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DEVELOPMENTAL AND GERMINATION STUDIES OF THE SUGAR PALM (ARENGA PINNATA MERR.) SEED

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By

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MAY 1994

Chairperson: **Associate Professor Y.L. Hor, Ph.D.**

Faculty: **Agriculture**

Very little detailed data on the development and germination of the sugar palm seed (*Arenga pinnata* Merr.) is available. Therefore studies on the two features were conducted.

Changes in the physical and physiological characteristics of the fruit and seed during their development from anthesis until 38 months thereafter were elucidated in the first part of the study. The sugar palm fruit and seed were found to develop very slowly, requiring three years to ripen, and physiological maturity of the seeds was attained at 36 months after anthesis. Progressive embryo growth was not observed until 16 months after anthesis and maximum embryo weight was achieved at 30 months.

Towards maturity, thickening of endosperm cell walls occurred progressively until it filled almost the entire cell cavity at 36 months after anthesis, resulting in a hard and bony structure of the endosperm, characteristic for many palm species. Biochemical studies on the composition of

food reserves in the mature seed revealed that carbohydrate comprises more than 50% of the reserves present, which mainly consists of mannan.

The second part of the study was on germination and seedling development. It was found that the mature seeds were dormant because no germination was observed during four months at ambient temperature, although Tetrazolium tests showed them to be viable. However, *in vitro* germination of excised embryos revealed that immature embryos were capable to germinate since they were fully developed at 16 months after anthesis. And after deoperculation, the seeds germinated readily in two weeks. This shows that like many other palm species, the sugar palm seed also has a coat-imposed dormancy, exerted by the tissues which cover the germination pore. Approximately 700 gram force was needed to rupture this structure. The optimum temperature for germination was 35°C, but for continued seedling growth 30°C was optimum.

Seedling development was of the remote non-ligular type. The radicle and plumule emerged after five and six weeks' germination. Three different structures were observed in the germinating seed, namely the residual endosperm, degraded endosperm and the haustorium which developed from the cotyledon. The haustorium digests the endosperm and translocated hydrolysed reserves to the developing seedling.

The activities of two mannan hydrolising enzymes, ß-mannosidase and Ó-galactosidase were assayed during germination and early seedling development. The highest enzyme activities were observed in the degraded endosperm. The simple sugars detected were sucrose in the residual endosperm, sucrose and mannose in the degraded endosperm, and sucrose, glucose and fructose in the haustorium.

Abstrak disertasi yang dikemukakan kepada Senat Universiti Pertanian Malaysia sebagai memenuhi syarat untuk mendapatkan Ijazah Doktor Falsafah.

KAJIAN PERKEMBANGAN DAN PERCAMBAHAN BIJI BENIH ENAU (KABUNG) (*Arenga pinnata* Merr.)

Oleh

T. CHAIRUN NISA HARIS

MEI 1994

Pengerusi: **Profesor Madya Y.L. Hor, Ph.D.**

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Sedikit sekali data terperinci yang tersedia mengenai perkembangan serta parcambahan biji benih enau (kabung) (*Arenga pinnata* Merr.). Oleh kerana itu, suatu kajian ke atas kedua hal tersebut telah dijalankan.

Perubahan-perubahan sifat-sifat fizikal serta fisiologi buah dan biji benih enau (kabung) semasa perkembangannya daripada antesis sehingga selepas 38 bulan telah dikisahkan di dalam bahagian pertama kajian ini. Buah serta biji benih enau didapati tumbuh dan berkembang sangat lambat, selama tiga tahun diperlukan untuk masak, dan kematangan fisiologi biji benih dicapai pada 36 bulan selepas antesis. Pertumbuhan embrio yang pesat tidak terlihat sebelum 16 bulan selepas antesis dan berat maksimum embrio dicapai pada 30 bulan.

Menjelang kematangan, penebalan dinding sel endosperma berlaku dengan pesat sehingga ia memenuhi hampir keseluruhan rongga sel pada 36 bulan selepas antesis, dan mengakibatkan endosperma menjadi keras serta menyerupai tulang, iaitu satu sifat khusus bagi kebanyakan spesies palma. Kajian biokimia ke atas komposisi bahan makanan simpanan di dalam biji

benih yang matang menunjukkan bahawa kandungan karbohidrat adalah melebihi 50% daripada bahan makanan simpanan di dalam biji benih tersebut, yang terutamanya terdiri daripada mannan.

Bahagian kedua kajian ini ialah mengenai percambahan biji benih serta perkembangan anak benih. Telah dijumpai bahawa biji benih masak adalah dorman, sebab ianya tidak bercambah dalam jangka masa empat bulan pada suhu ambien, walaupun uji Tetrazolium menunjukkan bahawa ianya adalah hidup. Walau bagaimanapun, percambahan *in vitro* daripada embryo menunjukkan bahawa embrio muda dapat bercambah setelah berkembang sepenuhnya pada 16 bulan selepas antesis. Dan selepas penyah-operkuluman, biji benih mula bercambah dengan mudah dalam masa dua minggu.Ini menunjukkan bahawa seperti banyak spesies palma lainnya, biji benih enau juga mempunyai kedormanan yang disebabkan oleh kulit biji (testa), akibat daripada tisu yang menutupi liang percambahan. Tekanan seberat lebih kurang 700 gram diperlukan untuk memecahkan struktur ini. Suhu optimum untuk percambahan ialah 35°C, tetapi bagi pertumbuhan anak benih selanjutnya, 30°C adalah suhu optimum yang terbaik.

Perkembangan anak benih enau adalah dari jenis 'remote non-ligular'. Akar dan tunas muncul setelah lima dan enam minggu bercambah. Tiga struktur yang berbeza dapat dilihat di dalam biji benih yang sedang bercambah, iaitu endosperma residual, endosperma terhadam, serta haustorium yang tumbuh daripada kotiledon. Haustorium menghadamkan endosperma dan mentranslokasikan makanan yang terhidrolisis daripada tisu ini kepada anak benih yang sedang menumbuh.

Aktiviti daripada dua enzim penghidrolisis mannan, iaitu ß-mannosidase dan Ó-galactosidase telah di esei semasa percambahan dan perkembangan awal anak benih. Aktiviti enzim yang paling tinggi telah didapati di dalam endosperma terhadam. Gula sederhana yang telah dikesan adalah sukrosa di dalam endosperma residual, sukrosa dan mannosa di dalam endosperma terhadam, serta sukrosa, glukosa dan fruktosa di dalam haustorium.

CHAPTER 1

INTRODUCTION

The sugar palm belongs to the subfamily *Arecoideae*, and tribe *Caryoteae* (Moore, 1960; Dransfield and Uhl, 1986). The plant was earlier given a number of taxonomic names, such as *Saguerus rumphii*, and *Arenga saccharifera* Labill., but in 1917 Merrill through the International Congress of Botany in Vienna officially renamed it as *Arenga pinnata* (Mogea, 1991).

Distribution of this palm ranges from West India, through South East Asia, to West Irian. It is endemic to Malaysia, Indonesia and other South East Asian countries; and can be found in altitudes ranging from sea level up to 1400 m (Heyne, 1927; Miller, 1964; Sastrapraja *et al.*, 1978).

The palm has a number of local names, and in Indonesia alone Heyne (1927) reported approximately 150 local names for this species, indicating its multiple uses by the villagers.

Uses and Economic Potentials

The uses of the sugar palm in the every life of people in the humid tropics had been widely reviewed (Heyne, 1927; Burkill, 1935; Dransfield, 1976a; 1976b). Almost all parts of the tree can be utilised, but the most important product from which it derives its name is the palm sap, which forms the material for palm sugar. Palm sugar was recently reported to have a hypocholesterolaemic effect on rats (Hori *et al.*, 1992).

The sap is tapped from the male inflorescence, collected in large containers, and concentrated by evaporation into a viscous sugary mass. It is then poured into moulds while hot and then left to cool and solidify. The quantity of sap obtained from a single sugar palm peduncle is comparable to that obtained from ten coconut peduncles (Miller, 1964). Apart from production of palm sugar, the sap is also drunk fresh (called nira), or fermented into an alcoholic beverage. Further fermentation of the sap will produce vinegar, which through distillation will yield pure alcohol. Hence sugar palm sap forms the basis for the production of palm sugar, palm wine, vinegar and alcohol.

Besides the sap, other parts of the palm also have the following uses (Miller, 1964; Mogea, 1991; Mogea *et al.* 1991):

Fruits: The seeds of young fruits, when soft and mucilagenous, are consumed after being boiled with coconut milk and sugar. They can also be preserved in heavy syrup into a product called 'kolang-kaling', which is also canned.

Leaves: The leaves like that of coconut are used for thatch, or woven into baskets and mattings. The midribs of the leaflets are made into brooms, while young leaves are used for cigarette wrappings or consumed as salads.

Stem: The outer part of the stem consists of wood which is extremely hard and durable. This wood is used for flooring, furniture and and hand grips of tools. The inner part of the stem contains sago. In West Java this sago is called 'tapioca aren' and is the raw material for the meehun and sohun (noodle) industry. For the production of one ton of 'tapioca aren', 10 to 20 trees are needed, which suggests that one tree can produce 50 to 100 kg of sago (Muhtadi, 1991). The quantity of sago is maximum at the time when the plant is going to be tapped, but is much reduced in older plants after tapping has ceased.

Leaf sheath fibers (ijuk): The leaf sheath fibers can be exported and it is used as reinforcement in concrete and road constructions. It is also used for making brooms, brushes and roofing materials, or woven into ropes which are very durable.

Another potential of this multipurpose tree is its suitability for reforestation or rehabilitation of unproductive, erosion-prone sites, as the tree can grow on a wide range of soil types and altitudes. The roots are densely distributed and are reported to penetrate into the soil up to three meters deep. Hence they can be adapted to steep slopes (Wee and Rao, 1980; Muhtadi, 1991; Mogea *et al.*, 1991). Planting of the tree is quite simple as it does not need site preparations and after planting the tree needs little care.

As the sugar palm plays an important role in the economic life of the rural people (Hodge, 1958; Dransfield, 1976a; Mahmud, 1991), and is easily cultivated, promotion of this tree is highly desirable. In fact this palm has been recommended for agroforestry systems, which can increase farmers' income and rural employment (Sumitro, 1991).

Problems

The sugar palm is propagated by seeds. Unfortunately, seed germination under natural conditions is slow and sporadic owing to seed dormancy. Reports on the period of seed germination is also variable as

Masano (1989a) reported the seeds can germinate within 30 to 50 days after sowing, while Loomis (1958) and Kobernik (1971) reported it to require approximately six months. Information on other aspects of the fruit and seed such as fruit and seed development, seed extraction and germination are lacking. The lack of such information has been suggested to be one of the main reasons why the sugar palm has not been widely cultivated (Masano, 1989b).

Owing to the economic importance of the sugar palm, and the need for information on the production and germination of high quality seeds for successful establishment of sugar palm plantations, the present study was conducted with the following objectives:

1. To elucidate the patterns of fruit and seed development so as to establish the optimal time for harvesting high quality fruits and seeds.

2. To gain information on the cause of seed dormancy and methods of overcoming it.

3. To establish the pattern of seed germination and seedling development of the sugar palm.

4. To obtain information on the composition of seed reserves and their hydrolysis during germination and early seedling development.

CHAPTER 2

LITERATURE REVIEW

Development of the Fruit and Seed

Palms are Angiosperms, therefore fruit and seed development start after the process of double fertilisation. Following this process, the ovary will develop into a fruit and the ovule into a seed (Maheshwari, 1950; Bhatnagar and Johri, 1972; Sen, 1976; Copeland and McDonald, 1985).

The sugar palm, which is a caryotoid palm, is monoecious and usually hapaxanthic. This means that the axis of the tree is determinate, the vegetative apical meristem becoming transformed at a certain stage to develop the complex reproductive axis (Corner, 1966; Tomlinson, 1990). Flowering commonly proceeds in a basipetal direction, from above downwards. Flowers develop in triads. Female flowers have a tricarpellate, syncarpous ovary with three uniovulate locules, and three stigmas. Generally, all three carpels are functional in the sugar palm (Uhl and Moore, 1971; Hidajat, 1987). Pollination of palm flowers are usually performed by insects, but wind pollination also occurs. There is no data on the exact time of pollination in sugar palm flowers, but it is suspected to take place directly after anthesis (Hidajat, 1987; Hidajat and Pramesti, 1990).

The tricarpellate, syncarpous gynoecia of palms show in general three methods of development after fertilisation (Dransfield, in Tomlinson, 1990):

1. All three ovules become enclosed in a common endocarp, as in the cocosoid palms.

2. The three (or fewer by abortion) ovules each have a separate endocarp in a spherical unlobed fruit with basal stigmas.

3. The three ovules each have a separate endocarp and basal stigma, but the fruit becomes lobed according to the number of functional ovules.

The sugar palm fruit belongs to the second category of fruit development.

Tomlinson (1990) described the palm fruit as a berry or a fibrous drupe, with a fruit wall (pericarp) consisting of three layers; the exocarp, the mesocarp and the endocarp. The middle mesocarp may be fleshy or fibrous while the inner endocarp may be thin (berry) or thick and sclerified (drupe).

The exocarp surface is usually smooth, but this may also vary enormously. Most distinctive are the lepidocaryoid (scaly-fruit) palms such as *Salacca* in which the fruit resembles a pine cone as it is covered with regularly arranged reflexed scales. In others, the surface may be spiny or hairy. Fruits with a rough, corky texture such as *Manicaria* are occasionally found, and appear to be an adaptation for water dispersal.

The mesocarp may also be related to fruit dispersal. Fruits that are adapted for water dispersal may either have a spongy mesocarp (cocos and nypa), or a jelly-like mesocarp when they are heavier (*Caryota*). Otherwise the mesocarp is fleshy as in the case of date (Tomlinson, 1990).