Scientia Horticulturae 175 (2014) 251–257

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Growth dynamics of tree nursery seedlings: The case of oil palm

Essegbemon Akpo[a,b,c,*], Tjeerd Jan Stomph[a], Dansou K. Kossou[b], Paul C. Struik[a]

[a] Centre for Crop Systems Analysis, Wageningen University, PO Box 430, 6700 AK Wageningen, The Netherlands
[b] Faculté des Sciences Agronomiques, Université d'Abomey-Calavi, BP 526 FSA/UAC, Cotonou, Bénin
[c] Centre de Recherche Agricole Plantes Pérennes, Institut National des Recherches Agricoles du Bénin, BP 01 Pobè, Bénin

ARTICLE INFO

Article history:
Received 12 August 2013
Received in revised form 23 May 2014
Accepted 18 June 2014
Available online 6 July 2014

Keywords:
Growth dynamics
Growth rate
Growth model
Pot size
Substrate
Fertiliser

ABSTRACT

Tree seedling survival in the field partly depends on management during seedling production. Insight into how nursery practices affect seedling growth dynamics would generate understanding in how to optimise tree seedling production. The objective of this study was to analyse the growth dynamics of oil palm seedlings to evaluate the effects of bag size, substrate type, and fertiliser supply, and their interactions. An experiment was run in 2011 (March to November 2011) and repeated in 2012 (April to October 2012) using three bag sizes, four substrates, and three levels of fertiliser supply ($3 \times 4 \times 3$ factorial design). Seedling height, collar diameter and number of leaves were measured over time. Seedling growth was analysed by comparing treatment effects at monthly intervals. Data were also fitted to growth curves to analyse treatment effects on absolute and relative rates of increase in seedling height, collar diameter and number of leaves.

While substrate and fertiliser supply effects were fairly constant over time, bag size effects increased with larger variance explained over time. We observed that bag size effects overtook substrate, fertiliser and interaction effects from about two months onwards. Seedling height and collar diameter followed an exponential growth while number of leaves increased linearly over time. Analysis of generated data with the different growth models indicated that seedling growth rates were mainly under the influence of bag size, followed by substrate. Interactions between nursery practices, although significant sometimes, did not account for a large part of experimental error. Implications for tree seedling management are further discussed.

1. Introduction

For tree nurseries in general, seedlings are sorted using several criteria, including seedling provenance, physiological quality, pest and disease tolerance, etc. (Konnert and Ruetz, 2003). Among these, physiological quality criteria are prioritised for seedling establishment after planting (Villar-Salvador et al., 2004). The production of planting material that insures seedling survival under changing and sub-optimal biotic and abiotic field conditions requires good knowledge of nursery management practices during seedling development. Besides generally investigated environmental factors controlling plant growth (e.g., light, temperature, and water), management practices (e.g., pot size, substrate, fertiliser supply, and planting density) are reported to greatly affect physiological quality of tree nursery seedlings (Dominguez-Lerena et al., 2006). Effects of pot or bag size (Aya, 1974; Close et al., 2004; Krizek and Dubik, 1987; Nesmith and Duval, 1998; Poorter et al., 2012), quality of substrate (Ahmad et al., 2012; Lazcano et al., 2009; Radhouani et al., 2011) and fertilisers applied (Javid et al., 2011; Saint Pierre, 2012) on seedling growth were underscored for both annual and perennial plant species.

Bag size, substrate quality, and fertiliser supply are among the top most important management factors that influence tree seedling production (Oliet et al., 2004; Poorter et al., 2012). An account of the way those effects occur throughout seedling growth is an important aspect as it can contribute to optimising production of tree nursery seedlings. In the literature, much emphasis is placed on overall effects of management practices on seedling development. For tree nursery seedlings in particular, studies are still lacking regarding insight into the temporal dynamics of seedling growth as affected by bag size, quality of substrate, fertiliser supply

Abbreviations: CRA-PP, Centre de Recherches Agricoles Plantes Pérennes [Agricultural Research Centre for Perennials].

* Corresponding author at: Faculté des Sciences Agronomiques, Université d'Abomey-Calavi, BP 526 FSA/UAC, Cotonou, Bénin. Tel.: +229 97 48 17 78.

E-mail addresses: e.akpo@yahoo.fr, akpo.essegbemon@gmail.com (E. Akpo), tjeerdjan.stomph@wur.nl (T.J. Stomph), dansoukossou@yahoo.com (D.K. Kossou), paul.struik@wur.nl (P.C. Struik).

http://dx.doi.org/10.1016/j.scienta.2014.06.020
0304-4238/

and their interactions. More specifically, it is often not well documented at what point in time, e.g., pot size, substrate or fertiliser effects manifest themselves and in what direction they evolve; whether those effects increase or decrease over time or remain more or less constant. This study addressed specifically these issues and thereby aimed to contribute to knowledge that could underpin options for improved management.

To investigate above mentioned issues, we used oil palm as an example of a tree nursery crop. We elaborate upon a former paper by Akpo et al. (2014) on effects of nursery management practices on seedling phenotype. That paper revealed large differences between treatment effects at the end of two experiments (Akpo et al., 2014). In comparison to substrate and fertiliser supply, bag size was the factor that showed the largest effects on seedling growth. The paper, however, did not report: (1) at what point in time the different treatments started to differ and how these differences developed over time; and (2) which treatment combinations showed similar growth rates. To investigate them, this paper analysed seedling growth dynamics of oil palm as a major crop.

Oil palm is a major crop with increasing demands for its products for human use worldwide (Henderson and Osborne, 2000; Koh, 2011; Mekhilef et al., 2011). Land area planted with oil palm is expected to increase in most production countries in years ahead (Castiblanco et al., 2013; Sayer et al., 2012; Wicke et al., 2011). In some oil palm growing countries (e.g., Bénin, Ghana, and Nigeria), smallholder farmers constitute main players and produce the bulk part of national production (Carrère, 2010). Successful smallholder plantations – in a context where farmers rely on nursery holders to purchase seedlings – depend on availability of suitable seedlings at planting time. Like many tree nursery seedlings [e.g., Sullivan et al., 2001; Sullivan and Sullivan, 2008], oil palm seedlings are sensitive to rodent pest damages at early phase of transplanting to field (Buckle et al., 1997; Puan et al., 2011). Well-raised nursery seedlings are more likely to survive under field conditions than poorly raised ones.

To conduct a plant growth study of tree seedlings, a timeline collection of seedling dry weights constitute one of the ways of analysis. To monitor treatment effects and yet circumvent a high number of seedlings through destructive seedling sampling over time allometric variables as seedling height, collar diameter and number of produced leaves were observed. For oil palm, these allometric variables were reported to highly correlate with total dry weight and are reliable proxies to evaluate oil palm seedling growth (Lucas, 1980). Besides the importance of the correlation between dry weight, collar diameter and height, the relevance of height and collar diameter in characterising plant growth was used in literature for several tree species (Asif et al., 2013; Bowman et al., 2013; Hari et al., 1977; Nyombi et al., 2009; Özel and Ertekin, 2011; Wang et al., 2012). For growth of tree plant species, Bowman et al. (2013) observed that height and diameter are the commonly measured tree attributes to characterise its growth because of their strong correlations with wood volume and biomass. The objective of the study was to analyse the growth dynamics of oil palm seedlings to evaluate the effects of bag size, substrate type, and fertiliser supply, and their interactions.

2. Material and methods

The study was conducted in Sakété district, Bénin. The experiments were run in 2011 from March 4th to November 4th (8 months period) and in 2012 from April 6th to October 6th (6 months period). Total monthly rainfall (40 mm–260 mm), monthly average minimum temperature (22 °C–25 °C), maximum temperatures (31 °C–34 °C), and average relative humidity (60% and 84%) during study periods are presented in Fig. S1.

2.1. Experimental design

A full 3 × 4 × 3 factorial experiment with 36 treatments was conducted and carried out in 5 replications, each year. Factors and levels were: bag size with 3 levels [small: 25 cm × 30 cm (5 L), medium: 31 cm × 31 cm (8 L), and large: 40 cm × 40 cm (15 L)]; four types of soil substrate (forest soil, household waste substrate, arable soil, and arable soil with animal manure) and fertiliser supply with three levels (no fertilisation: 0 g per seedling during experiment periods, split dose: 5 g per seedling every 15 days, and full dose: 10 g per seedling every 30 days). Fertilisers consist in urea (46% N) and NPK (10%, 20%, 20%), that were used alternatively. Forest soil was the top 20 cm of soil collected under a plantation of *Eucalyptus camadulensis* (Dehnh). 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 with oil palm or had never held oil palm seedlings. Animal manure was collected as the top 5 cm from an area where cattle stayed overnight. Arable soil and animal manure were mixed in a volume proportion of 2:1.

Each treatment replicate consisted of six bags with one seedling per bag per replication. Seedlings were arranged in two rows and spaced in a 60 cm × 60 cm grid. In both years, genetically identical seedlings of 4 months old were collected from the oil palm research centre (CRA-PP research centre in Pobè, Bénin). The batches of seedlings were raised in the same pre-nursery under shade in 10 cm × 15 cm bags and watered three times a week until the age of 4 months when they were brought to the experimental site. Fibrous waste of processed palm nuts was used as mulch around individual seedlings per bag (Von Uexkull and Fairhurst, 1991) two weeks after transplanting. Three months after seedling transplanting, the pesticide Dursban (chlorpyrifos; 0.4 ml per 20 seedlings) was used once to control foliage pests. Fertiliser application started with urea two weeks after transplanting. Throughout the experiment, 1 L of water was supplied per seedling three times a week.

At the time bags were filled, two samples of 500 g of each substrate were collected and air dried for later chemical analyses. Samples were analysed using classical methods of soil nutrient analysis in laboratory (Pansu and Gautheyrou, 2006). The pH was determined using glass electrodes. Further methods were: Walkley and Black method for organic carbon, Kjeldahl method for total nitrogen, Bray (I) method for phosphorus, and ammonium acetate method for potassium, calcium, magnesium and exchangeable cations (Table 1). Analysed nutrients were the most important ones for physiological quality of oil palm seedlings (Turner, 2003; Corley and Tinker, 2003).

Due to lethal effects of full dose fertiliser in small bags, data are reported on 32 treatments.

2.2. Data collection

From the second (2011) or first (2012) month onwards, after seedling transplanting, observations were made monthly on seedling height, stem collar diameter and number of leaves.

Seedling height was measured from the plant base to apical level of leaves, by stretching leaves upward in the direction of the stem. Collar diameter was taken as the mean of two measures taken at perpendicular angle at the stem base where roots sprout from shoot. Number of leaves was recorded through counting all leaves that appeared since the time seedlings were transplanted. Growth variables were measured on four randomly selected seedlings out of six per experimental unit.