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Effects of nursery management practices on morphological quality attributes of tree seedlings at planting: The case of oil palm (*Elaeis guineensis* Jacq.)

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ABSTRACT

Even though oil palm production is associated with forest clearance and environmental degradation, it is also considered a potential carbon sink. For oil palm to fulfil its potential role in environmental sustainability, high quality seedlings are required. Nursery managers in Benin who produce oil palm seedlings for owners of small farms ignored recommended practices and developed their own. To evaluate the efficacy of their nursery management practices in terms of seedling growth, 2 experiments were conducted. Three polybag sizes (5 L, 8 L, and 15 L) in combination with 4 types of soil substrates and 3 fertiliser treatments were implemented in both experiments in a factorial design. Biomass (shoot, root, shoot-to-root ratio) and allometric (seedling height, number of leaves, length of most developed leaf, root-collar diameter) variables were measured 8 or 6 months after transplanting.

Polybag size was the main factor determining oil palm seedling growth in both experiments. Applying 10 g fertiliser once a month was harmful to seedling survival with lethal effects in 5 L polybags. Arable soil with animal manure in 8 L polybags without any fertiliser supply sustained seedling growth well; this practice seemed to be the best balance between quality and production cost although 15 L polybags produced the best seedlings. Growth variables were highly correlated. Height and root-collar diameter constitute good candidates to estimate seedling biomass production non-destructively. The treatment effects on total biomass produced were similar for the 2 experiments.

Given the observed large effects of polybag size on seedling growth, our findings suggest that fertiliser addition or substrate selection cannot overrule container size effects; the latter should be considered carefully for (forest and crop) tree seedling production in nurseries.

1. Introduction

Oil palm (*Elaeis guineensis* Jacq.) is an important perennial crop in South East Asia, South America, and Africa (Cao et al., 2011). Its oil is valued in human diet, body care, animal feed, detergents, and bio-energy (Foo and Hameed, 2010; Palatty et al., 2013; Russo et al., 2012). Known as an efficient competitor with other oil crops in terms of production per acreage (Fairhurst and Mutert, 1999), oil palm is a potential carbon sink (Wicke et al., 2008). It is largely produced in tropical countries where owners of small farms are the main planters. For owners of small farms to establish a successful plantation with desired early fruiting, the use of vigorous planting material is required (Bah and Rahman, 2004; Ibrahim et al., 2010). Many factors influence seedling growth during the nursery stage. These include water, nutrients, shading, soil substrates, age of transplanting, weeds, pests and diseases (Bah and Rahman, 2004; Jacquemard, 1995; Poorter et al., 2012a;Witt et al., 2006). Some of these factors (e.g., nutrients, soil substrates) can be controlled by nursery managers.

In Benin, some nurseries are established by the government to supply seedlings to owners of small farms. This seedling supply system is organised in such a way that farmers are forced to

Abbreviations: CRA-PP, Centre de Recherches Agricoles Plantes Pérennes [Agricultural Research Centre for Perennials]; FCFA, Franc de la Communauté Financière Africaine [Currency of the African Financial Community].

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purchase planting material from these nurseries. The oil palm research centre (CRA-PP) developed a protocol of seedling production that consists of a number of recommendations to ensure good quality seedling delivery. For instance, it is recommended that nursery managers use forest soil preferentially, or household waste as substrate. Both substrates are transported at high costs while especially good forest substrate is scarce as not many forests are left in Southern Benin where land pressure is high (Koudokpon et al., 1994). The recommendations also include the use of 15 L polythene bags (polybags), but nursery managers consider that too large and requiring too much substrate and labour to fill. Yet, based on such a protocol, the nursery managers were trained and licensed as formal nursery holders. While producing seedlings in their own nurseries, nursery managers deviated from the recommended practices to optimise their seedling production enterprise. During a diagnostic study carried out in 2010 in Southern Benin (Akpo et al., 2012), farmers complained about the morphological quality attributes of seedlings they purchased. Nursery managers readapted the recommended practices and developed alternative ways of seedling production. Nursery managers for instance used soil substrate collected around the nursery place alone or in combination with animal manure and some used smaller polybags than recommended. As some of the practices did not seem to guarantee seedling quality, this research aimed to evaluate which nursery managers' developed production practices sustain seedling quality at planting.

The influence of nursery management practices on seedling quality has been partially studied on a range of plant species including *Eucalyptus* (Close et al., 2010; Teixeira et al., 2008), date palm (*Phoenix dactylifera* L.) (Aisueni et al., 2009), pine (*Pinus palustris* Mill.) (South et al., 2005), *Acacia koa* (Dumroese et al., 2011), and *E. guineensis* (Aya, 1974; Teixeira et al., 2009). These studies drew on a few aspects of seedling growth at the same time and most of them were conducted in research station settings and far from actual nursery production conditions. In the particular case of oil palm, literature on seedling behaviour vis-à-vis nursery management practices is scarce and this calls for more research on the subject.

Nursery containers have been reported as one of the main factors affecting the successful growth of trees (Dominguez-Lerena et al., 2006; Poorter et al., 2012a). Lambert et al. (2010) observed lower survival of tree seedlings (e.g., *P. palustris*) grown in smaller containers. Poorter et al. (2012b) mention the reduction of photosynthesis efficacy of plants grown in smaller containers. The growth substrate also influences plant growth and development as reported by Óskarsson (2010) for downy birch (*Betula pubescens* Ehrh.) and by Bayley and Kietzka (1996) for pine (*Pinus patula* Schiede & Deppe). The substrate itself, or through addition of (chemical) fertilisers, might impose salinity that is reported to decrease plant (root) growth (Jacobs et al., 2003; Javid et al., 2011; Wong, 1985).

This general knowledge of effects of nursery practices on seedling growth coupled with the Benin context raises the following issues: (1) the forest soil substrate used at current land pressure may be sub-optimal compared to the intended forest soil and so the alternative substrates nursery managers opted for may be preferable ones; (2) smaller polybags may have an effect on available nutrients and on rooting space that will compromise seedling size at planting, but may provide a significant cost reduction; (3) inorganic fertiliser application in smaller polybags may compromise seedling survival while it is unknown whether this can be avoided by providing the same total amount of fertiliser applied incrementally throughout the nursery phase; (4) it is also not documented whether polybag size, fertiliser supply, or substrate will show the largest effects on seedling growth. To understand these agronomic issues and contribute to the knowledge of nursery seedling production, a full factorial experiment with 3 factors was carried out twice.

A secondary aspect of this study was to find the better ways to non-destructively determine seedling quality. Lucas (1980) reported high correlations between some growth parameters of oil palm seedlings.

We were specifically interested in treatment interactions, correlations between growth variables, the best proxy to estimate biomass in a non-destructive way, as well as financial implications. The common planting age of oil palm seedlings lies between 6 and 8 months (8 months as recommendation and 6 months as often used by nursery managers). For this reason, treatment effects on seedling growth were measured at 8 months during the first experimental year (2011) and at 6 months in the second experimental year (2012).

2. Material and methods

The study was carried out in 2011 from March 4th to November 4th and in 2012 from April 6th to October 6th in Southern Benin, Sakété district, where recently problems in quality of oil palm seedlings have been reported (Akpo et al., 2012). In Southern Benin (6.4° N to 7.3° N and 1.5° E to 2.8° E), farming is the main activity for local communities. The agricultural landscape is mainly characterised by oil palm plantations, pineapple [*Ananas comosus* (L.) Merr.] farms, and food crop farms (with maize [*Zea mays* L.], cassava [*Manihot esculenta* Crantz], cowpea [*Vigna unguiculata* (L.) Walp.]). The climate is transitional equatorial with 2 rainy seasons, from March to July and from September to November, separated by 2 dry seasons. The annual rainfall decreases from 1400 mm in Sakété (east) to 950 mm in Grand-Popo (west) (MEPN, 2008). The annual average temperature ranges from 23 to 32 °C (MEPN, 2008; Tchibozo et al., 2005) as compared to the required minimum of 18 °C and maximum between 28 and 34 °C for oil palm (Jacquemard, 1995).

2.1. Experimental design

A full 3 × 4 × 3 factorial experiment was conducted and carried out with 5 replications. Factors and levels were: polybag size with 3 levels (5 L, 8 L, and 15 L); type of soil substrate with 4 levels (forest soil, household waste, arable soil, and mixture arable soil + animal manure) and fertiliser supply with 3 levels (no fertilisation, split dose: 5 g per seedling fortnightly, and full dose: 10 g per seedling monthly). Forest soil was the top 20 cm of soil collected under a plantation of *Eucalyptus camadulensis* (Dehnh), the most readily available forest soil type. Household waste substrate was collected from a pile of decomposed waste and sieved to 8 mm. Arable soil was collected from a field near the experimental site that had never been planted to oil palm. Animal manure was collected as the top 5 cm from an area where cattle stayed overnight. The arable soil and animal manure were mixed in a volume proportion of 2:1.

Each polybag size × substrate × fertiliser combination consisted of 6 polybags (arranged in 2 rows of 3) with 1 seedling per polybag. In both years, the same cross of genetically identical seedlings of 4 months old was collected from the oil palm research centre. The batch of seedlings was raised from November 4th 2010 to March 4th 2011 and from December 6th 2011 to April 6th 2012 in the same nursery, under shade in 0.8 L polybags, and watered 3 times a week until the age of 4 months before being moved to the experimental site where treatments were applied. Fibrous waste of processed palm nuts was used to mulch seedlings (Von Uexkull and Fairhurst, 1991) 2 weeks after transplanting. Three months after seedling transplanting to the experimental site, the pesticide