A MORPHOLOGICAL AND PHYSIO-ECOLOGICAL STUDY OF PTEROCARPUS ANGOLENSIS DC.

BY

SELLO DAVID PHALATSE

Submitted in partial fulfilment of the requirements
for the degree Magister Scientiae
In the Department of Botany
In the Faculty of Mathematics and
Natural Sciences.

University of the North
Private Bag X1106
SOVENGA

FEBRUARY 1986

Supervisor : Prof D.R.J Van Vuuren.

CONTENTS

PAGE

CAPTIONS FOR FIGURES

CHAPTER 1

INTRODUCTION

1.1 Background:

Pterocarpus angolensis DC. was first described by A.P. De Candolle in 1825 from the type specimen gathered in Angola by an unknown collector (Groome et al., 1957; Von Breitenbach, 1973). Subsequent morphological description of the species, its distribution, uses, and to a lesser extent, its reproduction biology, have been given by various workers like Pardy (1951); Gordon (1954); Groome (1955); Pedro et al., (1966); Palmer & Pitman (1972); and Von Breitenbach (1965,1973). The generic name 'Pterocarpus', is derived from the Greek words "Pteros" meaning "wing", and 'Karpos' meaning "fruit", while the specific epithet 'angolensis' is from Angola, the country where it was first collected (Von Breitenbach , 1973).

1.2 Taxonomy:

This species is a member of the order Leguminales which is treated by some authors as consisting of three separate families, namely, Mimosaceae, Caesalpiniaceae and Papilionaceae or Fabaceae. Others however, treat the order as comprising one family, Leguminosae, with three subfamilies, Mimosoideae, Caesalpinioideae and Papilionoideae; the latter being subdivided into several tribes.

Dyer (1975) and Palgrave (1977) follow the conservative treatment of the order Leguminales and *Pterocarpus angolensis* is classified by them under the family Leguminosae, subfamily Papilionoideae. Hutchinson (1973) and Von Breitenbach (1973) however, place it under the family Fabaceae (Papilionaceae). The genus *Pterocarpus* is the only representative of the tribe Pterocarpeae (Hutchinson, 1964) in South Africa.

1.3 Common Names:

In the different geographical regions of South Africa, *Pterocarpus angolensis* is known by several different common and trade names. These names are mainly derived from the characteristic red juice which exudes when the plant is cut, or from the characters and usage of the wood. In the Republic of South Africa and some neighbouring states it is known as kiaat, Transvaal teak, bloedhout, bloodwood, sealingwax tree, bastergreinhout, morotômadi (Tswana), moroto (N. Sotho), mutondo (Venda), umBilo, Umvangazi (Zulu), umVangatsi (Swazi) and mokwa (Tsonga). Some Venda groups refer to it as muvunḓambaḓo to express the hardness of its wood, and this name literally means "the breaker of an axe". According to De Winter et al., (1966) this name is also used for Acacia caffra Willd. by some Venda people.

According to Smith (1966) the common Afrikaans name, kiaat, is derived from "kajate", because of some real or fancied resemblance of the timber of Pterocarpus angolensis to that of the true kiaathout, Tectona grandis L. Smith (1966) mentions that the name kiaat is also assigned to several other trees like Peltophorum africanum Sond; and Strychnos decussata (Pappe) Gilg; but according to him the name is today largely employed for Pterocarpus angolensis. The English vernacular, teak, is according to Smith (1966) also a general name applied usually with a geographical prefix to several timber trees of which the wood resembles that of the real teak (Tectona grandis); Transvaal teak refers to Pterocarpus angolensis.

1.4 Uses:

1.4.1 Commercial Uses:

Pterocarpus angolensis is commercially acclaimed for its beautiful and valuable timber. The wood is strong, durable and very suitable for furniture (Palmer & Pitman, 1972), and other woodcraft items such as canoes, stools, trays, drums (Von Breitenbach, 1973), and for woodcarvings. Due to its suitability and durableness in furniture making, it is stated by Van Wyk (1972) that the South African source has been virtually exhausted and that manufacturers are forced to import the timber from Zimbabwe and Mozambique. On the other hand, Palmer & Pitman (1972) state that the wood from Zimbabwe and South West Africa/Namibia is lighter and softer than the South African wood.

According to Groome (1955) and Groome et al., (1957), the sapwood which is creamy-white, is of inferior quality as compared to the heartwood, which varies from pale golden or olive-brown through mixtures of reds and browns to dull purple-red brown. This wood has excellent working qualities and takes a very good polish.

1.4.2 Medicinal Uses:

The red juice produced by this plant is said to be a good cure for skin sores, ringworms, blood disorders, and to get rid of intestinal parasites (Watt & Breyer-Brandwijk, 1962; Palmer & Pitman, 1972; Van Wyk, 1973; Palgrave, 1977). It is also used as an effective dye and as a colourant in pharmaceutical preparations (Van Wyk, 1973). Palgrave (1977) also mentions that the juice is used to cure nose-bleeding.

A powder obtained from the inner red bark of roots when mixed with fat is used as a body ointment (Palmer & Pitman, 1972; Palgrave, 1977). A decoction of the roots is believed to cure malaria, gonorrhea, intestinal parasites and black water fever (Watt & Breyer-Brandwijk, 1962; Palgrave, 1977). Cleaned roots soaked in water are used to treat corneal ulcers, followed by steaming the patient with boiling water in which flowers have been placed.

A hot infusion of the inner bark, together with that of fig and other trees is used to induce lactation by massaging it on the breast (Watt & Breyer-Brandwijk, 1962; Palgrave, 1977). Crushed flowers, fowl manure and fruits of shrubby species of Solanum in equal amounts, are burned and mixed with fat and used as a cure for ringworms, while the ash of seeds is applied to inflamed areas of the skin and bleeding gums (Watt & Breyer-Brandwijk, 1962; Palgrave, 1977).

According to Watt & Breyer-Brandwijk (1962) and Van Wyk (1973), chemical analysis of the sap has shown that it contains tannin, oils and crystalline phenol. The latter is also reported to have been isolated by King and co-workers from the heartwood, and they called it muningin, with the chemical formula: 6:4-dihydroxy-5:7-dimethoxy-isoflavone (Watt & Breyer-Brandwijk, 1962). It is also reported by Watt & Breyer-Brandwijk (1962) and Palmer & Pitman (1972) that working with the heartwood can cause skin irritation and asthma.

1.5 Propagation of the plant:

Pterocarpus angolensis has presented foresters with the problem of cultivating it satisfactorily on a large scale, particularly by means of seed. A few methods of propagation, inter alia, cuttings and truncheons, have been tried in the past with some measure of success, while propagation by seed has been virtually impossible due to the difficulty in germinating the seeds. Palmer & Pitman (1972) reported that one enterprising forester obtained good germination after allowing the seeds to be thoroughly nibbled in a termite heap. This implies that the seeds must first be hulled and scarified before sowing, a function performed in nature by micro-organisms.

The other major problem reported in this regard is that of annual die back of the seedlings (Boaler, 1966; Von Breitenbach, 1973). While this phenomenon recurs, the roots continue to grow, becoming stronger, larger and carroty, thus creating handling problems to nurseries during transplantations (Von Breitenbach, 1973). This annual die back of aerial shoots may continue for over five years, carrying the plants through at least two stages, namely, the suffrutex and sapling stages. In the latter stage, the plants acquire permanent and healthier stems (Boaler, 1966; Von Breitenbach, 1973).

In this study therefore, an investigation was undertaken to look into the possibility of reducing or overcoming the problem of cultivating this species, with special emphasis on improving the capacity of seed germination. In approaching this problem, other related aspects such as fruit development, seed production and morphology, as well as the general morphology and anatomy of the seedling, were also investigated. The outcome of this study, it is believed, could have beneficial economic implications for the future.

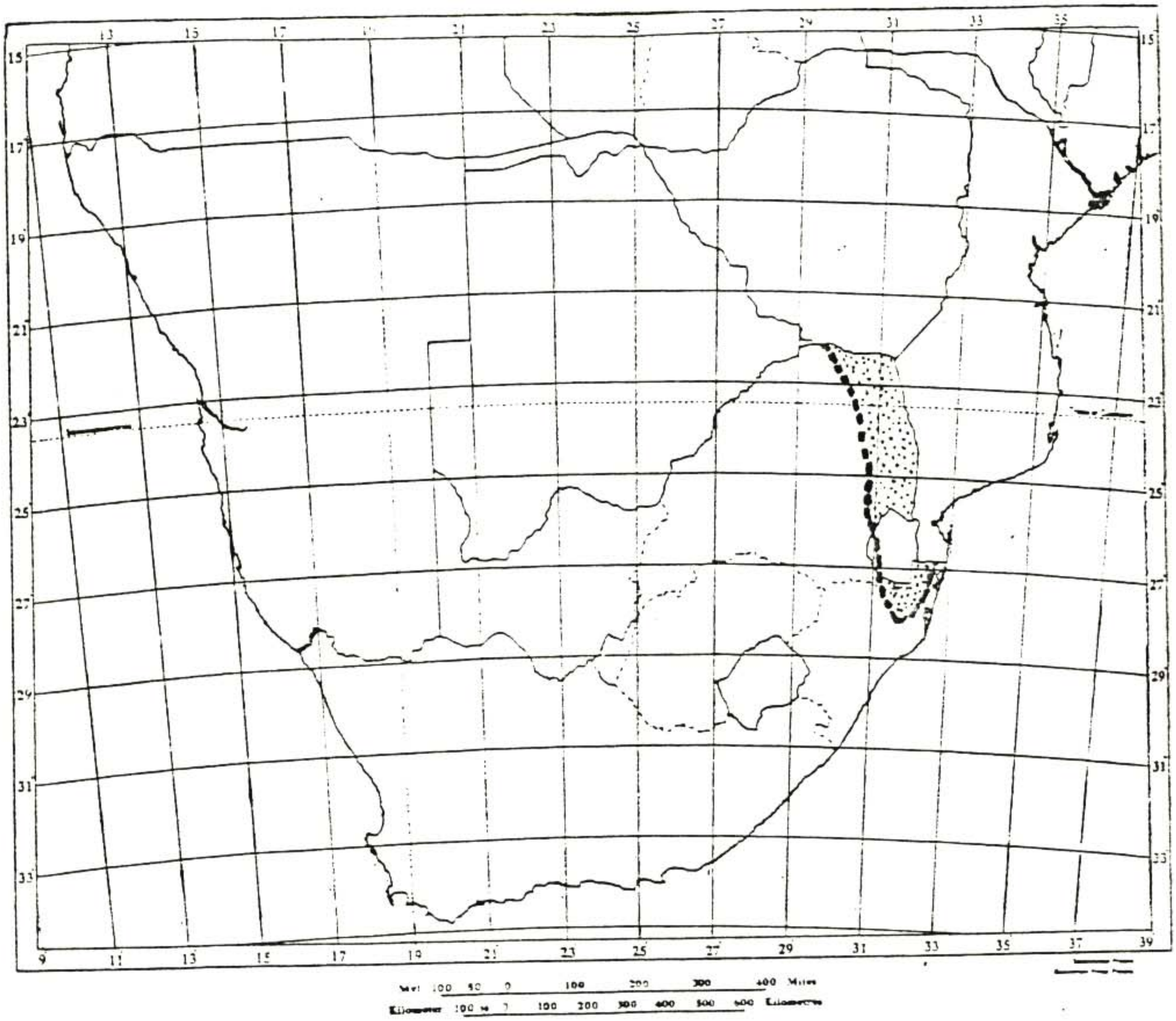


FIGURE 2.1 : Geographical distribution of P. angolensis in the Republic of South Africa.

CHAPTER 2

DISTRIBUTION OF THE SPECIES

2.1 Geographical Distribution:

Pterocarpus angolensis DC. is a subtropical woodland tree occuring abundantly from Angola in the west, and stretching eastwards through southern Zaire, Zambia, Tanzania and Zimbabwe, into Mozambique. Southerly it is found in northern South West Africa/Namibia, the Caprivi strip and northern Botswana.

In the Republic of South Africa this species is found from Nothern-, through Northeastern Transvaal, in the Lowveld of Eastern Transvaal, through Swaziland into Northern Natal. This northeastern track southerly, is along the Soutpansberg mountain range and along the Drakensberg mountains in the east (Van Wyk, 1971; Von Breitenbach, 1973; Acocks, 1975).

Herbarium specimens at the Botanical Research Institute show that the Eastern Transvaal localities of the species include Barberton, Nelspruit, Lydenberg and Pilgrims Rest while the Northeastern Transvaal localities are Tzaneen, Acornhoek and the Kruger National Park. Central distribution includes Haenertzburg, Houtbosch (Pietersburg) and Duiwelskloof, while in the north there are the Soutpansberg and Sibasa (Venda).

2.2 Physiographical factors influencing distribution:

Acocks (1975) lists P. angolensis among typical trees of the Lowveld Sour Bushveld, which is transitional between the Lowveld and the North-eastern Mountain Sourveld. This species prefers good and fertile soil conditions, the soils being of granitic or doleritic origin (Groome et al., 1957). These soils range from sandy, through sandyloam, to clayey which are light-textured and well drained. (Groome et al., 1957; Palmer & Pitman, 1972; Von Breitenbach, 1973).

The tree is light demanding (Von Breitenbach, 1973) and is found growing mainly along the lower eastern slopes and steeper foothills, on rocky outcrops and escarpments. In the Republic of South Africa it is found at the foothills of the Drakensberg mountains from Northern Natal, through Swaziland and Eastern Transvaal northwards, and along the Soutpansberg further north (Acocks, 1975). Rainfall in these regions ranges from 500mm to over 1000mm per annum, and the minimum temperature in the warmest months is about 20^0C while it is about 4^0C in the coldest months (Von Breitenbach, 1973).

Limitations of the species distribution include altitudinal range of up to about 1650m above sea level, climatic factors such as rainfall and temperature, which limit distribution both northerly and southerly; the species not being found in the two-season rainfall areas in the north, and also not in cold areas with high and well distributed rainfall in the south (Von Breitenbach 1973).

CHAPTER 3

GENERAL MORPHOLOGY OF THE MATURE PLANT

3.1 Introduction:

The general features of Pterocarpus angolensis have been widely described by various workers in the past. These include names like Pardy (1951); Boaler (1966); De Winter et al., (1966); Gordon (1971); Von Breitenbach (1965, 1973) and Palgrave (1977). While these workers appreciate and value the timber obtained from this plant, its anatomical features have been treated in more detail mainly by Mozambican researchers like Petro et al., (1955) and Cardoso (1962), while Kromhout (1975) in South Africa described it briefly in his comparative studies of indigenous South African timbers.

In this chapter therefore, the general features of the species are briefly reviewed. The material used have been obtained from plants growing in the Koedoe Valley near Mooketsi in the North-eastern Transvaal.

FIGURE 3.1 : Pterocarpus angolensis. Mature trees at Mooketsi valley.

3.2 General Features of the Plant:

3.2.1 The Stem:

3.2.1.1 External Morphology:

Pterocarpus angolensis is described by the above workers as a medium sized tree, which may reach a height of about twenty metres when growing under ideal conditions. Gordon (1971) describes it as a fine stately tree with an average height of eight metres. Trees growing in the Koedoe Valley were estimated to be between eight and ten metres in height.

The trunk may be relatively short, branching within one to two metres above the ground. The mode of branching of the trees is monopodial, but due to the strong development of side branches, it sometimes gives the appearance as if the tree is dichotomously branched (Fig.3.1). These branches spread out into a flattish crown (Pardy, 1951; Van Wyk, 1972; Von Breitenbach, 1973). The older branches tend to be wavy or crooked, at times strongly so, while in some cases they appear fairly straight. The internodes, as seen in younger or terminal branches, are very short, with fairly large leaf scars with raised margins.

The bark on younger branches is greyish-brown and pubescent. In older stems and branches it is dark grey to blackish. Here too, the bark is characteristically rough and fissured (Pardy, 1951), that is, cracking into oblong blocks or plates (Boaler, 1966; Von Breitenbach, 1973). The roughness in slender and more or less terminal branches is mainly due to the leaf scars. It is stated by previous workers mentioned above, that the inner bark and outer wood contain a red juice or gum which exudes when the bark is slashed or the tree is cut.

3.2.1.2 Internal Morphology:

3.2.1.2.1 Procedure:

Older stem branches collected from trees in the Koedoe Valley area were fixed in Formalin: Alcohol: Acetic acid (F.A.A.) and then prepared for sectioning according to Johansen (1940). Transverse, radial and tangential longitudinal sections were made by means of a Reichert sliding microtome, stained with safranin and analin blue, using an Elliot Shandon Varistain machine.

3.2.1.2.2 Discussion:

Tansverse sections showed that the stems are covered on the outside by a periderm. This is a secondary protective tissue consisting of three regions, namely, the phellem, phellogen or cork cambium and the phelloderm. Both the phellem and phelloderm are formed from the cork cambium with the phellem towards the outside and phelloderm towards the inside (Sporne, 1974; Fahn, 1982). Cells of the phellem are non-living, flattened and without intercelullar spaces. They may or may not be suberized, and are thinwalled or slightly thickwalled. The phelloderm or secondary cortex (Fahn, 1982) is made up of living cells which can only be distinguished from cortical cells by their radial alignment with the other two layers. The phellogen is basically cortical or subepidermal in origin, but as the trunk increases in diameter, with subsequent cracking of the first formed cork or periderm, successive cork cambia develop progressively further inwards (Cutter, 1971; Sporne, 1974; Fahn, 1982), to include even secondary phloem. In this instance, when the cork cambium is formed from secondary phloem, that part of the phloem outside the newly formed cork cambium segment, dies.

According to Cutter (1971) all the tissues outside the vascular cambium, including the periderm, are collectively referred to as the bark. This is divided into two parts, namely, the inner and outer bark. The inner bark represents the living part and the outer, the dead part

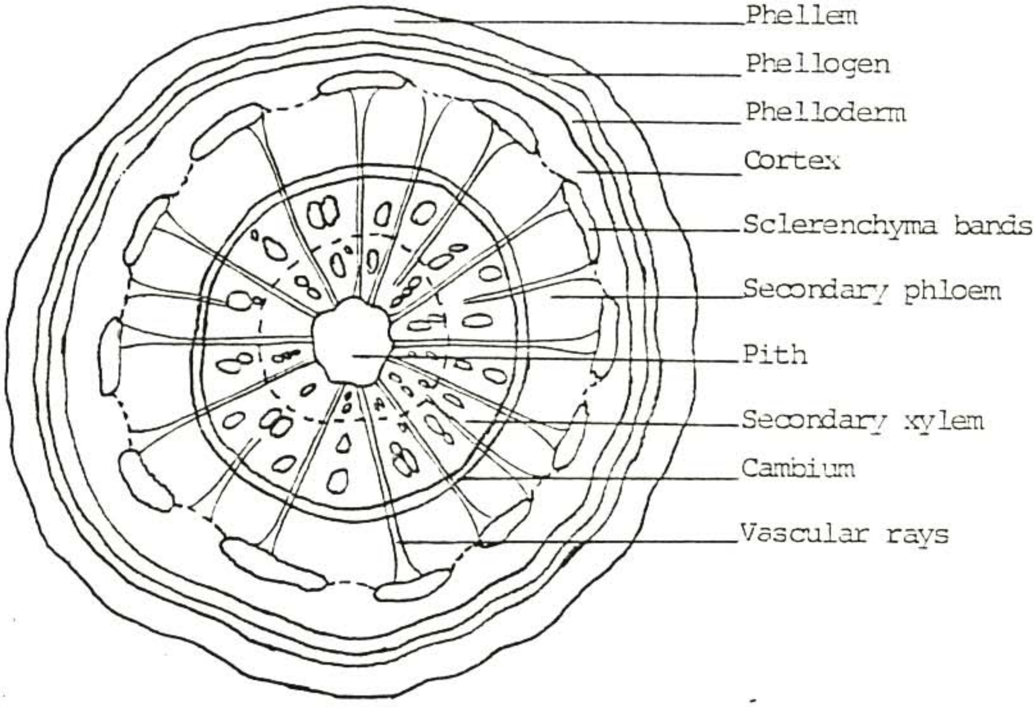


FIGURE 3.2A :Diagram of a transverse section of an older stem(3½months).

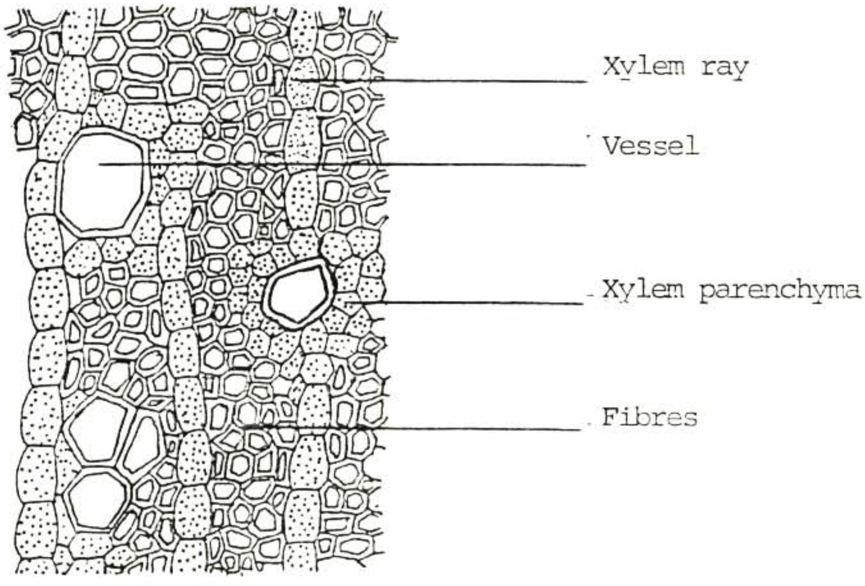


FIGURE 3.2B : Drawing of a portion of a cross section of the wood.

(Fahn, 1982). The dead outer bark, according to Fahn (1982) includes all cork layers, together with the cortical and phloem tissues external to the innermost phellogen.

The cortex is composed of a few layers of thin-walled parenchyma cells. Within this cortex, small groups of stone cells as well as secretory cells are present. The secretory cells are larger, solitary or in groups of two or three; some contain granules staining reddish to pinkish red, while others have contents staining yellowish or brownish yellow. Starch grains are also present in some ordinary cells.

The secondary phloem forming the living part of the bark, consists of two systems, an axial system derived from the fusiform initials of the cambium, interpenetrated by a ray system, derived from the ray initials (Esau, 1965a). The axial system consists of the sieve tubes, companion cells, phloem parenchyma cells, sclereids, phloem fibres and secretory cells. The functioning sieve tubes are found near the cambium in the youngest part of the secondary phloem. In the older parts of the phloem, further away from the cambium, the sieve tubes are crushed and more or less obliterated. These parts of the phloem consist mainly of phloem parenchyma cells, but scattered among the phloem parenchyma are secretory cells. These secretory cells are larger in size than the phloem parenchyma and their contents stain yellowish.

Small groups of sclereids may also be present in the older parts of the phloem. Fibres, arranged in the form of bands or small groups are found mainly along the periphery of the secondary phloem. These fibre groups appear like bundle caps, which in many plants develop from the protophloem paranchyma cells (Esau, 1965a). The ontogenetical development of these fibre groups has not been investigated, but most probably in Pterocarpus angolensis they also represent protophloem fibres.

The ray system of the secondary phloem consists of secondary phloem rays, which are uni- or biseriate, and these rays stretch to just below the fibre groups. Cells of these rays, as well as the secondary phloem parenchyma, are rich in starch grains.

Like the secondary phloem, the secondary xylem also consists of an axial and ray system, derived from the fusiform and ray initials respectively.

The axial system consists of vessels, tracheids, fibres and xylem parenchyma cells. The secondary xylem is composed mainly of thickwalled lignified fibres. These fibres show a definite radial seriation as seen in cross section (Fig.3.2.B). Sparsely dispersed vessels are present, and these occur mainly single or also in radially arranged groups of two to three.

The xylem parenchyma of the axial system is associated with the vessel elements (paratracheal) and in arrangement it differs from aliform to aliform confluent, forming undulating bands of parenchyma.

The xylem rays are fairly numerous and closely arranged and are mainly uniseriate and homogeneous. Rays of two or three rows of cells wide may also be present. In radial sections, these rays may be up to twelve cells high.

The pith is parenchymatous, small, and its outer cell layers contain secretory cells.

3.2.2 The Leaf:

The leaves of P. angolensis DC. are alternate and imparipinnately compound. At the base of

FIGURE 3.3 : Pterocarpus angolensis in flower and leaf-flush on younger branches.

are up to eight millimeters long (Palgrave, 1977). The pinnae are subopposite to alternate, ovoid to elliptic-lanceolate with blunt or sharply pointed tips (Von Breitenbach, 1973). The upper surfaces of the pinnae are smooth, while the lower surfaces are hairy, particularly when young. In this young state the pinnae are also conduplicate, appearing brownish green. The petioles and petiolules are covered with silky hairs. The petioles are again thickened at the base to form the pulvinus. After abscission, a fairly large leaf scar is left behind, and these leaf scars contribute to the roughness of the terminal branches. The rachis generally carries seven to ten pairs of pinnae with the terminal or odd pinna being slightly larger and more rounded.

Leaf-flush occurs after or simultaneously with flowering. In this fashion, the trees remain leafless for the better part of the dry season since leaf-fall occurs fairly early.

3.2.3 Flowers and Pods:

Pterocarpus angolensis produces flowers between August and November on new growth. These flowers are orange-yellow and sweetly-scented (Von Breitenbach, 1973; Dyer, 1975; Palgrave, 1977). They are borne in lax, axillary or terminal racemes and are typically papilionaceous and pentamerous (Groome, 1955; Gordon, 1971; Von Breitenbach, 1973).

The flowers are strongly zygomorphic. The calyx segments are fused, the tube being 5-dentate at the top. These calyx lobes are shorter than the tube.

The stamens are either diadelphous (9+1) or monadelphous, in which case the staminal tube is partially divided into two sets of five on either side of the ovary (Groome, 1955; Pedro et al., 1955; Dyer, 1975). Anthers are dorsifixed and dehisce longitudinally, and are of equal size.

The ovary is superior, unilocular and contains two to three marginal ovules. It is shortly stalked and covered with silvery hairs. The style is filiform and protrudes slightly upwards from the staminal tube. The stigma is simple and terminal.

Flowers remain open for a period of two to four weeks (Boaler, 1966; Gordon, 1971; Palmer & Pitman, 1972). Young flowers were found to be damaged by insects which fed on them, possibly still in the bud, since both the calyx and corolla were affected.

The fruits are distinctive circular indehiscent pods (Palgrave, 1977) with thickened and hardened bristly centres. Surrounding this central portion is a broad membraneous wing (Palgrave, 1977). This wing is wavy and has a deep crescent or semilunar notch near the stalk (Van Wyk, 1972). This notch contains at its free end, the remains of the style, in this case forming the basal beak. These pods may remain hanging on the tree for a long time, and when the trees are leafless, they become so conspicuous thus making visual recognition of this species easy (Groome et al., 1957).

CHAPTER 4

DEVELOPMENT AND MORPHOLOGY OF THE FRUIT

4.1 Introduction:

The fruit of P. angolensis DC. is a winged circular pod. The seed-bearing central portion of the pod is thickened, and densely covered by long, slender but tough bristles. This feature distinguishes the pods of this species from those with similar shape and size. (Von Breitenbach, 1973). In size these pods range from about six to twelve centimeters in diameter, the bristles being up to two centimeters long, while the thickened central portion is about three centimeters in diameter (Boaler, 1966; Palmer & Pitman, 1972; Von Breitenbach, 1973). The pods are mainly two loculed, one or both of which may be empty (Boaler, 1966) and rarely three loculed.

4.2 Material and Procedure:

Flowers and young fruit at different stages of development were collected between the months August and October from trees at the Koedoe valley in the vicinity of Mooketsi. This material was fixed in FAA preservative, and prepared for sectioning according to Johansen (1940). Longi-

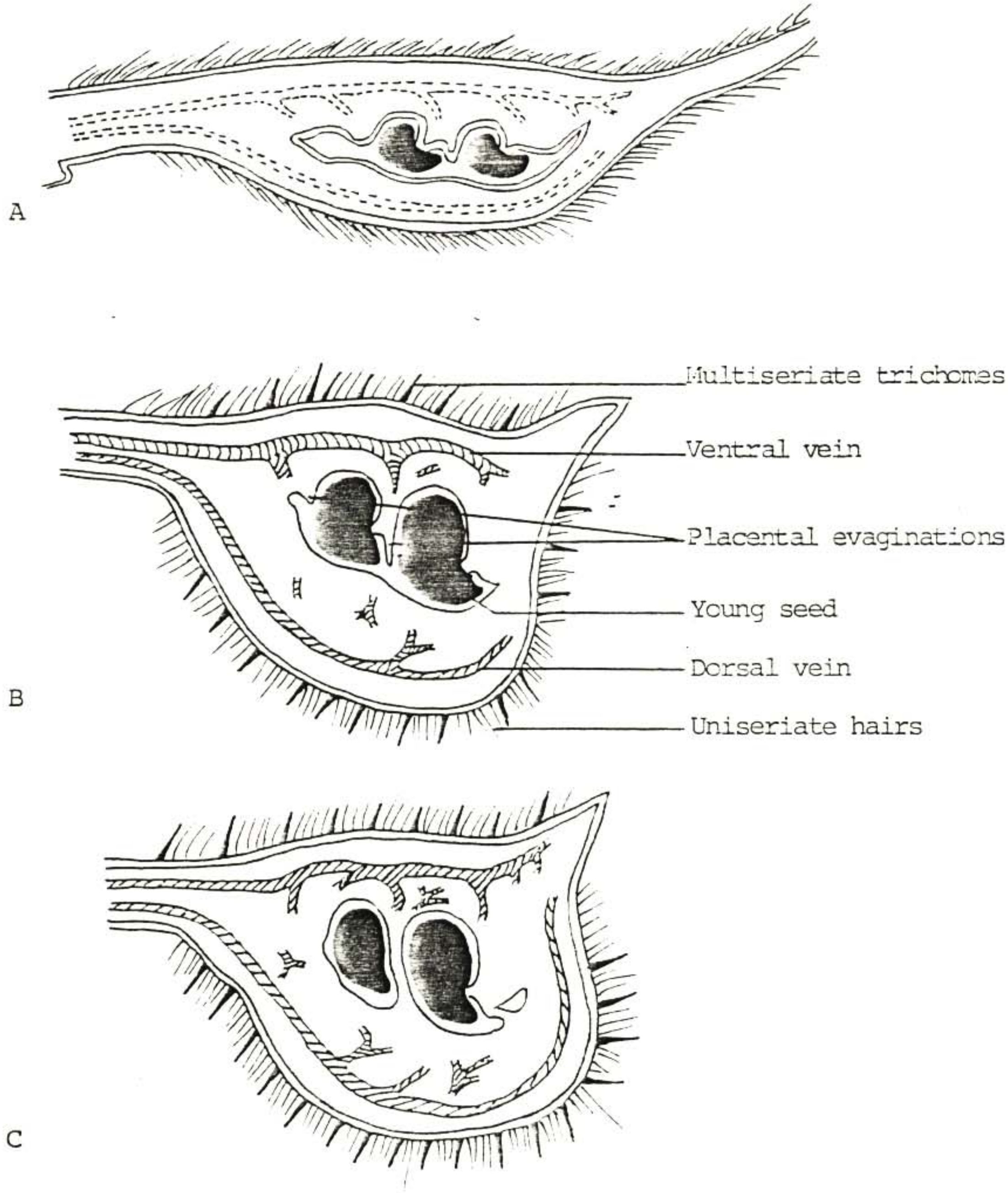


FIGURE 4.1 A–C : Diagrams showing longitudinal sections of the young fruit at different stages of development.

tudinal and transverse sections were made from ovaries and fruits of different ages, to study their developmental stages. These sections were cut by means of a Reichert sliding microtome, and stained with safranin and analin blue, using an Elliot Shandon Varistain machine.

4.3 Results and Discussion:

4.3.1 External Morphology:

The young ovary of Pterocarpus angolensis DC. is similar to other ovaries found in the Papilionaceae. It has a short pubescent stalk. The style is tubular, curving slightly upward, and has a small terminal stigma. The ovary is unilocular with two to three marginal ovules.

Development of the young fruit commences after fertilization, and this development starts with the thickening of the pericarp and bulging of the locule to accommodate the enlarging young seeds. This growth however, does not take place equally along the long axis of the young fruit as is usually the case in the Papilionaceae, whereby the characteristic elongated legume fruit is formed. In P. angolensis, growth occurs largely along the dorsal main vein (dorsal suture), while very little growth occurs along the ventral suture. As a result of this uneven growth, the young fruit rapidly assumes a circular form (Fig.4.1 B-C). Tough bristles develop also at this stage to cover the thickened central portion of the fruit.

4.3.2 Internal Morphology:

In the following discussion, the terms exo-, meso- and endocarp are used for different layers of the pericarp.

In a transverse section of the young ovary, the above three layers can be distinguished. The exocarp is represented by the outermost epidermis, made up of a single layer of thinwalled cells. Two types of multicellular epidermal hairs develop on this layer at an early stage (Fig.4.2 A-B). These are the uniseriate epidermal hairs similar to those found on the ovary stalk, and the bristles which are more than one cell row thick. These bristles seem to develop after fertilization. They are limited to the bulged portion of the young fruit, while the uniseriate hairs are also found on the wing. These bristles become vascularised during development of the fruit, and their vascular bundles become continuous with the vascular supply of the fruit (Fig.4.2 C-D).

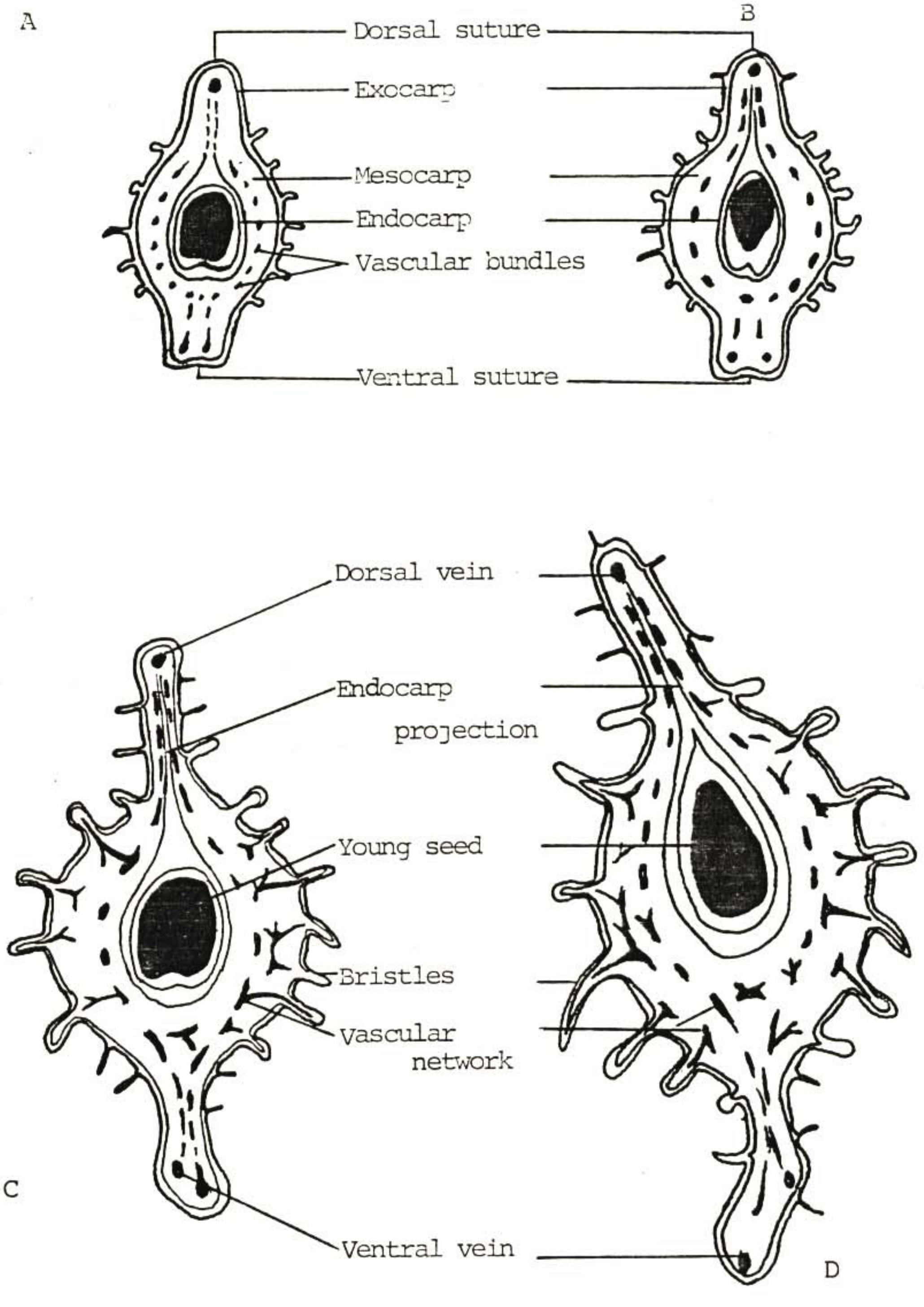


FIGURE 4.2 A-D. Transverse sections(diagrammatic) showing different stages in fruit development.

The mesocarp is represented by the mesophyll tissue of the pericarp. This mesophyll is composed of parenchymatous cells with vascular bundles and secretory cells distributed within it. In the young fruit these vascular bundles form a single circle in the mesocarp. The active growth of the pericarp that results in its thickening after fertilization, takes place primarily in the mesocarp. Together with this growth, branching of the vascular system takes place, resulting in a network of bundles throughout the mesocarp, except for the region where the endorcarp extends into the wing on the side of the dorsal suture.

The vascular bundles forming the above mentioned network, develop fibrecaps which later become larger than the bundles themselves. Cell walls of these fibres become thick and lignified. As the fruit dries out at maturity, the thinwalled parenchyma elements collapse, leaving behind the vascular bundles with their fibrecaps as a rough fibrous network.

In the young ovary the innermost epidermis is composed of a single layer of thinwalled, almost rectangular cells, and this is the endocarp. At the onset of fruit development, these thinwalled cells undergo several periclinal divisions, forming a tissue of storied cells. On the side of the dorsal suture, the endocarp tissue extends for a short distance into the wing of the fruit. In the mature fruit, the larger part of this tissue differentiates into fibres, forming the smooth, fairly hard sclerenchyma wall of the locule. Only the innermost three to four cell layers next to the locule remain thinwalled and parenchymatous. The hard endocarp of the fruit of P. angolensis thus develops from the adaxial epidermis, and morphologically speaking, can be regarded as a multiple epidermis. On the side of the dorsal suture, where there is an extension of the endocarp into the wing, sclerification of the endocarp cells is not as complete as in the rest of the tissue. Cell groups of the endocarp bordering this extension on the outside become sclerified, thus forming two rows of sclerenchyma bundles.

4.3.3 Development of the wing:

Development of the wing also takes place just after fertilization. This development occurs along both sutures, that is, the dorsal and ventral suture, but mainly dorsally. Transverse sections of the young ovary and fruit showed that along the sutures, there are longitudinal ridges, the one along the ventral suture being

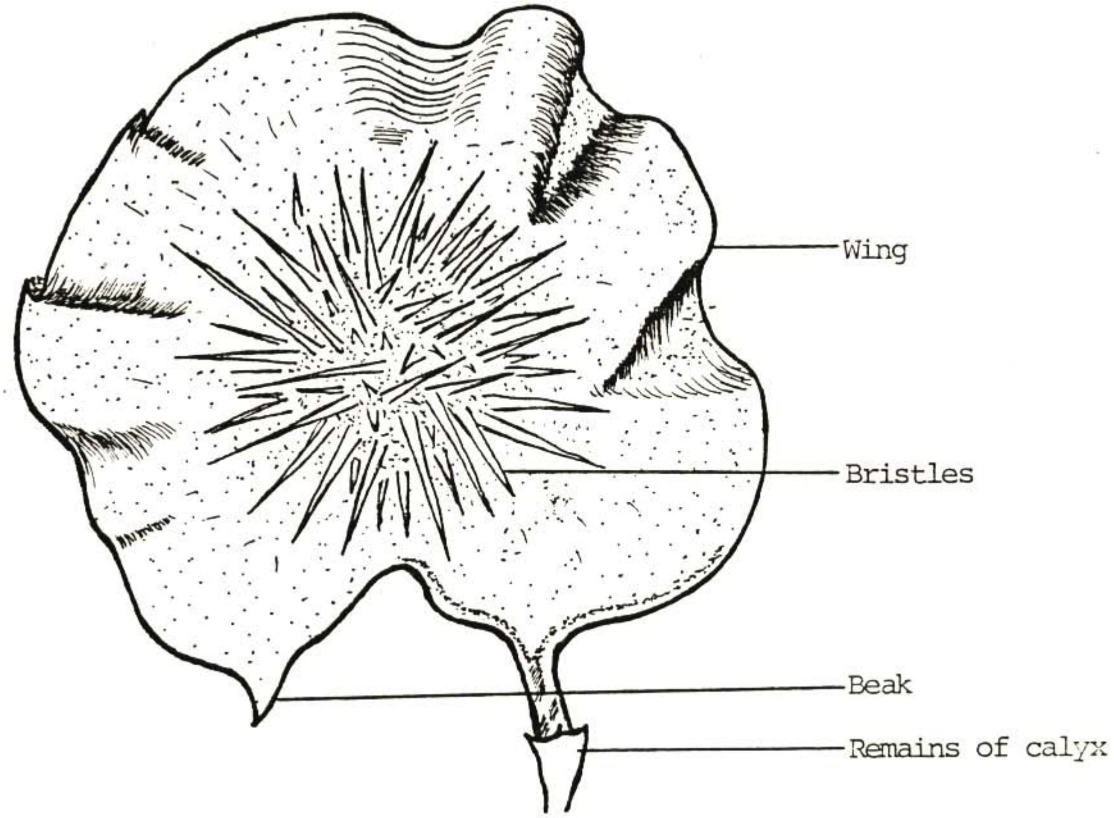


FIGURE 4.3 *Pterocarpus angolensis*. Mature fruit

medially fissured. Three vascular bundles are found within these ridges, one along the dorsal suture, and two along the ventral suture - one within each lobe of the ridge (Fig.4.2.A-B).

The cells forming the slopes of these ridges, both the exocarp and mesocarp cells, immediately below the vascular bundles, undergo repeated anticlinal divisions through which the ridges elongate, thus forming a wing around the fruit. These anticlinal divisions take place more rapidly along the dorsal side of the fruit as compared to the ventral side. No cell divisions take place in the mesophyll cells on the outside of these vascular bundles, hence these bundles become displaced away from the locule, and are therefore found along the margins of the wing. This is also true of the remains of the style, which, due to rapid growth of the fruit along the dorsal side, is displaced by the developing wing. In the mature fruit therefore, the style is found located near the fruit stalk as a pointed beak (Von Breitenbach, 1973). Between this beak and the fruit stalk there is usually a crescent notch in the wing (Fig.4.3). The mature fruit therefore, has a thickened central portion densely covered by long, stiff bristles.

Around this portion is a thin, broad, undulating membraneous wing. These fruits may remain hanging on the tree for a very long period.

Some of the fruits fail to develop a wing, and are generally reddish-brown in colour, with a prominent lateral beak. The entire structure resembles the head of a small bird. Boaler (1966) reported that such malformed fruits are at times found containing seed.

4.3.4 Reorientation of the seeds inside the fruit:

The young ovary of P. angolensis usually contains two, at times three marginal ovules. After fertilization, parts of the placenta at which the young seeds are attached, start forming evaginations into the locule towards the dorsal suture (Fig.4.1.A-C). In this manner, their original, marginal position is changed, with their lower ends coming to face the dorsal suture. These evaginations seem to occur at regular intervals along the locule irrespective of the number of seeds contained, but the size or length of the locule. This then results in the mature fruit having one or two small compartments on either or both ends. These compartments may either be found empty or containing aborted or underdeveloped seeds.

At maturity of the fruit these evaginations are hardened, forming very hard partitions of the locule (Dyer, 1975). This hardening is not only confined to these partitions but to the floor of the locule as well, that is the placental or ventral side of the locule.

It has been mentioned that as the pod reaches maturity and dries out, the thinwalled parenchyma cells of the mesocarp collapse, leaving behind the network of toughened fibrecaps. This is also true of the thinwalled endocarp cells bordering the locule, as well as the unsclerified cells of the endocarp projecting into the base of the wing on the dorsal side. As these cells collapse, they leave behind a narrow slit along the dorsal suture. This slit becomes more evident when the wing and the surrounding network of toughened fibres are carefully removed.

The slit runs the entire length of the dorsal suture, and is only interrupted along its course by the hardened partitions of the locule. The immediate walls forming the "lips" of this slit are fairly thin and fragile as compared to the rest of the fruit wall. This structure of the fruit wall is responsible for the slight opening of the pod on one side due to "repeated wetting and drying" as stated by Groome et al., (1957), Boaler, (1966) and Von Breitenbach (1973).

Due to the reorientation of the young seeds during fruit development, the lower ends of the mature seeds come to lie directly opposite this slit. Troup (1921) in his discussion of the Indian species of the genus, mentions that during germination the radicle emerges from the side of the pod opposite the stalk, and that the pod is raised above the ground, falling with the expansion of the cotyledons. Otherwise the cotyledons are extricated by the arching of the hypocotyl, the pod being left on or in the ground. In this manner therefore, the reorientation of the seeds is most probably an adaptation favouring germination of the seed while still contained within the indehiscent fruit, whereby easy emergence of the radicle is fascilitated.

4.4 Conclusion

The fruit of P. angolensis DC. is a circular winged pod with a basal beak and bristly centre. Its development differs from the normal type of fruit development in the Papilionaceae. It would be most probably similar to that of other winged pods of members of the family with a basal beak, as illustrated in Von Breitenbach's monograph (Von Breitenbach, 1973) on Pterocarpus angolensis.

The ovary is however similar to ovaries of other members of this family. After fertilization the ridges found on the upper and lower sides of the ovary, develop into the wing of the fruit, which is, ontogenetically therefore, derived from the outermost epidermis (exocarp) and the mesophyll (mesocarp) of the young ovary.

As stated by Troup (1921) seeds of Indian species germinate while still contained in pods. If this is true for P. angolensis, it may therefore be concluded here that the reorientation of the seeds, presence of the slit and the structure of the pericarp along the dorsal suture are all adaptations to fascilitate germination of the seeds while still enclosed by the decomposed or decomposing percarp.

CHAPTER 5

MORPHOLOGY OF THE SEED

5.1 Introduction:

The morphology of leguminous seeds has been extensively studied by various researchers in the past. Corner (1951) studied and compared the structure of seeds from various members of the leguminous families and/or subfamilies. He states that the structure of the seed has fundamental importance in classification, and that in the Papilionatae this may even be used in the generic rank. Hyde (1954) described the hilum with respect to seed ripening and the permeability of the testa in some Papilionaceae. Robbertse (1973) discussed the morphology, testa and germination of various *Acacia* species (Mimosaceae) in South Africa, while McNaughton (1974) also gave a brief description of the seed of *Erythrina caffra* Thunb.

5.2 General Features of the Seed:

The seed of *P. angolensis* DC. is approximately thirteen millimeters by nine millimeters in size (Von Breitenbach, 1973) and pinkish to dark brown in colour (Groome et al., 1957). The shape is basically ovate to oblong and

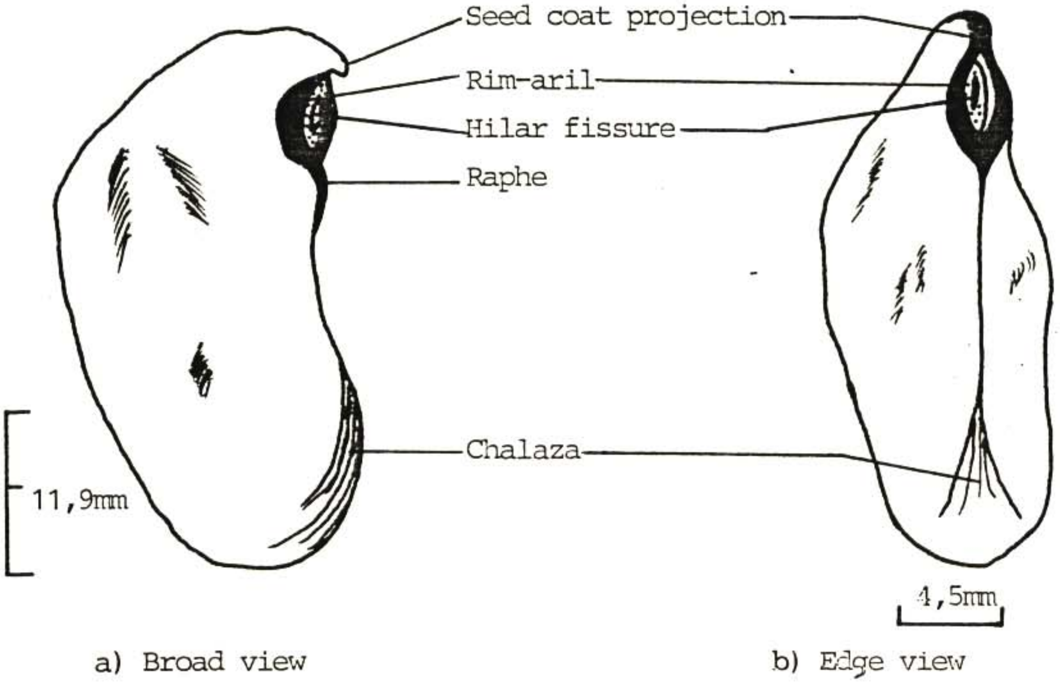


FIGURE 5.1 : External morphology of the seed of Pterocarpus angolensis.

the seeds are laterally flattened or slightly bulged. At the radicle end, the seed coat forms a small rounded projection which in most cases is slightly curved towards the hilum, thus obscuring the micropyle (Fig.5.1A).

The hilum itself is oblong to elliptic and bordered on the sides by prominent ridges, the rim-aril. Due to the presence of the rim-aril, the hilum is sunken below the surface of the seed. At the centre, along the longitudinal axis, is a narrow slit, the hilar fissure (Fig.51b). This in turn is surrounded by a creamy white tissue representing the remains or head of the funiculus (Corner, 1951). The ridges forming the rim-aril join above the hilum and continue upward as the raphe. The testa in general is fairly smooth and shiny due to a waxy covering.

5.3. The Testa:

5.3.1 Procedure:

Seeds used in the study of the testa were abraded on one side with a fine sand paper and soaked in water for twenty four hours to render the testa suitable for sectioning (Marañon & Santos, 1932). Free hand transverse sections were made by means of a razor blade at the hilar region. These sections were stained with picro

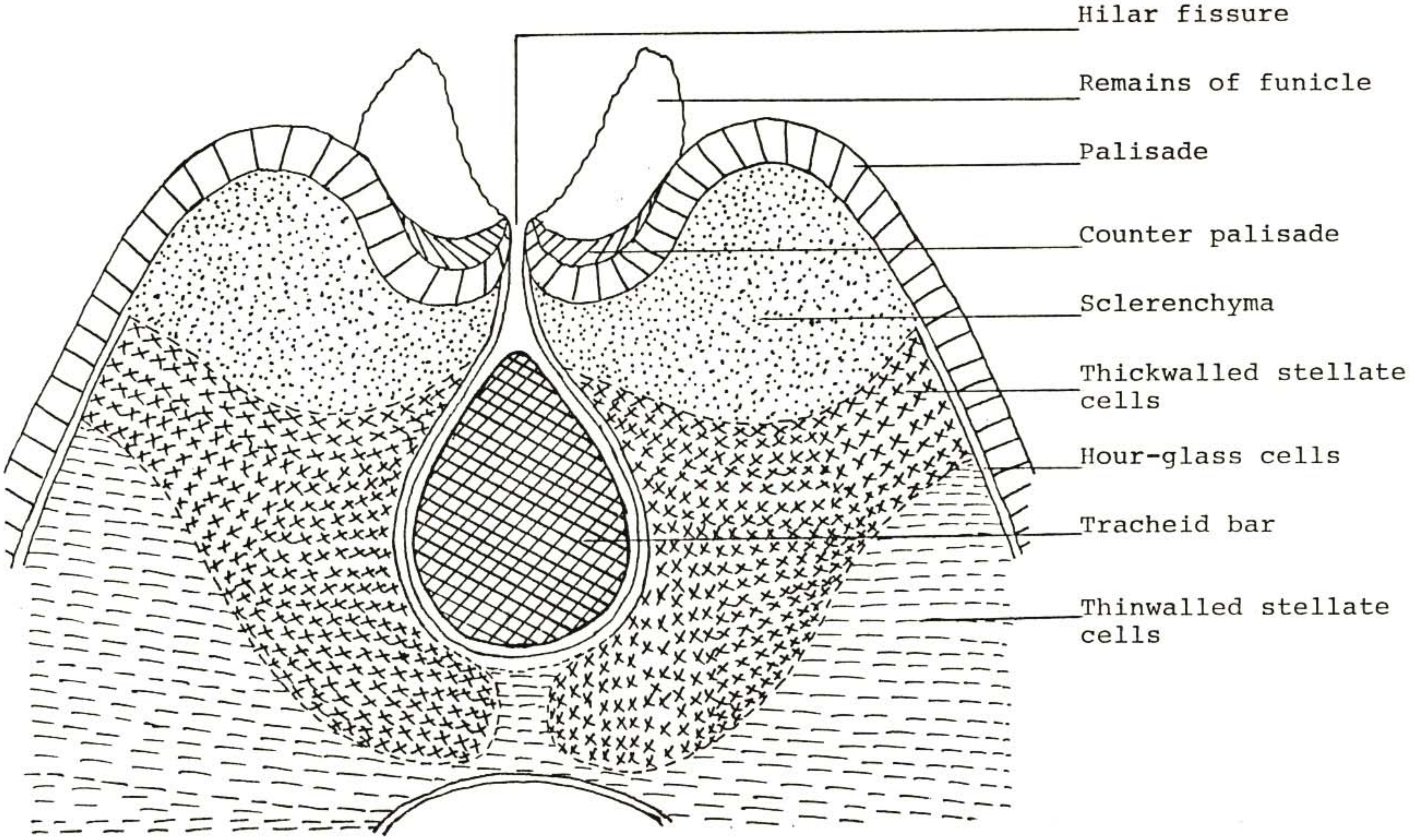


FIGURE 5.2 : Transverse section of the testa at the hilar region

analin and safranin, and mounted in Canada balsam.

5.3.2 Results and Discussion:

Transverse sections at the hilar region of the seed of P. angolensis showed that the structure of the hilum and the distinct layers of the testa are similar to those reported for other papilionaceous seeds. These layers are the palisade, hour-glass cells or osteosclereids, and the mesophyll (Robbertse, 1973; McNaughton, 1974). These layers are depicted in Fig. 5.2.

5.3.2.1 The Hilum:

In P. angolensis the hilum is oval in shape and lies in a fairly deep depression, bordered by the rim-aril (Corner, 1951). At the bottom of this depression is a narrow slit, the hilar fissure, which is the only interruption along the outermost layer of the testa. This slit leads into the tracheid bar made up of a group of short tracheids with large pits (Corner, 1951; Hyde, 1954; McNaughton, 1974).

5.3.2.2 The Palisade:

This is a single layer of columnar cells derived from the outer epidermis of the outer integument (Corner, 1951). Two layers of palisade are however found within the hilar depression, with the outer layer being called the counter-palisade. According to Cutter (1971) and Fahn (1982) the cells of the funicle attached to the palisade layer are transformed into a layer of palisade, forming the counter-palisade, similar to that of the seed coat. This counter-palisade is, on the side of the seed, fused with the palisade of the seed coat and on the opposite side, it is in contact with the parenchymatous remains of the funiculus. This condition, that is, where the counter-palisade lies within the hilar depression, resembles that of _Lupinus arborescens_ L. as illustrated by Hyde (1954) and that of _Crotalaria retusa_ L. by Corner (1951).

In many seeds an optical line, the linea lucida, runs across the cells of the palisade, parallel with and near the surface. According to Cutter (1971) and Fahn (1982) the light refraction differs in these regions from that in other parts of the cells. Corner (1951) on the other hand mentions that this line is absent in many seeds except in the hilar palisade. This line could not be observed in seeds of _P. angolensis_. It is also reported for _Erythrina caffra_ Thunb by McNaughton (1974).

5.3.2.3 The Hour-glass Cells:

Underlying the palisade is a single layer of short columnar, slightly waisted cells with thickened cell walls and intercellular spaces. These are called hour-glass cells (Corner, 1951; McNaughton, 1974). Robbertse (1973) used the term "osteosclereids" for these cells, describing them as "murgbeenvormige selle" (marrowbone shaped cells). This layer stretches from a point more or less in level with the top of the tracheid bar or just below the base of the hilar depression. They are therefore absent in the rim-aril. According to McNaughton (1974) these cells are derived from the subepidermal or hypodermal layer of the outer integument.

5.3.2.4 The Mesophyll:

The mesophyll is found adjacent to, and below the hour-glass cells (McNaughton, 1974). The cells vary in size and shape, depending on their position in the testa.

In P. angolensis transverse sections of the hilar region show that the tissue from just below the hilar depression, and stretching sideways and upward into the ridges of this depression, is sclerenchymatous (Hyde, 1954) and constitute the rim-aril. This tissue is in contact with the palisade since the hour-glass cells do not continue into the rim-aril.

Following this sclerenchyma, and surrounding the rest of the tracheid bar, is a band of tissue with small, thickwalled, stellate cells. This tissue is broadest in the immediate vicinity of the tracheid bar, tapering gradually or abruptly towards the hour-glass cell layer. These stellate cells become progressively larger, thinwalled and with larger intercellular spaces, further away from the tracheid bar. They also become much more branched than the thickwalled stellate cells adjacent to the sclerenchyma of the rim-aril, and cover the entire inner surface of the testa.

The cell layers of this mesophyll nearest, and surrounding the cotyledons, appeared crushed, and this was probably the result of imbibition. The innermost layer, directly in contact with the cotyledons is parenchymatous, with the outer tangential and radial cell walls slightly thickened and staining reddish (McNaughton, 1974).

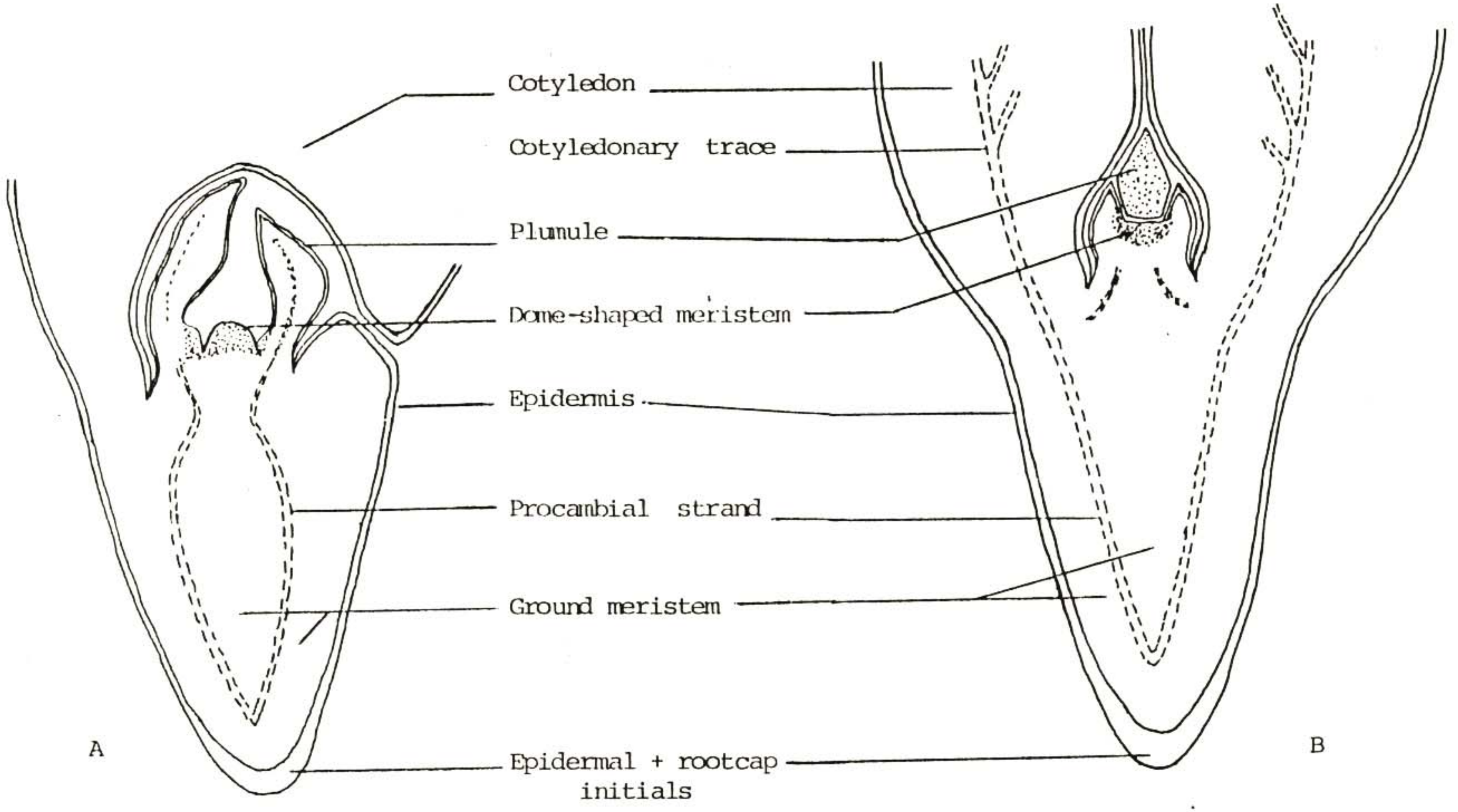


FIGURE 5.3 : Diagrams of longitudinal sections of the embryo axis, showing the broad view (A), and the edge view (B).

5.4. The Embryo:

5.4.1 Procedure:

Seeds used for the study of the embryo were first abraded and soaked in water for about twenty four (Marañon & Santos, 1932). The testa was then carefully removed, the seeds fixed in F.A.A. and prepared for sectioning according to Johansen (1940).

Serial transverse and median longitudinal sections were made, using a Reichert sliding microtome. These sections were stained with safranin contrasted with fast green FCF stain (Johansen, 1940). Some seeds were split open longitudinally in between the cotyledons to expose the plumular-hypocotyl-radicle axis.

5.4.2 Results and Discussion:

The seed of P. angolensis DC. is exalbuminous, and the embryo consists of two large, thick, white to creamy cotyledons which are closely appressed and enclosing a very small plumular hook. Marañon and Santos (1932) refer to this hook as a very small epicotyl bearing two minutes, immature leaves.

Outside the cotyledons and continuous with the plumule, is a very short, almost straight hypocotyl-radicle axis. The hypocotyl is represented by the fairly stout portion which tapers towards and into the radicle.

Longitudinal sections were cut to show an edge view and also a flat view of the embryo axis (Fig. 5.3 A and B). These sections show that the embryo axis is short and straight or almost so. These sections further show that the epidermis of the radicle arises from the same group of initials as the root cap, from the tip of the radicle. At the plumular end is a dome-shaped group of meristematic cells situated between the two immature leaves of the epicotyl. The rest of the embryo axis consists of a large parenchymatous ground tissue. Lying within this tissue and towards its periphery, are the procambial strands which converge towards the radicle tip (Fig. 5.3B).

In transverse sections (Fig.5.4 A-E), the procambium forms a more or less ringlike zone composed of small compactly arranged cells. The centre of this ring consists of a parenchymatous ground tissue with the cells filled with starch grains. Sections cut towards the point of cotyledonary attachment show that this ring has assumed a more or less rectangular shape,

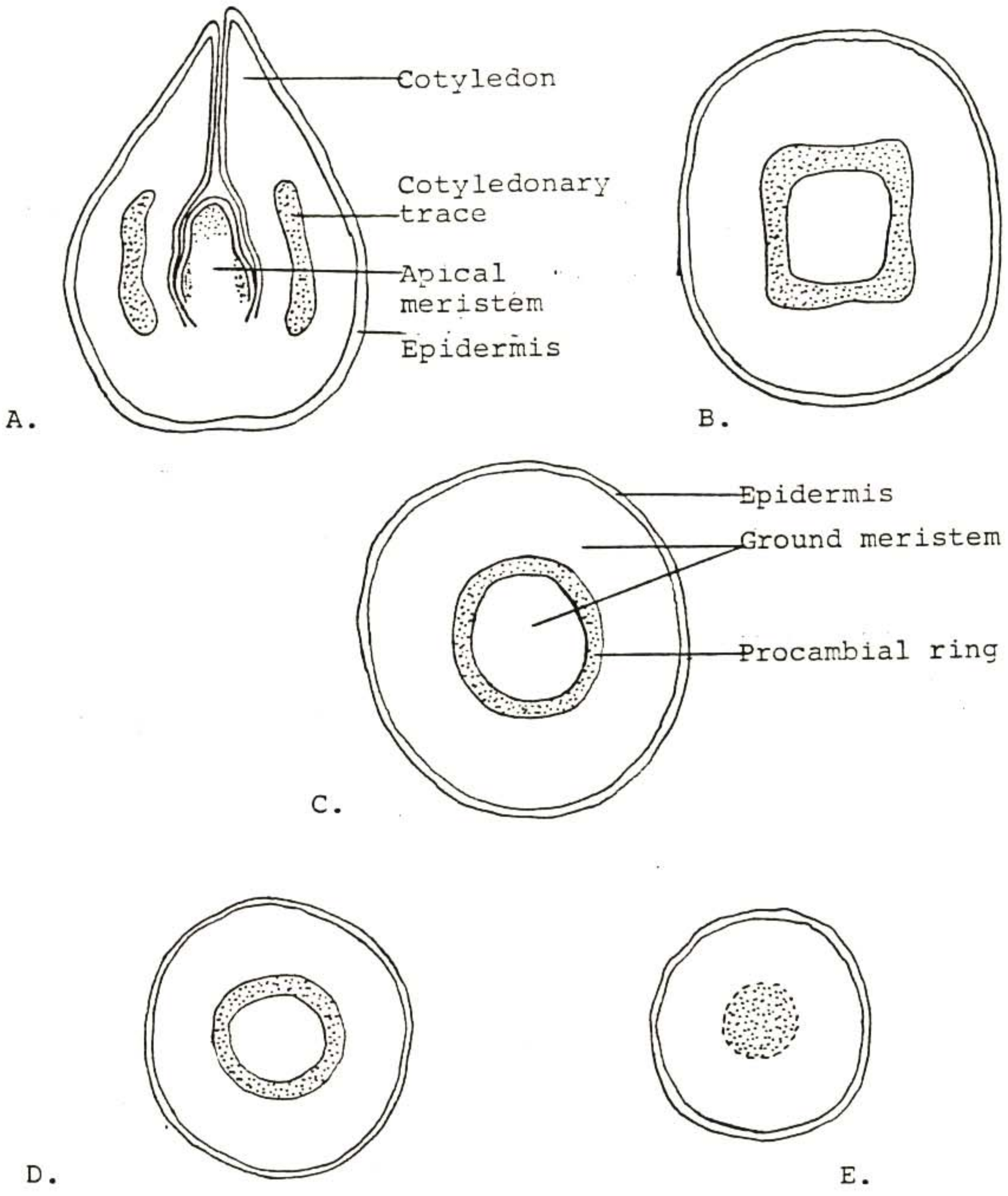


FIGURE 5.4 A-E : Diagrams of transverse sections of the embryo axis at different levels, from the point of cotyledonary attachment (A), to the root-tip (E).

with clearly defined, thickened corners (Fig.5.4B). The two halves of this procambial ring opposite and below the cotyledons, enlarge further and are ultimately seen entering the cotyledons as cotyledonary traces. The residue from these cotyledonary procambia then converge towards the dome-shaped meristem in the plumular hook (Fig.5.4A).

5.5 Conclusion:

The seed of Pterocarpus angolensis DC. is similar to the other previously described papilionaceous seeds. The microscopical structure of the seed coat conforms to the descriptions given by Corner (1951) for Crotalaria retusa L. and by Hyde (1954) for Lupinus arborescens L. In all these cases, the outer-palisade is restricted to within the hilar depression. This situation is different from that of Erythrina caffra Thunb. as described by McNaughton (1974).

As also mentioned by Corner (1951), the rim-aril in the seed of P. angolensis, surrounds the head of the funiculus and is adherent to the hilum. The seed is exalbuminous, with the embryonic axis straight. The cotyledons are large, upright, with thinwalled parenchyma cells filled with starch grains.

CHAPTER 6

SEED PRODUCTION AND GERMINATION

6.1 Introduction:

As mentioned in Chapter 3, P. angolensis DC. produces flowers between August and November (Groome et al., 1957; Boaler, 1966; De Winter et al., 1966, Palmer & Pitman, 1972). Flowering occurs either before, or simultaneously with leaf-flush. Trees in the Koedoe valley near Mooketsi showed first signs of opening of flower buds during mid-September with the majority blooming late September and early October. This was followed immediately by leaf-flush.

6.2 Development and Ripening of the Fruit:

It is stated by Boaler (1966) that flowers of P. angolensis DC. are insect-pollinated, mainly due to their bright colour and sweet scent. Fertilization is followed immediately by fruit development. At the onset of fruit development, the petals fall, the pericarp thickens and the locule enlarges. Morphological and anatomical changes taking place during fruit development have been discussed in Chapter 4.

The young fruit is at first green, and ripening is slow, starting at the earliest by January.

They reach maturity by April, when they become greyish-brown and fully dry (Groome et al., 1957). Mature fruits as stated previously, may remain hanging on the tree until the following season or even longer.

6.3 Production of Viable Seeds:

Fruits were collected from the Koedoe valley in the vicinity of Mooketsi - Northeastern Transvaal during the period February to July. During collection, these fruits were grouped into separate batches, namely, fresh fruits and older fruits. Fresh fruits were those mainly collected from the trees, with fresh intact wings. They also included some recently fallen, undamaged fruits picked from the ground. Older fruits, probably from the previous years' crops, were gathered from the ground, and had pericarps and wings at different stages of decomposition.

The pods were mechanically opened by means of a pair of pruning shears. During this process, these pods were further subdivided into four categories according to the number of seeds they contained (Boaler, 1966). Seeds which were well filled and well developed, with a fresh pinkish brown to dark brown colour, were classified as good or viable, whilst those which were not well filled and with a very dull colouration

TABLE 1: Distribution of seed numbers per fruit and percentage seed production.

	FRUIT					SEEDS						
	BLOCK A	BLOCK B				BLOCK C			BLOCK D			BLOCK E
	Number of fruits	No. of fruits with 0,1,2 & 3 seeds				Expected number of seeds from B			Number of seeds obtained from B			Total number of viable seeds from D
Batches Collected		0	1	2	3	1	2	3	1	2	3	(1 + 2 + 3)
1	654	5	513	133	3	513	266	9	223	119	5	347
2	541	17	399	122	3	399	244	9	146	64	-	210
3	911	17	696	190	8	696	380	24	220	129	12	361
4	1524	71	1202	250	1	1202	500	3	804	250	-	1054
5	805	35	691	74	5	691	148	15	586	96	6	688
Grand Total	4435	145	3501	769	20	3501	1538	60	1979	658	23	2660
Percentages		3,3	78,9	17,3	0,5	100	100	100	74,4	24,7	0,9	52

were classified as non-viable, according to Groome et al., (1957). However, it was found that in some older fruits, the seeds were of very dark brown colour (mahogany), still well filled, and viable. This sorting of seeds into viable and non-viable, was therefore mainly based on the fullness of the testa, since colour alone could be misleading.

The total number of good seeds (Table 1, Block E), made up about fifty two percent (52%) of the total of 5099 expected seeds (Table 1, Block C) from 4435 pods collected and opened (Table 1, Block A). This figure agrees appreciably with that of Boaler (1966) namely, fifty percent (50%) as compared to the ninety percent (90%) of Groome et al. (1957). It was also found that from the total number of pods opened, about seventy nine percent (79%) were one-seeded; seventeen percent (17%) two-seeded while only 0,5% were three-seeded, and three percent (3%) were empty (Table 1, Block B).

6.4. Dehiscence:

Previous investigators like Groome, (1955); Pedro et al. (1955); Groome et al. (1957); Palmer & Pitman (1972) and Von Breitenbach (1973) agree that pods of *Pterocarpus angolensis* DC. are indehiscent or that they open slightly on one side. This slight opening is said to be due to "repeated drying and wetting" (Boaler, 1966; Von Breitenbach, 1973).

After careful removal of the wings, bristles and fibrous network, it was found that walls bordering the dorsal suture are fairly thin and fragile. These walls are slightly parted, thus forming a narrow slit along the entire suture. The formation of this slit has been discussed in Chapter 4.

6.5. Germination:

The work already done on leguminous seeds include amongst others, description of the external morphology of the seeds; structure of the seed coat and its permeability to water and oxygen; embryology and factors affecting germination. These investigations were carried out by workers like Corner (1951) on the general features of leguminous seeds; Hyde (1954) on the function of the hilum in hard seeds of the Papilionaceae; McNaughton (1974) on the embryology and germination of Erythrina caffra Thunb. and Robbertse (1973, 1974) who covered various aspects on the seeds of Acacia species (Mimosaceae). The general conclusion drawn by these investigators is that the majority of these seeds are resistant to water penetration, hence they are said to be "hard seeds".

According to Mayer & Poljakoff-Mayber (1963) the seed coat of many members of the Leguminosae are very hard, resistant to abrasion, covered with a waxy layer, and appear to be entirely impermeable to water. Methods such as mechanical abrasion, impaction, use of organic solvents and treatment with acids (Noggle & Fritz, 1976; Salisbury & Ross, 1969, 1978), have been employed to overcome this problem of impermeability in leguminous seeds. Treatment with concentrated sulphuric acid has been widely and successfully used by different investigators.

6.5.1 Imbibition and germination of seeds:

6.5.1.1 Introduction:

The process of germination is defined by Devlin (1975) as that sequence of steps, beginning with the uptake of water and leading to the rupture of the seed coat by the radicle or shoot. The major factors influencing germination are water, oxygen, temperature and light (Bidwell, 1974). The seed as a resting structure, is usually extremely dehydrated, and surrounded by an essentially impervious cover, the seed coat. Therefore, the first and very important stage of germination is rapid water uptake by imbibition. This is largely determined by the condition of the seed coat. The latter may therefore cause dormancy of the seed, preventing the uptake of water and respiratory gases, and by mechanically restricting the growth of the embryo (Delvin, 1975).

6.5.1.2 Imbibition:

The process of imbibition generally leads to swelling of the seeds with the ultimate rupture of the seed coat. This swelling is accompanied by an increase in the fresh mass of the seeds. The uptake of water is at first rapid, but becomes gradually slower with time.

6.5.1.2.1 Procedure:

The first experiment carried out was to determine the permeability of the testa of the seeds of <u>P. angolensis</u> DC. to water. The method followed in this experiment, and subsequent ones, was the weighing method described by Salisbury & Ross (1969) as the "tissue volume method". The seeds used were all unscarified, obtained from fresh and older seed groups separately.

Four sets of seeds, that is, two from each group, were weighed out to ±5g. These were then placed in four autoclaved, 9cm glass petri dishes, on three layers of Whatman No.1 filter papers. The filter papers were moistened with

15ml of distilled water. The petri dishes were marked Y1 and Y2 for fresh seeds, and 01 and 02 for older seeds before they were put in an incubator at 30^0C. The seeds in each set were reweighed in twenty four hours' intervals for four days, to determine any change in their fresh mass, using a Mettler H8 balance. Before each mass determination, seeds were blotted dry to get rid of excess moisture.

In the second experiment only fresh seeds were used. These seeds were first scarified in three different ways to break the impermeability of the testa to water which became apparent in the first experiment. The three methods of scarification used were:- (i) soaking the seeds in concentrated sulphuric acid for 45 minutes and then rinsing them thoroughly in distilled water and afterwards allowing them to dry; (McNaughton, 1974) (ii) cutting off of the seed coat projection at the radicle end, using a sharp knife and taking care not to damage the radicle; and (iii) abrading the seeds on one side, using a fine sand-paper.

In each of the above methods, four sets of seeds, each again weighing ±5g. were prepared after treatment. The respective petri dishes were labelled A1 to A4 for abraded seeds; B1

Table 2: Effects of different scarification methods on imbibition of the seeds of *Pterocarpus angolensis* DC

Petri dish sets	Number of seeds (61)	CHANGE IN MASS (g) PER HOUR					
		ABRADED SEEDS					
		0	1	2	3	4	12
A1	15	4,985	7,483	7,892	8,297	8,548	11,255
A2	15	4,884	6,806	7,705	7,980	8,234	10,767
A3	17	4,902	6,920	7,526	7,771	8,008	10,152
A4	14	4,974	7,341	8,080	8,303	8,692	11,361
MEANS		4,936	7,138	7,901	8,088	8,371	10,884
SEED COAT PROJECTION CUT OFF							
B1	14	5,010	5,040	5,576	5,686	5,872	9,128
B2	16	4,962	5,120	5,715	5,901	6,031	
B3	15	4,987	5,083	5,264	5,311	5,441	10,166
B4	16	5,024	5,136	5,502	5,702	5,956	8,897
MEANS		4,996	5,095	5,514	5,650	5,825	9,435
ACID SCARIFIED SEEDS (45Minutes)							
C1	16	4,835	5,637	6,498	6,765	7,102	10,131
C2	16	4,941	5,752	6,510	6,858	7,126	10,350
C3	13	4,528	4,931	5,844	6,102	6,430	9,426
C4	16	4,971	5,492	6,412	6,596	6,984	10,291
MEANS		4,819	5,453	6,316	6,580	6,911	10,050

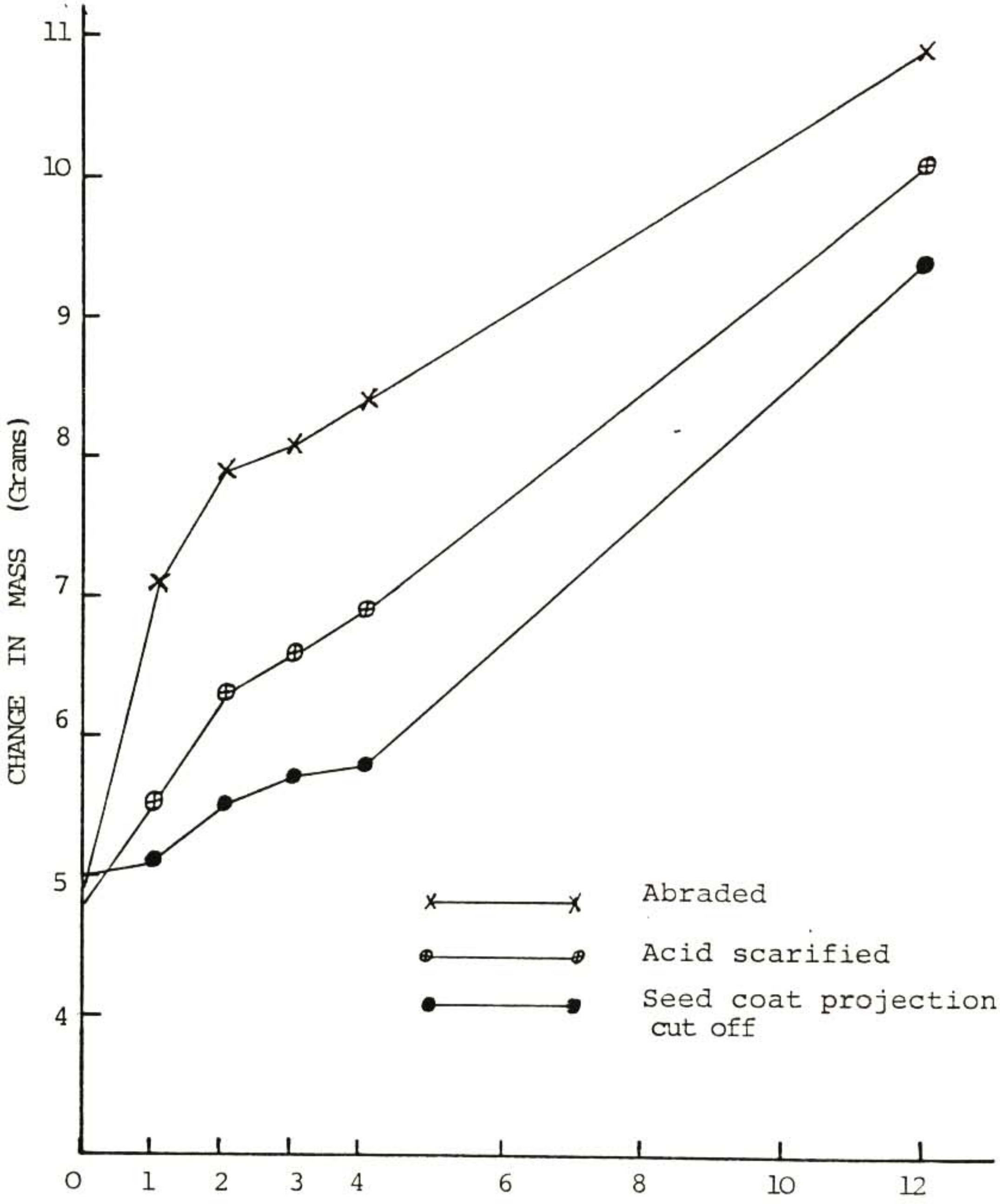
to B4 for seeds where the seed coat projection had been cut off, and C1 to C4 for acid scarified seeds.

The four sets of seeds from each batch, that is A,B, and C, contained a total of sixty one seeds. Abraded seeds were placed on moistened filter papers with the abraded sides in contact with paper (McNaughton, 1974). Changes in mass of the three batches were determined hourly for the first four hours, and then after twelve hours. The mean mass of each batch of seeds in each treatment were plotted against time (Fig.6.1).

6.5.1.2.2 Results and Discussion:

It became apparent from the results obtained in the first experiment that the seeds of *Pterocarpus angolensis* DC. have seed coats that are impermeable to water. All of the fresh seeds did not show any change in mass, while a very slight increase in mass was noticed from a few among the older seeds. This could only mean that the testae of these seeds have been corroded either by micro-organisms, or other natural factors could have played a role in reducing their impermeability to water. Some of these swollen seeds became mouldy and the fungi causing this were identified as species of *Penicillium*, *Cladosporium* and *Alternaria*.

FIGURE 6.1 Effect of different scarification methods on imbibition



When seeds were soaked in concentrated sulphuric acid, the cuticle peeled off (Hamly, 1932), and broke away from the seeds when washed in distilled water. Seeds soaked for longer periods of up to sixty minutes showed extensive corrosion of the testa, and this could also be noticed on the cotyledons as small burnt spots. This treatment therefore not only removed the thick cuticle but also perforated the testa to become readily permeable to water and respiratory gases as well (Hyde, 1954; Robbertse, 1973; McNaughton, 1974).

McNaughton (1974) when investigating seed germination in <u>Erythrina</u> <u>caffra</u> Thunb., soaked the seeds in concentrated sulphuric acid for two hours. Salisbury & Ross (1969) mention however that seeds of some species may be soaked briefly, for a few minutes to an hour. In this study, it was found after several trials, that soaking the seeds for fourty five minutes was sufficient.

Among the three scarification methods used, the results showed that abraded seeds imbibed water fairly rapidly with the second best being acid scarification. Any further determinations in change of mass were stopped after the first twelve hours' interval since emergence of the radicle could already be observed among acid

Table 3: Effect of scarification on percentage germination of the seeds Pterocarpus angolensis DC

Petri dish sets	Number of seeds	ACCUMILATIVE NUMBER OF GERMINATED SEEDS PER DAY						
		ABRADED SEEDS						
		1	2	3	4	5	6	7
A1	15	0	0	0	1	2	2	4
A2	15	0	0	2	2	4	4	6
A3	17	0	0	2	2	2	2	7
A4	14	0	0	2	2	3	3	3
TOTAL	61	0	0	6	7	11	11	20
% GERMINATION		0	0	9,8	11,5	18,0	18,0	32,8
SEED COAT PROJECTION CUT OFF								
B1	14	0	0	1	3	3	4	9
B2	16	0	0	5	6	7	8	10
B3	15	0	2	3	5	5	5	9
B4	16	0	2	8	11	12	12	12
TOTAL	61	0	4	17	25	27	29	40
% GERMINATION		0	6,6	27,9	41,0	44,3	47,5	65,6
ACID SCARIFIED SEEDS (45 Minutes)								
C1	16	0	11	14	14	16	16	16
C2	16	0	3	11	14	14	14	15
C3	13	0	9	12	12	12	12	13
C4	16	0	8	15	15	15	16	16
TOTAL	61	0	31	52	55	57	58	60
% GERMINATION		0	50,8	85,2	90,2	93,4	95,1	98,4

scarified seeds. The results obtained are represented in Table 2.

6.5.1.3 Germination:

The above experiment on imbibition was continued to study the effect of the three methods of scarification on the germination of the seeds. Emergence of the radicle from the seed coat (Fig.6.2) was taken as an indication of germination (Lang, 1965 in McNaughton, 1974).

6.5.1.3.1 Procedure:

The germinated seeds were counted every twenty four hours for a period of seven days. An extra 10 ml of distilled water was added to each petri dish to avoid drying of the filter paper. This counting was made from each petri dish in a batch, and the sum total of the figures obtained was expressed as percentage germination from each batch (Table 3). These percentages were then plotted against time in days (Fig.6.3).

Apart from the seeds germinated in petri dishes, a batch of twenty five acid scarified seeds, and another of twenty five unscarified older seeds were sown directly, in groups of five, in pot plant soil contained in black plastic bags. These bags measured ±18cm in diameter and ±24cm in height, and filled with soil to

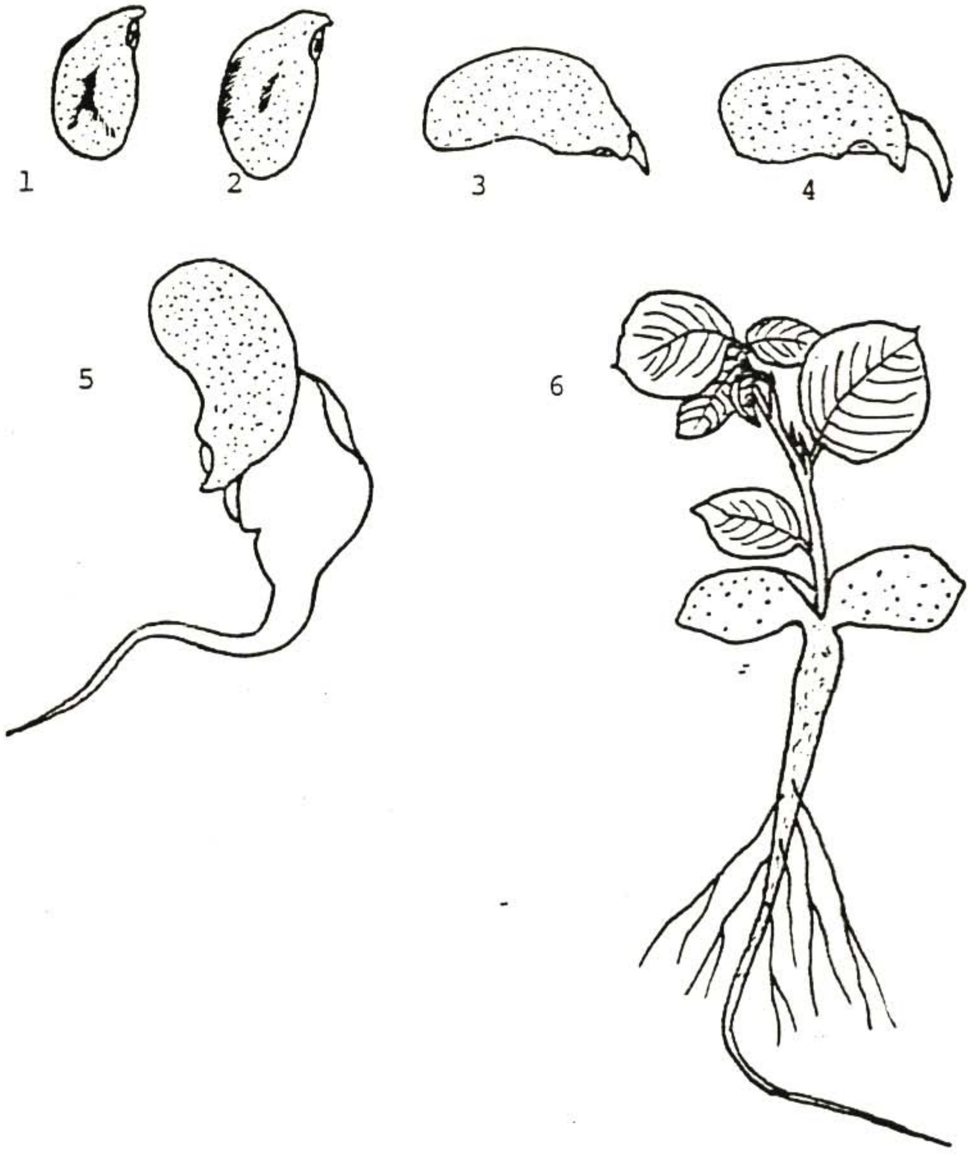
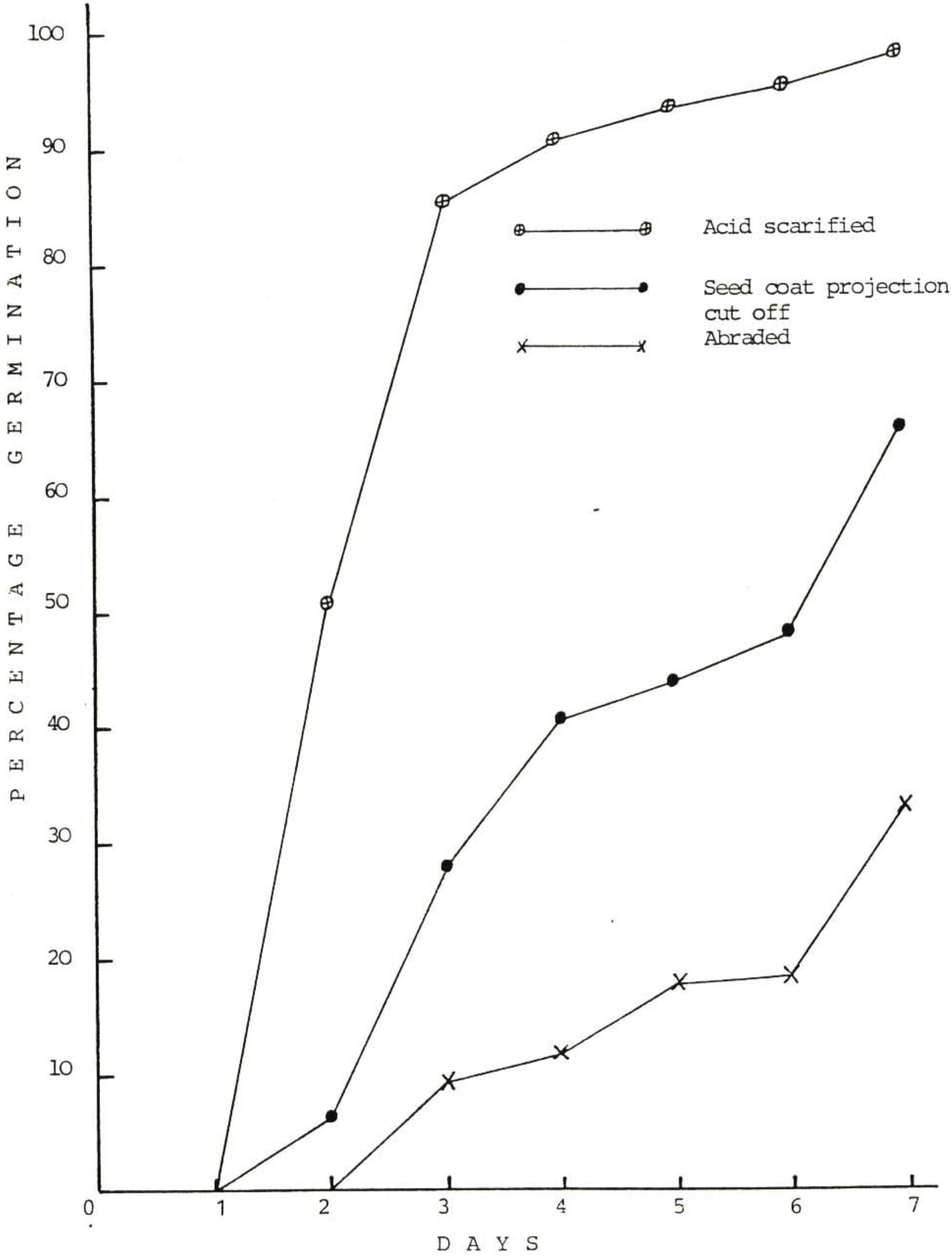


FIGURE 6.2 : Diagrammatic representations of germination stages in seeds of <u>Pterocarpus</u> <u>angolensis</u>.

1-2 = imbibed seeds; 3-5 = germinating seeds; 6 = 27 days old seedling.

FIGURE 6.3: Effects of different scarification methods on percentage germination



about 2cm below their tops. The seeds were placed $\pm$5mm below the soil surface. The bags were kept in the laboratory wherein the room temperature ranged between 20^0C and 28^0C for the entire experimental period of thirty days.

Some of the seedlings that resulted from germination of these seeds, were transplanted outdoors after three months, while the remainder were left in the laboratory. The seedlings were transplanted into $1m^2$ holes which were $\pm$0,5m deep. Decomposed manure was added at the bottom and thoroughly mixed with the dug out soil before planting.

6.5.1.3.2 Results and Discussion:

Although the abraded seeds imbibed water more readily during the first few hours as compared to acid scarified seeds, germination results (Table 3) showed that the latter germinated much better. Some of the abraded seeds had their testa cracking transversely, with the two portions separating gradually, thus revealing the creamy cotyledons. In these seeds, the radicle failed to pierce the testa, but instead pushed the lower portion away as it enlongated. Such seeds were also counted as having germinated.

On the other hand, the cut off seed coat projection at the radicle end of the seeds was expected to fascilitate radicle emergence, thus giving better germination results. This however, was found not to be the case, and failure of the radicle to emerge promptly, was interpreted as a mechanical growth restriction of the embryo by the hard seed coat.

Acid scarified seeds sown in the soil gave 62% germination at the end of the thirty days while older unscarified seeds gave only 20% germination within the same period. This low germination percentage of untreated seeds enhances the fact that P. angolensis DC. produced hard seeds like most members of the Papilionaceae. It also shows that the testa could have been previously punctured or worked on by micro-organisms (McNaughton, 1974) or other scarifying agents while lying on the ground before collection of the fruits.

Seedlings transplanted outdoors progressed poorly as compared to those kept in the laboratory. It was found that the shoots of these young plants were frequently destroyed by insects like caterpillars or grass-hoppers (Boaler, 1966) which fed mainly on their leaves and young soft branches. Their roots, however, remained strongly developed. Those plants kept in the laboratory, besides being well developed and growing fairly fast, were later found to have been attacked by red spider, a phenomenon that was also noticed in naturally growing plants during various periods of fruit collection.

6.6 Conclusion:

Pterocarpus angolensis DC. produces fruits that are mainly one- to two-seeded, and rarely three-seeded as shown in Table 1. The poor or slow germination capacity of the seeds can be ascribed to two main factors, namely, the hard, slightly dehiscent pericarp and the hard impermeable testa which also restricts growth of the embryo. This species therefore, shares this characteristic of an impervious seed coat with other members of the Papilionaceae.

The results also show that the hulled seeds must first be scarified before sowing (Gordon, 1971). Such a treatment results in satisfactory germination. In nature this is brought about by the activity of micro-organisms (Salisbury & Ross, 1969, 1978) which can, on the other hand, damage the seeds completely, thus reducing their viability much further. Trampling by larger animals on thoroughly or partially decomposed pericarps may also be of value in overcoming this problem of impermeable seed coats.

CHAPTER 7

EXTERNAL MORPHOLOGY AND ANATOMY OF THE SEEDLING.

7.1 Introduction:

The external morphology of the seedling of Pterocarpus angolensis DC. has been described by Groome et al. (1957) in their brief discussion of the early stages of development of the plant; Boaler (1966) when studying the ecology of this species in Tanzania, and Von Breitenbach (1973) in his monograph on the species. Both Boaler (1966) and Von Breitenbach (1973) mentioned that the seedlings die back annually, while the root system develops continually. According to these authors, this phenomenon of annual die back carries the seedlings into the sapling stage, wherein the plants acquire permanent, healthier aerial shoots. The internal morphological changes of the seedling, particularly the root, are not elucidated in the available literature. An attempt was therefore made during this study, to clarify these changes associated with seedling development.

7.2. Material and Procedure:

Seeds germinated to obtain seedlings for this investigation were first acid scarified as described in Chapter 6. These treated seeds were then divided into three groups of twenty five seeds each and germinated as follows:- the first group was incubated in 9cm glass petri dishes on moistened filter paper at 30°C; the second group was sown directly in pot plant soil in black plastic bags (See Chapter 6, par.6.5.1.3.1), the seeds being planted about one centimetre below the soil surface. The third group of seeds was sown in vermiculite in rectangular fibre glass containers measuring approximately 30cm in length, 18cm in breadth, and 16cm in height. These seeds were germinated and grown to obtain material for morphological investigations of the seedling at different ages.

Seeds germinated in petri dishes were used to study early stages of germination, and for purposes of anatomical studies as well. Seedlings at different ages, namely, three-, five-, and seven days, were removed and fixed in F.A.A. Those grown in vermiculite were used to study the root system and the aerial shoots, both externally and internally. They were uprooted after seven, fourteen, twenty one, twenty eight days, and after three months, respectively. These were also fixed in F.A.A. and then prepared for sectioning according to Johansen (1940).

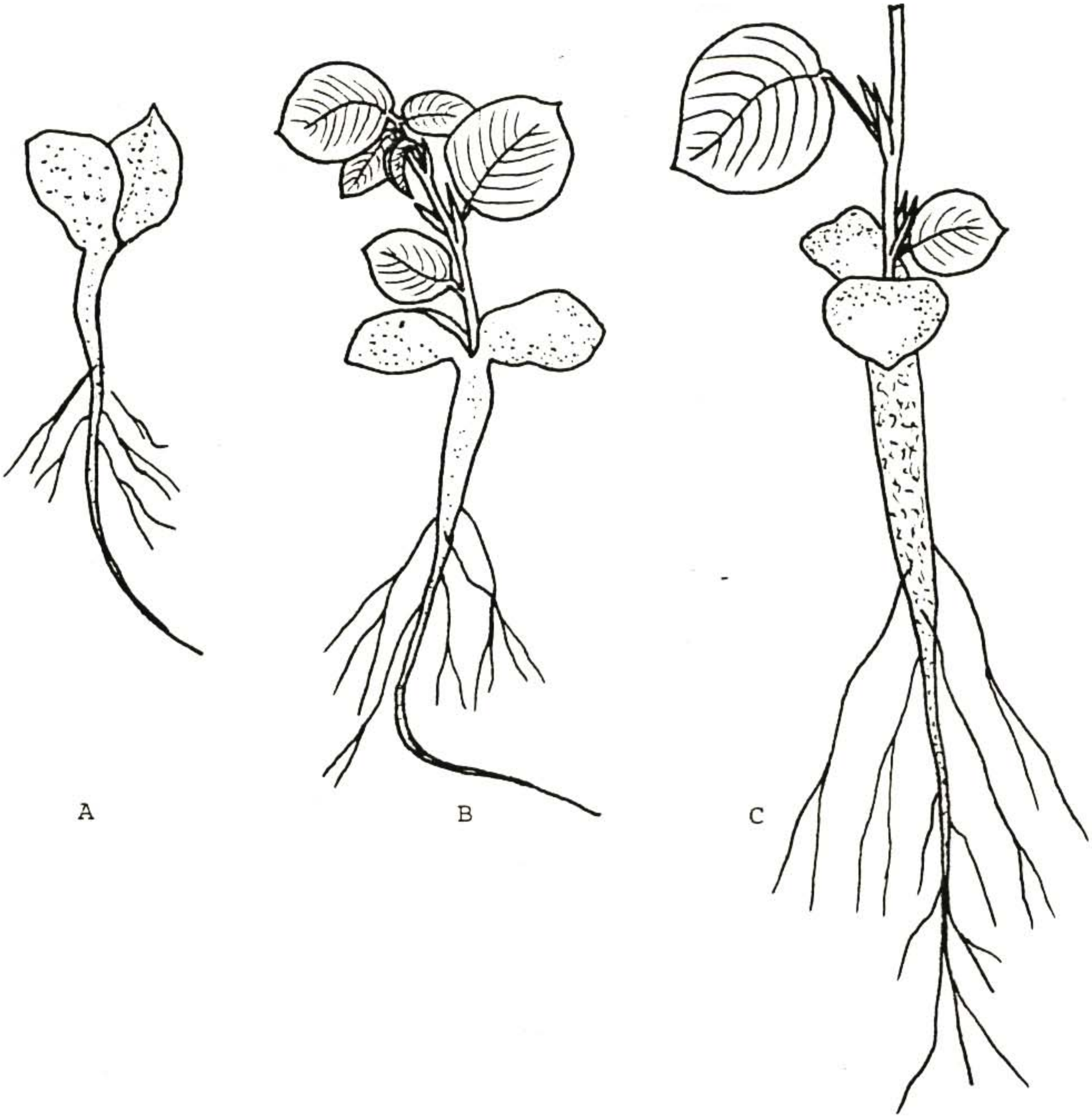


FIGURE 7.1 A–C : Diagrammatic representations of seedlings of Pterocarpus angolensis, grown in vermiculite. A, 4 days old; B, 27 days old; C, 3½ months old.

Transverse sections at different levels of the primary root, hypocotyl, stem, cotyledons and leaves (pinnae) were made to study the developmental sequence of the vascular tissue, as well as other component tissues. These sections were made by means of a Reichert sliding microtome, adjusted to 15 microns. The sections were stained with safranin and analin blue, using an Elliot Shandon Varistain machine.

7.3 Results and Discussion:

7.3.1 Seedling External Morphology:

Germination in P. angolensis DC. is epigeal, the radicle elongating and emerging through the cracked seed coat and growing downwards (Troup, 1921; Groome et al., 1957; Von Breitenbach, (1973). In the meantime, the hypocotyl which at this stage has increased in circumference, elongates and grows upward, carrying with it the cotyledons to just above the soil surface.

After shedding the testa, the cotyledons become large and fleshy. At first they are pale green, turning to a deeper green colour when fully grown. They are subsessile, opposite, obovate to oblong. During the first three to four days, they are the only evident aerial portion of the seedling except for the short hypocotyl below (Fig.7.1A). Careful removal of one of the cotyledons from a four days old seedling revealed a fairly small and weak, pale green plumule at the base of the cotyledons. These cotyledons were found to persist for over three months, remaining green throughout until they become abscised (Fig.7.1B-C).

The epicotyl when emerging, is slender and pale green, with a laterally borne conduplicate leaf. The first two or three foliage leaves are simple, obovate or sub-obovate and alternate, with a pair of stipules at the base of the petioles. Both the young stem and leaves are pubescent, with leaves bearing trichomes on the lower epidermis. The subsequent three to four leaves that develop along the stem are trifoliate, with the terminal pinnae the broadest (Fig.7.1B). Peels of silicon grease made from both sides of the leaves (Witham et al., 1971), revealed that these leaves or leaflets bear paracytic stomata on the lower epidermis.

Below the cotyledons is a fairly thick hypocotyl which in a seven days old seedling is pale green and glabrous. In these young seedlings a distinct line of demarcation is visible between the primary root and hypocotyl. This primary root tapers gradually towards the tip, and bears fibrous secondary roots.

In a three months old seedling (Fig.7.1C), the primary or taproot is stout and carrot-like (Troup, 1921; Groome, 1955; Groome et al., 1957; Von Breitenbach, 1973), being much larger and stronger than the aerial shoot. This thickened root is basically storage in function, the reserves of which may be necessary for the regeneration of aerial shoots after each die back phenomenon. This is interpreted by various other researchers as an adaptation to a fire factor (Exell & Stace, 1972; Von Breitenbach, 1973).

7.3.2 Anatomy of the Seedling:

Although a number of papers has been published on the external morphology of the seedling of P. angolensis DC., no information concerning the seedling anatomy could be found in the literature. The object of this study was thus to investigate the anatomical aspects of seedling development.

7.3.2.1 The Root:

7.3.2.1.1 Primary Structure:

Transverse sections of young roots show that they are typically dicotyledonous, with the following tissue sequence, starting from the outside:-

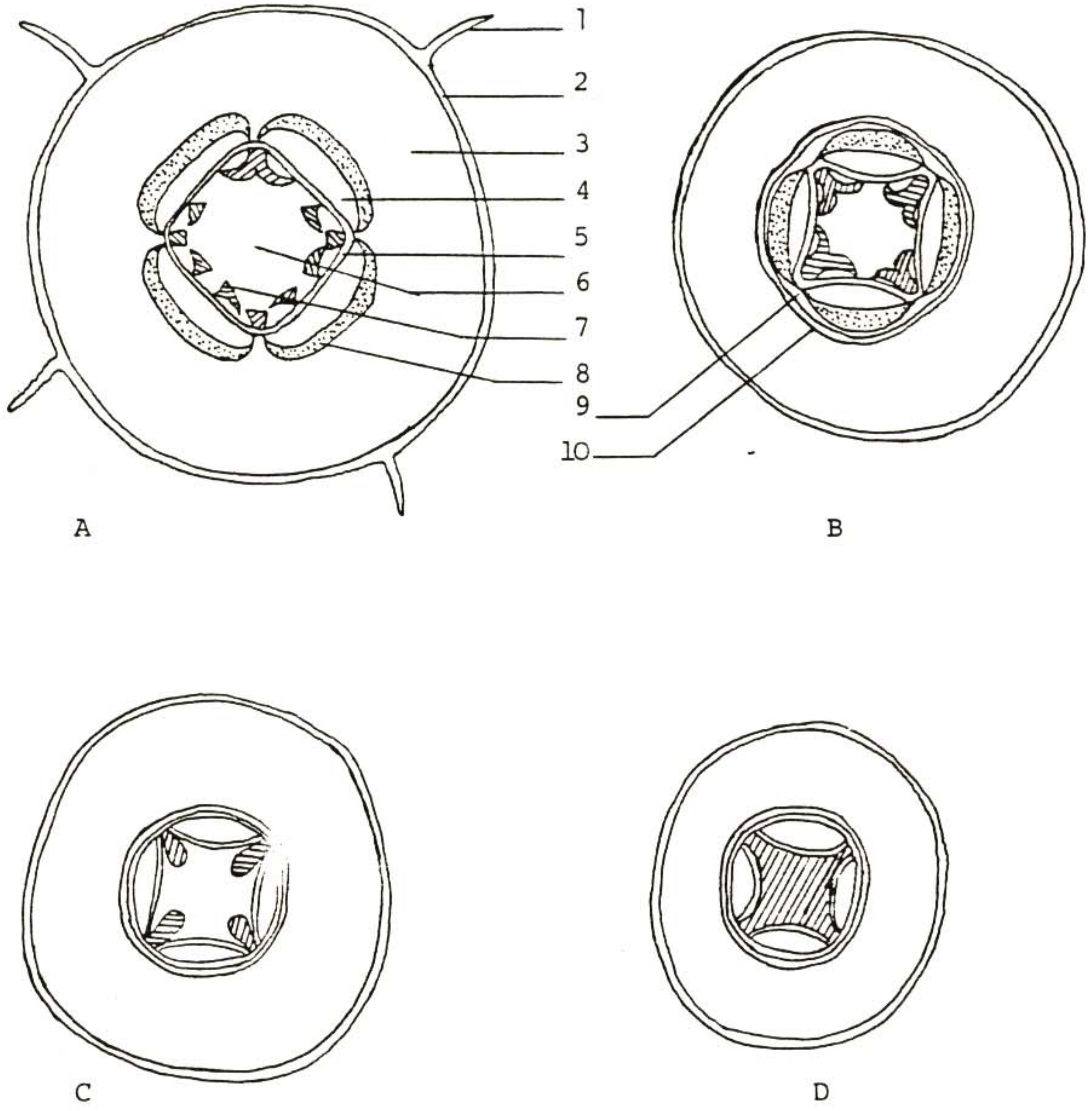


FIGURE 7.2 A–D : Diagrams of transverse sections of the young root, from the roothair zone (A), to the root-tip (D).

1 = roothair; 2 = epidermis; 3 = cortex; 4 = primary phloem;
5 = cambium; 6 = pith; 7 = primary xylem strands; 8 = protophloem fibres;
9 = pericycle; 10 = endodermis.

(i) Epidermis:- This consists of a single layer of somewhat irregularly shaped thinwalled cells. Root hairs are present, and confined to a region near the root tip. These hairs die off on the more mature portions of the root (Fahn, 1974).

(ii) Cortex:- Underlying the epidermis is a rather extensive tissue, the cortex. It consists of parenchyma cells which, in older sections, are filled with starch grains.

(iii) Endodermis:- The endodermis represents the inner boundary of the cortex (Fahn, 1974, 1982), and consists of a single layer of cells. These cells have casparian strips, which are very clearly visible in sections of young roots on the radial and transverse walls.

(iv) Pericycle:- This is made up of two to three parenchymatous cell layers just beneath the endodermis. It forms the outer boundary of the vascular cylinder.

(v) The Vascular Tissue:- This tissue occupies the central portion of young roots. Transverse sections cut towards the root tip show that the primary xylem is tetrarch, with the primary phloem groups situated in the angles formed by the star-shaped xylem. Maturation or differentiation of these primary vascular tissues, that is, primary xylem and phloem, is centripedal, the protoxylem and protophloem occuring in peripheral positions. This condition in the xylem is referred to as exarch, and is clearly visible in transverse sections made towards the root tip (Fig.7.2.D).

The primary phloem groups are separated from the primary xylem by two to three layers of thinwalled, undifferentiated parenchyma cells, one layer of which later becomes the cambium. At first therefore, the cambium consists of four separate strips of tissue (Cutter, 1971). Above each primary phloem group is a band of sclerenchyma with fairly thickened but unlignified cell walls.

No pith is present near the root tip, but in sections cut higher up, a parenchymatous pith is present. Such a pith is also found in Erythrina caffra Thunb. (McNaughton, 1974). This however, according to McNaughton (1974), is an unusual phenomenon in the Leguminosae. On the other hand, Compton (1912b) mentions that the stele takes the opportunity afforded by the increased diameter to acquire a pith, and expand. In this regard therefore, a correlation exists between the diameter of the vascular cylinder and the presence or absence of the pith (Fahn, 1974, 1982).

7.3.2.1.2 Vascular Transition and the Hypocotyl:

According to Compton (1912b) the early recognition of the stem and the root as distinct morphological units, directed attention to the region of the main axis where the change from root to stem is located. This region, called the transition region, has been described and discussed by workers like Eames & MacDaniels (1947); Esau (1962, 1965a) and Fahn (1974, 1982). These researchers agree that this change involves the reorientation of the radially arranged, independent exarch xylem and centripetal phloem of the root, into bundles containing collateral xylem and phloem, in this case the xylem being endarch.

Eames & MacDaniels (1947) maintain that the transition region may occur at the top of the radicle; at the very base of the hypocotyl, or near its centre, or even its upper part.

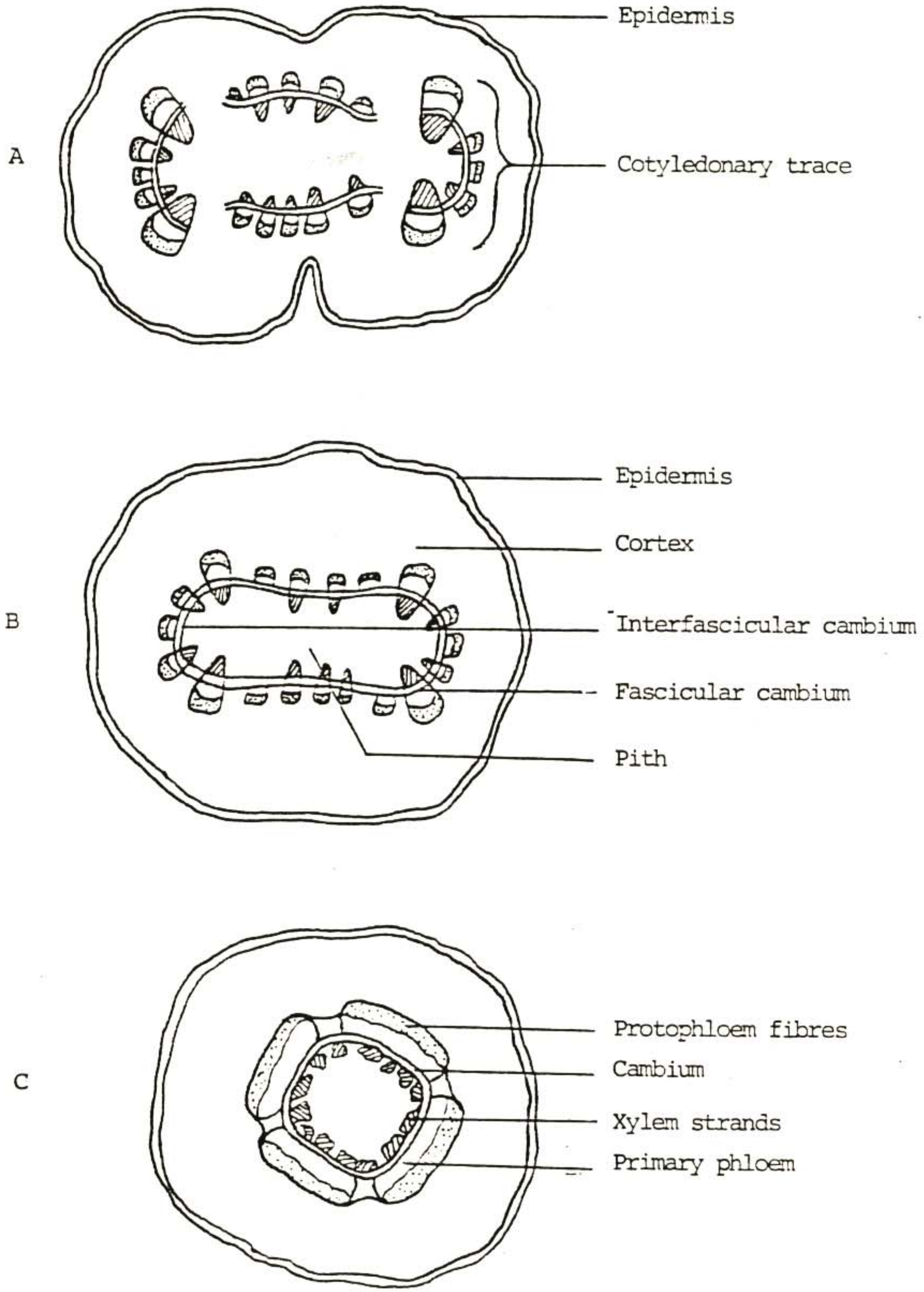


FIGURE 7.3 A-C : Diagrams of transverse sections of the hypocotyl at different levels of 5mm intervals, from just below the point of cotyledonary attachement (A).

They mention furthermore that this change from root to stem is accompanied by a considerable increase in the diameter of the stele.

Transverse sections made from a seven days old seedling of P. angolensis DC. just above the root tip showed four exarch xylem strands surrounding a parenchymatous pith. These xylem strands are more or less triangular in shape as seen in transverse section (Fig.7.2C), with their apices (protoxylem poles) directed outward. According to Weaver (1960) this arrangement precedes forking and inversion of the exarch xylem of the root and the changeover into the endarch condition. This was found to be the case in sections made higher up, as shown in Fig.7.2B.

Above this region of forking and inversion, the development of the xylem is almost completely endarch, and it is this region that is here regarded as the base of the hypocotyl. Multiplication of the vascular bundles (Weaver, 1960) or the xylem groups, is observed from just above this point upwards (Fig.7.3C). Transverse sections made towards the point of attachment of the cotyledons show cotyledonary traces departing in a double-trace unilacunar pattern. These traces consist of two larger lateral

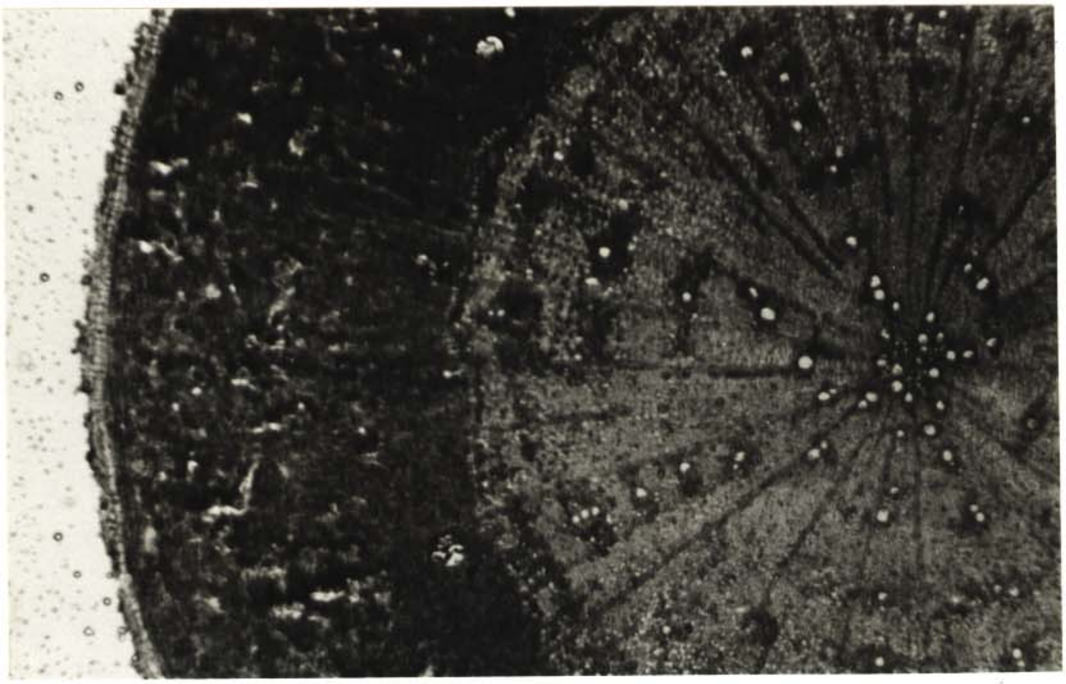


Figure 7.4 : Transverse section of an older root.

bundles with three to four smaller ones later differentiated from the interfascicular cambium. All these bundles are completely collateral like those found in the stem (Fig.7.3A-B).

7.3.2.1.3 Secondary growth and structure:

The roots of most dicotyledons undergo secondary growth during which a vascular cambium develops to give rise to secondary xylem and secondary phloem, with a phellogen or cork cambium formed which produces periderm (Cutter, 1971). In the root of P. angolensis, like in other dicotyledons, the vascular cambium arises from the undifferentiated cells between the primary xylem and primary phloem, and later, from the pericyclic cells located opposite the protoxylem groups. Initially therefore, as mentioned earlier, the vascular cambium is made up of four separate strips.

In the early stages of secondary growth, the vascular cambium is not circular but more or less rectangular in outline (Fig.7.2B). As new cells are added to the phloem on the outside of the cambium, and to the xylem on the inside, and due to the fact that the amount of xylem formed is usually in excess (Cutter, 1971), the primary phloem as well as the cambium are gradually pushed outward. The cambium therefore assumes a circular shape during this process.

The secondary vascular tissues formed by the cambium assume the form of a continuous cylinder which completely embed the primary xylem. While this development is going on, periclinal divisions in the pericycle also take place. A phellogen arises among the outer cells of the proliferated pericycle. The expansion of the vascular cylinder due to secondary growth and proliferation of the pericycle, causes the rupture and sloughing off, of the endodermis, cortex and epidermis. The phellogen gives rise to a periderm in the same way as described in Chapter 3, par. 3.2.1.2.2.

Transverse sections of the roots of older seedlings show that the bulk of the secondary xylem consists of compactly arranged thickwalled fibres. The cell walls of the fibres are at this stage unlignified. Sparsely dispersed vessels are present and these occur either singly or in groups of two to three. The axial parenchyma associated with these vessels is banded confluent in the outer younger regions of the secondary xylem, becoming aliform to vasicentric towards the centre of the root. The rays are mainly uniseriate, and the ray parenchyma cells as well as the parenchyma of the axial system contain large amounts of starch grain.

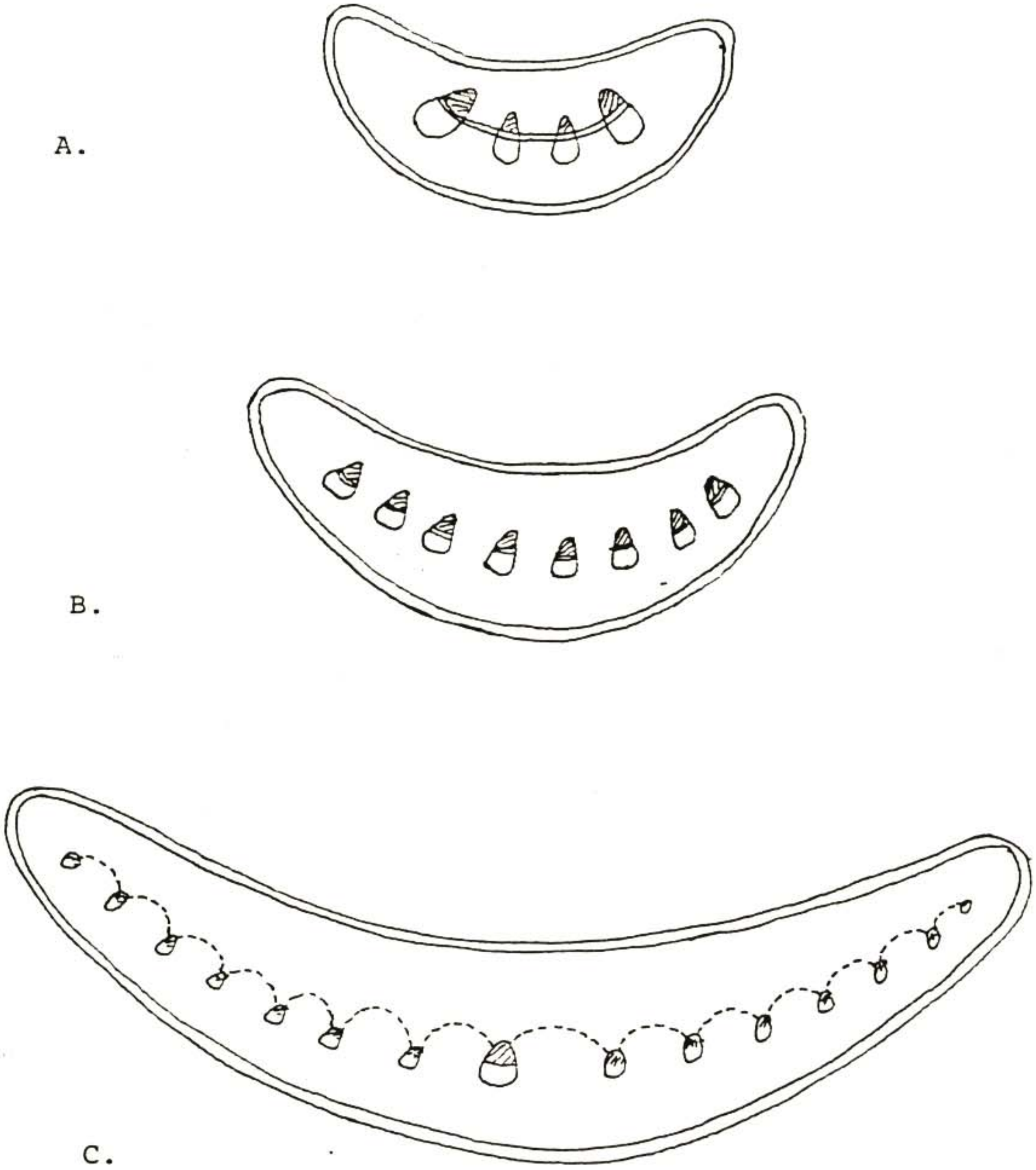


FIGURE 7.5 A -C : Diagrams of transverse sections of the cotyledon. A, cotyledonary stalk; B, base of the blade; C, middle of the blade.

Comparison of sections cut at different levels showed that the presence or absence of the pith is dependent on the diameter of the root (Compton, 1912b; Fahn, 1974, 1982). As the root tapers downward, the amount of the pith becomes progressively reduced. In those sections cut further down, where there is very little pith or no parenchyma cells at all, the four triangular primary xylem strands mentioned earlier on, are discernible (Fig.7.4).

The secondary phloem of the root is similar in structure to that of the stem (See Chapter 3). Cells of the phloem rays as well as the secondary phloem parenchyma cells, contain large amounts of starch grains which tend to obscure the structure of the phloem.

7.3.2.2 The Cotyledon:

Transverse sections from the short cotyledonary stalk show that the vascular supply of the cotyledons consists of four or more separate bundles. These are made up of two large lateral bundles and two or more smaller bundles initiated from the interfascicular cambium whilst in the hypocotyl (Fig. 7.5A). These sections therefore show that the cotyledonary traces observed in the hypocotyl (Fig.7.3A), enter the cotyledons unchanged.

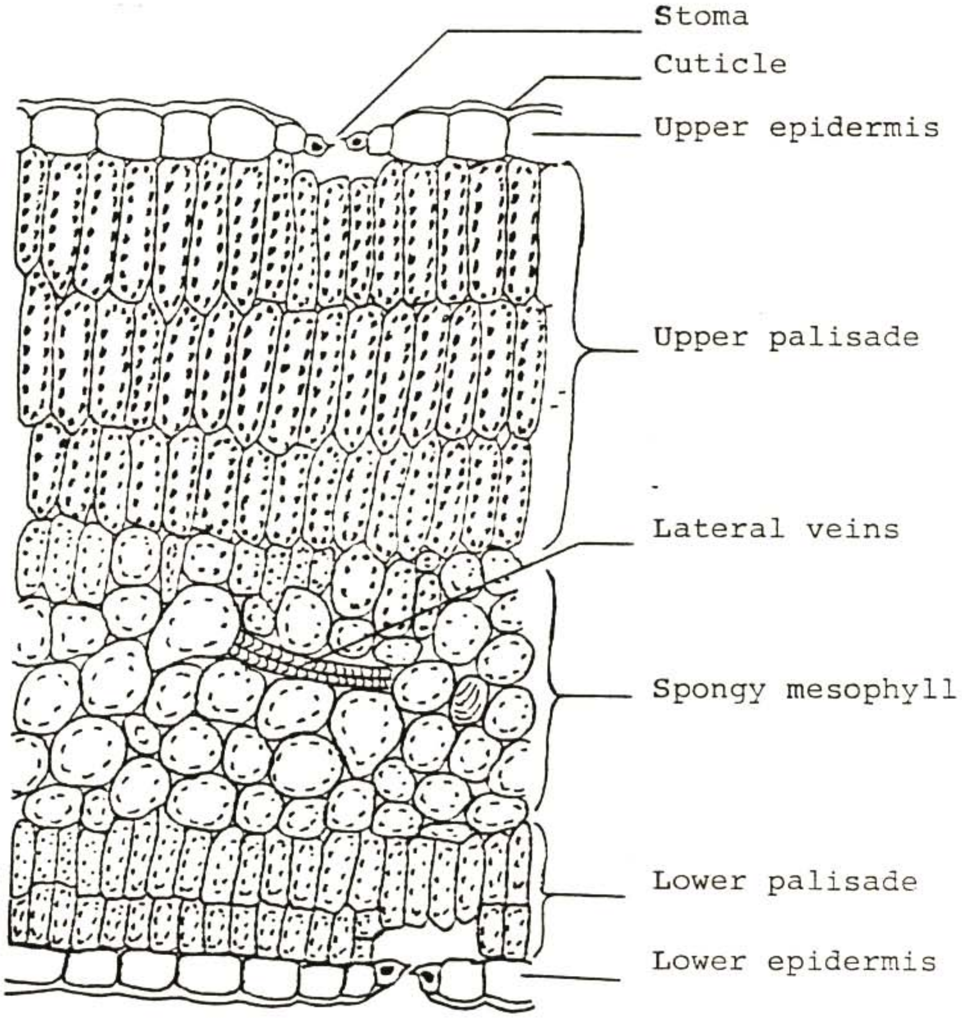


FIGURE 7.6 : Drawing of a portion of the cotyledon in transverse section.

In the cotyledonary stalk the vascular bundles are more or less in a crescent shape. They soon break up into several smaller bundles as they enter the blade, and spread out into the blade as deeply seated veins. Transverse sections from the centre of the blade do not show a distinct midvein but a wavy or undulating line of small veins extending the entire breadth of the blade (Fig.7.5C).

The epidermis is one cell-layer thick, and covered on the outside by a thin layer of cuticle. Epidermal cells are irregular in shape and size, and bear stomata which are slightly sunken. These stomata occur on both the lower and upper epidermis. Each stoma is subtended by a small air chamber, and the guard cells have ledges that are medially situated. When stomata are closed, these ledges overlap.

Below the upper epidermis there are three to four layers of columnar, tightly packed palisade cells. These cells appear storied and contain many densely packed chloroplasts (Fig.7.6). In the lamina of the cotyledon, palisade tissue also occurs above the lower epidermis, but this palisade is less well developed than that on the adaxial side. It consists of two to three layers of short columnar cells. The spongy

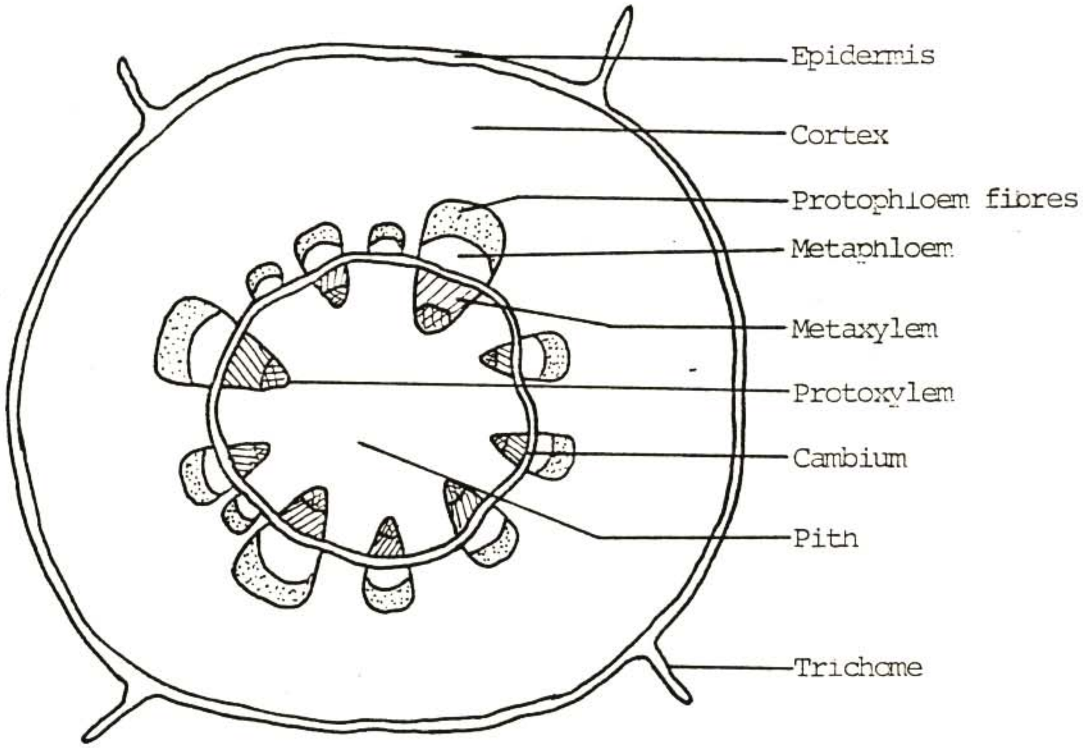


FIGURE 7.7 : Diagram showing a transverse section of a young stem.

mesophyll is situated between the upper and lower palisade layers, and consists of fairly closely packed, nearly isodiametric cells. The vascular bundles of the lamina are embedded within the spongy mesophyll, just below the upper palisade layers.

7.3.2.3 The Stem:

7.3.2.3.1 The Young Stem:

In studying the primary structure of the stem, transverse sections were obtained from the stems of seedlings at various stages of development, namely, seven-, fourteen-, and twenty eight days old seedlings. These sections were made at different levels of the internodes, and the same techniques were used as in the case of the roots. The following is a general sequence of tissues observed:-

(i) Epidermis:- The epidermis is one cell layer thick, with the cells appearing more or less irregular in shape and size. Uniseriate epidermal trichomes are present on some epidermal cells. Overlying the epidermis is a thin layer of cuticle.

(ii) Cortex:- Cells making up this tissue are fairly large and parenchymatous, with those in the outer layers containing chloroplasts. Secretory cells, occuring either singly or in groups are found scattered within the entire cortex.

(iii) Vascular tissue system:- This lies internal to the cortex (Fahn, 1974) and consists of a cylinder of separate, collateral vascular bundles. Sections cut from the middle of internodes show three larger bundles, and these are destined to form leaf traces at the first node above the sections.

In the seedling stem, tissue differentiation in these leaf trace bundles has progressed further than in the rest of the bundles. They are not only larger but also more mature than the rest. At the node the three leaf trace bundles diverge into the leaf, each leaving a leaf gap behind. The nodes are therefore trilacunar, with three traces.

Each primary vascular bundle has a fairly broad protophloem on the outside. After obliteration of the sieve tubes, the cells remaining in the protophloem differentiate into fibres (Esau, 1965; Cutter, 1971). These fibres constitute the thick-walled lignified fibre caps present on the outside of each vascular bundle.

(iv) Pith:- A parenchymatous pith is present in the centre of the stem, the pith cells containing a fair amount of starch grains. A few secretory cells are found in the outer regions of the pith.

7.3.2.3.2 Secondary growth and structure:

Secondary growth of the usual type takes place in the stems of <u>Pterocarpus</u> <u>angolensis</u>. Fascicular cambial segments are present in each vascular bundle, and these become interconnected by the interfascicular cambium which originates from the interfascicular parenchyma. The vascular cambium thus formed, gives rise to a continuous cylinder of secondary vascular tissues.

In the stems of seedlings secondary growth starts fairly early. Transverse sections of the stem of a fourteen days old seedling already showed the presence of a fair amount of secondary xylem. In a three months old seedling, the protophloem fibre caps were very prominent, and a continuous cylinder of secondary vascular tissues had already been formed. The structure of the secondary tissues has been described

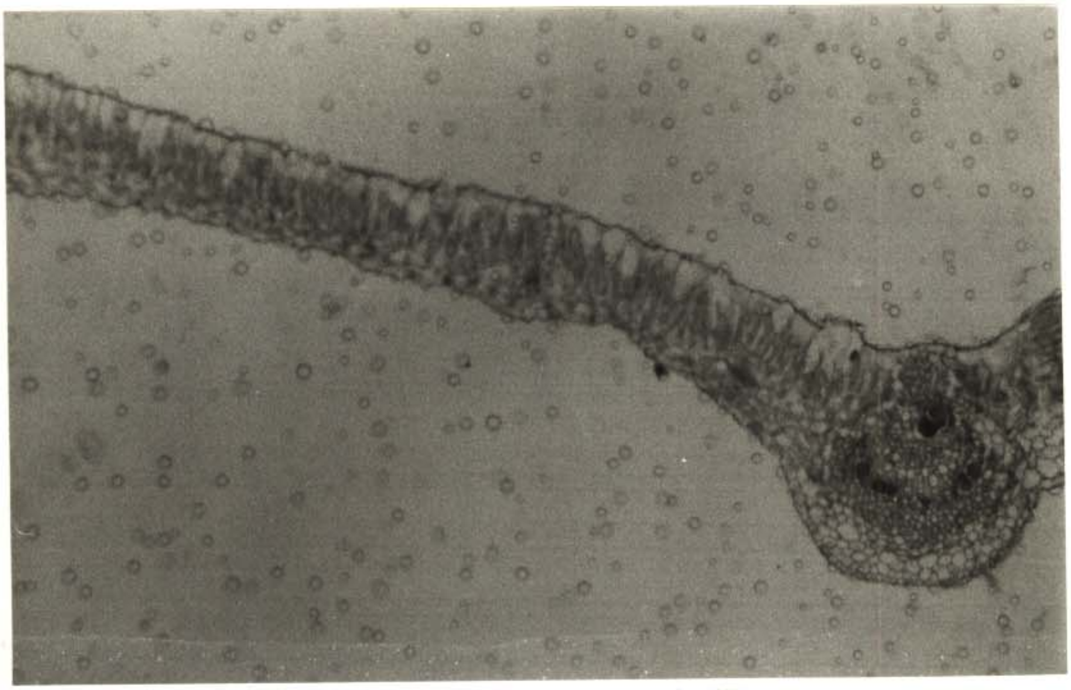
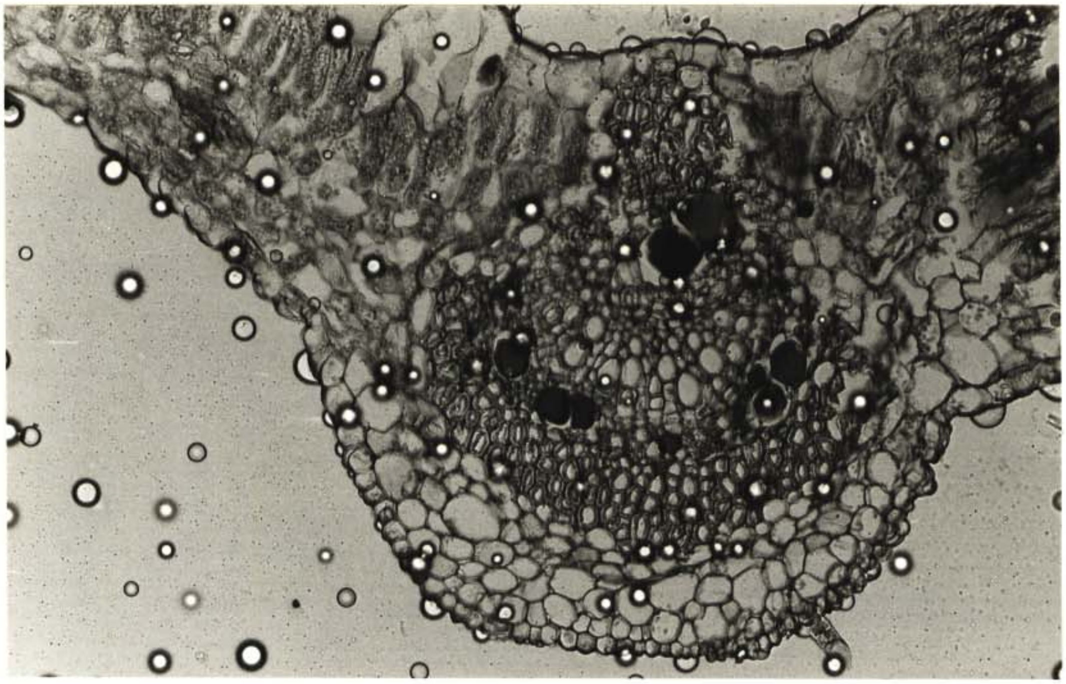


Figure 7.8 A : Transverse section of the leaf blade



in Chapter 3.

7.3.2.4 The Leaf:

The description that follows pertains to transverse sections made from both unifoliate and pinnae from trifoliate leaves. For purposes of convenience, these pinnae are referred to as leaves throughout the discussion.

7.3.2.4.1 The Blade:

The leaf of Pterocarpus angolensis is typically dorsiventral. The epidermal layer, that is both the upper and lower epidermis, is covered on the outside by a distinct layer of cuticle. The upper epidermis consists of a single layer of irregular, fairly large and more or less wedge-shaped cells, with their broad sides outermost (Fig.7.8A). The lower epidermis on the other hand, has more uniform cells which are slightly smaller in size. Uniseriate trichomes, similar to those found on the stem, are found on the lower epidermis together with numerous, slightly sunken stomata.

Below the upper epidermis is a single layer of columnar palisade mesophyll cells. This is followed by three to four layers of irregularly shaped cells of the spongy mesophyll, with large intercellular spaces. The cells of both

layers of the mesophyll contain chloroplasts.

The midvein is very prominent, consisting of an open vascular bundle with an abaxially situated phloem (Fig.7.8B). This vascular bundle is surrounded by a sheath of sclerenchyma which adjoins the upper epidermis. Similar sheaths are also found around the small lateral veins. Below the midvein, and between the bundle sheath and the lower epidermis, are a few parenchyma cells which are devoid of the chloroplasts. Also present in the phloem of the midvein, are a few secretory cells.

7.3.2.4.2. The Petiole:

A similarity exists between the tissues of the petiole and those of the stem (Esau, 1965; Fahn, 1982). The epidermis of the stem is continuous with that of the petiole. Cross sections from the petiole at its base and also just below the lamina, show a single layer of epidermal cells with uniseriate hairs similar to those found on the stem and lamina. On the outside, the epidermis is covered by a cuticle. A broad cortex, very similar to that of a young stem, is present. The leaf traces enter the base of the petiole while still in the same arrangement as they parted from the stem, that is, as three collateral vascular bundles having prominent protophloem fibre caps, with the median bundle lowermost (Fig.7.9A-E). Hereafter these

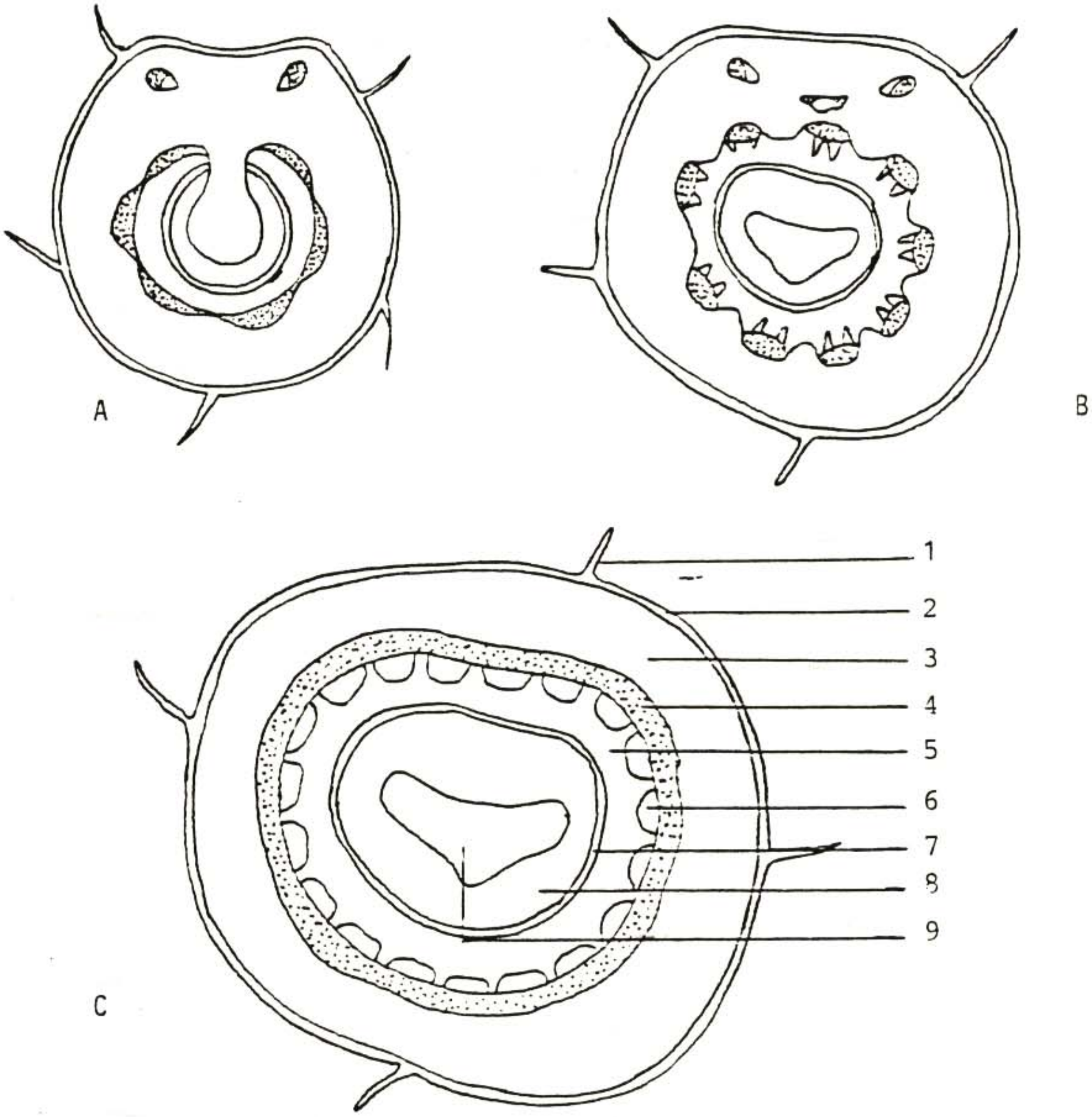


FIGURE 7.10 A–C : Diagrams of transverse sections of the older petiole at different levels. A–B, rachis showing groups of sclerenchyma below the dorsal groove; C, petiolar base with secondary vascular tissues.

1 = trichome; 2 = epidermis; 3 = cortex; 4 = sclerenchyma ring;
5 = secondary phloem; 6 = phloem parenchyma with secretory cells;
7 = cambium; 8 = secondary xylem; 9 = pith.

bundles merge laterally while the extreme portions of the two lateral bundles branch off, to give rise to the stipular vascular supply (Eames & MacDaniels, 1974).

Above the level of divergence of the stipular vascular bundles, the three leaf trace bundles are completely merged to form a ring enclosing a parenchymatous pith in the centre. The latter however is somewhat bilobed and with numerous scattered secretory cells.

A slightly developed longitudinal groove is present on the upper side of the petiole. Within each of the two ridges of this groove there is a small strand of sclerenchyma. Associated with the two sclerenchyma strands on their inner sides are small vascular bundles. These two bundles diverge from the main vascular system of the petiole just above the level of divergence of the stipular bundles. Towards the tip of the leaf the vascular tissues comprising these bundles diminish in amount and the bundles tend to disappear.

A fair amount of secondary vascular tissue is present in petioles of older leaves (Fig.7.10C). In the secondary xylem the vascular rays are mainly biseriate, but broadening out in the secondary phloem. Large secretory cells are present in the secondary phloem portions of the vascular rays. The vascular tissue is bounded on the outside be very prominent protophloem fibre caps.

The structure of the petiole thus resembles that of the stem, although, because of smaller diameter of the petiole, the protophloem fibre caps appear to be rather massive in the petiole.

7.4 Conclusion:

Germination in Pterocarpus angolensis is epigeal, the cotyledons persisting for some time, and remain green until they are shed. The root system is extensive, with a very strong taproot. The plumular hook is on the other hand fairly small and weak on germination. Growth of the aerial shoot is slow initially and it takes a considerable time to get under way.

The anatomy of the seedling is typically that of a woody dicotyledon. The aerial shoots were found to be characterized by an abundance of secretory cells, while the root has a large amount of starch grains in almost all parenchymatous cells including the phloem parenchyma. Here the secretory cells are very scanty. The nodes are trilacunar, and the identity of leaf traces is kept through the major portion of the internodes, particularly in younger stems.

CHAPTER 8

GENERAL DISCUSSION AND CONCLUSIONS.

Although South Africa contains a wealth of indigenous trees, knowledge about the raising of indigenous trees and shrubs is, in many respects still imperfect (Geldenhuys, 1975). Various reasons can perhaps be given for this lack of interest in the cultivation of indigenous trees. In the first place, South Africa as a whole is a very poorly wooded country. The great central plateau which covers the vast part of South Africa, has a fairly low rainfall which is also very irregular in distribution. Furthermore, the central plateau receives its rain mainly in the summer while the winters are cold and dry. These climatic conditions are not really suitable for tree growth and contributed to the lack of interest in the raising of indigenous trees.

Secondly, it cannot be denied that the quick growing exotics have great economic use. The exotic timber species are planted mainly in the higher rainfall areas along the eastern and southern escarpment and adjacent coastal regions. These afforested areas supply to a large extent the timber needs of South Africa, and the Directorate of Forestry is largely concerned with the establishment and management of plantations of fast growing trees for wood production. The fact that fast growing suitable exotic trees are available perhaps also contributed to the lack of interest in the cultivation of indigenous trees. However, the exceptional qualities of the wood of many indigenous trees cause them to be much sought after for all kinds of special purposes. The demand for the available quantity of indigenous timber of suitable size is therefore far in excess of the supply.

A third reason for the lack of interest in the cultivation of indigenous trees is the widespread belief that they are difficult to grow, temperamental, and above all, slow. Information concerning these aspects is available for the more important indigenous forest tree species (Phillips, 1931; Laughton, 1937). With regard to the tree species occuring in the woodland regions of South Africa, very little information is available.

Turning now to <u>Pterocarpus angolensis</u>, which is a woodland tree, information concerning the exploitation of its wood is practically non-existing. Palmer & Pitman (1961) mention that years ago a minor trade in Kiaat existed which was dependent on ranching operations. Kiaat timber was sawn into planks in winter and in spring when the cattle were driven back to the highveld, these Kiaat planks were taken along and sold. According to Palmer & Pitman (1961) Kiaat timber was known by the public, and used mainly for rough work. Scott (1936) wrote, "Until quite recently this timber (Kiaat) was practically unknown as far as the general public was concerned but is now in great demand both by private individuals and furniture firms". Laughton (1937) wrote, "In recent years Kejatenhout (Pterocarpus angolensis DC.) has found great favour as a furniture wood and has been exploited to some extent. This is however a tree of the open Savannah forests which cover large areas of the Low Veld....." From these reports it can be concluded that 40-50 years ago, South African Kiaat timber was freely available. Since those times the position has changed drastically. Van Wyk (1972) states that the South African source of Kiaat wood has been virtually exhausted and practically all kiaat wood used in this country is imported from neighbouring states.

With regard to the cultivation of Pterocarpus angolensis, Van Wyk (1972) mentions that in the Kruger National Park problems were encountered with the germination of the seeds from this tree. No further information is given. According to

Von Breitenbach (1965) the hard pods must first be broken open to remove the seeds, but better results are usually obtained by vegetative propagation using hardwood cuttings and truncheons.

Morphological studies of the fruits of Pterocarpus angolensis have shown that these fruits are very hard and indehiscent or only slightly dehiscent. The pods must therefore be broken open to remove the seeds before sowing. From the results of the experiments on seed germination, it is clear that for good results the seeds must be scarified. Among the three methods of scarification used, acid scarified seeds gave the best results. Acid scarification is a simple process involving very little time and labour. For the cultivation of Pterocarpus angolensis this method should give very good results. As regard the development and morphology of the seedling, it was noticed, as it has also been reported by previous workers, that the root system developed extensively and strongly as opposed to the aerial shoots. The taproot becomes carroty and stores large amounts of starch. This stored food is used to sustain the plant during the die back periods (Boaler, 1966; Von Breitenbach, 1973). It is also mentioned by Boaler (1966); Exell & Stace (1972) and Von Breitenbach (1973) that this manner of growth is an adaptation to the recurrent fires, characteristic of the African Woodland. These carrot-like roots present transplantation problems to nurseries (Von Breitenbach, 1973). Young plants grown from seeds used in the germination experiments were however transplanted in the campus garden of the University of the North without any problems. It must perhaps be stated that these seedlings had been cultivated in plastic bags and were transplanted when still fairly young. These young plants did not undergo the die back phenomenon, and insects feeding on the tender branches and leaves were the main problem. The growth rate of these young plants or trees is slow. Five years after transplantation they have reached a height of more or less 1 meter. Although the campus of the University of the North is not completely frost free, these young trees seem to be doing quite well. In this study the various factors to be considered when transplanting the seedlings of *Pterocarpus angolensis* have not been investigated but the degree of success with the seedlings in the campus gardens was encouraging.

In South Africa the stage has been reached that the different authorities should encourage wider cultivation of *Pterocarpus angolensis* as large exploitable trees become very rare. Kiaat is a slow growing tree but the wood is valuable. In those areas where it would do well, land belonging to the state or private individuals, which are not used for other purposes, could be planted with Kiaat. This study has shown that such a venture could be successful.

CHAPTER 9

SUMMARY

Pterocarpus angolensis DC. is a subtropical tree that provides a valuable timber which is tough and durable. It is a light-demanding plant, and in South Africa found growing along the east-facing mountain slopes and foothills of the eastern escarpment.

In this study the general aim was to get insight into the morphology and development of the species, from the seedling to the mature plant. The seedling morphology included anatomy of the stem, root, leaves and cotyledons. In all these investigations, anatomical sections were prepared according to Johansen's Plant Microtechnique (1940).

Points of special interest included the following:

1. Development and morphology of the fruit, from just after fertilization to maturity, with special reference to the fruit wall and changes associated with it. The most significant feature observed here, is the reorientation of the young seeds during the early stages of development.

This phenomenon is accompanied by compartmentalization of the locule brought about by the evaginations arising from the placental side of the locule towards the dorsal suture. These evaginations were found to occur at more or less regular intervals, thus dividing the locule into one, two or three compartments. One other feature about the fruit wall is the development of multiseriate bristles at the thickened central portion of the fruit, and a membraneous wing along the dorsal and ventral sutures.

2. Morphology of the seed, seed production, and with special reference to the seed coat, embryo, seed germination and permeability to water. The seed coat is typically leguminous, and like that of the tree lupin, has the hilar fissure depressed, so that the counter palisade is found within the "trough" of the rim-aril. The embryo on the other hand, is very small and almost straight.

   Percentage yield in seed production was based on the total number of fruits collected and opened, while viability was assessed on the basis of the colour and fullness of the testa. The testa was also found to be impermeable to water, and on this account, three methods of scarification were employed and compared, in order to fascilitate or improve imbibition, and subsequently, germination. The treated seeds were incubated in glass petri dishes at 30^{0}C. Imbibition was determined by the weighing method while germination was determined on the basis of radicle emergence from the testa.

All the fruits, flowers and other material used in this study were collected from the Mooketsi area in Northeastern Transvaal, along and in the vicinity of the Koedoe valley.

OPSOMMING

Pterocarpus angolensis DC. is 'n subtropiese boomsoort waarvan die sterk en duursame hout baie waardevol is. Die plant is ligliewend en in Suid Afrika groei dit gewoonlik langs die laer berghellings en voetheuwels van die Oostelike Platorand en die aangrensende laeveld.

Die algemene doelstelling van hierdie studie was om insig te verkry in die bou en ontwikkeling van die spesie vanaf die saadstadium tot die volwasse plant en ook om sekere aspekte rakende saadkieming te ondersoek. In die anatomiese ondersoeke is daar deurgaans van standaard mikrotegniek metodes, soos deur Johansen (1940) beskryf, gebruik gemaak.

In die ondersoeke is die volgende aspekte veral beklemtoom:-

1. Die ontwikkeling en bou van die vrug vanaf die stadium net na bevrugting tot die volwasse stadium. Besondere aandag is aan die vrugwand en die veranderinge wat dit ondergaan, gegee. 'n Merkwaardige eienskap wat hier waargeneem is, is die heroriëntering van die jong sade gedurende die vroeë stadia van vrugontwikkeling.

Hierdie verskynsel gaan saam met die verdeling van die vrughok in twee of meer kamers deur uitstulpings wat vanaf die plasentale kant van die vrughok na die dorsale naat daarvan ontwikkel. Uitstulping vind min of meer op reëlmatige afstande plaas, en verdeel die vrughok in twee of drie kamers. Nog eienskappe van die vrugwand is die ontwikkeling van meersellige borselhare op die sentrale verdikte deel van die vrug, en van 'n harde perkamentagtige vlerk langs die dorsale en ventrale nate van die vrug.

2. Die bou van die saad, saadvorming, en die saadhuid met die klem op saadkieming. Die saadhuid stem ooreen met dié van ander peulplante, en soos by die boomlupine, is die groef van die hilum ingedruk sodat die teen-palisade in die trog van die rand-aril gevind word. Die embryo is klein en byna reguit.

   Die persentasie saadproduksie is gebaseer op die aantal vrugte wat versamel en oopgemaak is terwyl lewensvatbaarheid beraam is op grond van die kleur en gerondheid van die testa. Die testa het ook ondeurlaatbaar vir water geblyk te wees en drie metodes van skarifikasie is toegepas om deurlaatbaarheid te verhoog. Die behandelde sade is in glas petribakkies by 30^0C gekiem. Die wateropname van die sade is deur die weegmetode bepaal en die verskyning van die kiemwortel deur die testa as susksesvolle saadkieming gereken.

Al die navorsingsmaterial wat in hierdie ondersoek gebruik is, is in die Koedoe vallei, in die Mooketsi-gebied Noordoostelike Transvaal, versamel.

ACKNOWLEDGEMENTS

I would like to express my gratitude to my supervisor Professor D.R.J. Van Vuuren for his interest and willingness to advise. His patience, suggestions and guidance have been highly appreciated.

My hearty thanks also go to the staff of the Botanical Research Institute in Pretoria, who were so kind and helpful, in allowing me to make use of the Herbarium material, and providing me with some of the photographs, the distribution map and other illustrations or drawings used in this work.

The Public Relations Office (Technical section) of the University of the North is also thanked for having been that kind in processing my films.

Greatful thanks go to Mahlapane Lehohla for typing this dissertation. Finally, I would like to thank all those who helped in any way during the course of this study.

REFERENCES

ACOCKS, J.P.H. Veld types of South Africa 2nd Ed. Mem. Bot. Surv. S. Afr. No 40.

BIDWELL, R.G.S. 1974. Plant physiology. Macmillan Publishing Co. Inc. New York. Collier Macmillan Publishers. London.

BOALER, S.B. 1966. The ecology of Pterocarpus angolensis DC. in Tanzania. H.M.S.O. London.

CARDOSO, J.G.A. 1962. Anatomy of Pterocarpus angolensis timber. S.A.J. Sci. 58:207.

COMPTON, R.H. 1912a. An investigation of the seedling structure in the Leguminosae. J. Linn. Soc. (Botany) 41:1-122

COMPTON, R.H. 1912b. Theories of the anatomical transition from root to stem. The New Phytologist. 11:13-25

CORNER, E.J.H. 1951. The Leguminous seed. Phytomorphology 1:117-150

CUTTER, E.G. 1971. Plant anatomy: Experiment and interpretation. Part 2 Edward Arnold. London.

DELVIN, R.M. 1975. Plant physiology. 3rd Ed. D. Van Nostrand Company.

DE WINTER, B., DE WINTER, M. & KILLICK, D.J.B. 1966. Sixty six Transvaal trees. Voortrekkerpers. Pretoria.

DYER, R.A. 1975. The genera of Southern African flowering plants. Vol.1. Dept. Agric. Tech. Ser. Pretoria.

EAMES, A.J. & MACDANNIELS, L.H. 1947. An introduction to plant anatomy. McGraw-Hill book Company. New York.

ESAU, K. 1962. Anatomy of seed plants. John Wiley & Sons. Inc. New York.

ESAU, K. 1965a. Plant anatomy. 2nd Ed. John Wiley & Sons. Inc. New York.

ESAU, K. 1965b. Vascular differentiation in plants. Holt, Rinehart and Winston. New York.

EXELL, A.W. & STACE, C.A. 1972. Taxonomy, Phytogeography and Evolution. Editor D.H. Valentine. Academic Press. London. New York.

FAHN, A. 1974. Plant anatomy. 2nd Ed. Pergamon Press.

FAHN, A. 1982. Plant anatomy. 3rd Ed. Pergamon Press.

GELDENHUYS, C.J. 1975. Die kweek van inheemse bome. Dept. van Bosbou, Pretoria. Pamflet 150.

GORDON, T. 1971. Indigenous Trees of Rhodesia-<u>Pterocarpus</u>

angolensis DC. The Rhod. Sci. News. 5(5):154

GROOME, J.S. 1955. Muninga (Pterocarpus angolensis DC.) in the Western Province of Tanganyika. E.Afr. agr.J. 21:130-137.

GROOME, J.S., LEES, H.M.N. & WIGG, L.T. 1957. A summary of information on Pterocarpus angolensis. Forestry Abstracts 18(1):3-8 : 18(2): 153-162.

HAMLY, D.H. 1932. Softening of the seeds of Melilotus alba. Bot. Gaz. 93(4): 345-375.

HUTCHINSON, J. 1964. The genera of flowering plants. Clarendon Press: Oxford.

HUTCHINSON, J. 1973. The families of flowering plants. Oxford University Press: Oxford.

HYDE, E.O.C. 1954. The function of the hilum in some Papilionaceae in relation to the ripening of the seed and the permeability of the testa. Annals of Botany (N.S.) 18(70):241-256.

JOHANSEN, A.D. 1940. Plant Microtechnique. McGraw-Hill Book Co. Inc. New York.

KEET, J.D.M. 1950. Forests of the Okavango Native Territory. J.S. Afr. Fores. Ass. Vol.19:77-88.

KICHNER, R. & ANDREW, W. 1971. Effects of various treatments on hardening and softening of seeds in pods of barrel medic (*Medicago trunculata*). *Aust. J. exp. agr. and anim. husb.* 11:536-540).

KROMHOUT, C.P. 1975. 'n Sleutel vir die mikroskopiese uitkening van die vernaamste inheemse houtsoorte van Suid Afrika. Bull. 50. Department of Forestry. Pretoria.

LAUGHTON, F.S. 1937. The sylviculture of the indigenous forests of the Union of South Africa with special reference to the forests of the Knysna region. Dept. of Agriculture and Forestry. Forestry series no 7:1-168.

MARANON J. & SANTOS, J.K. 1932. Morphological and chemical studies on the seeds of *Erythrina variegata* var. *orientalis*(L.) Merril. *Philipp. J. Sci.* 48:563-580.

MAYER, A.M. & POLJAKOFF-MAYBER, A. 1963. The germination of seeds. Pergamon Press. London.

MCNAUGHTON, J.E. 1974. Studies on the embryology, seed germination and seedling morphology of *Erythrina caffra* Thunb. M.Sc. Dissertation. University of Port Elizabeth.

MILLER, H.A. & WETMORE, R.H. 1945a. Studies in the developmental anatomy of *Phlox drummondii* Hook. I. The embryo. *Amer. J. Bot.* 32:588-599.

MILLER, H.A. & WETMORE, R.H. 1945b. Studies in the Developmental anatomy of Phlox drummondi Hook. II. The seedling. Amer. J. Bot. 32:628-634.

NOGGLE, J.R. & FRITZ, G.J. 1976. Introduction to plant physiology. Prentice-Hall.

PALGRAVE, K.C. 1977. Trees of Southern Africa. Editor Dr. E.J. Moll. C. Struik Publishers.

PALMER, E. & PITMAN, N. 1961. Trees of Southern Africa. Vol.1 A.A. Balkema. Cape Town.

PALMER, E. & PITMAN, N. 1972. Trees of Southern Africa Vol.2 A.A. Balkema. Cape Town.

PARDY, A.A. 1951. Notes on indigenous trees and shrubs of South Rhodesia - Pterocarpus angolensis DC. Rhod. Agric. J. 48:322.

PEDRO, E.R., SEABRA, L., FERREIRINHA, M. & DE SAU, E. 1955. Pterocarpus angolensis DC. Garcia de Orta 3:11-31.

PHILLIPS, J.F.V. 1931. Forest-succession and ecology in the Knysna region. Mem. Bot. Surv. S. Afr. No.14.

ROBBERTSE, P.J. 1973. Die genus Acacia in Suid Afrika (met spesiale verwysing na die morphologie van die saad). Tydskrif vir Natuurw. 13:72-95.

ROBBERTSE, P.J. 1974. Ontkieming van die doringboomsaad. J.S. Afr. Bot. 40(4):269-273.

SALISBURY, F.R. & ROSS, C.W. 1969. Plant Physiology. Wadsworth Publishing Co. Inc. Belmont Carlifonia.

SALISBURY, F.R. & ROSS, C.W. 1978. Plant Physiology. Wadsworth Publishing Co. Inc. Belmont Carlifonia.

SCOTT, M.H. 1936. Utilization notes on the more common timbers of the Union of South Africa. Dept. of Agriculture and Forestry. Forestry series no 4:1-43.

SMITH, C.A. 1966. Common names of South African plants. Government Printer: Pretoria.

SPORNE, K.P. 1974. The morphology of angiosperms. Hutchinson Publishers Ltd. London.

TROUP, R.S. 1921. The sylviculture of Indian trees. Vol.1. (265-294). Clarendon Press. Oxford.

VAN WYK, P. 1972. Plants of the Kruger National Park - Ptercarpus angolensis. Custos 1(4):47-48.

VAN WYK, W.C.E. 1971, Bomeprag uit eie bodem - Die kiaat. Landbouweekblad 53(2731): 24-25.

VILLIERS, T.A. 1972. Seed dormacy. Seed biology Vol.II. Editor: T.T. Kozlowski.

VON BREITENBACH, F. 1965. Indigenous trees of Southern

Africa. Vol.3. Government Printer. Pretoria.

VON BREITENBACH, F. 1973. *Pterocarpus angolensis*. *Trees in South Africa.* Vol.25:58-80.

WATT, J.M. & BREYER-BRANDWIJK, M.G. 1962. The medicinal and poisonous plants of Southern and Eastern Africa. 2nd Ed. E. & S. Livingstone Ltd. Edinburg and London.

WEAVER, H.L. 1960. Vascularization of the root-hypocotyl-cotyledon axis of *Glycine max*(L) Merril. *Phytomorphology* 10:82-86.

WITHAM, E.H., BLAYDES, D.E. & DELVIN, R.M. 1971. Experiments in plant physiology. D. Van Nostrand Co.