

Germination and Seedling Structure of *Borassus flabellifer* L.

by

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(With ten text figures)

ABSTRACT

The structure of the mature embryo, the mode of germination, and the structure of the seedling of *Borassus flabellifer* were investigated. The embryo is more or less cylindrical, the plumule being completely enclosed by the sheathing portion of the cotyledon and the plumule and radicle being in the axis of the embryo. Germination is of the remotive tubular type, the cotyledon elongating and burying the plumule and radicle at a depth of 30-40 cm. in the soil. The seedling produces a single scale leaf, which contains abundant storage starch. The remotive tubular mode of germination appears to occur in the palm sub-families Borassoideae and Coryphoideae and the genera *Phoenix* and *Phytelephas*, and to be related to the structure of the mature embryo.

INTRODUCTION

The germination of the seed of *Borassus flabellifer* has been referred to by various authors, such as Tennent (1860) and Blatter (1926) and briefly by Gatin (1906) but although this palm is a common one cultivated in India, Burma and Ceylon, there appears to be little information available regarding the structure of its embryo and seedling.

This paper describes observations made on the structure of the embryo and seedling and the mode of germination of this palm.

MATERIALS AND METHODS

Fruits were collected from trees growing in the Royal Botanic Gardens, Peradeniya and in Jaffna. Seeds were germinated in the botanical garden of the University. Seedlings were also collected in Jaffna and Batticaloa.

Material for sectioning was fixed in FAA and customary methods of micro-technique were employed.

OBSERVATIONS

THE EMBRYO

The mature embryo is situated in the endosperm at the "germ pore", where the hard endocarp is thin (Fig. 1). The distal end of the embryo forms a slight projection, covered by a thin conical cap formed by the endocarp which is easily detached (Fig. 2), as in the 'soft eye' of the coconut.

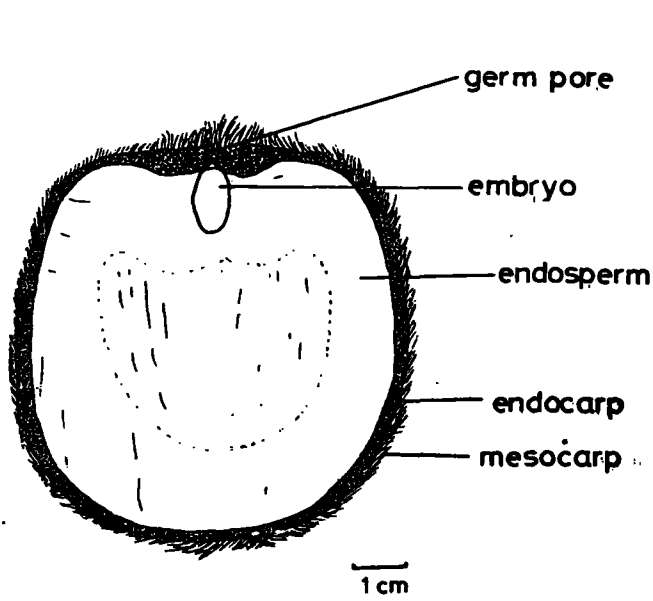


fig 1

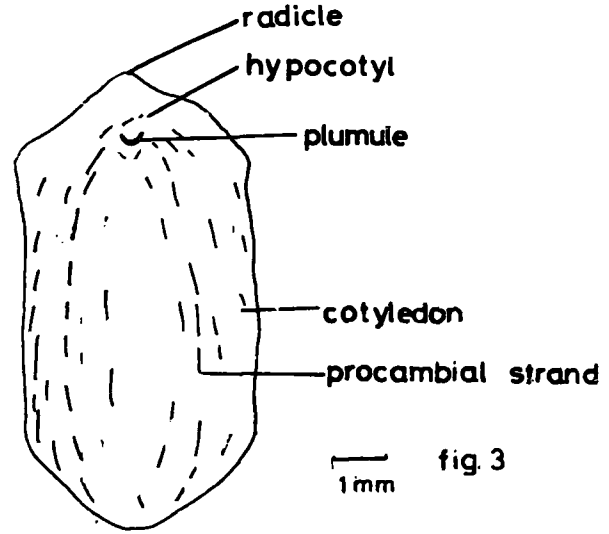


fig 3

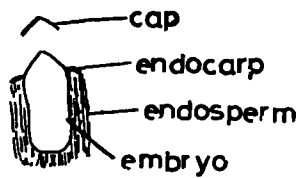


fig 2

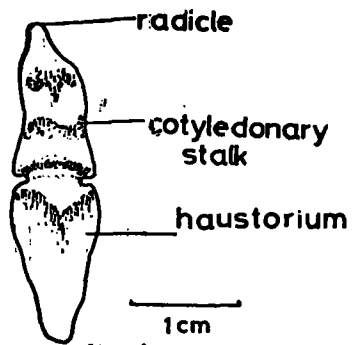


fig. 4

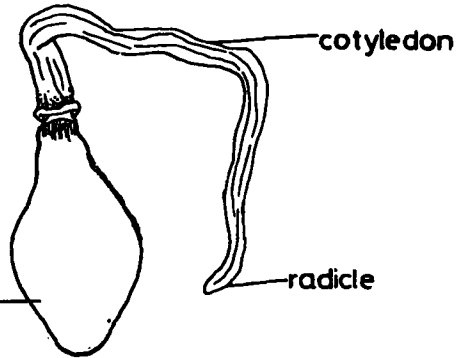


fig 5

The embryo is more or less cylindrical in its distal region, while the proximal region is slightly compressed on two opposite sides, the two regions being separated by a shallow groove. The proximal region is made up entirely of the cotyledon, which constitutes the bulk of the embryo. The cotyledon consists of uniform thin-walled parenchymatous cells which are closely packed together, and is traversed by procambial strands arranged longitudinally.

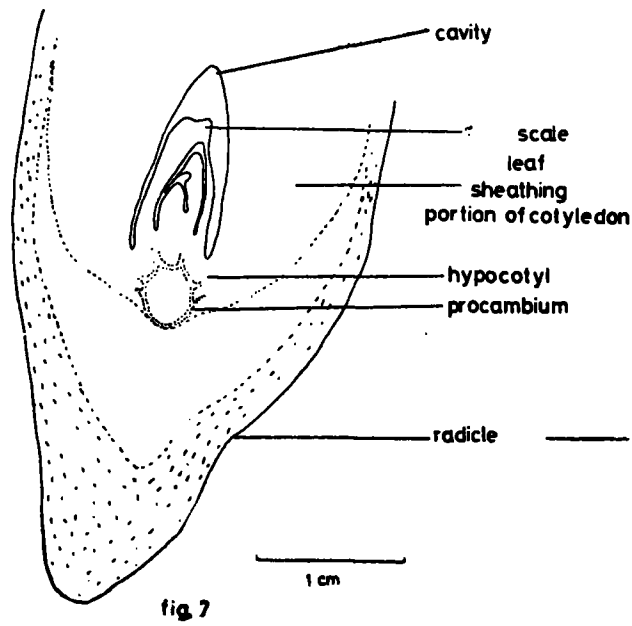
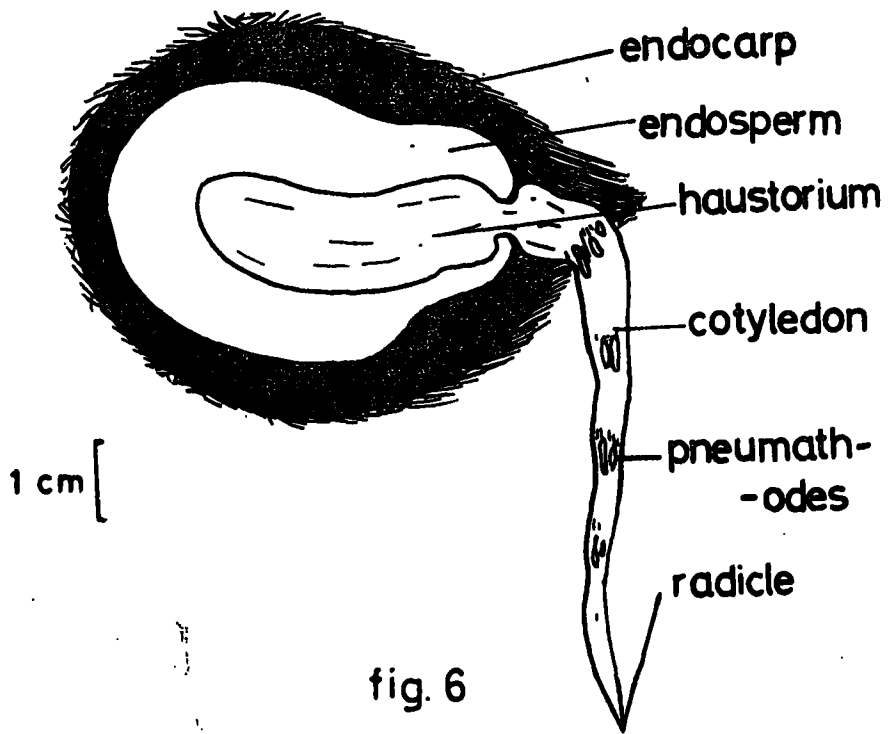
A longitudinal section of the embryo shows the plumule in the distal region, consisting of the apical meristem and a few leaf primordia, lying in a small cavity and enclosed by the sheathing portion of the cotyledon. The plumule and the radical are both situated in the axis of the embryo, and the root primordium is not well differentiated at this stage (Fig. 3). The tip of the radical appears as a minute projection at the distal end.

The endosperm consists of cells with greatly thickened walls containing reserve material as in *Phoenix dactylifera*. The reserves are mostly of hemicellulose and cellulose too appears to be present in these walls. The endosperm is hard and horny, and two regions may be distinguished: a central region consisting of larger cells and a harder peripheral region consisting of much narrower cells. The thickness of the cell walls is approximately the same in both regions.

GERMINATION AND SEEDLING STRUCTURE

During germination the proximal region of the cotyledon enlarges and elongates into the endosperm, digesting it and functioning as a haustorium. It gradually enlarges into the central region of the endosperm and finally fills up all the space previously occupied by the endosperm to form a spongy structure traversed by vascular bundles. Meanwhile the region between the proximal part and the plumule elongates forming the cotyledonary stalk. It carries the enclosed plumule and the radicle at its tip (Fig. 4) and forcing its way through the germ pore, grows downwards into the soil. The cotyledonary stalk develops into a solid cylindrical structure, often marked externally by pneumathodes, and bearing at its tip the radicle, which tapers to a point (Figs. 5 and 6). The distal part of the cotyledon between the radicle and the cotyledonary stalk is hollow. This is the sheathing portion, which encloses the plumule at its distal end.

Fig. 7 shows a longitudinal section through the distal region of one of these cotyledons. The enclosed plumule, root primordium and hypocotyl region may be distinguished. In an older seedling (Fig. 8), the hollow has elongated further with the growth of the cotyledonary sheath around it, and the scale leaf of the plumule may be seen, lying within the hollow, and with a tuft of hairs at its tip. These hairs probably help to protect and lubricate the tip of the scale leaf during its growth through the hollow. The external surface of the cotyledonary sheath is continuous distally with that of the radicle. Later, the radicle develops into the first root, followed by thin lateral roots growing out from the region of the hypocotyl.



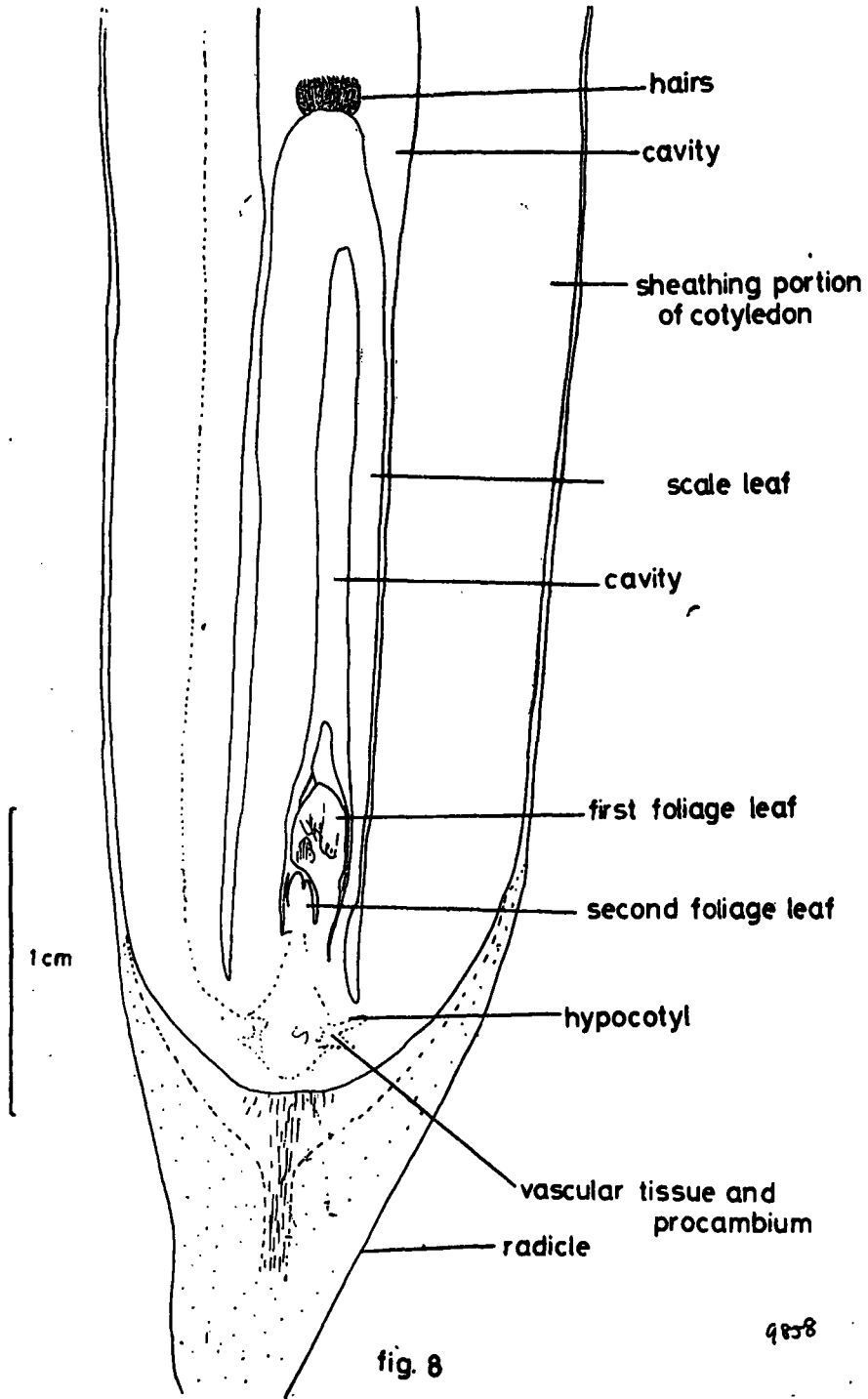
The growth of the cotyledon is accompanied by the rapid division of the cells and their elongation, and the tissues in the growing region have an appearance similar to those of a rapidly elongating root-tip. It was observed in older seedlings where the cotyledons were about 10 cm. long that most of the elongation took place in the region between 0.5 cm. and 2 cm. behind the tip, in the region of the cotyledonary sheath. The cotyledon is positively geotropic and if displaced from the vertical, curvature takes place in the region of maximum growth. In cotyledons which had been made to curve by placing them horizontally, it was observed that the scale-leaf within was also bent.

The cotyledon and cotyledonary sheath become firm and hard and the latter grows to a thickness of about 1 cm. by the growth and enlargement of its cells. It consists of parenchyma cells, smaller and closely packed at the periphery and larger and very loosely arranged within. A number of vascular bundles accompanied by sclerenchyma fibres run longitudinally through it. Later, with the further development of the plumule, its cells collapse and it becomes reduced to a dry, spongy structure 1 to 2 mm. in thickness. Later, about the time the first foliage leaf appears, only the papery outer layers of the cotyledonary sheath remain, around the scale leaf. The inner softer tissues have broken down, leaving only the fibrous vascular bundles. The fully grown scale leaf has enlarged to a size of about 30-40 cm. in length and about 3-4 cm. in breadth at its broadest part. It has no lamina but consists of only a thick sheath with a deep groove down its ventral side, and it tapers to a point at its apex on the dorsal side. The scale leaf is hollow, with a narrow channel about 4 mm. broad down its centre which is occupied by the first foliage leaf and, lower down, by the shoot apex, and it is thicker on the dorsal side and laterally than on the ventral side. Beneath the epidermis there are three layers of somewhat thick-walled parenchyma cells which are devoid of starch grains and beneath these cell layers is a ring of longitudinally arranged bundles of brown sclerenchyma fibres which are clearly visible externally as fine brown lines. The central region is occupied by large thin-walled parenchyma cells somewhat loosely packed with intercellular spaces and these cells are densely packed with starch grains. A number of vascular bundles accompanied by sclerenchyma fibres traverse this region longitudinally. This scale leaf is the edible part of the seedling, known as "kelingoo" locally.

The scale leaf is followed by the first foliage leaf. The young leaf is at first enclosed by the scale leaf, and has a tuft of hairs at its apex. It grows and emerges through the tip of the scale leaf. As this leaf enlarges, the scale leaf is stretched and becomes ruptured along the groove down its ventral side, where the tissues become withered and turn brown. The first foliage leaf appears above ground in a seedling 9-12 months old. This leaf has an oblanceolate plicate lamina 8-25 cm. broad with a truncate apex split into 5 teeth and with five clearly marked veins (Fig. 10). Later leaves tend to be narrowly oblanceolate to linear and larger.

DISCUSSION

The mature embryo of *Borassus flabellifer* is very similar to that of *Phoenix dactylifera*, the date, as described by Gatin (1906) and Troll (1959). The plumule and radicle are both situated in the axis of the embryo, as in date. In the date embryo, however, there is a slit in



the cotyledonary sheath in the region where the plumule is situated, corresponding to the radial slit directly over the plumule formed by the incomplete fusion of the cotyledon in the coconut embryo (Selvaratnam, 1952). No such opening was found in the mature embryo of *B. flabellifer*, and the cotyledon surrounds the plumule completely. In the coconut, during germination, the plumule grows out directly through this opening.

The modes of germination of palms have been classified (Pfitzer, 1885 ; Gatin, 1906) as (a) admotive and (b) remotive. In palms with admotive germination, e.g. *Cocos nucifera* (Corner, 1966), the cotyledon elongates just sufficient to push the plumule and radicle outside the testa and endocarp, where the radicle and the plumule proceed to grow into the first root and shoot respectively. In remotive germination, the cotyledon elongates to a considerable extent, carrying the plumule and radicle some distance away from the seed. Gatin (1906), following Martius, has divided remotive germination further into two types- tubular, where the descending cotyledon forms a tubular sheath around the plumule, as in *Phoenix*, and ligulate or ochreate, where the plumule is surrounded by a sheath, the ligule or ochrea, at whose base the cotyledon is attached, as in *Sabal*.

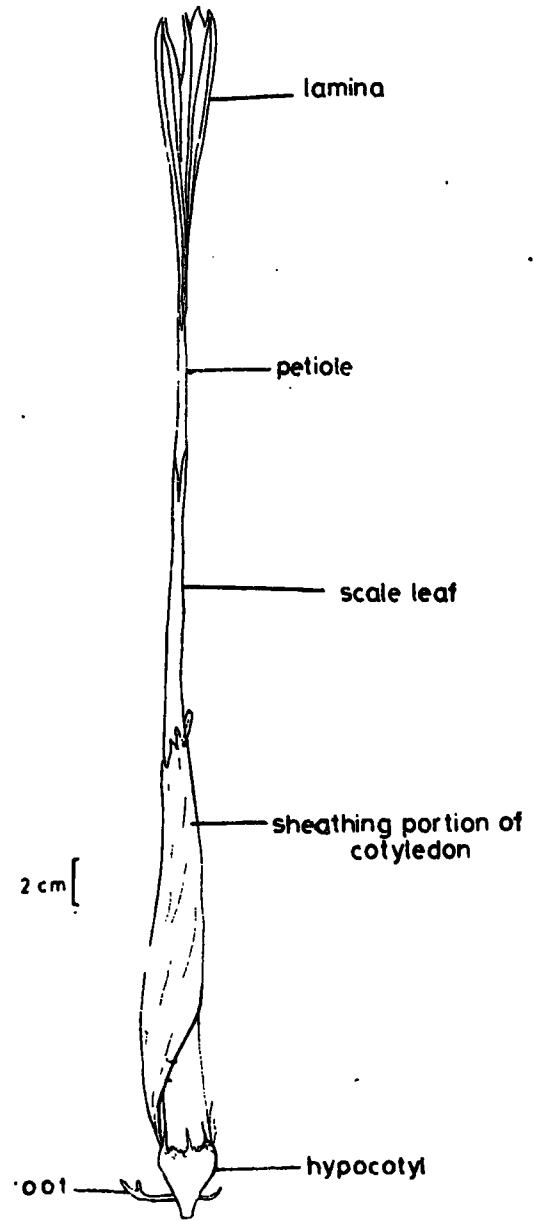
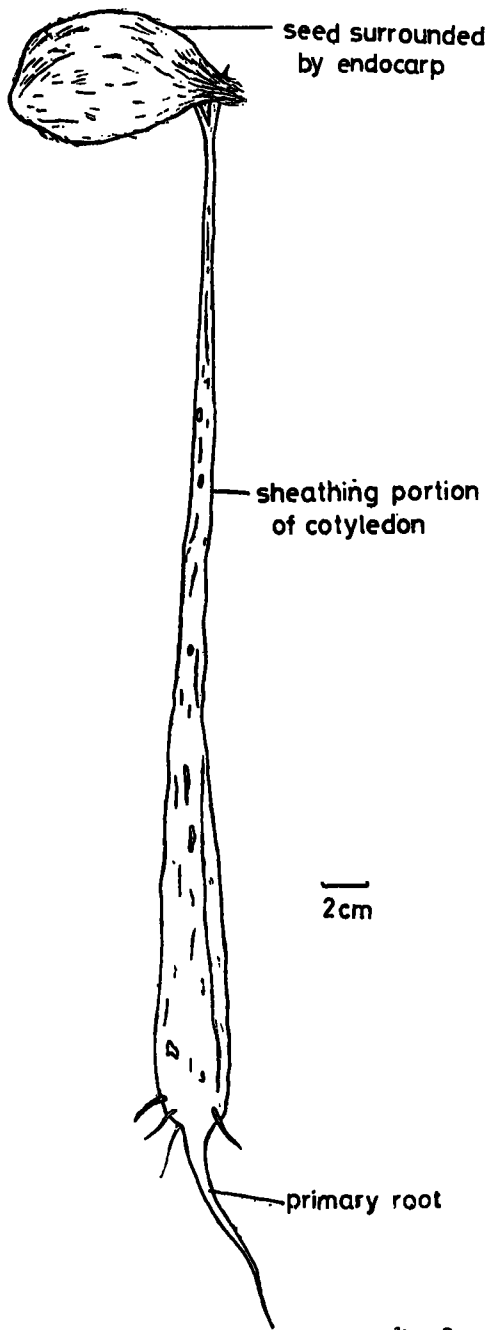
The germination of *Borassus flabellifer* is of the remotive tubular type, and resembles somewhat that of date. In the date, however, the leaves emerge from the cotyledonary sheath through the slit at its upper end (Troll, 1959), while in *Borassus flabellifer*, in the absence of such an opening, the scale leaf simply tears through the end of the sheathing portion of the cotyledon., which by this time has been reduced to a thin papery structure.

Corner (1966) states that remotive type of germination occurs among the Borassoid and Coryphoid palms. 15 genera mentioned in the available literature (Gatin, 1906 ; Corner, 1966) as having this type of germination are all members of these two sub-families, according to the classification of Corner (1966), with the exception of *Phoenix* and *Phytelephas*.

In the absence of more data, however, it is not possible to conclude if all or most members of these sub-families have this mode of germination. Of the two exceptions, *Phoenix*, the only genus in the Phoenicoideae, is probably related to the Coryphoideae, while the position of *Phytelephas* is doubtful (Corner, 1966 ; Tomlinson, 1961). The admotive type of germination occurs in 32 genera belonging to the other sub-families.

The mode of germination also appears to be related to the structure of the embryo. The palms with the remotive tubular type of germination, the structure of whose embryo is known, have the plumule and radicle in the axis of the embryo as in *B. flabellifer*, while the admotive types appear to have the plumule and radicle placed at an angle to each other and both turned away from the cotyledon, as in the coconut (Selvaratnam, 1952), and not in the axis of the embryo.

In the absence of more data it is again not possible to draw any conclusions about an association between remotive tubular germination and a straight embryo. Remotive tubular germination, however, could be advantageous or even necessary to this kind of embryo. Owing to the presence of the hard endocarp around the seed, the plumule and radicle need to be pushed out by the elongation of the cotyledonary stalk before further



development of the embryo can take place. In an embryo where the plumule and radicle are placed at an angle to each other, and both turned distally, as in the coconut, it is sufficient to push the distal end of the embryo just outside the endocarp to bring the plumule and radicle into a position suitable for further growth. But where the plumule and radicle are in the axis of the embryo, the distal end of the embryo is pushed further out, and the cotyledonary stalk curves down, bringing the plumule into a vertical position suitable for further growth.

This does not, however, explain the situation in *Lodoicea*, which is an extreme instance where the cotyledonary stalk is said to grow down into the soil to a depth of up to 2 feet and then horizontally for several feet more. Also, where the remotive ligulate type of germination occurs, according to Gatin (1906), the embryo is curved.

From a comparative study of germination in palms and other monocotyledons, Corner (1966) concludes that the remotive mode of germination in palms is "really the primitive palm method, and the simple case of the date is the reduced which becomes the normal method in other monocotyledons". The primitive method may have come to remain in the Borassoideae, Coryphoideae, Phoeniceae and Phytelephas. *Crinum* and Onion (Arber, 1926; Fahn, 1969) demonstrate this method of germination among the other monocotyledons.

According to Tomlinson (1961) the elongation of the cotyledon seems to be an ecological adaptation in palms of dry habitats. *Borassus* is a palm of dry habitats, thriving in sandy soil in regions of low rainfall, and the burial of the plumule deep in the soil may help in the survival of the seedling. Indeed, no part of the stem is seen above ground for 6 or 7 years (Blatter, 1926). The primitive mode of germination may have been retained by these palms growing in dry situations as an adaptation to their habitat.

Borassus flabellifer appears to be the only palm where sufficient food is stored in the scale leaf to make it an article of food for humans and of commerce. (For an account of the uses of the scale leaf, see Blatter, 1926). This may be an extreme instance of a situation occurring in other palms too. The food deposited here is that translocated by way of the cotyledon from the endosperm of the seed which is digested by the cotyledonary haustorium, and it serves as an underground store for the nourishment of the developing seedling. When the endosperm has been fully digested and its store transferred to the scale leaf, the cotyledon withers away.

SUMMARY

1. The mature embryo of *Borassus flabellifer* is more or less cylindrical. The bulk of the embryo is made up of the cotyledon, while the plumule and radicle are at the distal end, the plumule entirely enclosed by the sheathing portion of the cotyledon. The plumule and radicle are both situated in the axis of the embryo.

2. During germination the proximal part of the cotyledon grows into the endosperm and enlarges, functioning as a haustorium. The region between this and the plumule elongates, to form the cotyledonary stalk, which grows downward into the soil, carrying the plumule and radicle at its tip.

3. The first leaf formed by the plumule is a scale leaf, which elongates to a size of about 30-40 cm. in length and 3-4 cm. in breadth. It contains a great deal of storage starch in its cells, and forms the edible part of the seedling.

4. The scale leaf is followed by the first foliage leaf, which has an oblanceolate plicate lamina with a truncate apex.

5. The mature embryo is similar to that of *Phoenix dactylifera*, and the mode of germination is that described as remotive tubular, which occurs in the palm sub-families Borassoideae and Coryphoideae and the genera *Phoenix* and *Phytelephas*.

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EXPLANATION OF FIGURES

- Fig. 1. Seed of *Borassus flabellifer*, cut longitudinally.
 Fig. 2. Part of seed cut longitudinally, showing position of the embryo at the germ pore. The cap formed by the endocarp is shown separately.
 Fig. 3. Longitudinal section of the embryo.
 Fig. 4. and 5. Embryo from germinating seed. The constriction corresponds to the germ pore.
 Fig. 6. Germinating seed, cut longitudinally, showing entire embryo.
 Fig. 7. and 8. Longitudinal sections of distal region of cotyledons from germinating embryos.
 Fig. 9. Germinating seed. The plumule is enclosed within the disintegrating cotyledonary sheath.
 Fig. 10. Seedling about one year old. The first foliage leaf, the scale leaf and the remains of the cotyledonary sheath may be seen.

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