Abstract

Eucalyptus is ~~one of~~ among the important ~~fast~~ fast-growing species, and is typically managed on short rotation to sustain ~~economy with~~ the production of timber, pulpwood, charcoal, and fire-wood. In order to sustain the plant material supply with efficient and ~~cost~~ cost-effective means, ~~macro~~ macro-propagation using cutting is required ~~instead~~ as an alternative to ~~seed~~ clonal seeds for uniform plant material seedling production. However, information on early root development of *E. pellita* ~~is still~~ remains to be lacking in terms of ~~from these two propagation types,~~ seed and stem cutting of *E. pellita* seedlings. ~~The objectives of this~~ This study ~~were,~~ aims to compare the root development of two different propagation seedlings of *E. pellita*; and to study the effect of ~~different~~ various nitrogen ~~concentrations~~ concentration levels ~~towards~~ on two types of propagation of *E. pellita* seedlings. The study was conducted using *E. pellita* seedlings from two types of propagation, namely, seed and stem cuttings, along with three ~~(3)~~ different nitrogen concentrations (0, 50, and 200 kg N ha^{-1}). Shoot biomass, root intensity (RI), total root intensity (TRI), root biomass, root length density (RLD), and specific root length (SRL) were recorded. Most of the root parameters ~~showed~~ demonstrated a significant ~~significant~~ difference in stem cutting, as compared to seed cutting. In conclusion, *E. pellita* seedlings from stem cutting was greater in terms of root distribution compared to propagation by seeds at the nursery stage, and ~~the~~ 50 kg N ha^{-1} was the ~~best~~ optimal nitrogen ~~concentrations~~ concentration level from the considered levels to be applied to the *E. pellita* seedlings. More research is required for ~~studying~~ investigating the root distribution from these two types of propagation in ~~the~~ real field soil, ~~as~~ since different environmental factors may affect the growth performance of *E. pellita*.

Introduction

Plantation ~~forestry~~ forestry using *Eucalyptus* spp. in Sabah ~~has began~~ started in the 1970s (Harwood & Nambiar, 2014) as part of a ~~an effort for~~ forest conservation effort (Zaiton et al., 2020). *Eucalyptus* is ~~one of~~ among the important ~~fast~~ fast-growing species that is typically managed on short rotation to sustain ~~economy with~~ the production of timber, pulpwood, charcoal, and fire-wood (Zaiton et al., 2018; Zhou et al., 2018). Sabah Softwood Berhad (SSB) is the first private forest plantation ~~companies~~ company in Sabah ~~who~~ that pioneered using ~~fast~~ fast-growing timber species, where *E. deglupta* was initially introduced during the early plantation development (Enters et al., 2002). However, it was unsuccessful, and was later replaced with other superior species ~~including~~ such as *Acacias*, due ~~to less economic,~~ poor growth performance (Zaiton et al., 2020) and foliar pathogens (Japarudin et al., 2015).

Since ~~almost~~ nearly three decades, *A. mangium* and hybrids ~~are~~ have been the ~~main~~ primary species ~~that~~ planted in Sabah, especially in some forest plantation companies such as Acacia Forest Industries

Sdn Bhd (AFI), Sabah Forest Development Authority (SAFODA) and SSB. However, *A. mangium* and hybrids~~s~~ performance are affected mainly by serious fungi *Ceratocystis* disease (Tarigan et al., 2011; Japarudin et al., 2015), wilt (Japarudin et al., 2015), and *Ganoderma philippii* (Mohammed et al., 2014), which have caused death to about 10 to 20% of the *Acacia* trees in plantations (Wong., et al. 2015). Therefore, *E. pellita* is an alternative option for the ~~fast~~ fast-growing timber production industry. Since 2008, most of forest plantation companies in Sabah and Sarawak have been involved in using *Eucalyptus* species in plantations (Zaiton et al., 2020).

-*Eucalyptus pellita* F. Muell, or red mahogany, is a ~~medium~~ medium-~~to~~ to-large tree that can grow up to 40 m in height and over 1 m in diameter (Harwood 1998; Dombro 2010). *E. pellita* is native to Papua New Guinea and northern Queensland, Australia (Hung et al., 2015; Yahya, 2020; Yew et al., 2015). ~~E. pellita~~ It has good growth and a high survival rate because of its wider range of adaptability with sites and favourable stem form (Yahya, 2020). Currently, *E. pellita* plays an important role in reforestation in countries such as Brazil, Cuba, Indonesia, Malaysia and the Philippines (Hung et al., 2015). Furthermore, *E. pellita* is used for a variety of products such as fine furniture (Clarke et al., 2009), pulp production ~~in many countries~~ (Eldridge et al., 1993; Poke & Raymond 2006) and high quality writing and printing paper or tissue products (Raymond 2002; Raymond & Schimleck 2002; Schimleck et al., 2006).

-In order to sustain the plant material supply with efficient and ~~cost~~ cost-effective means (Kuppusamy et al., 2019), ~~macro~~ macro-propagation using cutting ~~is required~~ can be used instead of ~~seed~~ clonal seeds for uniform plant material seedling production. Cutting ~~method~~ is the most widely used technique, and is cheaper for larger multiplying seedlings of *Eucalyptus*~~-~~, ~~due~~ due to easier handling as compared to the ~~micro~~ micro-propagation method (Sulichantini et al., 2014).

However, although there exist ~~a lot of~~ many studies ~~previous literatures about~~ on *E. pellita*, ~~but~~ there ~~are no or~~ is a limited amount of information ~~about~~ on root growth of *E. pellita* at early development ~~or from these two types,~~ from seed and stem cutting of *E. pellita* seedlings. This is probably due to the difficulty in ~~studying~~ investigation belowground, and also due to methodological problems. With ~~Such~~ such information, it is ~~will be~~ useful for forest plantation ~~companies~~ company management in enhancing the understanding on ~~strategy~~ strategies to optimize yield production with the appropriate agronomic or silvicultural approach. In ~~the~~ this present study, we used ~~different~~ various types of planting material sources from seed and stem cutting of *E. pellita*~~-~~, and ~~study~~ studied their root traits at three different nitrogen concentrations. We hypothesied that, both above and belowground, ~~of~~ *E. pellita* seedlings from stem cutting ~~are~~ were greater than ~~the~~ seedlings from seed propagation. ~~Therefore~~On this basis, ~~the aimed of this study were~~the objectives of this study were formulated as follows~~,~~: i) to compare the root