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# Effects of soil substrate quantity and sowing method on cocoa (*Theobroma cacao* L.) seedlings growth in Togo

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**Cocoa is one of the outstanding cash crops in Togo, but the orchards are old and require the rehabilitation trough replanting and good cocoa seedlings. A study was conducted in nursery to investigate the effect of soil quantity and sowing method on cocoa seedlings growth. The treatments were a quantity of depleted bulk soil in two pots (2120 and 1055 cm$^3$) and the cocoa seeds were sown by three methods: Direct sowing in pot and replanting small seedling growth after 10 and 15 days on seedbed. The seedlings were regularly watered in the same conditions and data were collected on growth parameters (seed germination ratio or seedlings lifting percentage, root length, stem girth, plant height and number of leaves). As demonstrated by the results, the growth parameters of cocoa seedlings in the two quantities of soil are not significantly different ($p<0.05$). Therefore, no difference is found between the effects of soil quantity on seedlings growth, while it is affected by sowing method. Replanting cocoa small seedlings must be done 10 days after seed lifting. It is economic for farmers to use the small pots (1055 cm$^3$) for cocoa nursery instead of the big one as recommended actually.**

**Key words:***Theobroma cacao* L., soil quantity, direct sowing, replanting.

## INTRODUCTION

Cocoa (*Theobroma cacao* L.) is one of the outstanding cash crops in Togo. Cocoa contributes 1.3% to the Gross Domestic Product of Togo in 2010 (l'Institut National de la Statistiqueet des Etudes Economiques et Démographiques [INSEED], 2015). Togolese cocoa orchards were estimated at 23,290 ha, most of which

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were declining: 40% of cocoa farms have 5 to 20 years old and 32% older than 20 years old. The cocoa network occupies 17% of agriculture active labour in Togo. An annual estimated cocoa beans production is around 6000 Mg with an average yield of 242 kg.ha$^{-1}$(Direction de la Statistique, de l'Informatiqueet de la Documentation [DSID], 2014). Therefore, there is need to intensify its production by yield improvement through rehabilitation of old and non-producing cocoa plantations and by renewing the orchard through increased land area cultivated or new plantation establishment (Oyewole et al., 2012; Ogunlade, 2008).

In an attempt to increase the cocoa farms yields with the target of increasing sustainable supply to the world market, farmers are encouraged to replant their old cocoa farms and this is managed under the project called "Projetd'Appui au SecteurAgricole (PASA)" funded by World Bank with counterpart contribution from Togolese Government. In this context, farmers need good cocoa seedlings for replanting their plantations. Unfortunately, cocoa seedlings growth faces a lot of challenges in cocoa production lands in Togo such as cocoa pot transportation from nursery to orchard disagreements, because of pots heaviness and cocoa beans losses due to relative late of seeds sowing in pot already filled. Over the past few years, farmers have developed an unusual approach to grow cocoa seedlings by using coffee pot (21 × 8 cm$^2$) instead of cocoa one (27 × 10 cm$^2$) to reduce soil volume then pot heaviness. They sow cocoa seeds on seedbed before replanting it in pot when they are free.

Several authors worked on cocoa seedlings growth conditions in nursery. Harun and Ismail (1983) worked on cocoa seedlings shading regimes while many researchers reported results on soil quality, not too much on soil quantity. Publishers communicated enough results on soil texture, soil chemical composition, soil supply of nutrients and soil nutrients requests for cocoa seedlings or tree production, mostly on soil supply of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg). Furthermore, the direct sowing of cocoa beans in pot was almost suggested as a sowing method (Akanbi et al., 2014; Koko, 2014; Oyewole et al., 2012; Koko et al., 2009; Mohd.Yusoff et al., 2007; Hartemink, 2005).

With the works of Jardin and Snoeck (1985), Snoeck and Jardin (1992) and Snoeck et al. (2006), nutrient requirements for cocoa tree growth can be computed by Soil-Diagnostic Method. In this approach, soil quality and soil quantity is required to evaluate the real needs for cocoa trees. So in nursery, the seedling growth depends on the available nutrients containing in a specific soil volume in the pot. Although, soil quality is found to have an effective effect on cocoa tree growth (Akanbi et al., 2014; Koko, 2014; Koudjega and Tossah, 2009; Mohd.Yusoff et al., 2007), its quantity influence on growth and performance of cocoa seedlings have not yet received adequate research attention as well as sowing method in nursery in Togo conditions.

Therefore, the objectives of this study were to determine the effect of soil quantities on cocoa seedlings growth and to evaluate the influence of different sowing methods on cocoa seedlings growth.

## MATERIALS AND METHODS

The experiment in nursery was conducted for five months and half in the Vegetal Material Production Center of Ezimé in Togo. This center is linked to Unité Technique Café Cacao (UTCC, a Cocoa and Coffee Extension Service in Togo). It is located between latitude 07°29'31" N and longitude 0°56'83" E lying on an altitude 252 m above sea level, 4 km from Amlamé town, along National Road N°5.

A Randomized Complete Block Design with four replications and two factors, soil quantities and sowing methods, was used for the control of spatial variability (van Es and van Es, 1993; van Eset al., 2004). Each plot consisted of 25 pots separated by 20 cm from each other and one cocoa bean or one cocoa small seedling was directly sown or replanted into each of the pot. Watering was done regularly later in the evening to field capacity every two days interval.

The plastic pots used were the ordinary polyester black plastic bag with dimensions of 21 × 8 cm, called "coffee pots" (1055 cm$^3$) and 27 × 10 cm called "cocoa pots" (2120 cm$^3$). The cocoa seeds were gotten from Ghana Cocoa Board and a hybrid varieties seeds obtained by crossing and mixing the following genetic materials: 77 × 42 (33%), 77 × 85 (34%), and 77 × 67 (33%). Depleted soil (0 to 20 cm) from the center was collected at the beginning of the trial, air dried, crushed and sieved handily to serve as potting media. This soil is described as a silty clay, rich in organic matter (55 g.kg$^{-1}$), poor in nitrogen (2 g.kg$^{-1}$) and phosphorus (21.9 mg.kg$^{-1}$). Exchangeable bases levels were low (0.3 K, 13.4 Ca and 5.9 Mg meq%) with cation exchange capacity (CEC) equal to 21.1 meq% and the pH was 6.7 (Koudjega and Tossah, 2009). Bulk soil was properly mixed to ensure homogenous soil and filled into each perforated plastic pot of different capacity leaving some space for watering and then placed under shade with dimensions 4 × 3 × 2 m$^3$, controlled to prevent the passage of 80% of light (Mohd.Yusoff et al., 2007). The seeds were sown on December 8th, 2014 by three methods: direct sowing in pot (0 day after lifting, DAL) and replanting small seedlings growth after 10 days on seedbed, then after 15 days on seedbed (10 and 15 DAL).

The following growth measurements were taken at two months interval during the experiment from January 15th, 2015 (1.5 Months After Planting, MAP) up to May 18th, 2015 (5.5 MAP): seed germination ratio or small seedling lifting percentage, root length, stem girth, plant height and number of leaves. The seed germination ratio is calculated by dividing the number of seedlings alive two weeks after sowing over the number of seed sown in the pot in each treatment multiplied by hundred. The seedlings lifting percentage is calculated by dividing the number of seedlings alive one month after replanting over the number of small seedlings replanted in the pot in each treatment multiplied by hundred. For root length measurement, three seedlings in pot in each treatment were sacrificed, then soil in the pot was removed and the root was measured on graduated paper. The root length in each treatment is the average of the three length measured on the three seedlings roots. For stem girth size, the diameter at the base of all seedlings in each treatment was measured, then the averaged circumference of the seedling base was calculated. The plant height was measured from the seedlings base up to the plant summit.

Analysis of variance (ANOVA) and Duncan Multiple Range Test

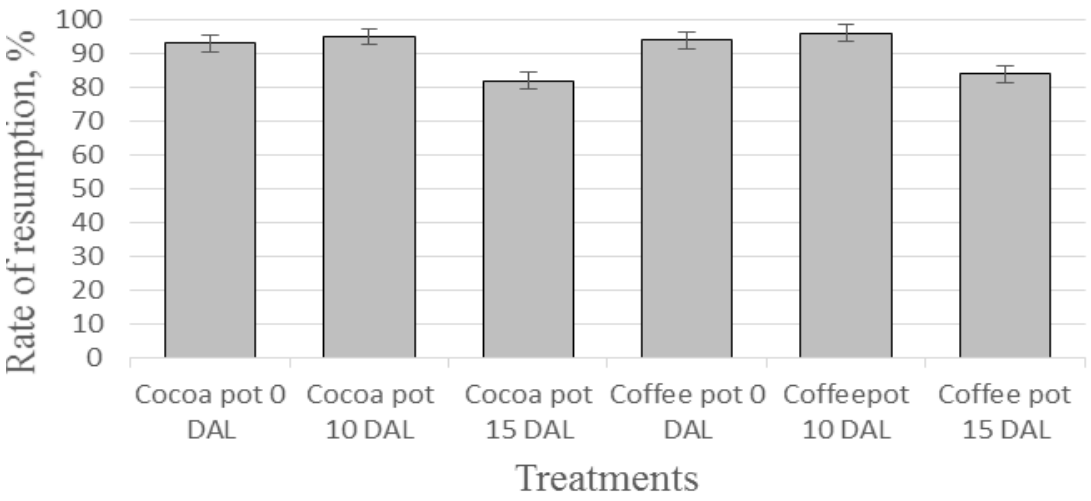


**Figure 1.** Resumption rates as affected by soil substrate quantities and sowing method.

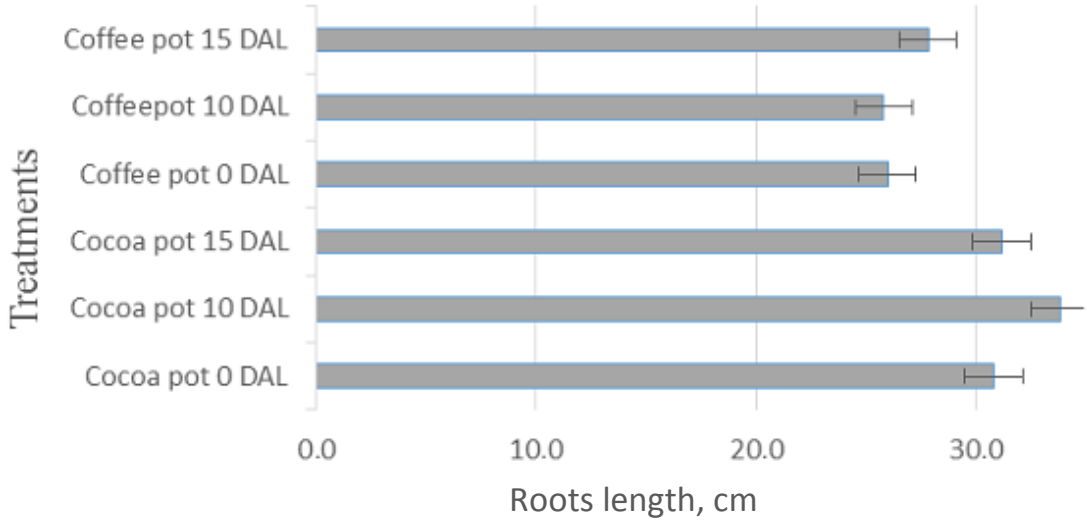


**Figure 2.** Roots length as affected by soil substrate quantities and sowing methods.

(DMR) were used on a statistical software STATISTICA version 5.5 (StatSoftInc, 1999) at 5%.

## RESULTS

The cocoa seedlings lifted very well in almost all the treatments during the trial (Figure 1). The best resumption or germination ratio appeared at 10 DAL in both cocoa and coffee pots, and averaged, respectively at 95±3.8 and 96±3.3%. There were no significant effects of the two types of pots on seedling lifting (90±7% for cocoa pots and 91±6% for coffee pots), while the sowing methods revealed a negative impact of later replanting of small cocoa seedlings. With replanting 15 DAL, cocoa seedlings lifted averagely at 84±9.2% in coffee pots and 82±12% in cocoa pots.

No significant difference was found in the cocoa seedlings roots length across all treatments ($F_{(5,24)}$=0.29; p=0.91). The root length was the same (29.3±3.2 cm) in the two soil quantities and across the three sowing methods. However, it was noticed that all roots from cocoa pots were beyond 30 cm and those from coffee pots were less than 30 cm (Figure 2) with no statistical difference between them.

The stem girth of cocoa seedlings (Table 1) in both cocoa and coffee pots were significantly influenced by sowing methods during the trial. At 1.5 MAP, the direct

**Table 1.** Effects of soil quantity and sowing methods on cocoa seedlings stem girth (cm).

| Soil quantity | Sowing method | 1.5MAP | | 3.5MAP | | 5.5MAP | |
|---|---|---|---|---|---|---|---|
| | | Means | SD | Means | SD | Means | SD |
| 1055 $cm^3$ (Coffee pot) | 0 DAL | $1.27^{a}$ | 0.05 | $1.35^{d}$ | 0.01 | $1.75^{bc}$ | 0.21 |
| | 10 DAL | $1.02^{b}$ | 0.07 | $1.67^{b}$ | 0.02 | $2.00^{a}$ | 0.10 |
| | 15 DAL | $0.93^{b}$ | 0.05 | $1.80^{a}$ | 0.01 | $1.92^{ab}$ | 0.18 |
| 2021 $cm^3$ (Cocoa pot) | 0 DAL | $1.27^{a}$ | 0.05 | $1.35^{d}$ | 0.07 | $1.58^{cd}$ | 0.18 |
| | 10 DAL | $1.02^{b}$ | 0.07 | $1.47^{c}$ | 0.09 | $1.40^{d}$ | 0.09 |
| | 15 DAL | $1.02^{b}$ | 0.07 | $1.64^{b}$ | 0.07 | $1.48^{d}$ | 0.05 |
| Means | | 1.09 | 0.06 | 1.55 | 0.04 | 1.67 | 0.14 |
| F | - | 18.35 | | 55.20 | | 10.95 | |
| p-level | - | 0.00 | | 0.00 | | 0.00 | |

DAL: Day after lifting; MAP: months after planting. SD: standard deviation. Means in the same column denoted by same letters are not significantly different with ANOVA and DMR at 5%.

**Table 2.**Effects of soil quantity and sowing methods on cocoa seedlings height (cm).

| Soil quantity | Sowing method | 1.5MAP | | 3.5MAP | | 5.5MAP | |
|---|---|---|---|---|---|---|---|
| | | Means | SD | Means | SD | Means | SD |
| 1055 $cm^3$ (Coffee pot) | 0 DAL | $13.25^{a}$ | 0.64 | $23.38^{a}$ | 4.72 | $30.50^{a}$ | 2.40 |
| | 10 DAL | $13.23^{a}$ | 1.25 | $19.75^{a}$ | 2.54 | $26.92^{ab}$ | 3.25 |
| | 15 DAL | $13.65^{a}$ | 0.76 | $23.80^{a}$ | 0.90 | $23.33^{b}$ | 3.93 |
| 2120 $cm^3$ (Cocoa pot) | 0 DAL | $13.68^{a}$ | 0.92 | $22.27^{a}$ | 2.41 | $26.15^{ab}$ | 3.26 |
| | 10 DAL | $13.95^{a}$ | 0.27 | $19.73^{a}$ | 1.44 | $30.25^{a}$ | 3.33 |
| | 15 DAL | $13.38^{a}$ | 1.77 | $23.73^{a}$ | 4.72 | $19.10^{c}$ | 1.24 |
| Means | - | 13.52 | 0.93 | 22.11 | 2.79 | 26.04 | 2.90 |
| F | - | 0.29 | | 1.85 | | 10.01 | |
| p-level | - | 0.91 | | 0.15 | | 0.00 | |

DAL: Day after lifting; MAP: months after planting; SD: standard deviation. Means in the same column denoted by same letters are not significantly different with ANOVA and DMR at 5%.

sowing (0 DAL) generated the best seedlings stem girth average with 1.3±0.1 cm, then 15 DAL in coffee pots showed the best seedlings stem girth at 3.5 MAP (1.8±0 cm) and finally at 5.5 MAP, treatments with replanted small cocoa seedlings (10 and 15 DAL) in coffee pots revealed the best cocoa seedlings stem girth with 2.0±0.1 and 1.9±0.2 cm, respectively.

The tallest plants at 5.5 MAP were produced by both direct sowing in coffee pots and replanted small cocoa seedlings at 10 DAL in cocoa pots (30.5±2.4 and 30.3±3.3 cm, respectively). At the same stage, plants in coffee pots were averagely taller than those in cocoa pots with 26.9±3.6 and 25.2±5.6 cm, respectively (Table 2). Statistically, no difference was found in plant height before 5.5 MAP.

There was no significant difference in the leaves number at the final stage and averaged at 12±1 leaves on cocoa seedlings (Table 3). Soil quantities and sowing methods had no effect on cocoa seedlings leaves production at 5.5 MAP.

Soil quantities seem to have no influence on cocoa seedlings performance (Figure 3) while sowing methods have impacted the plant length, stem girth and leaves number (Figure 4). A weak positive correlation was found, at 5.5 MAP, between plant height and seedlings resumption, then plant height and leaves number finally between plant height and stem girth size ($0.03 \leq R^2 \leq 0.56$). A strong positive correlation is noted between leaves number and stem girth size ($0.47 \leq R^2 \leq 0.70$). So, as quick as the cocoa seedlings are lifted, more stem girth is

**Table 3.** Effects of soil quantity and sowing methods on cocoa seedlings leaf number.

| Soil quantity | Sowing method | 1.5 MAP | | 3.5 MAP | | 5.5 MAP | |
|---|---|---|---|---|---|---|---|
| | | Means | SD | Means | SD | Means | SD |
| 1055 $cm^3$ (Coffee pot) | 0 DAL | $5^{a}$ | 0.6 | $10^{a}$ | 2.2 | $12^{a}$ | 1.1 |
| | 10 DAL | $4^{abc}$ | 0.5 | $9^{ab}$ | 0.6 | $12^{a}$ | 1.9 |
| | 15 DAL | $3^{c}$ | 0.5 | $7^{c}$ | 0.6 | $11^{a}$ | 2.6 |
| 2120 $cm^3$ (Cocoa pot) | 0 DAL | $4^{abc}$ | 0.0 | $11^{a}$ | 0.6 | $11^{a}$ | 2.0 |
| | 10 DAL | $4^{abc}$ | 0.6 | $8^{bc}$ | 0.7 | $14^{a}$ | 1.6 |
| | 15 DAL | $3^{c}$ | 0.5 | $8^{bc}$ | 0.4 | $11^{a}$ | 1.3 |
| Means | - | 4 | 0.5 | 9 | 1.3 | 12 | 1.0 |
| F | - | 4.84 | | 6.60 | | 1.53 | |
| p-level | - | 0.01 | | 0.00 | | 0.23 | |

DAL: Day after lifting; MAP: months after planting; SD: standard deviation. Means in the same column denoted by same letters are not significantly different with ANOVA and DMR at 5%.

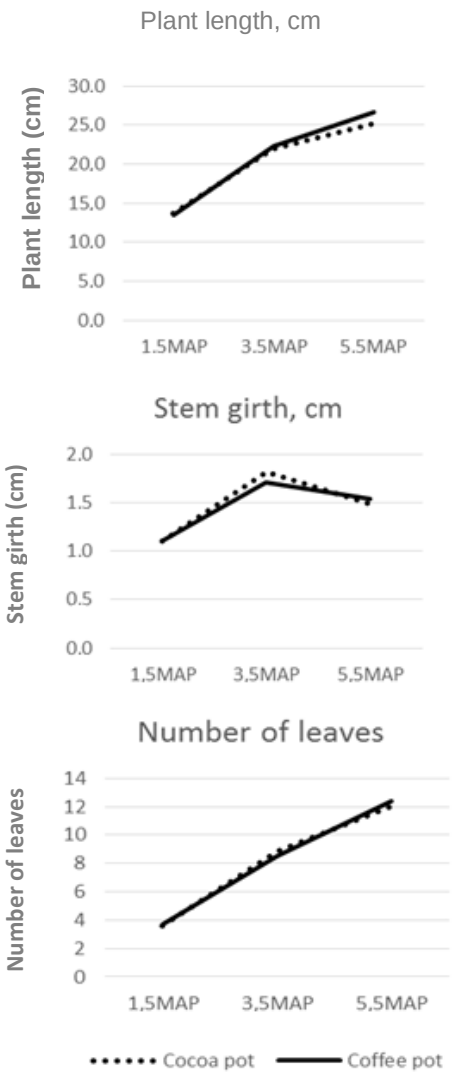


**Figure 3.** Cocoa seedlings growth as affected by soil quantities.

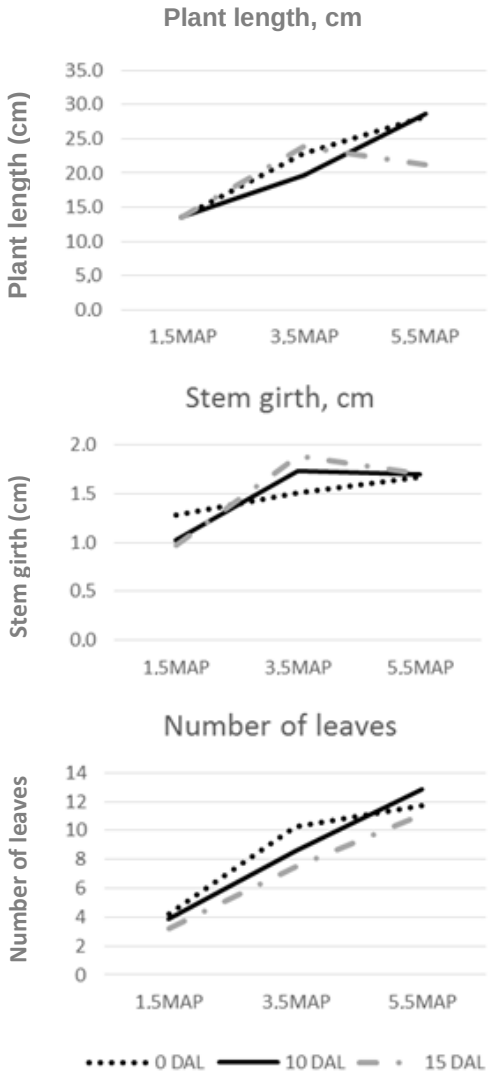


**Figure 4.** Cocoa seedlings growth as affected by sowing methods.

raised, more plant grown then more leaves appeared.

## DISCUSSION

The lifting percentage of the small seedlings or germination ratio of cocoa seeds, in both coffee and cocoa pots, was superior to 90% as recommended by Togolese seeds norms, except in the case of replanting small seedling 15 DAL where the ratio is still good (≥80%) according to West African countries seeds production norms. The cocoa seedling root length after 4 to 5 months growth must be around 30 to 40 cm according to Oro (2011) and LoorSolorzano (2007). Results from the current study (29.3±3.2 cm) seem to be similar to the previous results. Oyewole et al. (2012) worked on cocoa seedlings in Nigeria and published at 6 MAP a stem girth that ranged from 1.9 to 3.1 cm and plant height between 17 and 59 cm. Bismark (2011) published that, in Ghana, the cocoa seedling height must be 25 to 43 cm at 5 MAP, while leaves number must be 8 to 18. These finds are in agreement with the results of the current study where the cocoa seedling stem girth is 1.4±0.1 to 2.0±0.1 cm and cocoa seedling height is 19.1±1.2 to 30.5±2.4 cm, while leaves number is 11 to 14. So, the agronomic performance of cocoa seedlings obtained in this trial is in agreement with those obtained in Nigeria and Ghana. No significant difference was found between the cocoa pots and the coffee pots on cocoa seedling growth confirmed by Bismark (2011) who also found no difference in water sachets, Cocobod poly bags and International Institute of Tropical Agriculture (IITA) poly bags that are used to grow cocoa seedlings in Ghana. The positive correlation found between cocoa seedling growth variables explains the relationship between these variables. More cocoa seedling upsurges more stem girth increases, more leaves number rises.

Actually, to produce cocoa seedlings for 1 ha, farmers need 1800 plastic pots as recommended by extension services. Cocoa pot cost on the market is 15 FCFA, whereas coffee pot price is 8 FCFA. Therefore, farmers can reduce their charge by 7 FCFA per pot. This represents an important benefit of 12600 FCFA per hectare for nursery preparation for small holders' farmers in cocoa production lands in Togo without counting the easiness of coffee pots filling and its carrying from nursery to cultivated area.

## Conclusion

The growth and performances of cocoa seedlings nursed in different pots seem to be the same in all treatments according to the plants growth variables measured and statistically tested. The two soil quantities had no effects on cocoa seedlings growth and no influence of the three sowing methods was found on cocoa seedlings growth except the replanting 15 DAL. Therefore, the use of "coffee pots" (21 × 8 cm) for cocoa seedlings production instead of the cocoa pots (27 × 10 cm), as recommended actually, is economic for farmers who can reduce their charge in nursery. As an alternative for cocoa seeds direct sowing, replanting cocoa small seedlings growth on seedbed must be done at the latest 10 days after seeds are raised. If soil quantities have no significant influence on cocoa seedlings, it will be interesting to know how the plant nutrients uptake and nutritional pool will be in these specific soil quantities in the pot.

## Conflict of Interests

The authors have not declared any conflict of interest.

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