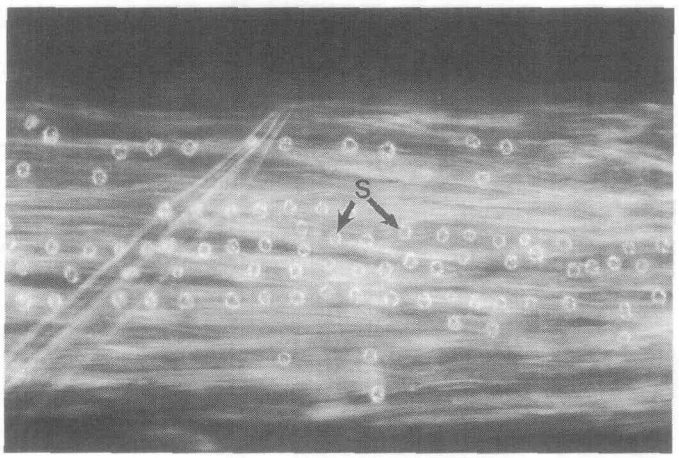

Figure 10. Silica grains located on the surface of a fibre bundle (polarised light, × 50)

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