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Secondary Thickening of the Stem in *Amaranthus hybridus* subsp. *cruentus* (L.) Thell.

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ABSTRACT

Transections of the stem region close to the shoot apex show the occurrence of an outer, complete ring of procambium and an inner group of discrete procambial strands. From the outer ring, small, discrete vascular bundles and vascular cambium originate, while the inner group forms the discrete, medullary vascular bundles with intrafascicular cambium. Secondary thickening is essentially due to the activity of the cylinder or complete ring of vascular cambium that originates from the procambium. The medullary intrafascicular cambia also form some secondary tissues. The vascular cambium produces secondary xylem inwards and secondary phloem outwards as in the normal secondary thickening process. The distinctive feature, however, is perpetual discreteness of the medullary vascular bundles. No successive series of cambia or secondary vascular bundles are formed.

INTRODUCTION

In the West African subregion, the amaranths are important vegetable crops, especially *Amaranthus hybridus* subsp. *cruentus*, which is noted for its tender, soft leaves and young stems. The older parts of the stem are usually discarded presumably because of the fibre content. These fibres are xylary and attributable essentially to the secondary growth process, which has been observed in several members of Amaranthaceae to be anomalous as it deviates from the normal process that occurs in most woody plants (Balfour, 1965; Esau, 1977). The usually discarded older portions, by virtue of the fibre content may, however, have a potential application in such fibre-related industries as pulp and paper making.

An understanding of the secondary growth process through which most of these fibres are formed would thus benefit any efforts to maximize both subsistence and industrial uses of the crop. The present study, therefore, attempts to examine the process of the secondary thickening in this species. This is with a view to providing anatomical informations that may be relevant to subsequent research efforts to monitor and control the level of fibre content in the stems of this herbaceous species.

MATERIALS AND METHODS

Stems of various ages were collected from an identified population of *Amaranthus hybridus* subsp. *cruentus* (L.) Thell. growing in the Biological Garden, University of Ilorin, Ilorin, Nigeria. Transverse sections from different levels of the stems were cut at 15 μm, using a sledge microtome with freezing stage. Sections were stained in 1 % aqueous safranin and mounted in glycerine jelly. Observations were recorded with photomicrographs.

RESULTS

In the stem region, about 1 mm below the shoot apex, transverse sections show the occurrence of an outer cylinder or complete ring of procambium and an inner group of discrete procambial strands (Fig. 1). From the procambial cylinder secondary xylem and phloem differentiate (Figs. 2 and 3). Other tissues observable within and near the differentiating procambium include the vascular cambium, pericycle and starch sheath (Figs. 2 and 3). The discrete procambial strands also differentiate into primary, collateral vascular bundles with xylem and phloem tissues and a strip of intrafascicular cambium between them (Figs. 3 and 4).

The position of the complete ring or cylinder of vascular cambium is peripheral as in most woody plants. The origin of this cylinder of vascular cambium is, however, in the procambium. The secondary thickening process is essentially due to the activity of this cambium. It produces cylinders of secondary xylem inwards and secondary phloem outwards (Figs. 3~5). The xylem consists of radial rows of xylem vessels with fibres and some parenchyma, while the phloem consists of the sieve tube elements, fibres and parenchyma (Figs. 3~5). No centrifugal initiation of successive cambia or formation of successive series of secondary vascular bundles is observed. The intrafascicular cambia of the medullary vascular bundles also produce scondary tissues in the normal way. However, these bundles remain surrounded by parenchyma cells, thus the intrafascicular cambia do not link up by means of interfascicular cambium formation to form a complete ring, as in most woody plants (Figs. 3~5; Esau, 1965, 1977).

During the secondary thickening, the integrity of the epidermis with cuticle is essentially maintained. However, localized periderm formations with lenticels may be seen in places where the epidermis is ruptured (Fig. 6). The angular collenchyma of the outer cortex gradually becomes more prominent (Fig. 4). The parenchyma cells of the inner cortex also transit from isodiametric shape to a slightly oval shape with wider tangential diameter (Figs. 1 and 4). A central core of pith parenchyma is maintained at the centre of the stem (Figs. 4 and 5).

DISCUSSION

The process of the secondary growth in *Amaranthus hybridus* subsp. *cruentus* appears to be similar in some respects to the normal process described for most woody plants (Esau, 1965, 1977). The secondary increment is due to one perpetually active cambium which produces cylinders of secondary xylem inwards and secondary phloem outwards. This cambium thus forms no successive series of discrete secondary vascular bundles, as reported for some members of the families Chenopodiaceae, Amaranthaceae and Nyctaginaceae (Balfour, 1965; Philipson and Ward, 1965; Studholm and Philipson, 1966). This is further in contrast to observations of some other species where the secondary increment is due to successive series of new cambia formed at the periphery of the stem (Esau and Cheadle, 1969; Baird and Blackwell, 1980; Fahn and Zimmermann, 1982).

Other distinctive features of the anatomy of the secondarily thickened stem of *Amaranthus hybridus* subsp. *cruentus* are the origin of the vascular cambium cylinder from the procambium and the maintenance of discrete medullary vascular bundles. The intrafascicular cambia produce secondary tissues which are, however, confined to the bundles. The intrafascicular cambia are not linked together through formation of interfascicular cambia to form a complete cylinder.

Since the secondary tissues observed in the present study are attributable to the cylinder of vascular cambium that derives from the procambium, a control of the secondary growth process may therefore be directed at or geared towards hormonal/genetic control or manipulation of the procambium in any subsequent studies. Other features of interest are the adjacent shoot apex, leaf primordia and young leaves, which are usually believed to be the major sources of plant growth hormones. The meristematic activities of the procambium may be influenced through experimental excision of the hormonal sources or through application of specific concentrations or combinations of growth hormones or growth inhibitors.

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EXPLANATION OF FIGURES

Fig. 1. Transverse section (T.S.) of stem about 1 mm below the shoot apex. Note the outer, cylinder of complete ring of differentiating procambium (arrow), and inner group of differentiating, discrete procambial strands (s). ×80.

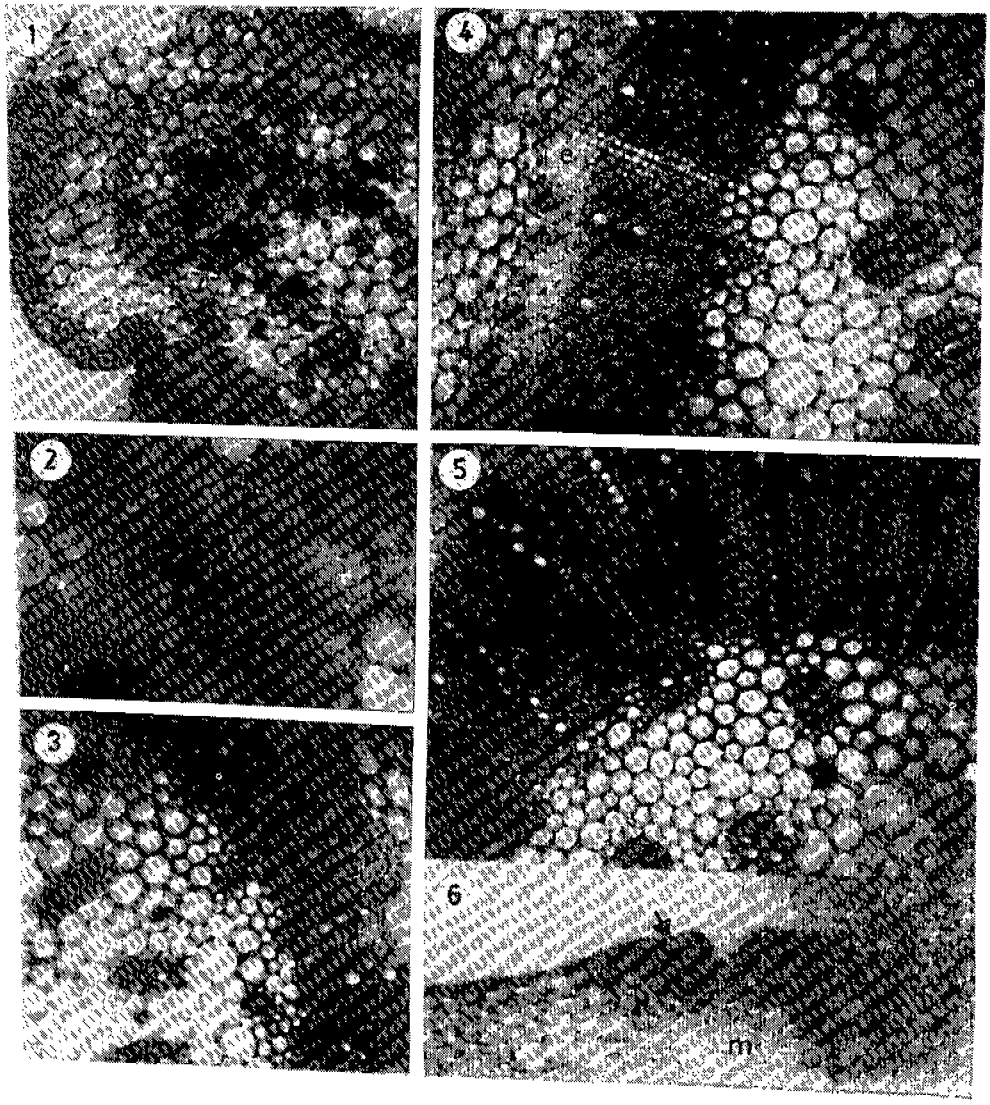
Fig. 2. T.S. part of stem older than in Fig. 1, showing developing cylinder of secondary xylem or wood (w) and a narrow zone of secondary phloem (e). ×400.

Fig. 3. T.S. older part of the stem with extensive and more prominent cylinders of secondary xylem (w) and secondary phloem (e) than in Fig. 2. Note also the presence of discrete, medullary, collateral vascular bundles (v). ×200.

Fig. 4. T.S. stem older than in Fig. 3 with more prominent zones of vascular cambium, secondary xylem (w), and secondary phloem (e). Also note inner cortex, angular collenchyma, epidermis and medullary vascular bundles (v). ×200.

Fig. 5. T.S. stem older than in Fig. 4 with wider zones of secondary xylem (w) and secondary phloem (e). ×200.

Fig. 6. T.S. Interrupted epidermis (arrow) with localized periderm formation beneath, consisting of tangentially elongated cells having roughly rectangular outline (m). Note the outer zone of smaller cells with intercellular spaces, forming the lenticel. ×200.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