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Formulation of Cocoa (Theobroma Cacao L.) Nursery Media Using Organic Waste

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ABSTRACT
This study examined the potential of cocoa pod husk (CPH), poultry manure (PM), biochar (BIO), and sawdust (SD) as potting media for raising cocoa seedlings (Theobroma cacao L.). Eight different mixtures of these organic materials, labelled T2 to T9, were compared to topsoil (T1). The media were incubated for 12 and 2 weeks, and their properties were evaluated. Results showed bulk densities ranging from 0.37 to 1.21 g cm^{-3}, with topsoil having the highest density. The pH ranged from 7.45 in topsoil to 9.15 in T3. Total nitrogen (TN) levels varied from 0.10% to 2.07%, with T4, T7, and T9, incubated for 12 weeks, exhibiting the highest significant ($p < 0.05$) TN. The highest available phosphorus (AP) was observed in T3, T5, and T8 incubated for 12 weeks (2723.00, 2563.00, and 2808 mg/kg, respectively). Exchangeable potassium (K) was highest in the 2-week treatments T2 (2.55 cmolc/kg), T3 (2.53 cmolc/kg), and T6 (2.47 cmolc/kg). Plant performance and nutrient uptake were significantly better in the 12-week treatments than in the 2-week counterparts. The results indicate that T6 and T9, incubated for 12 weeks, performed better than the other treatments and are therefore recommended for raising cocoa seedlings.

Keywords: Formulation, cocoa pod husk, sawdust, biochar, poultry manure, cocoa seedlings.

1. Introduction

Cocoa plantations have historically been established using seedlings raised in nurseries with only topsoil as the growth medium, and these soils are either suitable or moderately suitable (COCOBOD, 2010). With the new emphasis on cocoa rehabilitation, there will be a need to increase cocoa seedling production, which will require large quantities of soil for nursery work. However, assessing such large amounts of suitable soil will pose a significant challenge, as the practice of extracting topsoil is not environmentally sustainable because it depletes and damages the land from which it is collected (Sosu, 2014). Furthermore, the heavy reliance on forest topsoil for raising cocoa seedlings is a major obstacle to large-scale cocoa seedling production. Therefore, it is essential to explore alternative growing media to reduce the use of topsoil. Current research focuses on organic-based potting media that are cost-effective, readily available, accessible, and suitable for plant growth and development. Consequently, there is a need to identify a suitable alternative medium for raising cocoa seedlings. The use of agricultural and organic industrial wastes such as rice husk, cocoa pod husk, biochar, cocopeat and sawdust as soil amendments and potting media for raising seedlings has been gaining popularity recently (Quaye et al., 2019; Anda et al., 2010; Adejobi et al., 2013).

Cocoa pod husk is a significant by-product of the cocoa industry in Ghana, accounting for over 70% (w/w) of the mature fruit (Ayeni et al., 2008). It offers opportunities to improve soil physical properties, thereby supporting seedling growth. As an organic fertilizer, cocoa pod husk is often discarded, yet it can be utilized to produce potting media, reducing waste. Therefore, efforts should be made to incorporate the husk into potting media for cocoa seedling production (Adu-Dapaah et al., 1994; Onwuka et al., 2007; and Dogbatse et al., 2019).

Sawdust is the waste product of wood processing. The use of sawdust as a mulch and soil amendment has been studied and used for raising seedlings and vegetables in many countries (Gungula and Tame, 2006). Sawdust is composed of about 40% lignin and about 60% cellulose, along with small amounts of waxes, resins, and oils (Odedina et al., 2007). Sawdust breaks down into humus, which can improve soil structure, increase aeration and water retention, and enhance microbial activity (Odedina et al., 2007). It has a high C: N ratio, which can cause nutrient imbalance and nutritional problems for plants; however, it can be a beneficial potting media amendment when used correctly (Sosu, 2014).

Poultry manure (PM) is considered a valuable organic resource for providing nutrients to crops (Evers, 2002 and Singh et al., 2004). It has a higher fertilizing value than other livestock manure, because it is richer in nitrogen (Hirzel, 2007), helps build soil organic matter and improves structural stability by improving the soil characteristics; such as aeration, water holding capacity, bulk density, aggregation, cation exchange capacity and activity of beneficial microflora (Roe et al., 1997, Jilani et al., 2007, and Deksissa et al., 2007).

Biochar is a soil improver and has been shown to add value to media in terms of fertility, particularly to acidic ones (Rodriguez et al., 2009). Its influence on the physical properties, exchange and buffering capacities of the growing media and providing a rich source of nutrients for plants has been observed (Rondon et al, 2007). Also, biochar can act as a growing media conditioner, enhancing plant growth by supplying and, more importantly, retaining nutrients and improving the physical properties of the media (Rondon et al, 2005)

Although these organic materials offer numerous benefits as soil amendments and nursery mediums, few studies have focused on combining them to create soilless growth media suitable for raising cocoa seedlings by farmers in Ghana.

This study aimed to assess the effectiveness of cocoa pod husk, poultry manure, biochar, and sawdust formulated as potting media on the growth of cocoa (Theobroma cacao L.) seedlings.

2. Materials and Methods

2.1 Study Area

The experiment was conducted in the main nursery at the Cocoa Research Institute of Ghana (CRIG) at New Tafo - Akim (06°13’ N and 00°22’ W) in the Eastern Region of Ghana. The area is characterized by a bimodal rainfall regime with the major season in March to June and the minor season in September to November. The mean annual rainfall ranges between 1,250 mm and 1,750 mm.

2.2 Soil and Media Formulation

Topsoil (T1) was collected from the CRIG main nursery. Dry cocoa pod husks (CPH), stored for about six months, were gathered from nearby cocoa farms in New Tafo-Akim and its surroundings. The dried cocoa pod husks were shredded into smaller pieces. Sawdust (SD) was sourced from a nearby sawmill in

New Tafo. The biochar was produced by charring corn cobs using the pit method. Poultry manure (PM) was obtained from a poultry farm in Koforidua, Eastern Region. The collected biomass—cocoa pod husk, sawdust, biochar, and poultry manure—was mixed in varying proportions to create different treatment mixtures as shown in Table 2. Each treatment's media constituents were thoroughly combined to ensure a uniform mixture. The various media mixtures were then separately heaped and incubated for 12 weeks. During the 10th week of incubation for the first media mixtures, another set with the same constituent combination and proportions was set up and incubated. The two sets of incubations concluded at week 12 for the first batch and week 2 for the second batch. Both incubation periods were conducted after adding 20% v/v water (see Table 1) and were incubated concurrently.

Table 1. Treatment combination ratios used in the study

TREATMENT CODE	TREATMENT DESCRIPTION (v/v)				
	CPH	SD	PM	BIO	TOPSOIL
T1 (Control)	0	0	0	0	100
T2	10	8	1	1	0
T3	9	8	2	1	0
T4	8	8	3	1	0
T5	7	8	4	1	0
T6	11	8	1	0	0
T7	5	4	1	0	0
T8	3	3	1	0	0
T9	2	2	1	0	0

2.3 Physical properties

The bulk density of the soil and formulated media was determined using the method described by Day et al. (1998). Porosity and water holding capacity of the soil were determined by using the method described by Trautmann and Krasny (1997), whilst the porosity and water holding capacity of the formulated media were determined by using the method described by Gessert (1976).

2.4 Chemical properties

The growing media were sampled for pH determination in a 1:10 and 1:2.5 (w/v) ratio for the topsoil (Gaskin et al., 2008), total nitrogen (TN) using the Kjeldahl digestion method (Bremmer and Mulvaney, 1982), available phosphorus (AP) employing the Truog method (Truog, 1930), and measured calorimetrically on a spectrophotometer. Exchangeable bases were determined by the ammonium acetate pH 7.0 method (Black, 1965), and the filtrates were analyzed with an atomic absorption spectrophotometer for potassium (K). Organic carbon was measured using the Walkley and Black method (1934). After harvesting, the growth media were sampled again to analyze residual plant nutrients.

2.5 Nursery set-up and Maintenance at the nursery

The two sets of the growth media, based on their incubation times (2 and 12 weeks), were packed into polythene bags with a uniform size of 6 cm x 8 cm. The polythene bags were filled with the formulated media at a height of 6 cm to allow for irrigation water and perforated at the two corners of the bottom to allow drainage of excess water. The control treatment received foliar fertilization (NPK 10:10:10). The experiment was laid out in a Complete Randomized Design with three replications.

All the polythene bags were then arranged on a thick polythene sheet to prevent the roots from penetrating the ground and potentially absorbing nutrients. Each polythene bag was sown with two hybrid cocoa seeds (MAN 15-2: a promising high-yielding cocoa genotype), with 16 experimental units within each replicate. The seeding was done concurrently across the two incubation periods. After emergence, the cocoa seedlings were thinned out to one seedling per polythene bag at 15 days old. The seedlings were kept under shade and watered as necessary to maintain the soil moisture at field capacity. Foliar fertilizer (NPK 10:10:10) was applied to the control at a rate of 30 mL per 15 L of water at monthly intervals using a pneumatic knapsack sprayer. Weeds were removed by handpicking as needed. Confidor 200 O-TEQ, a systemic insecticide, was applied quarterly to the seedlings at a rate of 30 mL in 15 L of water using a pneumatic knapsack sprayer to prevent insect damage.

2.6 Determination of plant growth parameters

Plant growth parameters were recorded one month after sowing and then at bi-monthly intervals for four months. Seedling height was measured using a standard meter rule, and stem diameter was measured with digital callipers.

Plants were harvested just at the surface of the soil in the fourth month of growth. Plant parts were grouped into above-ground and below-ground biomass. The above plant parts were placed in labelled envelopes and oven-dried at 75 ^{0}C for 48 hours to attain a constant weight. Dried plant parts were milled, and nutrient uptake was determined using standard methods.

2.7 Data Analysis

The data collected were subjected to analysis of variance. Treatment means were compared using the standard error of difference (SED). All statistics were performed using the GenStat statistical package.

3.0 Results

3.1 Properties of raw materials used

The physicochemical properties of the feedstocks used in the formulation of the various media are depicted in Table 2. The texture of the topsoil was loamy sand. The topsoil (TP) had a relatively higher bulk density compared to the remaining feedstock.

The PM had the highest TN (6.30 %), AP (551.43 mg kg^{-1}), EC (20.83 mS cm^{-1}) and exchangeable K (7289.89 cmol$_c$ kg^{-1}**)**, whereas SD had the highest OC of 39.39% (Table 2). This result is affirmed by the findings of Ayeni *et al.* (2008), who reported high concentrations of total N and available P in an earlier study.

Table 2: Physicochemical properties of the raw material

Properties	TP	Biochar	PM	CPH	SD
Sand (%)	86.23	-	-	-	-
Clay (%)	8.77	-	-	-	-
Silt (%)	5.00	-	-	-	-
Bulk density (g cm3^{-1})	1.23	0.32	0.71	0.38	0.24
pH	7.43	10.29	9.05	8.22	7.24
EC (mS cm^{-1})	0.25	16.56	20.83	7.39	1.31
OC (%)	3.24	9.96	20.07	39.00	39.39
TN (%)	0.09	1.11	6.30	0.33	0.32
AP (mg kg^{-1})	36.29	30.91	551.43	154.67	109.49

Ex. K (cmol$_c$ kg^{-1})	0.12	2.46	7289.89	2.42	2.84
Ex. Ca (cmol$_c$ kg^{-1})	0.35	13.92	4.31	14.68	15.17
Ex. Mg (cmol$_c$ kg^{-1})	0.14	24.97	1.45	20.01	4.47

EC = Electrical conductivity, TN = Total nitrogen, AP = Available phosphorus, Ex. K= Exchangeable potassium

3.2 Effect of incubation on physical properties of the growth media

The effect of the incubation period on the physical properties of the growth media is shown in Table 3. There were significant ($p < 0.05$) differences in bulk densities among the treatments; however, incubation period and treatment-IP had no significant ($p < 0.05$) effect on the bulk densities of the media (Table 4). The bulk densities of the media used were between 0.35 and 1.23 g cm$^{-3,}$ with the nursery soil recording the highest significant ($p < 0.05$) bulk density.

Table 3: Physical properties of the media after incubation

Treatment	BD (Mg m^{-3})		Porosity (%)		WHC ((%)	
	Incubation Period (IP)					
	2W	12W	2W	12W	2W	12W
T1	1.21	1.23	54.30	54.00	33.57	33.42
T3	0.37	0.38	63.6	57.46	45.15	38.27
T4	0.37	0.39	71.49	44.15	48.3	20.96
T5	0.39	0.36	72.95	68.86	49.24	42.51
T6	0.38	0.37	72.31	72.31	46.99	45.23
T7	0.38	0.35	71.71	71.71	47.06	46.92
T8	0.38	0.36	72.22	72.22	46.74	46.59
T9	0.38	0.35	71.27	71.27	47.12	46.54
Treatment	(0.01)*		(1.37)*		(2.19)*	
Incubation period	(0.01)^{ns}		(1.18)*		(1.90)*	
Treatment × IP	(0.01)*		(0.97)*		(1.55)*	

*$p < 0.05$; ns = not significant at 0.05. Values in brackets = SED, W = weeks

The lowest for the IP are T9, T7 (0.35 g cm^{-3}) and T3, T4 (0.37 g cm^{-3}) at 12 weeks and 2 weeks, respectively. The study revealed that there is no incubation effect on the bulk densities of the media, as both IPs had the same mean value of 0.48 g cm^{-3}. The mean porosity ranged from 39.33 to 72.95% for the media. There were significant differences in porosity among the treatments, IP and treatment-IP – IP interaction. T5 (72.95%) of 2 weeks IP and T6 (72.31%) of 12 weeks IP had significantly ($p < 0.05$) higher porosity than that of the other treatments. The 2-week IP had significantly ($p < 0.05$) higher porosity than that of the 12-week IP, and T6 was significantly ($p < 0.05$) higher than that of all the treatments, whereas T2 remained the lowest.

Water holding capacities were significantly different ($p < 0.05$) among the treatments, IP and treatment-IP, with values ranging from 27.95 to 49.24. T7 (12 weeks) (46.92) and T5 (2 weeks) (49.24) were significantly higher than the other incubated media. The 2-week IP was significantly different (*p* <0.05) from that of the 12-week IP.

3.3 Effect of incubation time on some chemical properties of the growth media.

The effect of incubation time on some chemical properties of the media is presented in Figures 1 to 8. There were insignificant (p <0.05) changes in pH (7.41 -7.45) of T1 throughout the incubation period. About 78% of the growth media recorded significantly (p <0.05) higher pH at week-2 of incubation.

The organic carbon content of the media ranged from 1.38% to 23.19%. About 50- 60% of the growth media recorded higher carbon content during week week-1 of incubation. Generally, there were no significant differences in the carbon content of most of the growth media during the incubation period. Surprisingly, during week 12, T5 recorded organic carbon content (22.13%) values higher than those of the other incubated counterparts.

Except for T1, which did not show significant differences (p <0.05) in N content during the incubation period, all the other growth media had their N content increasing significantly (p<0.05) with increasing incubation time. Total N content ranged from 0.10- 2.20% with T3 at week-12 recording the highest significant (p <0.05) N content.

Likewise, P content in T1 also recorded statistically similar values during the incubation period; however, all the other growth media recorded P values which increased with increasing incubation time. T3 recorded the highest significant (p <0.05) available P of 2808.00 mg $kg^{-1,}$ which was statistically (p <0.05) similar to that of T5 and T8, whilst T1 recorded the lowest value of 45.90 mg kg^{-1}.

The K, Mg, and Ca content of all the growth media except T1 decreased with increasing incubation time. The K content was highest at week 2, which saw a downward trend at week 12. The K content of the media was between 0.12 and 2.55 $cmol_c\ kg^{-1}$. There were significant differences between the incubation times of all the growth media. The Mg content ranged from 1.09 $cmol_c\ kg^{-1}$ in T1 to 12.64 $cmol_c\ kg^{-1}$ in T7. Calcium also recorded the lowest value of 7.45 $cmol_c\ kg^{-1}$ in T1 and the highest of 27.63 $cmol_c\ kg^{-1}$ in T7.

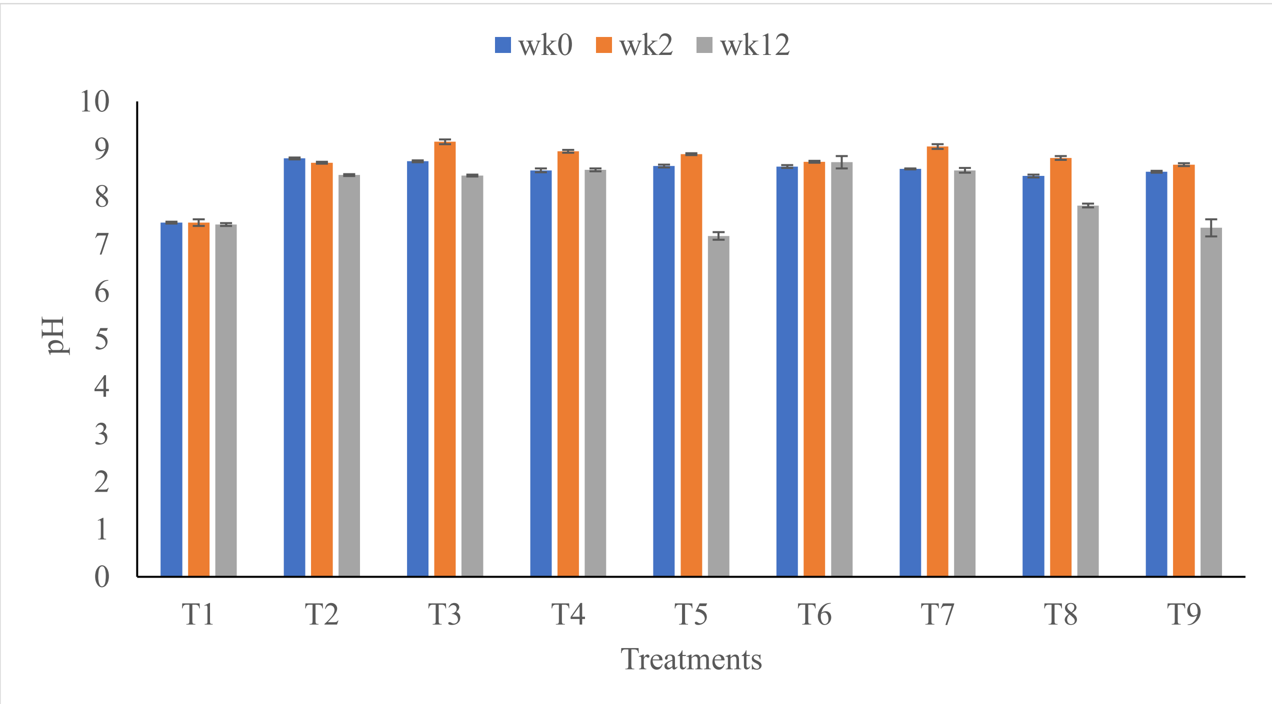

Figure 1: Effect of incubation time on pH of the growth media

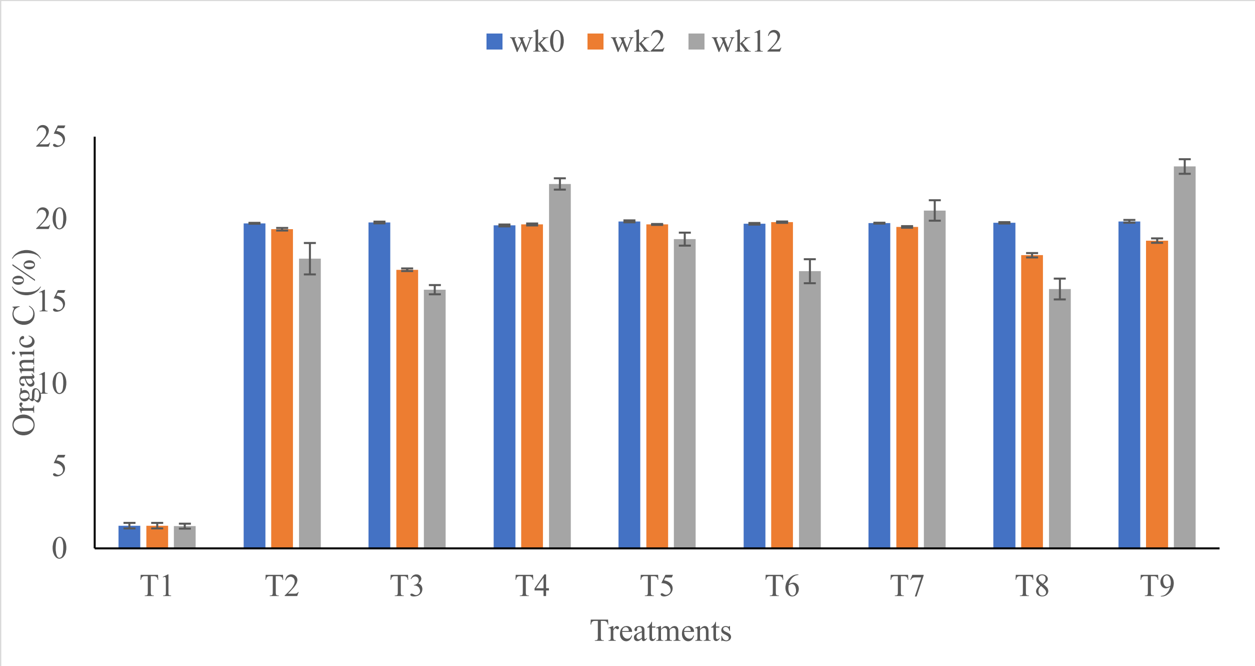

Figure 2: Effect of incubation time on organic carbon content of the growth media

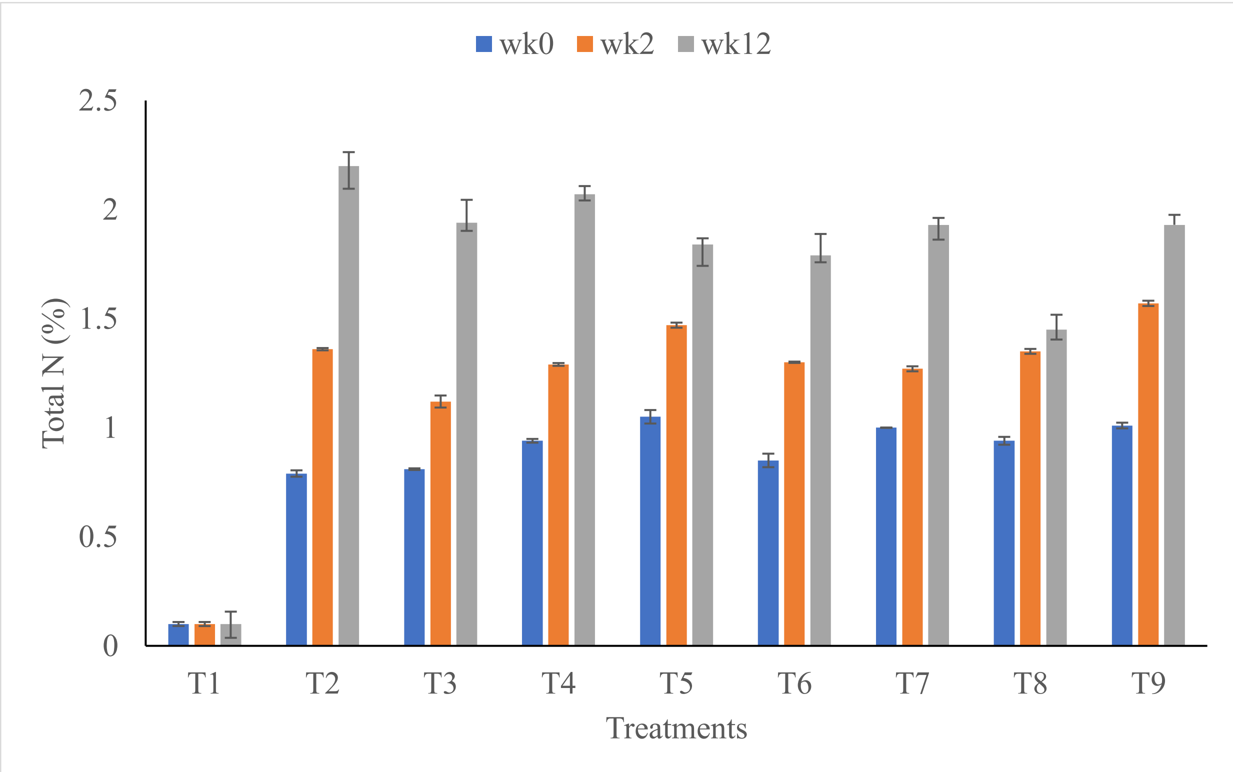

Figure 3: Effect of incubation time on total N content of the growth media

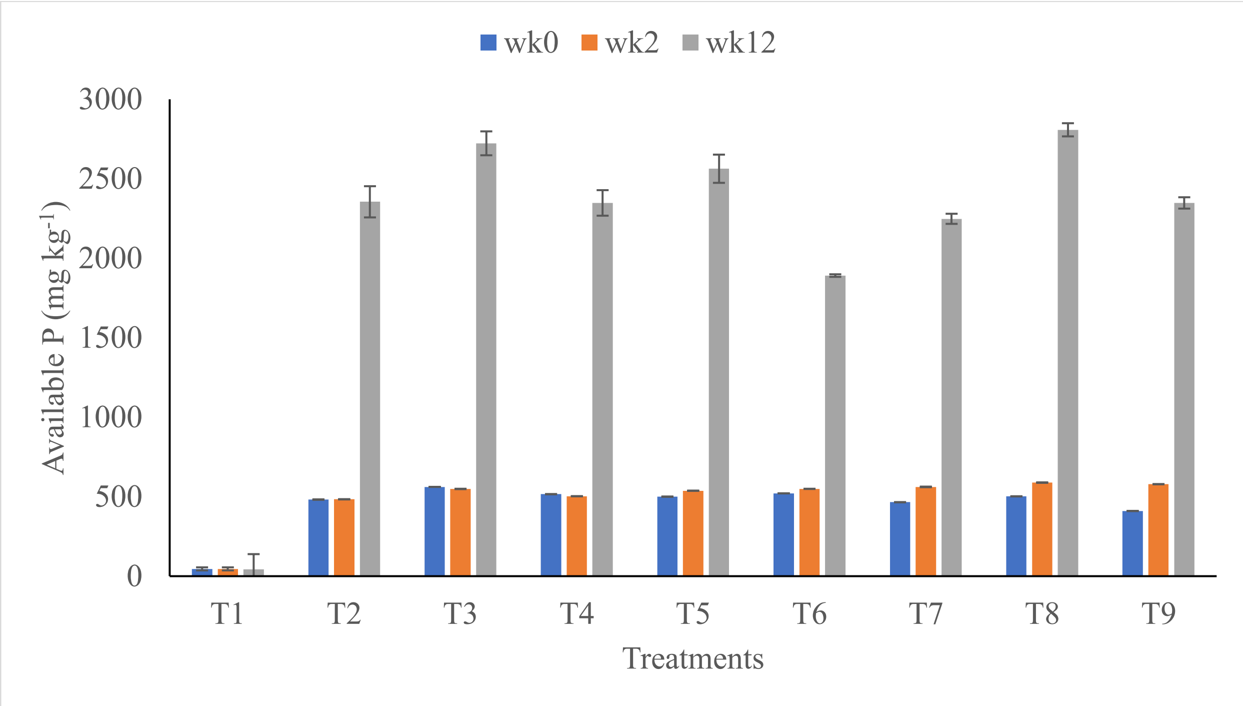

Figure 4: Effect of incubation time on available P content of the growth media

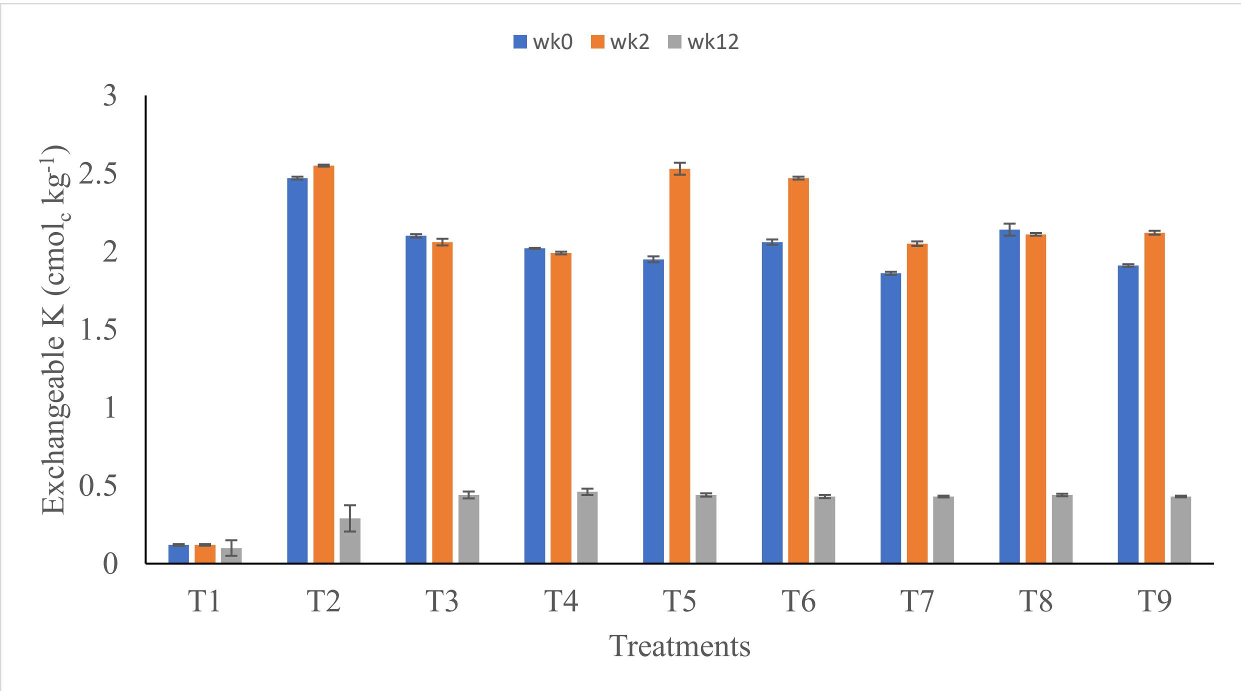

Figure 5: Effect of incubation time on exchangeable K content of the growth media

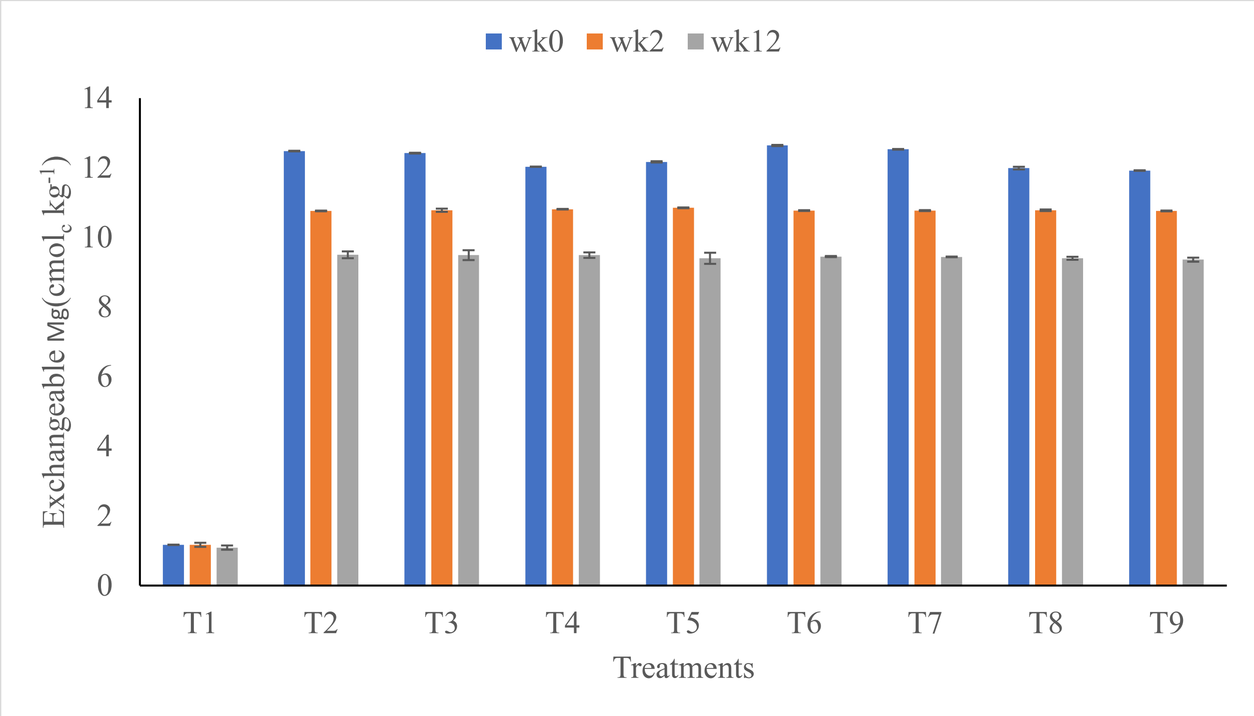

Figure 6: Effect of incubation time on exchangeable K content of the growth media

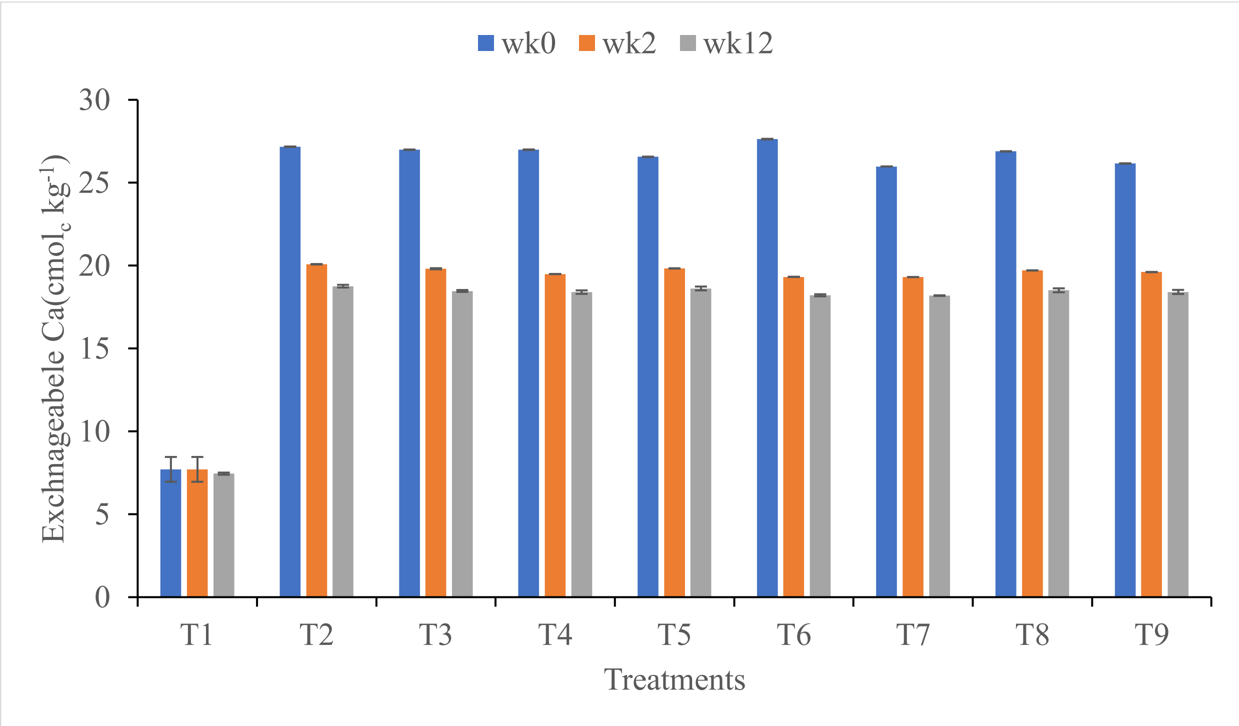

Figure 7: Effect of incubation time on exchangeable Ca content of the growth media

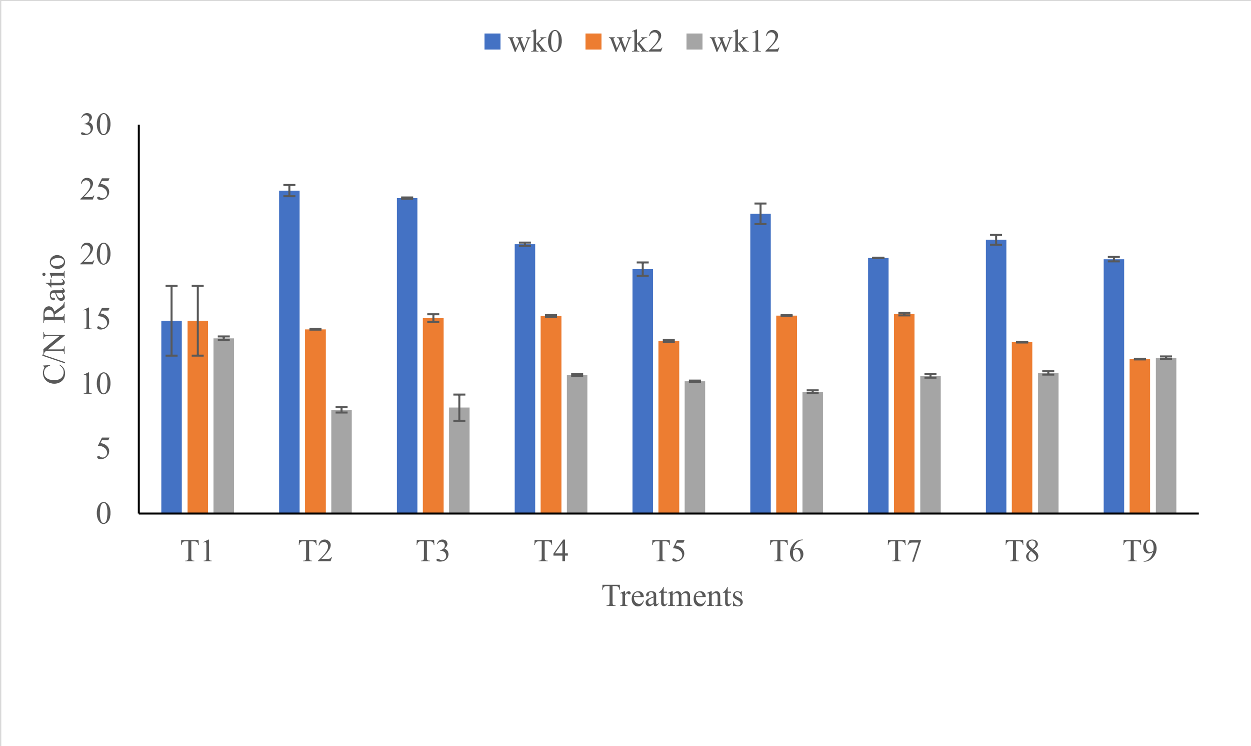

Figure 8: Effect of incubation time on the C/N ratios of the growth media

3.4 Media effect on cocoa seedling growth

The effect of growth media on measured seedling growth parameters is presented in Table 5. Two weeks of incubated topsoil (T1) recorded a mean plant height of 30.62 cm, whilst its 12-week counterpart recorded a mean plant height of 34.47 cm. There was no significant interaction effect in terms of treatments and treatment-IP of the media types with respect to height and stem diameter. But there was a significant ($p < 0.05$) difference in terms of IP on height and stem diameter. The 12-week IP seedlings had 31.08 cm and 0.59 cm of mean height and stem diameter, respectively, compared to the mean of 2-week IP (27.41 cm height and 0.48 cm diameter). The T6 and T9 (week 12) had a plant height of 33.17 cm, which did not differ statistically ($p < 0.05$) from that of T1 (34.47 cm).

3.5 Effect of media on soil nutrient uptake

The effect of growth media on plant nutrient uptake is presented in Table 6. Total N uptake for cocoa seedlings grown on 2-week incubated media ranged from 2.62 % for the T1 (control) to 3.61% for T9. Whilst week 12 ranged from 2.71% (control) to 6.73% (T3). Increasing the PM had no influence on the N uptake (T2- T4) at both incubation periods. Except for week-2 treatment 2, all the formulated media had a significantly ($p < 0.05$) stronger influence on N uptake than T1 (control). Nitrogen uptake was significantly ($p < 0.05$) higher in the plants in the 12-week incubated media than in the 2-week counterpart, except for T1 and T2.

There was a significant effect of treatment, IP and treatment-IP on seedlings' P uptake as shown in Table 6. Total P uptake for cocoa seedlings raised in the two-week incubated media ranged from 0.22% (T6) to 0.25% (T8). Whilst seedlings grown on 12 weeks of incubated media had total P uptake between 0.19% (T2) and 0.35% (T4). Except for T6, which recorded significantly ($p < 0.05$) lower P uptake, all the formulated media registered statistically ($p < 0.05$) similar P uptake as the topsoil (T1) at week-2 of incubation. In the 12-week incubation media, except T2 and T7, which had significantly ($p < 0.05$) lower

P uptake than T1, all the remaining treatments had significantly (p < 0.05) higher P uptake than T1. Generally, P uptake was significantly higher in the 12-week incubated media than in the 2-week counterpart.

The total K uptake ranged from 1.22% (T1) to 1.54% (T4) for the 2-week incubated media, whilst the 12-week incubated media recorded values between 1.01% for T2 and 2.67% for T9. The incubation period and the treatment did not have a significant (p <0.05) influence on the total K uptake by the cocoa seedlings.

Table 5: Media effect on the growth parameters of cocoa seedling

Treatment	Height (cm)		Diameter (cm)	
	Incubation Period (IP)			
	2W	12W	2W	12W
T1	30.62	34.47	0.49	0.64
T2	28.74	29.61	0.51	0.58
T3	28.19	29.26	0.48	0.59
T4	26.92	31.47	0.45	0.55
T5	27.32	30.85	0.47	0.61
T6	27.33	33.17	0.49	0.59
T7	27.49	29.97	0.48	0.60
T8	25.59	31.57	0.49	0.62
T9	27.56	33.17	0.48	0.61
Treatment	$(1.78)^{ns}$		$(0.29)^{ns}$	
Incubation period	(0.67)*		(0.11)*	
Treatment × IP	$(2.52)^{ns}$		$(0.41)^{ns}$	

Table 6: Effect of media on NPK uptake in the seedlings.

Treatment	TN (%)		TP (%)		TK (%)	
	Incubation Period (IP)					
	2W	12W	2W	12W	2W	12W
T1	2.62	2.71	0.24	0.24	1.22	1.22
T2	2.85	3.59	0.23	0.19	1.32	1.10
T3	3.41	6.73	0.24	0.26	1.43	1.44
T4	3.48	5.46	0.28	0.35	1.54	2.01
T5	3.48	5.28	0.27	0.27	1.53	1.37
T6	3.47	5.68	0.22	0.29	1.40	1.40
T7	3.50	6.38	0.24	0.16	1.30	1.39
T8	3.41	5.46	0.25	0.29	1.44	1.81
T9	3.61	5.38	0.24	0.35	1.23	2.67
Treatment	(0.46)*		(0.02)*		$(0.26)^{ns}$	
Incubation period	(0.18)*		(0.01)*		$(0.10)^{ns}$	
Treatment × IP	$(0.65)^{ns}$		(0.02)*		$(0.37)^{ns}$	

Table 7: Media residue chemical properties

Treatment	pH (H_2O)		EC (mS cm^{-1})		TN (%)		AP (mg kg^{-1})		Ex. K ($cmol_c$ kg^{-1})	
	Incubation Period (IP)									
	2W	12W	2W	12W	2W	12W	2W	12W	2W	12W
T1	7.02	7.28	0.36	0.06	0.14	3.67	305.00	208.00	0.06	0.09
T2	7.60	7.40	0.46	0.05	0.17	2.99	396.00	226.00	0.19	0.08
T3	7.08	7.09	2.00	0.40	1.91	3.06	2355.00	3698.00	0.58	0.13
T4	6.65	7.08	2.85	0.21	1.65	2.78	2740.00	4170.00	0.57	0.13
T5	7.15	6.79	1.53	0.12	1.74	3.16	3181.00	5067.00	0.59	0.15
T6	7.01	6.91	1.98	0.06	1.63	2.96	3373.00	6214.00	0.63	0.13
T7	7.1	6.77	2.20	0.22	1.76	3.03	3174.00	5342.00	0.59	0.14
T8	7.04	6.93	1.65	0.26	1.57	3.21	3129.00	4859.00	0.60	0.14
T9	6.95	6.92	1.74	0.38	2.02	3.41	3456.00	5037.00	0.63	0.15
Treatment	(0.13)*		(0.20)*		(0.18)*		(134.50)*		(0.02)*	
Incubation period	(0.05)^{ns}		(0.08)*		(0.07)*		(50.80)*		(0.01)*	
Treatment × IP	(0.19)^{ns}		(0.28)*		(0.25)*		(190.20)*		(0.03)*	

*p < 0.05; ns = not significant at 0.05. Values in brackets = SED

3.6 Residual nutrients in the potting media

There were significant ($p < 0.05$) interactions in residual TN, AP and Ex. K with respect to treatment, treatment-IP and IP effects (Table 7). The residual values for TN and AP appreciated after a 4-month planting period, which could be due to mineralization, whereas pH, EC and Exchangeable K were significantly ($p < 0.05$) lowered (Table 7). The pH of the residual growth media ranged from 6.65 (T4) to 7.60 (T2). The measured residual plant nutrients were significantly ($p < 0.05$) higher in the 12-week incubated media than in the 2-week incubated media.

4.0 Discussion

The lower bulk density of the soilless media than the nursery soil might be due to the higher volume-to-mass ratio of the organic materials used. Bulk density values below the restricted value of 1.60 g cm^{-3} will allow for easy root growth and development (McKenzie et al. 2004). The feedstock combinations also contributed significantly to the high nutrient content of the soilless media compared to the nursery soil. The higher porosity, water holding capacity and C/N ratio of the soilless media might be due to the nature of the feedstock. Organic materials have a sponge-like structure, which helps in moisture retention. Baiyeri and Mbah (2006) reported that a soilless potting medium that possesses high water holding capacity with optimum nutrients and aeration for plant growth is an added advantage to the nursery industry.

The increasing total N and available P with increasing incubation time might be a result of decomposition and mineralization of the feedstocks that led to the release of the nutrients into the formulated growth media. Several studies have reported the release of nutrients following the mineralization of organic materials with time (Garzon et al., 2011; Beesigamukama *et al.,* 2021; Li et al., 2022). Kelderer et al. (2008) reported a 0.4% and 0.6% increase in nutrient released from compost mineralization after 14 and 60 days, respectively, of incubation. Also, the release of N and the concomitant conversion of carbon into the atmosphere as carbon dioxide might have resulted in the low C/N ratio of the incubated growth media, which decreased with increasing time. However, the K, Ca, C and pH did not follow this trend.

The high content of N and P of the 12-week incubated media might be the reason for their superior performance to the 2-week incubated and the nursery soil in terms of plant height and diameter. One of the functions of nitrogen is the promotion of plant vegetative growth, and this is evident in the results obtained. The fact that treatments T6 and T9, incubated for twelve weeks, registered plant height similar to that of the topsoil indicates that those treatments can be used as a substitute for topsoil in raising cocoa seedlings and curb the adverse effect of topsoil wining on the environment. This would provide an alternate use for agricultural waste that mostly becomes an environmental nuisance after harvesting. Furthermore, the soilless media, by virtue of their lighter weight, would ease transportation compared to seedlings raised with topsoil.

Additionally, nitrogen and phosphorus uptake were higher in the 12-week incubated media due to the higher phyto-availability of the nutrients in the growth media. The residual growth media of the 12-week incubated media recorded higher TN and AP values after a four-month planting period, which might be due to the continuous mineralization processes. The decrease in pH after harvesting might be due to the release of H^+ as a result of mineralization of the feedstocks, coupled with the release of the same ion due to the plant's uptake of nutrients (Garzon et al., 2011). Additionally, continuous irrigation during the study might have introduced hydrogen ions, which might have culminated in the lower pH observed.

5.0 Conclusion and Recommendation

The formulated nursery media from agricultural waste can be used as a substitute for topsoil in raising cocoa seedlings for subsequent establishment in the field.

Moreover, for a farmer to raise good and healthy cocoa seedlings, the formulated growth media have to be incubated for 12 weeks before seeds can be sown. This would allow mineralization and release of available nutrients for plant absorption.

The authors recommend that a subsequent study be carried out in the field to assess the performance of the seedlings raised with the formulated soilless media under field conditions.

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6.0 References

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