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Germination and Early Growth Performance of Cocoa (*Theobroma cacao* L.) Seedlings in Planting Media

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ABSTRACT

Background and Objective: Growth media are substrates or materials that provide anchors and nutrients for seeds to germinate and plants to grow. The amount of nutrients in these media and their influences on plant growth cannot be overemphasized. However, the experiment was conducted to evaluate the effect of nursery growth media on the germination and growth performance of cacao seedlings from April to August, 2020. **Materials and Methods:** The experimental design used was a Completely Randomized Design (CRD) with five treatments, poultry manure plus river sand (PM+RS) at a ratio of 3:2, poultry manure plus river sand plus sawdust (PM+RS+SD) at a ratio of 3:1:2, poultry manure plus top soil plus river sand (PM+TS+RS) at a ratio of 3:2:1, poultry manure plus top soil plus sawdust (PM+TS+SD) at a ratio of 3:1:2 and Topsoil (TS). Each treatment was replicated three times. The parameters measured were the days of sprouting, germination rate, seedling height, girth, number of leaves and leaf area. The 15 kg of each treatment were placed in a 10 L plastic bucket perforated at the base. **Results:** The PM+RS+SD and PM+TS+SD were the highest values recorded. At 10 WAP (weeks after planting), 12 WAP and 14 WAP, PM+RS+SD and PM+TS+SD recorded the highest plant heights (cm) of 30.90, 32.40, 37.45 and 29.59, 32.30, 40.38, respectively which were significantly higher ($p<0.05$) in values than heights from other media. In respect of stem girth, PM+RS+SD was significantly highest and different from other media from 8 WAP to 12 WAP but was statistically the same with PM+TS+SD at 14 WAP. For the number of leaves produced, PM+TS+SD was significantly different, with 24.33 from others, except for PM+RS+SD, which had 22.33 at 14 WAP. For the leaf area, PM+TS+SD and PM+RS+SD performed better than others. **Conclusion:** In the context of this work, PM+RS+SD can be recommended for raising cocoa seedlings because of its ability to induce early germination, a very short period of achieving 100% fastest and the highest achievement of plant-assessed growth parameters.

KEYWORDS

Theobroma cacao, germination rate, poultry manure, seedlings, growth parameter

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INTRODUCTION

The cacao tree belongs to the family Sterculiaceae and the genus *Theobroma*. Its natural habitat is the lower story of the evergreen rainforest. There are over twenty species in the genus, but *Theobroma cacao* is the only one cultivated widely. Since its discovery in the 18th century in the Amazon Basin, its cultivation has spread to other tropical areas of South and Central America and indeed West Africa, which became the major producer from the mid-1960s. Recently, with the application of molecular marker, cacao was reclassified to belong to the family *Malvaceae*, cacao is a well-adapted agro-forestry plantation crop grown in hot, rainy climates[1]. Its cultivation is concentrated between 0 and 20 degrees North and South of the Equator, sometimes called the "Cacao Belt".

The crop is mainly grown by smallholders located around central market units for uniform and standard industrial handling after harvesting[1] cacao cultivation is nowadays undertaken either in agroforestry systems in which some part of the natural forest is left in place or newly cleared or converted land. This involves that new land must be cleared under ecologically not always satisfactory conditions.

According to Nya *et al*.[2] and Baiyeri and Mbah[3], domestication of tree crops like cocoa is a great challenge considering its poor seed germination capacity when freshly collected and sown. However, this can be increased considerably by pre-germination treatment. Therefore, the nursery establishment of *Theobroma cacao* and other species to produce the maximum number of quality seedlings with minimum cost, time and labor and appropriate seeds required[4]. Since it is known that the performance of seedlings in the main field is determined to a very large extent by their performance in the nursery Riikonen and Luoranen[5]. It is imperative to know the requirement for establishing a nursery for quality cocoa seedling production that is capable of surviving harsh conditions when planted out or transplanted to the main field. This work was therefore undertaken to assess the suitability of various growing media from readily available substrates for germination and production of high-quality seedlings of *T. cacao*.

MATERIALS AND METHODS

Study location: The experiment commenced from March to August, 2020 at the National Cereals Research Institute (NCRI), Amakama outstation in Umuahia South Local Government Area of Abia State, Nigeria. Abia State is located between Latitudes 4°7′ and 6°3'N and Longitude 7° and 8°E in the rainforest agroecological zone. The climate is humid tropical with a distinct wet season (April to October) and dry season (November to March). Annual rainfall in the area ranges from 1750 to 3000 mm, with peaks in July and September. The average temperature ranges between 27 and 35°C. Subsistent farming resources-poor farmers for food crop production are prevalent in the area[6].

Seed procurement and extraction: Fruits of *Theobroma cacao* (Amazon variety) were purchased from Ahiaeke cocoa plantation in Umuahia North LGA, Abia State, Nigeria. This community is a well-known community in *T. cacao* farming. The fruits were obtained from one tree. Viable seeds were sorted out by simple flotation techniques following the procedure of Agbogidi and Eshegbeyi[7].

Filling of potting material and seed sowing: Ten plastic buckets perforated at their bases were filled with 15 kg of the following planting media of (1) Poultry manure plus river sand (PM+RS) at a ratio of 3:2, (2) Poultry manure plus river sand+sawdust (PM+RS+SD) at a ratio of 3:1:2, (3) Poultry manure plus top soil plus river sand (PM+TS+RS) at a ratio of 3:2:1, (4) Poultry manure plus top soil plus sawdust (PM+TS+SD) at a ratio of 3:1:2 and (5) Topsoil (TS). The composted media were left for three weeks before the seeds were planted. Similarly, samples of the media were taken for analysis of physiochemical properties at the soil science laboratory, National Root Crops Research Institute (NRCRI), Umudike, Umuahia. Seeds were planted on the 5th of May, 2020. Six seeds were sown per bucket. The buckets were arranged on top of blocks to prevent the growth of the root into the ground and to avoid possible uptake of nutrients. Watering was done at two days intervals and weeds were handpicked. An ambient temperature within six weeks of planting, which was the period when seedling emergence was monitored,

varied between 28°C and 33°C. The temperature of the media was similar and, in most cases, about 2°C higher than the ambient during the first week of planting and thereafter media temperature equated to the ambient. As of the 4th week after planting, there was no more appreciable increase in the percentage of seedling emergencies. However, monitoring of seedlings continued till the 5th week of planting.

Experimental design: The experiment was laid out in a Completely Randomized Design (CRD) at the National Cereals Research Institute (NCRI), Amakama outstation, Abia State. The study involved the use of five planting media and three replicates.

Data collection: The daily observation was made to determine the effects of the five-planting media on the germination and germination rate of seeds of *T. cacao*. The germination count of seeds was ended and considered to have been completed when no additional germination took place in five weeks. The parameters measured were the days of sprouting, germination rate and above-ground growth parameters (plant height, number of leaves, stem girth and leaf area).

Seedling heights: These were measured from the collar region to the tip of the seedlings using the meter rule.

Stem girth: It was measured using a Vernier caliper at the collar base of the seedling by Odoemelam *et al*.[8].

Number of leaves: These were determined by manual counting on the seedlings.

Leaf area: The leaf area (cm^2) was measured with a ruler by multiplying the product of the length and the breadth multiplied by the correction factor of 0.75[9]. The growth variables were measured at 2 weeks intervals for 14 weeks.

Statistical analysis: Data collected were subjected to Analysis of Variance (ANOVA). The significant means were separated using Fisher's least significant difference (FLSD) at 5% probability (Aluko *et al*.[10]).

RESULTS

Growing media: The medium PM+RS+SD had the highest percentage of sand, medium PM+TS+RS had the highest percentage of silt and medium TS had the highest percentage of the day. Bulk density between 1.29 g cm^{-3} (for medium PM+TS+RS) to 1.39 g cm^{-3} (for medium PM+RS) and Porosity between 48.67% (for medium PM+RS+SD) to 51.32% (for medium PM+TS+RS).

Water holding capacity ranged between 15.11% (for growing medium TS) to 28.80% (for growing medium PM+TS+SD). The percentage of organic matter and organic carbon were lowest (3.36 and 1.95%, respectively) for the top soil growing medium and highest (6.45 and 3.74%, respectively) for the PM+TS+SD growth medium. Elemental composition was relatively similar except in the case N for the medium TS. In some cases, higher values were obtained in growing medium PM+TS+SD, although this potting medium had a lower pH compared to other media after medium TS, which recorded the lowest pH in Table 1.

Days of sprouting and percentage germination: The days at which the plants sprouted vary, the pots with the highest rate were medium PM+TS+SD which sprouted eight days after planting, followed by medium PM+RS+SD sprouted 10 days after planting, then PM+RS (13 days), PM+TS+RS (16 days) and TS (19 days) respectively (Fig. 1). The percentage was generally high and spanned through five weeks Table 2. However, percent seedling emergence was consistently highest in media PM+TS+SD and PM+RS and lowest in medium TS. There was no more appreciable increase in percentage emergence after the third week of planting.

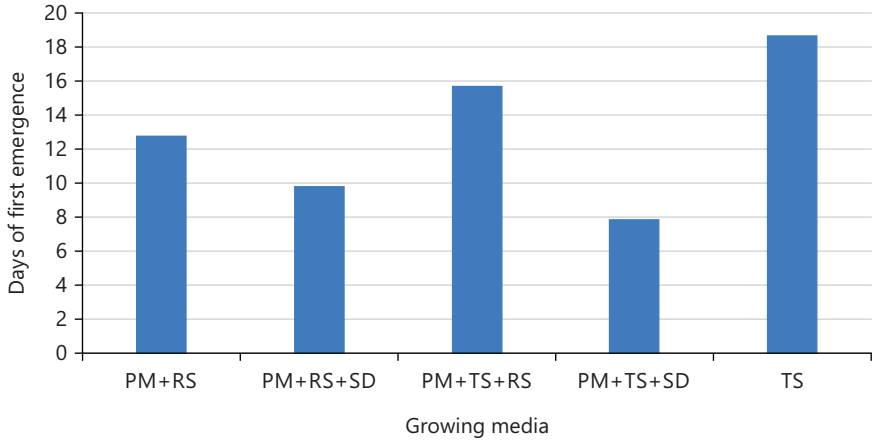

Fig. 1: Variation in the number of days of cocoa seedling emergence as influenced by growing media

TS: Top soil, PM+RS: Poultry manure plus river sand, PM+TS+RS: Poultry manure plus top soil plus river sand, PM+TS+SD: Poultry manure plus top soil plus sawdust and PM+RS+SD: Poultry manure plus river sand plus sawdust

Table 1: Physical and chemical properties of media used for raising cocoa (*Theobroma cacao* L.)

Properties	TS	PM+RS	PM+TS+RS	PM+TS+SD	PM+RS+SD
Physical					
Sand (%)	75.8	90.1	78.2	75.7	91.0
Silt (%)	10.0	6.8	12.0	11.1	6.1
Clay (%)	14.2	3.1	9.8	13.2	2.9
WHC (%)	15.11	20.63	26.13	28.80	26.72
Bulk density (g cm^{-3})	1.39	1.32	1.36	1.29	1.34
Porosity (%)	47.54	50.18	51.32	49.43	48.67
Chemical					
pH H_2O	5.8	6.6	6.9	6.1	6.7
pH KCL	4.6	6.1	6.3	5.8	6.0
Av. P (mg kg^{-1})	19.8	22.2	24.6	28.8	26.4
N (%)	0.125	2.29	2.38	2.56	2.47
OC (%)	1.95	3.56	2.49	3.74	3.62
OM (%)	3.36	6.14	4.30	6.45	6.24
Ca	5.2	8.8	9.3	9.8	9.5
Mg	2.8	4.5	5.2	6.4	5.6
K	0.36	0.58	0.66	0.88	0.72
Na	0.28	0.34	0.41	0.53	0.45
EAE	0.72	0.04	0.02	0.08	0.06
CEC	9.36	14.26	15.59	17.69	16.33

TS: Top soil, PM+RS: Poultry manure plus river sand, PM+TS+RS: Poultry manure plus top soil plus river sand, PM+TS+SD: Poultry manure plus top soil plus sawdust, PM+RS+SD: Poultry manure plus river sand plus sawdust, WHC: Water holding capacity, OC: Organic carbon, OM: Organic matter and CEC: Cation exchange capacity

Plant height: This effect of growing media on cocoa seedlings at various weeks after planting was shown in Table 3. The treatments were not significantly different at 6 WAP. At 8 WAP, medium PM+TS+SD had 26.52 cm, while other treatments ranged between 13.98 and 26.04 cm. At 10 WAP, there were significant differences among the treatments with medium PM+RS+SD having the highest value followed by medium PM+TS+SD, which was statistically similar in Table 3.

At 12 WAP medium PM+RS+SD and PM+TS+SD were significantly different from other treatments. At 14 WAP, medium PM+TS+SD has the highest plant height value (40.38 cm) which did not differ significantly from the plant height value (37.5 cm). However, the plant heights of PM+TS+SD and PM+RS+SD differed significantly from the heights obtained in growing media TS (21.7 cm) and PM+TS+RS (18.9 cm).

Table 2: Weekly germination percentage and rate of cocoa seeds as influenced by different media (%)

Media	1 WAP	2 WAP	3 WAP	4 WAP	5 WAP
PM+RS	73.33^{a}	86.66^{a}	100.00^{a}	100.00^{a}	100.00^{a}
PM+RS+SD	46.66^{ab}	60.00^{ab}	60.00^{b}	80.00^{ab}	86.66^{a}
PM+TS+RS	33.33^{b}	46.66^{b}	66.66^{b}	66.66^{b}	80.00^{a}
PM+TS+SD	73.33^{a}	86.66^{a}	100.00^{a}	100.00^{a}	100.00^{a}
TS	26.66^{b}	66.66^{ab}	66.66^{b}	73.66^{b}	73.33^{a}

Means with the same letter in the same column are not significantly different at p = 0.05, WAP: Weeks after planting, TS: Top soil, PM+RS: Poultry manure plus river sand, PM+TS+RS: Poultry manure plus top soil plus river sand, PM+TS+SD: Poultry manure plus top soil plus sawdust and PM+RS+SD: Poultry manure plus river sand plus sawdust

Table 3: Periodicity of plant height (cm) of cocoa seedlings as affected by different growth media

Media	6 WAP	8 WAP	10 WAP	12 WAP	14 WAP
PM+RS	17.51^{a}	26.04^{a}	26.88^{b}	28.61^{ab}	28.77^{ab}
PM+RS+SD	16.51^{a}	24.77^{ab}	30.90^{a}	32.40^{a}	37.45^{a}
PM+TS+RS	14.48^{a}	13.98^{b}	16.92^{c}	18.80^{b}	18.87^{b}
PM+TS+SD	19.35^{a}	26.52^{a}	29.59^{ab}	32.30^{a}	40.38^{a}
TS	14.38^{a}	19.89^{ab}	20.15^{bc}	21.58^{b}	21.74^{b}

Means with the same letter in the same column are not significantly different at p = 0.05, WAP: Weeks after planting, TS: Top soil, PM+RS: Poultry manure plus river sand, PM+TS+RS: Poultry manure plus top soil plus river sand, PM+TS+SD: Poultry manure plus top soil plus sawdust and PM+RS+SD: Poultry manure plus river sand plus sawdust

Table 4: Stem girth (cm) of cocoa seedlings as affected by different growth media

Media	6 WAP	8 WAP	10 WAP	12 WAP	14 WAP
PM+RS	0.45^{a}	0.57^{ab}	0.57^{b}	0.70^{ab}	0.70^{a}
PM+RS+SD	0.51^{a}	0.63^{a}	0.83^{a}	0.93^{a}	0.93^{a}
PM+TS+RS	0.42^{a}	0.47^{b}	0.55^{b}	0.60^{b}	0.72^{a}
PM+TS+SD	0.46^{a}	0.53^{ab}	0.66^{ab}	0.71^{ab}	0.93^{a}
TS	0.39^{a}	0.48^{ab}	0.48^{b}	0.53^{b}	0.62^{a}

Means with the same letter in the same column are not significantly different at p = 0.05, WAP: Weeks after planting, TS: Top soil, PM+RS: Poultry manure plus river sand, PM+TS+RS: Poultry manure plus top soil plus river sand, PM+TS+SD: Poultry manure plus top soil plus sawdust and PM+RS+SD: Poultry manure plus river sand plus sawdust

Table 5: Number of leaves of cocoa seedlings as affected by different growth media

Media	6 WAP	8 WAP	10 WAP	12 WAP	14 WAP
PM+RS	9.33^{a}	14.64^{a}	14.33^{a}	18.00^{a}	18.50^{ab}
PM+RS+SD	9.67^{a}	16.33^{a}	16.00^{a}	22.33^{a}	22.33^{a}
PM+TS+RS	8.67^{a}	14.33^{a}	17.00^{a}	19.00^{a}	20.00^{ab}
PM+TS+SD	9.00^{a}	14.67^{a}	18.00^{a}	19.67^{a}	24.33^{a}
TS	7.00^{a}	11.00^{a}	12.00^{a}	13.00^{a}	13.00^{b}

Means with the same letter in the same column are not significantly different at p = 0.05, WAP: Weeks after planting, TS: Top soil, PM+RS: Poultry manure plus river sand, PM+TS+RS: Poultry manure plus top soil plus river sand, PM+TS+SD: Poultry manure plus top soil plus sawdust and PM+RS+SD: Poultry manure plus river sand plus sawdust

Stem girth: The stem girth of cocoa seedlings as affected by the media at 6 WAP was not significant from the analysis of the stem girth of all five treatments in Table 4. However, at 8 WAP, there were differences in the media. And at 10 WAP, medium PM+RS+SD was significantly different from other treatments or media. The same was in 12 WAP, where medium PM+RS+SD was significantly different from other treatments. Although there was no significant difference among the treatments in 14 WAP, medium PM+RS+SD and medium PM+TS+SD had the highest (0.93 cm) stem girth.

Number of leaves: The number of leaves of the cocoa seedling is the least affected growth parameter by the treatments in Table 5. There was no significant difference obtained from the analysis of the number of leaves of all five treatments from 6 to 12 WAP. However, medium PM+RS+SD had the highest number of leaves on 6 WAP (9.67), 8 WAP (16.33) and 12 WAP (22.33), respectively. The TS recorded the lowest number of leaves (7.00, 11.00, 12.00, 13.00 and 13.00, respectively) in all the weeks compared to other media.

Table 6: Leaf area (cm^2) of cocoa seedlings as affected by different growth media

Media	6 WAP	8 WAP	10 WAP	12 WAP	14 WAP
PM+RS	82.93[a]	168.78[a]	168.79[ab]	198.88[ab]	198.47[ab]
PM+RS+SD	89.81[a]	166.67[a]	257.12[a]	270.92[a]	271.33[a]
PM+TS+RS	62.31[a]	94.84[b]	130.45[b]	137.88[b]	142.72[ab]
PM+TS+SD	76.09[a]	174.18[a]	232.61[a]	273.98[a]	275.33[a]
TS	54.67[a]	81.85[b]	90.18[b]	116.08[b]	121.53[b]

Means with the same letter in the same column are not significantly different at p = 0.05, WAP: Weeks after planting, TS: Top soil, PM+RS: Poultry manure plus river sand, PM+TS+RS: Poultry manure plus top soil plus river sand, PM+TS+SD: Poultry manure plus top soil plus sawdust and PM+RS+SD: Poultry manure plus river sand plus sawdust

Leaf area: The leaf area recorded at 6 and 8 WAP shows no significant difference between the treatments. However, medium PM+RS+SD had the highest leaf area (89.81 cm^2) and medium TS had the lowest leaf area (54.67 cm^2) at 6 WAP in Table 6. At the 8 WAP medium, PM+TS+SD recorded the highest leaf area (174.18 cm^2), which differed significantly from the medium TS had the lowest (81.55 cm^2). At 10 WAP, medium PM+RS+SD and medium PM+TS+SD recorded 257.12 and 232.61 cm^2, respectively, which was significantly different from other treatments. There was also a significant difference among the treatments at 12 and 14 WAP. At 12 WAP, the medium PM+TS+SD recorded the highest leaf area (273.98 cm^2) followed by medium PM+RS+SD (270.92 cm^2), medium PM+RS (198.88 cm^2) medium PM+TS+RS (137.88 cm^2) and medium TS (116.08 cm^2) in that order. At 14 WAP medium, PM+TS+SD also gave the highest leaf area (275.33 cm^2), with medium TS as the lowest leaf area (121.53 cm^2).

There were significant differences among the treatments at 10, 12 and 14 WAP (Table 6). The PM+TS+SD had the highest leaf area of 232.61, 273.98 and 275.33 cm^2 while medium TS had the lowest 90.18, 116.08 and 121.53 cm^2, respectively.

DISCUSSION

The significant media effects on the onset of seedling emergence and duration of emergence were probably due to differences in the chemical and physical characteristics of the media used. Differences in the physicochemical properties of growing media could be ascribed to the media components by Baiyeri and Mbah[3] and Wilson *et al.*[11]. Thus, the topsoil medium had the lowest value for water-holding capacity. Among the chemical attributes, its values for organic carbon, organic matter and percentage nitrogen were also the least. Conversely, due to the higher proportion of sawdust and a lower ratio of topsoil components, the PM+TS+SD medium had the least bulk density and highest water-holding capacity and high porosity. On a general note, the media's properties seem to agree with those of Baiyeri and Mbah[3]. Anthonio *et al.*[12] pined that better plant height is attained in mixed amended media than in sole media.

Greater scores of plant height (19.35, 26.52, 29.59, 32.20 and 40.38 cm) recorded for the medium PM+TS+SD throughout the study than the (topsoil) indicated that the use of soil amendment is beneficial to cocoa seedlings during the nursery. Akanbi and Togun[13] revealed that greater plant growth observed on organic amendment-treated media could be ascribed to the fact that the materials released a considerable amount of nutrients for plant use since their decomposition could enrich soil properties, which agreed with the present study. Ogbu[14] suggested that an ideal potting medium should provide porosity to enhance good aeration, which offers better growth to plants. The PM+RS+SD and PM+TS+SD offered these conditions necessary for the efficient growth of cocoa seedlings. The vegetative growth or leaf area generally depends on the nutrients absorbed from the substrate[12].

The present study recommended the cooperation of poultry manure with other materials in raising cocoa seedlings. It should be noted that there are some limitations to the present study. Therefore, additional studies need to be carried out to screen the poultry manure and other medium for pathogenic organisms which can cause plant diseases leading to poor growth or death of the seedlings.

CONCLUSION

It can be concluded that media with poultry manure (PM) did exceptionally well when compared to medium topsoil (TS). The amendment of medium or media with organic manure, such as poultry manure, in raising cocoa seedlings will enhance and improve the growth and performance of cocoa seedlings.

SIGNIFICANCE STATEMENT

This study affirms the use of medium or media in raising healthy cocoa seedlings, which will be transplanted to the main field. Growth media should contain the required nutrients for optimum plant growth. This will promote local production, increase the farmer's earnings and make cocoa raw materials available to industries. This study will help farmers and researchers uncover means of raising seedlings, especially cocoa seedlings which could be cost-effective and easy to set up, which before now were difficult to establish.

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