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ORIGINAL ARTICLE

Growth Performances of Cocoa (*Theobroma Cacao*) Varieties under Mature Oil Palm with Palm Oil Mill Effluent as Growing Media

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Abstract

Oil palm (*Elaeis guineensis*) is a leading edible oil-producing plant established in tropical countries which cause many negative impacts. Poor productivity of monoculture plantations and land and aquatic pollution caused by haphazard release of Palm Oil Mill Effluent (POME) are critical concerns. As a remedy, oil palm can be intercropped with cocoa by using POME as a potting media. In this study, we evaluated the growth of two different cocoa varieties with POME as the potting media under 20 years old oil palm shade. Two cocoa varieties (SCA6 x ICS6, and NA32 x ICS1) and three potting media (topsoil only, 40% topsoil with 60% POME, and 60% topsoil with 40% POME) were factorially combined in a randomized complete block design with three replicates under 40% shade, Faculty of Agriculture, University of Ruhuna. Growth parameters of the cocoa seedlings such as plant height, number of leaves, chlorophyll value, stem girth, root and shoot dry weights, root length, number of lateral roots per plant were measured using destructive and non-destructive sampling methods. The potting media consist of 40% topsoil with 60% POME showed significantly the highest plant height, number of leaves, chlorophyll value, stem girth, fresh and dry weight of shoot and roots and length of roots. Hence, potting media with 40% topsoil with 60% POME was recognized as the best potting media for the growth and development of cocoa seedlings of both varieties. Growth of cocoa seedling was well compatible under oil palm shade at full light condition with the use of POME as the potting media.

Keywords: *Cocoa varieties, POME, Potting media, Seedling growth, Shade*

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1. Introduction

Oil Palm is mainly cultivated as a monocrop in Sri Lanka, since 1967 (Arachchige et al. 2019). This was introduced first as an ornamental plant and later as a cash crop, which now has become a significant component in Sri Lankan economy. Oil palm is ranked after the major plantation crops such as tea, rubber, and coconut in the context of the agricultural and industrial sector of Sri Lanka with a significant contribution to the foreign exchange (Arachchige et al. 2019). There are about 10,000 hectares of oil palms cultivations across Sri Lanka (Hasanthi and Palihakkara 2020). At present, the land is a limiting factor and optimum utilization of lands, which necessitates proper land use planning (Mapa et al. 2002). It is important to obtain maximum benefits from prevailing oil palm lands.

Recent policy decisions to replace oil palm plantations with environmentally friendly crops in Sri Lanka further strengthen intercropping of mature oil palm lands and it is a practical solution to overcome upcoming challenges. There is a driving demand on cocoa (Theobroma cacao) bean to bar- chocolate and the cocoa sector is projected to grow in emerging economies mainly with its extensive popularity and wide use in the food industry (Beg et al. 2017). Cocoa as an agent of antioxidant, antihypertensive, antidiabetic, and anti-tumour, development of nutraceuticals from cocoa with specific biological activities improve healthy wellbeing of people (Domínguez-Pérez et al. 2020). Oil palm intercropping presents numerous benefits including raising the net income, reducing maintenance cost, maximizing land use, and increasing fertilizing impact (Nchanji et al. 2016). One major characteristic of cocoa and oil palm intercropping is that these two crops have different labour requirement calendars which do not overlap each other, and oil palm and cocoa intercrop provides a high Land Equivalent Ratio (Khasanah et al. 2020). Cocoa and oil palm intercropping have been found biologically compatible (Bourgoing and Todem. 2010). Exploration of the feasibility of oil palm intercropping system as a long-term strategic management option is vital to improve the land productivity, economy, and environmental performance (Khasanah et al.2020). Cocoa is usually grown in thinned forest shade (Bentley et al. 2004) and this shade could be supplied by the oil palm as well.

Palm Oil Mill Effluent (POME) is the wastewater discharged during the processing and direct removal of POME into the environment is not recommended due to the high Chemical Oxygen Demand and Biological Oxygen Demand (Poh and Chong 2009). Proper and safe disposal of POME will increase soil fertility and contribute to environmental sustainability (Lam and Lee 2011). The POME consists of nutrients such as phosphorus, nitrogen, calcium, magnesium, sodium, copper, lead, and exchangeable zinc (Ojonoma and Nnennaya 2007). These nutrients could be advantageous for the growth and development of cocoa seedlings. Therefore, the objective of the present study is to evaluate the suitability of palm oil mill effluent as a component of growing media for cocoa seedling growth under mature oil palm shade.

2. Materials and Methods

The experiment was conducted at the Faculty of Agriculture, University of Ruhuna in the low country wet zone (WL2a), from December 2020 to March 2021. A suitable land area with 20 years old oil palm with 40% shade level under full light condition was selected. The selected land was moderately flat and lies on latitude 6°03′39.4″N, longitude 80°34′ 21.5″E. The pH of the selected land area was determined and simultaneously topsoil composition was evaluated at TRI laboratory- Walahanduwa. The standard size (50 cm ×50 cm×50 cm) pits were prepared at 2.5 m × 2.5 m spacing. Cocoa seeds germinated in sand trays were transferred into polythene pots consist of sand, topsoil, coir-dust, compost in 1:1:1:1/4 ratio. Separate cocoa nurseries were maintained for the selected two varieties: SCA6 x ICS6, and NA32 x ICS1. Three months old cocoa seedlings with uniform and vigorous growth were selected while 72 seedlings with five leaves, 10±0.5 cm height and with an unfolded active bud were selected for field planting. All agronomic practices were equally done for both varieties. A factorial experiment with three potting mixtures; 1) topsoil only, 2) 40% topsoil with 60% POME, and 3) 60% topsoil with 40% POME) and two cocoa varieties; (SCA6 x ICS6, and NA32 x ICS1 was laid in RCBD design with three replicates. The POME and the topsoil were analysed for their nutrient composition and pH prior to seedling establishment. Growth parameters such as number of leaves, chlorophyll value using SPAD meter, leaf length using a ruler, stem girth using a venire calliper, plant height using a ruler, number of shoots per plant were measured at three weeks intervals non-destructively, while the number of roots, and shoot and root dry weighs per plant were evaluated at three months after establishment. Data were statistically analyzed by using SAS version 9.1 Software. The Duncan's Multiple Range Test was used to compare the means of treatments at 5% probability.

Table 1: Composition of topsoil- and POME-based potting media used for evaluation of the growth parameters of cocoa varieties in the field at the Faculty of Agriculture, University of Ruhuna in the low country wet zone, Sri Lanka.

Treatment combinations	Composition
Treatment 1	**Topsoil + SCA6 x ICS6 variety**
Treatment 2	**Topsoil + NA32 x ICS1 variety**
Treatment 3	**40% Topsoil and 60% POME+ SCA6 x ICS6 variety**
Treatment 4	**40% Topsoil and 60% POME+ NA32 x ICS1 variety**
Treatment 5	**60% Topsoil and 40% POME + SCA6 x ICS6 variety**
Treatment 6	**60% Topsoil and 40% POME + NA32 x ICS1variety**

3. Results and Discussion

The nutrient composition and pH observed in POME were higher than topsoil (Table 1). Nitrogen, phosphorus, potassium, and magnesium were relatively high in POME compared to the topsoil. There is a crucial need to increase nutrient use efficiency in long durational crops including cocoa. Similarly, altering the nutritional status of the cocoa land is a major strategy to enhance the productivity of cacao. According to Marrocos et al. (2020), cocoa production greater than 1600 kg of dry cacao beans ha−1 year−1 was observable with adequacy of macronutrients such as potassium, calcium, and magnesium, and micronutrients such as ferrous, zinc and manganous in the soil. Nitrogen limitation is also crucial for obtaining a high cocoa yield. According to Ribeiro et al. (2008), high nitrogen levels up to 240 mg Npot-1 improve stem girth, shoot and root dry weight, and shoot/root ratio in cocoa. According to Anokye et al. (2021), Potassium application positively affected on physiological responses of cocoa to water stress conditions and the application of 3 g of potassium per plant is very beneficial to face droughts. POME consists of all these required nutrients in high proportions. Aliyu (2012) stated that POME is a great source of high organic load, hence can effectively use as a fertilizer and, a cheap renewable residue for plants. Reference values for macro nutrients included in the table (Snoeck et al. 2016)

Evaluation of root and shoot parameters

Plant height and stem girth were significantly influenced by the potting media ($p<0.001$). Potting media 2, (40% topsoil and 60% POME) that consisted of high nutrients values showed the highest average plant height and stem girth in cocoa seedlings of both varieties. Potting media 1 which consist with topsoil only was low in nutrient and showed the lowest height and stem girth in cocoa seedlings of both varieties (Fig. 1). Fine-tune with our results, Adejobi et al. (2014) also evaluated growth of cocoa plant using organic wastes, cowpea pod husk, and tree crops wastes. A significantly higher plant height, stem diameter, leaf area, number of leaves, and dry root and shoot weights were observed in cocoa seedlings treated with organics. Cocoa is a highly sensitive plant to organic amendments (Lambert et al., 2020).

Table 2: Physio-chemical analysis of POME, topsoil samples and reference nutrient levels for growth of cocoa seedlings

Parameters	POME	Topsoil sample	Threshold levels
pH	**7.36**	**5.18**	**5.1-7**
Nitrogen	**11.2 mg g-1**	**1.9 mg g-1**	**2-4 mg g-1**
Phosphorus	**6 mg g-1**	**0.012 mg g-1**	**0.012-0.025 mg g-1**
Potassium	**4.4 mg g-1**	**0.034 mg g-1**	**0.04 mg g-1**
Magnesium	**3.6 mg g-1**	**0.022 mg g-1**	**0.18 mg g-1**

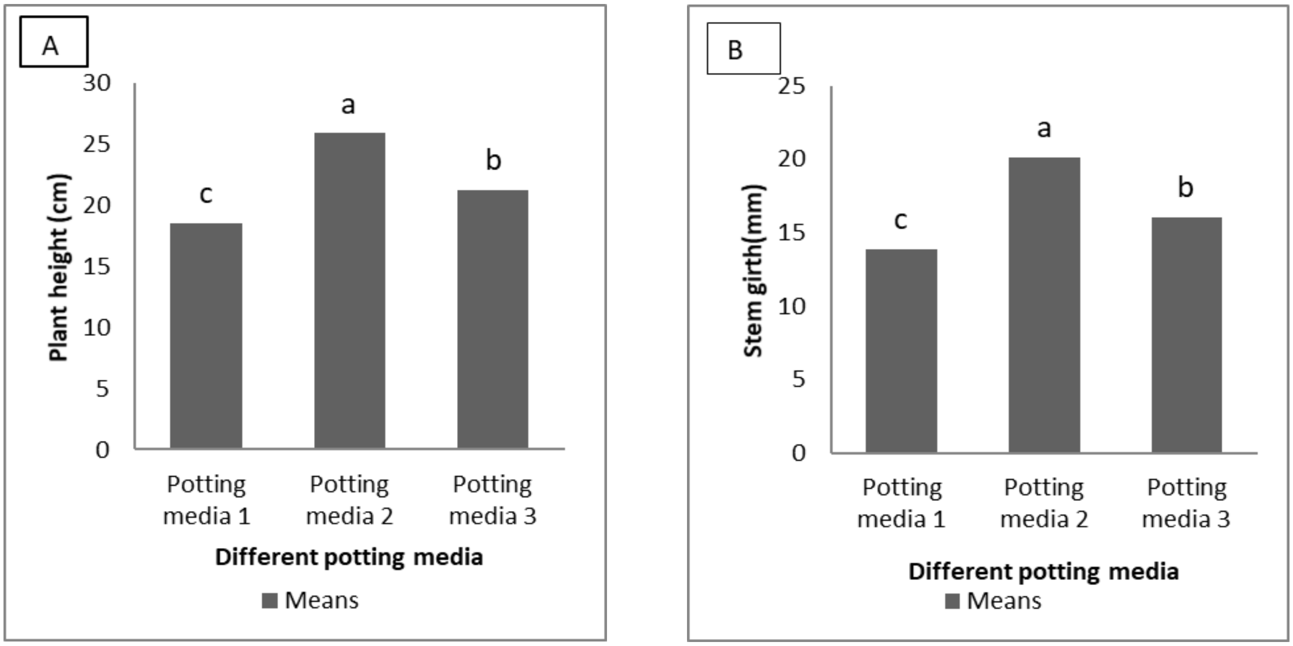

Figure1: Variation of heights (A), and stem girths (B) of cocoa seedlings in different potting media. (Means with similar letters are not significantly different from each other in α=0.05) (Potting media 1: Topsoil, Potting media 2 :40% Topsoil and 60% POME, Potting media 3 :60: Topsoil 60% and 40% POME)

The number of leaves and chlorophyll value (SPAD reading) were also significantly affected by the potting media (p=0.001). Potting media 2 which consisted of 40% topsoil and 60% POME showed the highest average number of leaves and chlorophyll value in cocoa seedlings. Potting media 1 which consisted of topsoil only showed the lowest average number of leaves and chlorophyll value (Fig. 2). According to Hettiarachchi et al, 2020, the number of leaves per plant, the highest leaf length, and the highest chlorophyll value in pineapple were significantly affected by POME application and recommended the addition of POME which can significantly contribute to enhancing soil organic matter as well. The results of the study were also analogous with the results of the study given. Root development is sensitive to the variations of the supply and distribution of nutrients in the soil. Mainly N, P, K, and Fe affect root growth and development such as root branching, lateral roots production, root diameter, nodulation, and root formation. The nutrient supply can affect directly and indirectly on root development process (Forde et al. 2001). Similarly, root dimensions including the number of lateral roots, root length, and diameters are essential to understand nutrient uptake dynamics in plant seedlings (Zobel et al. 2007). Roots are important organs to absorb water, nutrients, hormones, and to anchor the plant. Roots improve soil organic carbon by root-derived carbon, and microbial biomass (Fageria and Moreira 2011). In this study, root length and the number of lateral roots were significantly affected by the potting media (p<0.001). Potting media 2, which consisted with 40% topsoil and 60% POME showed the highest root length while the potting media 1 with the only topsoil showed the lowest root length. The highest number of lateral roots was recorded in potting media 1 which consist of the topsoil only, while potting media 2 which consist of 40% topsoil and 60% POME showed the lowest number of lateral shoots (Fig. 3). Generally, lower availability of K, Mg and Mn, in the potting media tend to restrict the root growth while, shortage of Ca, Fe and Zn have no effect on the shoot: root ratio (Ericsson 1995). Lack of nutrients in potting media 1 may be the reason for having a large number of lateral roots to increase nutrient absorption from the available potting media. According to Zobel et al. (2007) the fine root length and diameter of cocoa change with the nutrient concentration of the potting media and there was a significant interaction between root diameters and nitrate concentration of the potting media. Both the density of root hairs and their length are known to be highly sensitive to a range of environmental factors, including the nutrient application (Gilroy and Jones 2000).

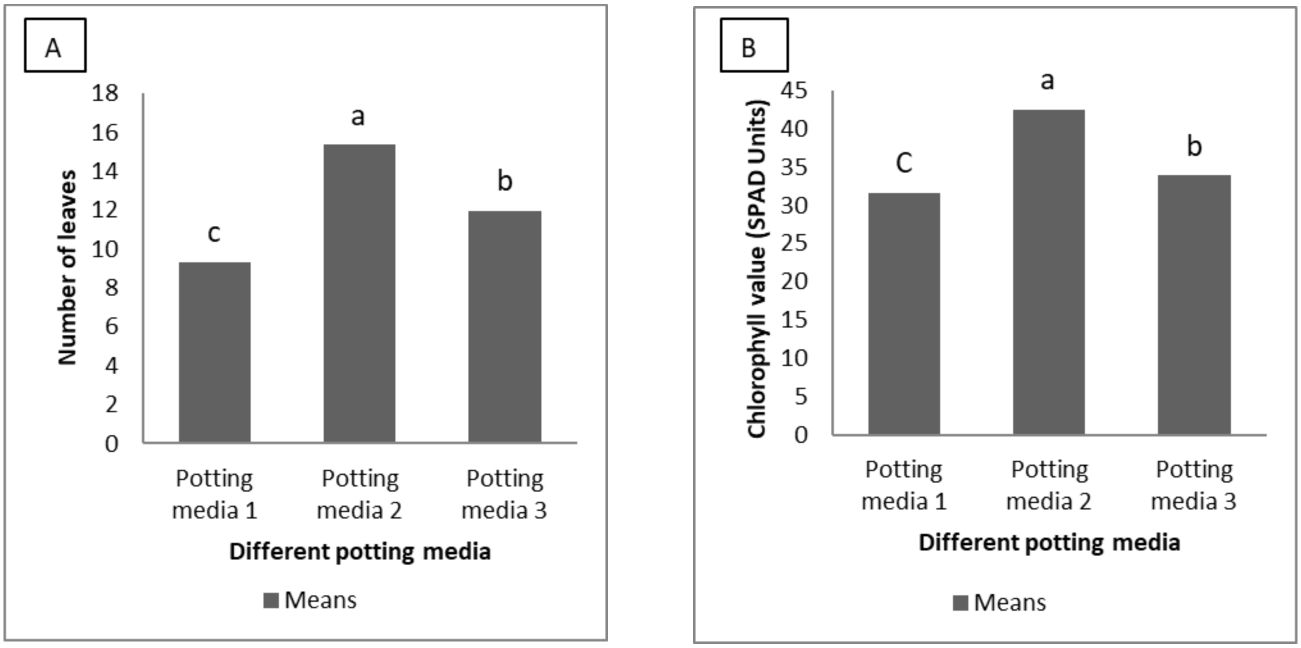

Figure 2: Variation of the number of leaves (A), chlorophyll value (B), in different potting media. (Means with similar letters are not significantly different from each other in α=0.05) (Potting media 1: Topsoil, Potting media 2: 40% Topsoil and 60% POME, Potting media 3: 60% Topsoil and 40% POME)

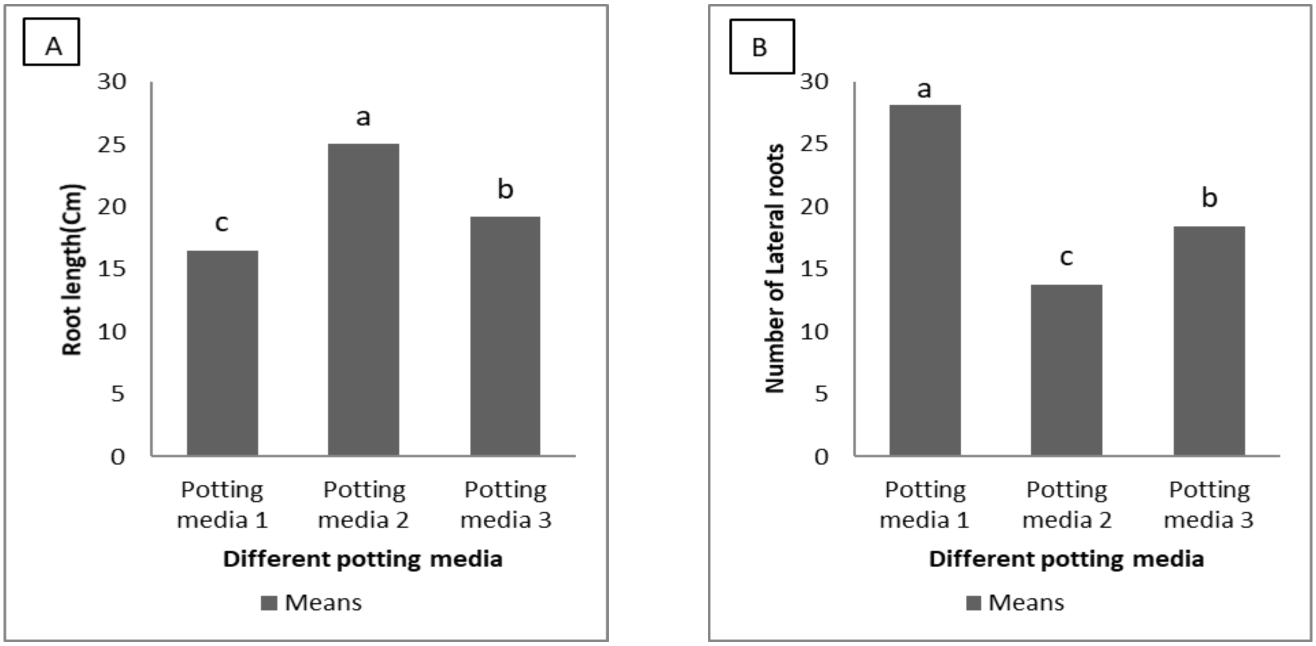

Figure3: Variation of root lengths (A), number of lateral roots (B), in different potting media. (Means with similar letters are not significantly different from each other in α=0.05) (Potting media 1: Topsoil, Potting media 2:40% Topsoil and 60% POME, Potting media 3:60% Topsoil and 40% POME)

The shoot fresh and dry weights were also significantly influenced by the potting media ($p<0.001$). Potting media 2and 3 showed the higher average fresh shoot weights than the potting media 1 with topsoil only showed the lowest average fresh shoot weight in cocoa seedlings. Potting media 2 consisted with 40% topsoil and 60% POME combination showed the highest average shoot dry weight in cocoa seedlings, while potting media 1 with topsoil only showed the lowest average shoot dry weight (Fig. 4). Similarly, significantly higher shoot: root ratio depicted in potting media 2 and potting media 3 with 60% POME and 40% POME respectively, while a higher shoot: root ratio could be an indication of a healthier plant. Two potting media treated with POME showed relatively high shoot growth may be due to the availability of sufficient nutrient components.

Ribeiro et al. (2008) also have stated that increased levels of nitrogen up to 480 mg N pot-1 increased dry weight of shoot and roots and shoot: root ratio in cocoa seedlings. Similar findings were observed by Arshad et al. (2015), where the optimum rate of POME (20 t ha-1) applied on Hibiscus sabdariffa plant showed the highest shoot growth with better growth performance.

The root growth of plants is controlled by genetic factors and influenced by external environmental factors. Mineral nutrition is a major influencing factor on the growth of plant roots. The root dry weight observed was significantly influenced by the potting media ($p<0.001$). Potting media 2 consisted with 40% topsoil and 60% POME showed the highest average root dry weight in cocoa seedlings, while potting media 1 which consisted of topsoil only showed the lowest average root dry weight (Fig. 5). As described by Hartemink (2005) application of P and K nutrients improved the growth and development of cocoa roots. Thus, increased absorbing surfaces and availability of high P and K in potting media 2 might have increased the dry root weight of cocoa seedlings. In nutrient-deficient soils, root weight was increased in a quadratic manner with the addition of fertilizers. This was resulted in high uptake of water and nutrients by roots with essential plant nutrients. Growth and yield parameters of cocoa seedlings were not significantly affected by the variety ($p>0.05$). Cocoa varietal response for POME was not significant in the present study. Supporting research findings, Edwin and Masters (2005) stated that there was no evidence on cocoa varieties differs in their response to different fertilizers, pesticides or labour on cocoa.

Seedling growth also showed a temporal variation during the study period. During the initial 6 weeks, there was a very slow increment in growth parameters like plant height, stem girth, number of leaves, and chlorophyll content mainly due to transplanting stress and adaptation to the new media conditions. Root and shoot growth were limited especially when soil moisture was low and heavy sunshine was received during this period. Franco et al. (2001) have found the influence of irrigation and temperature on root growth after being transplanted with minimum management in *Lotus creticus*. The average number of leaves was low during the early 6 weeks may be due to the adaptation of minimizing losses of water through evaporation. There is a rhythm in leaf initiation in cocoa seedlings and leaf occurred in both orthotropic and plagiotropic branches. First leaf flush started with 10 leaves and gradually expands the number of leaves. Second flush occurred at 40 days and periodically third, fourth flushes are emerged. This flushing process is independent of climate and other extraneous factors, and this also leads to have smaller number of leaves at the early weeks (Almeida and Valle 2007). With soil water deficit in early weeks, plant biomass accumulation in both shoot and roots were low and hence plant height, stem girth was low. Soil water availability influence on the canopy expansion rate of cocoa and this greatly influenced on light interception. During prolonged droughts, seedlings can come to a 'point of no return or permanent wilting point' that cause immature leaf fall, leaf wilting and yellowing, slow stem growth (Carr and Lockwood 2011). Chlorophyll a and b were influenced by both water and nutrient stress. Chlorophyll remained stable when there is stable soil water and chlorophyll content was gradually increased with time with the availability of ample amount of water and nutrient during the experiment. It was obvious that water and nutrient stress have a greater influence on plant growth parameters under oil palm (Dissanayake and Palihakkara 2019). However, there was an increment in plant height, stem girth, number of leaves and chlorophyll value in the last 6 weeks with the adaption and sufficient rainfall received (Fig.7). Moreover, collection of factors such as rainfall, sunlight, sunshine hours, temperature, humidity, altitude, soil nutrient condition, pest and diseases, farmer management practices can effect on the growth of cocoa, while this plant prefers calm conditions.

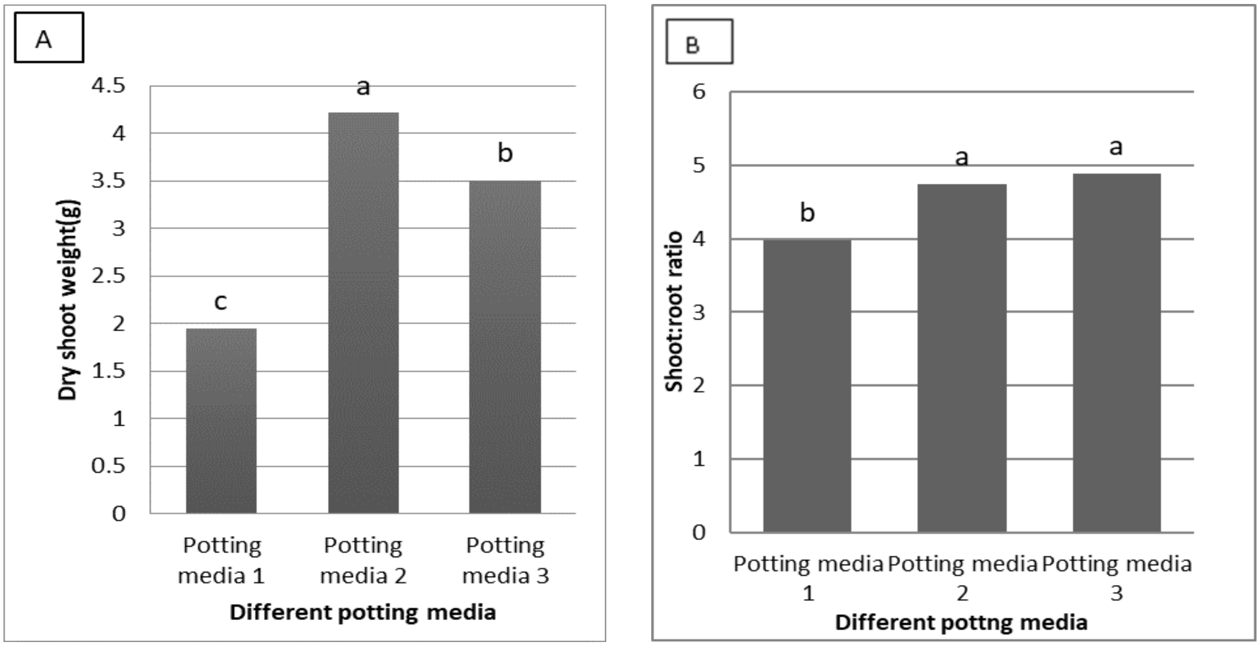

Figure 4: Variation of shoot dry weights (A), Shoot: root ration (B)in different potting media. (Means with similar letters are not significantly different from each other in α=0.05) (Potting media 1: Topsoil, Potting media 2:40% Topsoil and 60% POME, Potting media 3:60% Topsoil and 40% POME)

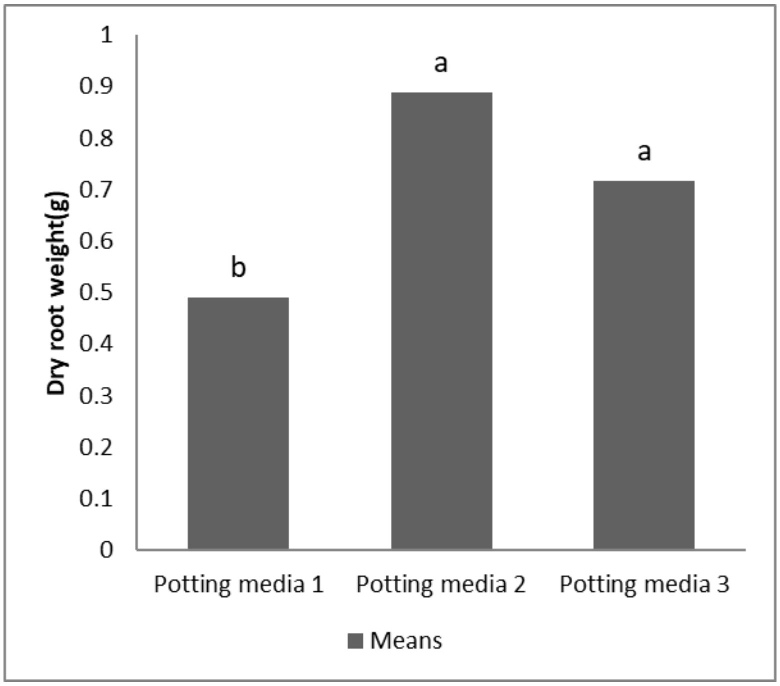

Figure 5: Variation of dry weight of roots in different potting media (Means with similar letters are not significantly different from each other in α=0.05) (Potting media 1: Topsoil, Potting media 2: 40% Topsoil and 60% POME, Potting media 3: 60% Topsoiland40% POME)

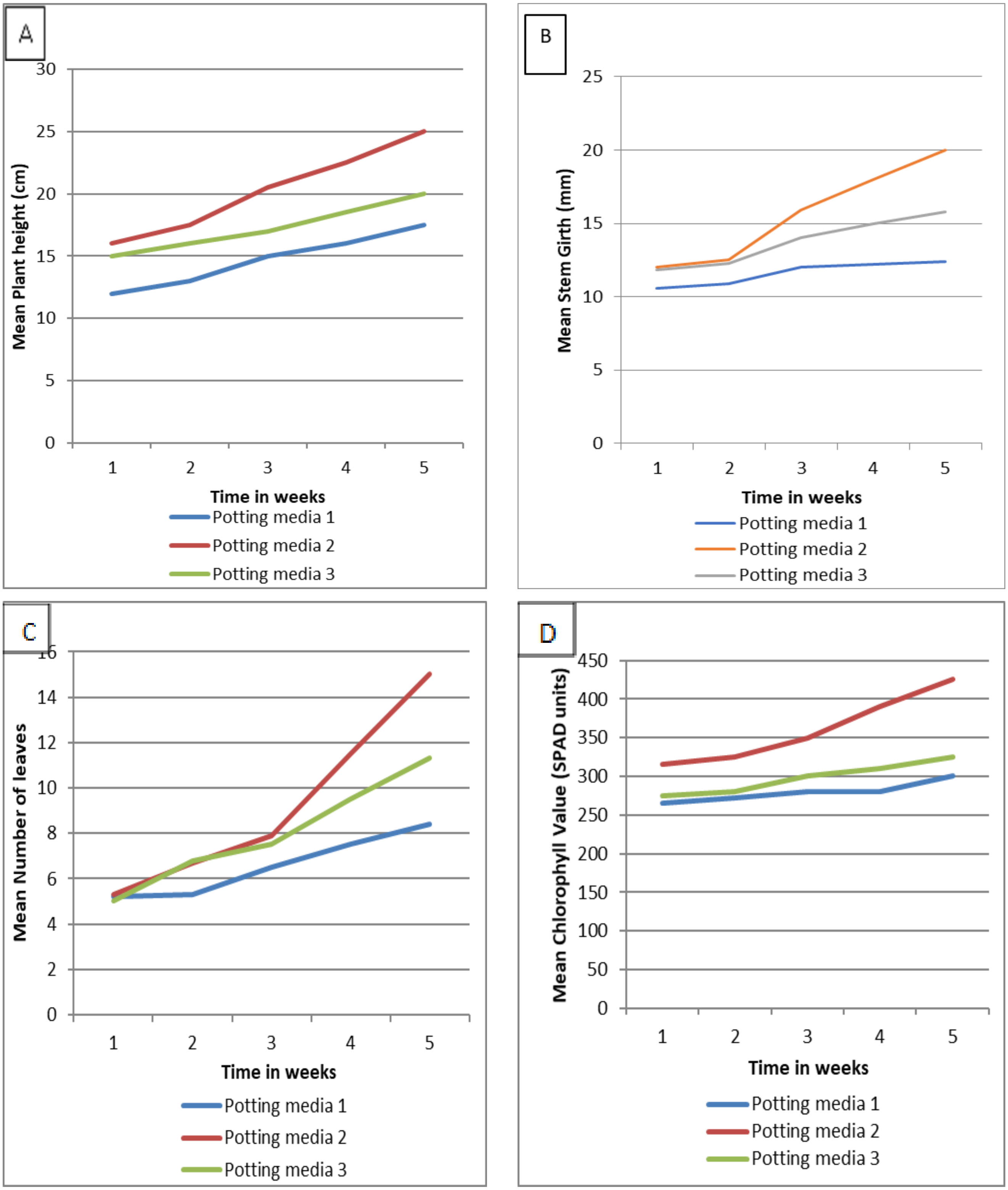

Figure 6: Variation of cocoa seedling height (A), stem girth (B), number of leaves (C), chlorophyll value in SPAD units (D) in weeks

Intercropping under oil palm was highly practiced by small and medium-scale farmers. They mainly use short-term plant varieties like banana, pineapple, yams, and turmeric (Dissanayake and Palihakkara 2019). Reddi et al. (2015) have discovered that okra and tomato also showed significantly higher yield under oil palm shade, but there is a wide scope of intercropping possibilities with mature oil palm shade.

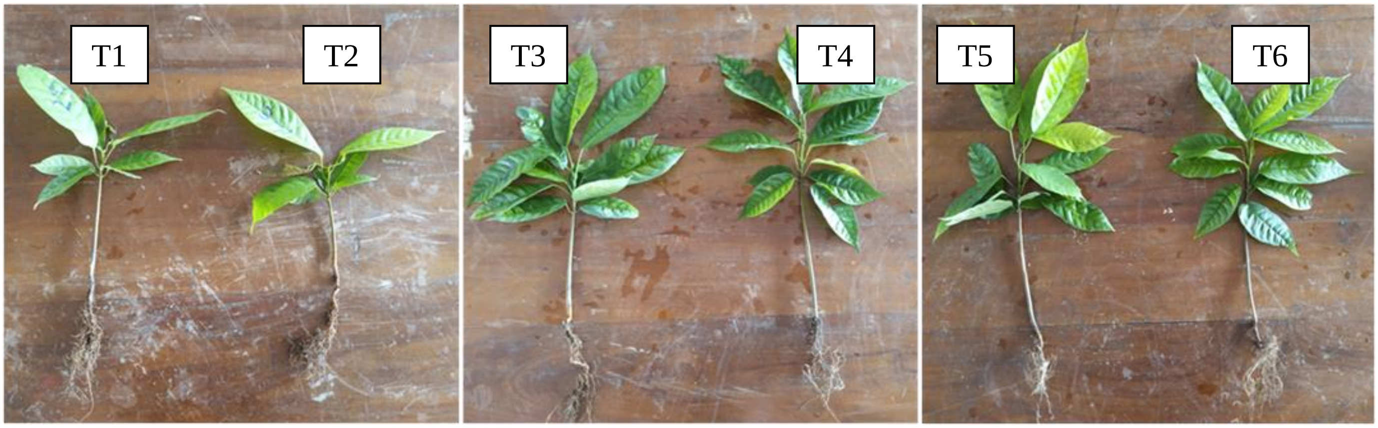

Figure 7: Uprooted cocoa seedlings from different treatments, 3 months after the establishment. (T1: Topsoil + SCA6 x ICS6 variety, T2: Topsoil + NA32 x ICS1 variety, T3: 40% Topsoil and6 0% POME + SCA6 x ICS6 variety, T4: 40% Topsoil and 60% POME + NA32 x ICS1 variety, T5: 60% Topsoil and 40% POME + SCA6 x ICS6 variety, T6: 60% Topsoil and 40% POME + NA32 x ICS1 variety)

4. Conclusions

Palm Oil Mill Effluent is a suitable potting media for SCA6 x ICS6, and NA32 x ICS1 cocoa seedlings to enhance growth and development. Both SCA6 x ICS6, and NA32 x ICS1 cocoa varieties can effectively grow under 20 years old oil palm shade during the initial growth period with the use of 40% topsoil and 60% POME potting media.

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Author Contribution: IRP conceptualized and designed the study. IRP and WDPR performed the experiments. EMUIE analyzed and interpret the data. All authors contributed in drafting the manuscript and IRP critically revised the manuscript

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