1 Introduction

Abstract

Oil palm, *EIaeis guineensis* Jacq., is an important source of vegetable oil. Oil is extracted from the fruit mesocarp (crude palm oil) and from the seed (palm kernel oil). Botanically, the fruit is a drupe, with the kernel protected by a shell (nut). The commercial oil palm is Tenera (thin shelled), which is a hybrid from crossing Dura (thick shelled) seed palms with Pisifera (no shell) pollen palms. Since the shell is maternal tissue, seed for commercial planting has a thick shell. Like most seeds with very thick shells, oil palm seeds are difficult to germinate, the seed naturally germinates sporadically over time, and dormancy can last for up to 2 years. The challenges for seed production are to overcome dormancy (by weakening the operculum to allow germination), synchronize germination, produce a high germination percentage and high-quality germinated seed, free of abnormality or fungal infection. The processes used involve temperature treatments, imbibition, adjustment of seed moisture content and fungal control.

1.1 History of Oil Palm Production and Crop Facts

The African oil palm has the latin name *Elaeis guineensis* Jacq.: the genus name is derived from the Greek 'elaion', meaning oil, and the species name indicates its West African origin. The crop was discovered by travellers to Africa in the 15th century, but the first plantings in Indonesia, which led to its rise as the world's pre-eminent oil crop, did not occur until the late 19th century, with the first four Deli palms planted in 1848 (Pamin, 1998). Large-scale plantations were established in the early 20th century in both Africa and South-east Asia as interest in the crop developed. These initial plantations were composed of Dura palms, which are characterized as having thick-shelled fruits (Fig. 1.1). In the 1920s, the first crosses were made in deliberate

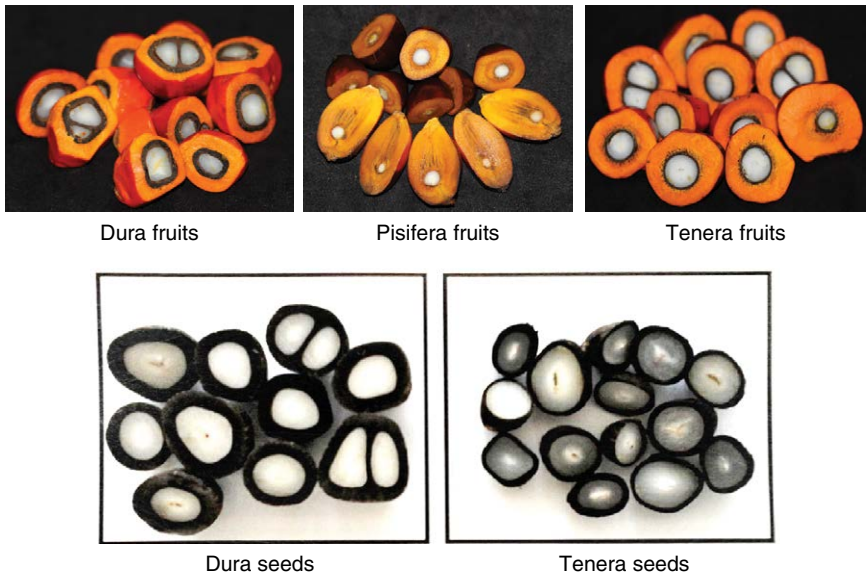

Fig. 1.1. The appearance of Dura, Tenera and Pisifera fruits (sliced open) and Dura and Tenera seeds (nuts, thick and thin shelled, respectively).

attempts to improve the crop through plant breeding, and in the 1950–1960s, the more productive Tenera types (a result of crossing Dura with Pisifera; see Beirnaert and Vanderweyen, 1941) took over as the favoured commercial material in both Africa and South-east Asia. Tenera genotypes are thin shelled, have thick, oil-bearing fruit flesh (mesocarp) and yield 30% more oil than Duras. Thus, crossing became an essential and major component in commercial oil palm seed production, as well as in breeding.

Oil palm is grown in the humid tropics, usually between latitudes 10° north and south of the equator, and covers over 8.5 million hectares (Mha) worldwide. It is grown mainly from seed, although clonal plantings of tissue culture-produced ramets are also practised. The crop is highly profitable and grown both on large-scale plantations and by smallholders (Sayer *et al.*, 2012). Ripe, fresh fruit bunches are harvested continually, at intervals of 7–14 days, and sent to local mills for oil and kernel extraction. Oil palm fruits provide both crude palm oil (CPO) and palm kernel oil (PKO), extracted from the fruit flesh (mesocarp) and kernel (endosperm), respectively. CPO is made up of palmitic (43%), oleic (39%), stearic (5%) and other fatty acids (Siew, 2002), and is a major source of provitamin A and vitamin E (Barcelos *et al.*, 2015). PKO is a high-quality oil containing lauric (up to 50%), myristic (15%) and other essential fatty acids (Sambanthamurthi *et al.*, 2000). Since oil palm is harvested continually, CPO represents a relatively stable commodity compared

to annual oil crops. The main CPO-producing countries are Indonesia (53% of global production) and Malaysia (38%); the largest consumers are India (28% of the market), Europe (22%) and China (22%).

1.2 Overview of Oil Palm Seed Production

Oil palm is the most popular oil crop in tropical regions. The first plantations of oil palm using commercially-produced seed were set up at the beginning of the 20th century. Malaysia developed the first oil palm seed market, launched in the 1970s, which included very strict planting programmes. Indonesia has the largest oil palm plantation area in the world and is the biggest CPO producer and the largest seed producer in the world.

Table 1.1. Oil palm D×P seed production capacity worldwide 2009. (From Khusairi *et al.*, 2010.)

Country	Seed production (million)
Asia	
Indonesia	250
Malaysia	81.5
Papua New Guinea	30
Thailand	13
India	2
Total	376.5
Central-South America	
Costa Rica	30
Honduras	2
Colombia	2
La Cabana	1.5
Ecuador	2
Brazil	1
Total	38.5
Africa	
Benin	6
Nigeria	2
Cameroon	2
Ghana	2
Democratic Republic of Congo	3
Ivory Coast	10
Total	25
Grand total	440

1.3 Biology and Genetics of Oil Palm

Oil palm (*E. guineensis*) is a long-lived perennial. It has a single apical meristem and does not sucker/conventionally reproduce asexually. After germination, there is a 3-year juvenile stage before inflorescences appear. These are produced in each leaf axil and are either male or female (monoecious), the first inflorescences produced after the juvenile growth phase (2 years) are normally male. Oil palm is an outbreeding species and pollination is affected predominantly by the weevil, *Elaeidobius kamerunicus*, which depends on oil palm inflorescences to complete its life cycle. Oil palm inflorescences are large and typically give rise to bunches containing 100–4000 fruits, depending on palm age. Fruits mature at about 150 days after pollination, turning from black to red, and the outer fruit begins to fall out/abscise from the bunch when it is ripe. The fruit is a drupe (stone fruit) composed of a fleshy mesocarp and a central kernel protected by a shell (endocarp). The kernel contains the products of fertilization: embryo and endosperm. In the wild, the mesocarp of fallen fruits rots or is eaten, leaving behind the kernel: germination takes place in favourable conditions by the emergence of a seedling shoot and root through the germ pore in the shell. Generally, one seedling is produced per seed, but up to three may occur.

Oil palm is diploid, with 16 pairs of chromosomes, but is thought to have evolved from an ancient tetraploid species as there is extensive genome duplication (Singh *et al*., 2013). It is highly heterozygous owing to its outbreeding reproductive system. Although oil palm can be artificially self-pollinated, inbreeding depression has been widely reported. Genetic maps of the oil palm genome have been developed (Mayes *et al*., 2000; Billotte *et al*., 2005) and the genome has been sequenced (Singh *et al*., 2013); thus, genetic markers may be deployed in screening for genes of interest in progeny from deliberate crossings.

1.4 Crossing and Seed Type

Commercial seed production is based on Dura (D) × Pisifera (P) crosses, which produce the desired thin-shelled Tenera (T). The predominant parental lines have been Deli Duras and AVROS Pisiferas. In addition to commercial seed production, seed needs to be germinated from breeding programmes in developing new varieties. Crop improvement through breeding has been limited by the genetic variation contained in elite Dura and Pisifera parental gene pools. In order to make progress in breeding, it became necessary to provide breeders with more genetic variation, and thus germplasm collections from wild, landrace and cultivated materials in West Africa (the centre of diversity) have been carried out. The West African Institute for Oil Palm Research (WAIFOR), Nigeria, was one of the first to do this. In recent years,

major oil palm breeding companies have joined collecting expeditions in West Africa (Okyere-Boateng *et al*., 2008; Sapey *et al*., 2012). Crossing programmes include D×P, D×D, D×T, T×T, T×D and T×P crosses (Forster *et al*., 2018; Setiawati *et al*., 2018), and germination for both thick- (D female) and thin- (T female) shelled seed is required.

1.5 Commercial Crossing

Tenera oil palm has become the predominant commercial fruit type. Tenera seed is produced by commercial seed companies by crossing Dura (thick shelled) with Pisifera (no shell) genotypes. Pisifera palms are often female sterile and do not set fruit. Pisiferas are therefore used as the male (pollen) parents in commercial production (Setiawati *et al*., 2018). There is no reason why fertile Pisiferas should not also be used as pollen parents, but there was a concern that the resulting Tenera progeny had a thicker shell (Menendez and Blaak, 1964).

Pisifera pollen is collected and stored ready for use in crossing. The shell thickness trait is controlled by a single gene, *Sh*, with Dura being homozygous thick shell (*Sh*/*Sh*), Pisifera being homozygous no-shell (*sh*/*sh*) and Tenera being heterozygous (*Sh*/*sh*). Seed production is a specialized and lucrative business; in 2014, Indonesian oil palm seed producers sold 102,826,918 seeds at an average cost of about US$0.8/seed. The oil palm industry is therefore dependent on quality-controlled crossing procedures and seed production.

1.6 Seed Production

The term ‘seed production’ in oil palm for breeding and commercial production refers to germinated seed, not biological seed. Seed (botanically a nut) is sold (commercial) and planted in nurseries (commercial and breeding materials) as germinated seed (Fig. 1.2).

Fig. 1.2. Germinated seed ready for sale and planting.

The process for both commercial and breeding seed production starts with deliberate and controlled crossing of parental lines, followed by bunch harvesting, removal of the fruit mesocarp and the delivery of fresh, ungerminated seed to a seed production facility. These and subsequent seed germination protocols are described in the following chapters.

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