Growth and Nutrient Uptake Response of Cocoa (*Theobroma cacao* (L.) Seedlings to Different Growth Media at the Nursery in Ghana

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Abstract

Cocoa (*Theobroma cacao* L.) seedlings are primarily grown in nurseries using topsoil as the main polybag medium. Some of these soils are acidic, highly weathered, and low in plant nutrients. The poor development of cocoa seedlings in nurseries has been attributed to the use of unsuitable potting media. This study aimed to assess the impact of incorporating rice husk biochar (RHB) and cocoa pod husk compost (CPHC) into soil, sawdust, and rice husk–based media on the growth and nutrient uptake of cocoa seedlings in the nursery. The experiment was laid out in a Completely Randomized Design (CRD) with three replicates. The experiment was carried out at the nursery site of Mabang Megakarya Selection programme at Mabang a substation of Cocoa Research Institute of Ghana. The treatments comprised three base-materials viz: Topsoil (TS), Rice husk (RH) and Sawdust (SD) amended with three rates of rice husk biochar (RHB) at 75%: 25%, 50%:50% and 25%:75% and two rates of cocoa pod husk-based compost (CPHC) at 90%:10% and 80%:20% (base-media: amendment on v/v). The respective amounts of media combinations were mixed thoroughly and filled into polybags with dimensions 18 cm wide x 25 cm high. Seedlings were raised from *C.69* clone mixed hybrid cocoa and seedling growth was assessed at bi-monthly intervals for six months. Chemical analysis of soil and organic materials were carried out using standard laboratory procedures. At six months after sowing, results indicate that seedlings raised in TS50:RHB50 (60.3 cm) media mix were significantly ($p<0.05$) taller and had the highest number of leaves per plant, the highest chlorophyll content, larger leaf area and longer tap root length. Stem diameter of seedlings raised in TS90:CPHC10 media mix was bigger than in the TS100 and TS50:RHB50 mix. Cocoa seedlings grown in TS50:RHB50 media mix had the highest dry matter yield. Nitrogen uptake was significantly ($p<0.05$) higher in TS50:RHB50 potting media mix while P, K, Ca, and Mg were higher in TS90:CPHC10 potting media mix than in the TS50:RHB50 mix. The results indicate that the best potting mixture of soil and biochar for growing vigorous cocoa seedlings is 50% top soil mixed with 50% rice husk biochar.

Keywords: Cocoa pod husk compost, rice husk biochar, topsoil, rice husk, sawdust, media and cocoa

Introduction

Efforts to rejuvenate old cocoa (*Theobroma cacao* (L.) plantations in Ghana require the Seed Production Division (SPD) of COCOBOD to produce millions of seedlings for field planting. This process heavily depends on large volumes of topsoil. However, topsoil availability is declining, and the poor performance of cocoa seedlings in nurseries is often attributed to the use of inappropriate potting media. The current topsoil is often acidic, has poor water-retention capacity, is low in organic carbon and bulky, making the transportation of nursery polybags over long distances difficult. Additionally, these soils are low in fertility, necessitating the use of chemical fertilizers to meet seedling nutritional needs. Their compact nature also limits root development and expansion (Quaye et al., 2017). Using such low-quality soils exclusively in nurseries has been shown to negatively affect cocoa seedling growth (Quaye et al., 2017). Relying solely on topsoil as a potting medium leads to ecosystem degradation in the areas from which it is sourced (Siregar et al., 2007). A growing medium refers to the substrate(s) used for cultivating plants (Landis et al., 2014). An ideal growing medium should be lightweight, provide adequate aeration, retain sufficient moisture, and supply essential nutrients to support healthy plant development. The selection of high-quality growing media is vital for effective nursery operations, as it lays the groundwork for strong root development. Therefore, identifying environmentally sustainable and efficient materials that can offer both structural support and necessary nutrients is essential for producing vigorous cocoa seedlings.

In Ghana, the accumulation of agricultural waste has risen significantly due to poor disposal practices, leading to negative environmental impacts (Duna, 2015). The improper disposal of agricultural residues has led to serious environmental concerns, including pollution, greenhouse gas emissions, climate change, and adverse effects on both human and animal health (Sadh et al., 2018). Although agro-industrial waste is typically rich in nutrients, if not properly managed or treated, it can become a breeding ground for pathogens and pose significant health risks (Ravindran et al., 2018). Consequently, there is a pressing need to identify and implement effective recycling strategies to mitigate these challenges. Utilizing organic materials as renewable resources for producing growing media has been proposed as a sustainable solution (Mehmood et al., 2013). Sawdust is regarded as a valuable organic material and has gained popularity as a growing medium in various industries due to its favourable physical properties. These include its appropriate rate of biodegradability, low specific gravity, high porosity, excellent water retention, moderate drainage, and good tolerance to bacterial activity (Maharani et al., 2010). Similarly, rice husk can be effectively utilized as a cultivation medium. Rice husk combined with compost and rice husk biochar has been shown to promote robust cocoa seedling growth (Quaye et al., 2017). Cocoa pod husk compost also improves seedling development, whether used as a potting medium or soil amendment (Ofori-Frimpong et al., 2010). Overall, organic materials derived from agricultural waste streams have been rightly identified as promising alternatives to topsoil for use as potting media (Shu-aib Jakpa et al., 2020; Adejobi et al., 2013). Although some studies have examined the use of organic materials as potting media for cocoa seedling production (Sosu, 2014; Bahrun et al.,2018 and Abdul-Razak et al., 2020), appropriate mixtures of soil, sawdust, rice husk, biochar, and compost as soil-based and soilless media for raising healthy cocoa seedlings have not been adequately investigated in Ghana. This study determines the effect of adding biochar and compost to soil, rice husk and sawdust as potting media for raising cocoa seedlings. It is expected that the findings of this study will identify the optimal ratios of soil, sawdust, rice husk, biochar, and compost that provide adequate plant-available nutrients and are environmentally friendly for raising healthy cocoa seedlings.

Materials and methods

Soil and experimental site

The experiment was carried out at the nursery house of Mabang Megakarya Selection Programme, a substation of the Cocoa Research Institute of Ghana. Mabang is in Ahafo-Ano North District of the Ashanti Region, with a geographical coordinate of 6°58'60" N and 2°13'0" W. Mabang is located within the Moist Semi-Deciduous North West (MSNW) ecotype with an annual rainfall of about 1257 mm and a temperature range of 26°C in August and 30°C in March.

Soil and organic materials for media preparation

The materials used for the experiment were topsoil of a Nitisol according to World Reference Base for Soil Resources (WRB 2014), (or Ultisol, USDA soil taxonomy, 2014), rice husk, sawdust, rice husk biochar and cocoa pod husk compost prepared with materials such as poultry manure and *Gliricidia sepium* leaves.

Top soil 0–20 cm deep was collected and all visible plant debris and stones removed and then used for the nursery. The soil samples were air-dried, crushed to pass through a 2 mm mesh sieve to allow for thorough and homogenous mixing with the amendments. Rice husk was collected from Asutuare rice mill and used to produce biochar at Cocoa Research Institute of Ghana, Tafo. Cocoa pod husk, poultry manure and *Gliricidia sepium* leaves were sourced from farmers' farms and used to produce compost at a ratio of 3:1:1 through controlled biological decomposition. Sawdust was obtained from the Tepa saw mill.

Characterization of soil and organic materials

Samples of soil, rice husk biochar, cocoa pod husk compost, rice husk and sawdust were air dried, crushed to pass through a 2 mm mesh sieve for analysis. Particle size distribution of soil samples was determined by the method of Bouyoucos (Bouyoucos, 1951). pH was determined electrometrically in distilled water at 1:2.5 (ISRIC, 1992), organic carbon (OC) by using the wet combustion method of Walkley and Black (Walkley and Black, 1934) and Total nitrogen (TN) by the Kjeldahl method (Bremner, 1965). Available phosphorus (avail. P) was determined using Bray and Kurtz method (Bray and Kurtz, 1943). Exchangeable basic cations (K, Ca and Mg) were extracted with 1 M ammonium acetate and the filtrate was analyzed by the atomic absorption spectrophotometer (Hanway and Heidel, 1952).

Nursery establishment and treatment combination

Standard nursery polybags measuring 18 cm × 25 cm, with perforations at the base, were filled with the various potting media treatments, watered, and left to stabilize for 72 hours before sowing cocoa seeds. The cocoa seeds were sown at a rate of two per polybag. Following germination, they were thinned to one seedling per bag. The seedlings were placed under a black shade net to minimize light intensity. The seedlings remained in the nursery for six months and were watered three times each week. Regular hand picking of weeds from nursery bags was carried out, to prevent weeds from serving as a host to pests and also competing with the seedlings for nutrients. All Cocoa Research Institute of Ghana nursery recommendation practices were carried out accordingly at the nursery house.

There were eighteen (18) treatments, arranged in a completely randomized design (CRD) with three replications. Each treatment unit had 20 seedlings. Topsoil (TS), rice husk (RH) and sawdust (SD) were used as the base media while rice husk biochar (RHB) and Cocoa pod husk base compost (CPHC) were used as amendments. Different proportions of biochar and compost were mixed thoroughly with soil, sawdust and rice husk and filled into nursery polybags. There were three levels of RHB (25%, 50% and 75%) and two levels of CPHC (10% and 20%) mixtures with TS, RH and SD. Only TS, RH and SD (100%) without amendment with RHB and CPHC served as controls. Cocoa seedlings' height,

TABLE 1
Treatment combinations used for the experiment

Treatment Number	Description (% combination of materials) on volume bases
1	100% TS
2	TS75 + RH Biochar 25
3	TS50 + RH Biochar 50
4	TS25 + RH Biochar 75
5	TS90 + Cocoa Pod husk compost 10 (CPHC 10)
6	TS80 + Cocoa Pod husk compost 20 (CPHC 20)
7	100% SD
8	SD75 + RH Biochar 25
9	SD50 + RH Biochar 50
10	SD25 + RH Biochar 75
11	SD90 + Cocoa Pod husk compost 10 (CPHC 10)
12	SD80 + Cocoa Pod husk compost 20 (CPHC 20)
13	100% RH
14	RH75 + RH Biochar 25
15	RH50 + RH Biochar 50
16	RH25 + RH Biochar 75
17	RH90 + Cocoa Pod husk compost 10 (CPHC 10)
18	RH80 + Cocoa Pod husk compost 20 (CPHC 20)

RH = Rice Husk, TS =Top soil, SD = Sawdust, RHB = Rice husk Biochar, CPHC = Cocoa pod husk compost

stem diameter, leaf number, leaf area, leaf chlorophyll content and dry biomass weight were taken at bi-monthly intervals for six months.

Plant nutrient uptake
The cocoa seedlings dried leaf samples were ground in a Wiley mill to pass through a 1 mm mesh sieve and used for their analysis of nutrient concentration. The average concentration of each of the leaf nutrient elements was multiplied by the leaf dry weight to obtain the uptake at the 6th month.

$$\text{Uptake}\ (g\ plant^{-1}) = \text{Nutrient concentration} \times \text{Dry weight of plant tissue} \ldots\ldots (1)$$

Data analysis
The data were subjected to statistical analysis using Analysis of Variance (ANOVA) in GenStat software (12th edition), and treatment means were separated and compared by Least Significant Difference (LSD) method. Significance level was set at 5 %.

Results

Properties of soil, raw organic materials, biochar and compost
Table 2 shows that the soil had a high sand content of 67.2% and silt and clay content of 12.0% and 20.8% respectively. The texture of the soil was sandy clay loam. The soil's silt and clay levels were sufficient to retain adequate moisture to support the growth of cocoa seedlings (Dogbatse et al., 2019). The wide silt-to-clay ratio indicated that the soil was highly weathered. The soil was acidic in water. The soil was low in electrical conductivity (EC), organic carbon (OC) content and nitrogen (N) content. The soil was low in available P. The low available P

content could be due to its acidic nature and/ or due to depletion of soil reserve P through intensive cultivation, without adequate external replenishment. Exchangeable bases were dominated by calcium with low values of magnesium and potassium. The soil has soil fertility constraints and therefore, needs to be ameliorated to reduce its acidity and to improve its other soil properties.

The results of the chemical properties of the organic materials indicated that, rice husk (RH) and rice husk biochar (RHB) were slightly acidic. Sawdust (SD) was slightly alkaline while cocoa pod husk compost (CPHC) was alkaline in nature. Electrical conductivity of CPHC, RH and SD were significantly ($p<0.05$) higher than in the RHB. Organic carbon of RH, SD and RHB were significantly ($p<0.05$) higher than CPHC (Table 3). Total N of CPHC was significantly ($p<0.05$) higher than RH, RHB and SD. Total P of CPHC was significantly ($p<0.05$) higher than SD, RHB and RH. Percent K of CPHC was significantly ($p<0.05$) higher than RHB, RH and SD. Percent Mg of CPHC was significantly ($p<0.05$) higher than SD, RHB and RH and % Ca of CPHC was significantly ($p<0.05$) higher than SD, RHB and RH (Table 3).

Germinating response of cocoa seeds

At 14 DAS, seeds in the TS mixed RHB and CPHC at TS50:RHB50, TS80:CPHC20 and TS75:RHB25 had significantly ($p<0.05$) higher germination (100%, 95% and 88.3%), respectively than those sown in TS100

TABLE 2

Some physical and chemical properties of the Topsoil used

Parameter	Value (Mean ± SEM)
Sand (%)	67.2 ± 0.00
Silt (%)	12.0 ± 0.01
Clay (%)	20.8 ± 0.00
Silt: clay ratio	0.58 ± 0.00
Textural class (USDA)	Sandy Clay Loam
pH	5.6 ± 0.0036
EC (µS cm^{-1})	405.63 ± 0.260
Organic C (%)	0.47 ± 0.0065
Total N (%)	0.16 ± 0.0002
C:N ratio	2.94 ± 0.0439
Avail. P (mg kg^{-1})	4.25 ± 0.1199
Exch. K (cmolc kg^{-1})	0.15 ± 0.00003
Exch. Mg (cmolc kg^{-1})	1.76 ± 0.001
Exch. Ca (cmolc kg^{-1})	4.94 ± 0.0003

SEM = Standard Error of the mean

TABLE 3

Some selected chemical compositions of the organic materials used for the experiment

Media	pH	EC (µS cm^{-1})	Organic C (%)	Total N (%)	C: N Ratio	Total P (%)	K (%)	Mg (%)	Ca (%)
Rice husk biochar	6.6	831.87	15.34	0.36	42.61	0.26	0.87	0.16	0.18
Sawdust	7.4	2261.00	16.77	0.35	47.91	0.28	0.53	0.18	0.54
Rice husk	6.4	2873.33	32.57	0.44	74.02	0.20	0.63	0.10	0.17
CPHC*	8.4	18310.00	13.59	1.30	10.45	1.94	2.90	1.63	6.34
p-value (@ 5%)	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**
LSD (@ 5%)	**0.07**	**203.30**	**0.32**	**0.01**	**0.97**	**0.04**	**0.07**	**0.09**	**0.16**
CV (%)	**0.5**	**1.7**	**0.8**	**0.7**	**1.1**	**3.0**	**2.7**	**8.2**	**4.5**

**CPHC = Cocoa Pod Husk Compost*

and TS90:CPHC10 (Table 4). Among the soilless media treatments, seeds sown in SD100 had 100% germination, which was significantly ($p<0.05$) higher than those sowed in RH100, RH90:CPHC10 and RH80:CPHC20 treatments. At 17 DAS, seeds sown in TS mixtures with TS50:RHB50 and TS80:CPHC20 had 100% germination which was significantly ($p<0.05$) higher than those sown in TS90:CPHC10 and TS100 (Table 4).

Growth performance of cocoa seedlings

Among the soil media mixes, the stem diameter of cocoa seedlings at 2 MAG and 6 MAG was bigger in TS90:CPHC10 (4.30 mm and 10.32 mm), while the smallest values were recorded in TS100 (3.74 mm) and TS75:RHB25 (8.79 mm). In the soilless media mixes from 2 to 6 MAG, cocoa seedlings grown in RH80:CPHC20 had the biggest stem diameter (3.80 mm, 5.98 mm and 8.37 mm), whereas the smallest stem diameters were observed in RH100 (2.12 mm, 3.00 mm and 3.85 mm) (Table 5)

From 2 to 6 MAG, the cocoa seedlings grown in soil media mixes recorded the highest number of leaves per plant in TS50:RHB50 (11.78, 18.11 and 22.22), while the lowest values were observed in TS80:CPHC20 (9.67) and TS75:RHB25 (14.78). For the soilless media mixes during the same period, the highest number of leaves per plant was found in RH80:CPHC20 (8.44, 13.44 and 14.69), whereas the lowest values occurred in RH100

TABLE 4

Effects of treatments on the germination percentage of cocoa

Treatment	14 DAS	17 DAS
Topsoil and topsoil mixes		
TS100	50.0	70.0
TS25:RHB75	88.3	93.3
TS50:RHB50	100.0	100.0
TS75:RHB25	60.0	75.0
TS80:CPHC20	41.7	63.3
TS90:CPHC10	95.0	100.0
Sawdust and sawdust mixes		
SD100	100.0	100.0
SD25:RHB75	76.7	98.3
SD50:RHB50	81.7	98.3
SD75:RHB25	98.3	100.0
SD80:CPHC20	86.7	91.7
SD90:CPHC10	96.7	100.0
Rice Husk and rice husk mixes		
RH100	48.3	76.7
RH25:RHB75	98.3	100.0
RH50:RHB50	98.3	100.0
RH75:RHB25	73.3	91.7
RH80:CPHC20	61.7	78.3
RH90:CPHC10	18.3	43.3
p-value (@ 5%)	<.001	<.001
LSD (@ 5%)	32.73	25.37
CV (%)	25.90	17.50

TS = Topsoil, SD = Sawdust, RH = Rice husk, RHB= Rice husk Biochar CPHC = Cocoa pod husk Compost, DAS = Days After Sowing, CV = Coefficient of Variation

(6.44, 6.67 and 5.44). (Table 5).

From 2 to 6 MAG, cocoa seedlings grown in soil media mixes recorded the tallest plant height in TS50:RHB50 (33.4 cm, 49.8 cm and 60.3 cm), while the shortest heights were observed in TS80:CPHC20 (25.21 cm and 34.31 cm) and TS75:RHB25 (43.42 cm). Among the soilless media mixes during the same period, cocoa seedlings grown in RH80:CPHC20 were the tallest (23.41 cm, 32.33 cm and 33.39 cm), whereas the shortest plants were recorded in RH100 (18.73 cm, 19.39 cm and 19.01 cm). (Fig 1).

Across the soil media mixes, the chlorophyll content of the cocoa seedlings at 4 and 6 MAG was highest in TS50:RHB50 (9.51 and 28.16 cm) and least in TS100 (5.9) and TS75:RHB25 (18.93). (Fig 2).

Comparing the soil media mixes, the leaf area of the cocoa seedling from 2 to 6 MAG was highest in TS50:RHB50 (2156 cm^2, 3405 cm^2 and 5307 cm^2) and least in TS80:CPHC20 (1215 cm^2) and TS75:RHB (2304 cm^2 and 3950 cm2). The leaf area of the cocoa seedling

TABLE 5

Effects of Treatment on Plant Stem Diameter and Number of Leaves

Treatment	Stem diameter (mm)			Number of leaves		
	2 MAG	4 MAG	6 MAG	2 MAG	4 MAG	6 MAG
	Topsoil and Topsoil Mixes					
TS100	3.74	6.15	9.01	11.11	15.00	17.56
TS75:RHB25	3.76	5.95	8.79	10.44	14.78	14.78
TS50:RHB50	3.88	6.61	9.90	11.78	18.11	22.22
TS25:RHB75	3.70	6.10	9.10	11.44	15.44	18.89
TS80:CPHC20	4.11	6.76	10.02	9.67	15.33	15.89
TS90:CPHC10	4.30	6.32	10.32	11.22	15.22	18.11
	Sawdust and sawdust Mixes					
SD100	3.24	4.22	7.14	7.22	5.89	10.78
SD75:RHB25	3.28	4.41	5.16	7.67	7.33	6.22
SD50:RHB50	3.47	4.38	5.08	7.22	6.11	6.44
SD25:RHB75	3.15	4.14	4.51	7.22	5.67	4.89
SD80:CPHC20	3.69	4.42	7.16	7.67	9.56	9.78
SD90:CPHC10	3.71	4.57	5.43	7.78	8.00	5.56
	Rice Husk and Rice husk Mixes					
RH100	2.12	3.00	3.85	6.44	6.67	5.44
RH75:RHB25	2.84	4.40	9.36	7.11	6.67	6.78
RH50:RHB50	2.91	4.06	4.92	7.00	6.89	7.56
RH25:RHB75	2.74	4.17	4.80	7.11	8.11	6.89
RH80:CPHC20	3.80	5.98	8.37	8.44	13.44	14.67
RH90:CPHC10	2.94	4.26	6.53	7.78	9.67	9.22
p-value (@ 5%)	<.001	<.001	<.001	<.001	<.001	<.001
LSD (@ 5%)	0.543	0.733	2.915	1.479	2.220	3.418
CV (%)	9.60	8.8	24.4	10.40	12.8	18.4

MAG=Months After Germination; TS =Topsoil, SD=Sawdust, RH=Rice husk, RHB= Rice husk Biochar, CPHC = Cocoa pod husk Compost, CV = Coefficient of Variation raised in the soilless media mixes from 2 to 6 MAG was highest in RH80:CPHC20 (1076 cm^2, 2423 cm^2 and 3362 cm^2) and least in RH100 (427 cm^2, 357 cm^2 and 132 cm^2) (Fig 3).

The tap root length of the cocoa seedling in the soil media mixes from 2 to 6 MAG, was longer in TS50:RHB50 (24.33 cm, 29.81 cm and 36.12 cm) and shorter in TS80:CPHC20 (10.78 cm) and TS90:CPHC10 (20.40 cm and 20.83 cm) (Table 6).

Among the soil media mixes, from 2 to 6 MAG, the leaf dry weight of the cocoa seedlings was highest in TS50:RHB50 (7.00 g, 18.80 g and 26.07 g) and least in TS80:CPHC20 (4.00 g and 16.90 g) and TS75:RHB25 (10.83 g). In the soilless media mixes, from 2 to 6 MAG, the leaf dry weight of the cocoa seedlings was

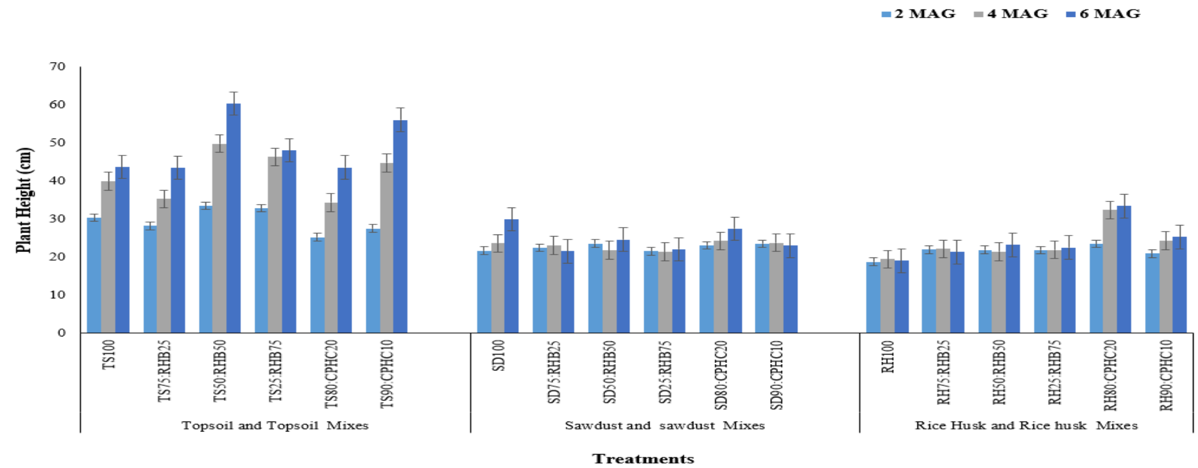

Figure 1 Treatment effects on Height of cocoa seedlings at 2, 4, and 6 months after germination (MAG)

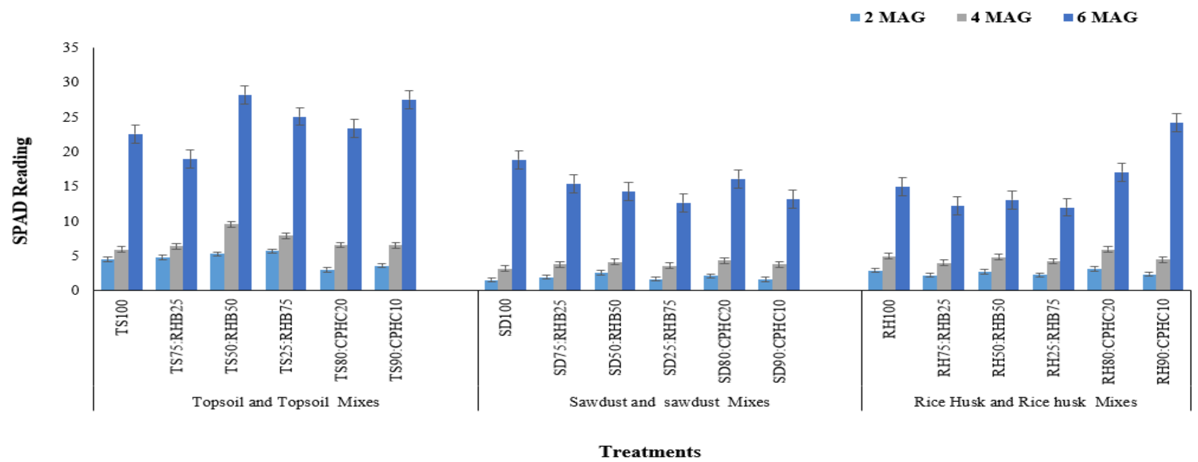

Figure 2 Treatment effects on leaf Chlorophyll content of cocoa seedlings at 2, 4, and 6 months after germination (MAG)

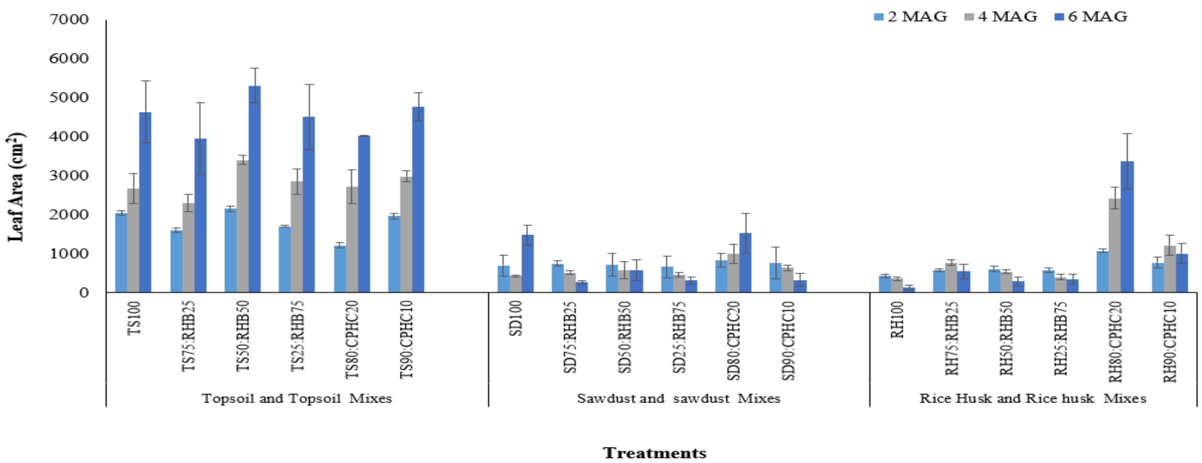

Figure 3 Treatment effects on leaf area of cocoa seedlings at 2, 4, and 6 months after germination (MAG)

highest in RH80:CPHC20 (4.67 g, 11.50 and 16.27 g) and least in RH100 (1.63 g and 1.57 g) and SD25:RHB75 (1.73 g) (Table 7).

The stem dry weight of cocoa seedlings grown in the soil media mixes from 2 to 6 MAG was highest in TS50:RHB50 (3.63 g, 11.63 g and 28.77 g) and lowest in TS75:RHB25 (2.77 g, 8.03 g and 18.23 g). For the soilless media mixes, at 4 and 6 MAG, the highest stem dry weight was recorded in RH80:CPHC20 (5.87 g and 13.77 g), while the lowest values were observed in RH100 (2.10 g and 3.10 g) (Table 7).

Across the soil media mixes, at 4 and 6 MAG, the root dry weight of the cocoa seedlings was highest in TS50:RHB50 (8.13 g and 22.17 g). In the soilless media mixes, from 2 to 6 MAG, the root dry weight of the cocoa seedlings was highest in RH80:CPHC20 (2.43 g, 6.57 g and 14.30 g) and least in RH100 (1.30 g, 2.70 g and 3.33 g) (Table 7).

From 2 to 6 MAG, cocoa seedlings grown in soil media mixes recorded the highest total plant dry weight in TS50:RHB50 (12.57 g, 38.56 g and 77.01 g), while the lowest values were observed in TS80:RHB20 (8.23 g and 54.06 g) and TS25:RHB75 (27.80 g) (Table 7).

TABLE 6

Effects of Treatment on seedling tap root length at different stages

Treatment	Tap Root Length (cm)		
	2 MAG	**4 MAG**	**6 MAG**
	Topsoil and Topsoil Mixes		
TS100	19.98	25.90	26.58
TS75:RHB25	22.72	23.93	24.42
TS50:RHB50	24.33	29.81	36.12
TS25:RHB75	17.83	26.19	27.22
TS80:CPHC20	10.78	22.50	22.99
TS90:CPHC10	15.62	20.40	20.83
	Sawdust and sawdust Mixes		
SD100	22.69	23.27	25.87
SD75:RHB25	26.42	26.62	29.73
SD50:RHB50	23.59	29.41	29.63
SD25:RHB75	21.93	26.84	20.94
SD80:CPHC20	15.52	24.06	24.43
SD90:CPHC10	18.12	23.83	24.17
	Rice Husk and Rice husk Mixes		
RH100	23.56	25.41	25.76
RH75:RHB25	25.64	25.72	21.56
RH50:RHB50	21.97	28.18	30.02
RH25:RHB75	22.38	24.30	28.18
RH80:CPHC20	21.62	27.64	27.76
RH90:CPHC10	19.13	22.51	27.14
p-value (@ 5%)	**<.001**	**0.1NS**	**<.001**
LSD (@ 5%)	**5.07**	**5.576**	**5.837**
CV (%)	**14.7**	**13.2**	**13.4**

MAG=Months After Germination; TS =Topsoil, SD=Sawdust, RH=Rice husk, RHB=Rice husk Biochar, CPHC=Cocoa pod husk Compost

TABLE 7

Effects of treatment on Plant dry weight of cocoa seedlings at different growth stages

	Leaf dry weight (g)			Stem dry weight (g)			Root dry weight (g)			Total Plant dry weight (g)		
Treatment	2 MAG	4 MAG	6 MAG	2 MAG	4 MAG	6 MAG	2 MAG	4 MAG	6 MAG	2 MAG	4 MAG	6 MAG
	Topsoil and Topsoil Mixes											
TS100	6.70	15.43	21.33	3.10	9.80	21.13	2.27	7.23	18.17	12.07	32.46	60.63
TS75:RHB25	5.53	10.83	17.93	2.77	8.03	18.23	2.27	6.13	13.13	10.56	24.99	49.29
TS50:RHB50	7.00	18.80	26.07	3.63	11.63	28.77	1.93	8.13	22.17	12.57	38.56	77.01
TS25:RHB75	5.70	13.43	20.07	3.13	8.97	20.37	1.83	5.47	14.37	10.67	27.80	54.81
TS80:CPHC20	4.00	15.03	16.90	2.93	8.20	22.23	1.30	5.37	14.93	8.23	28.60	54.06
TS90:CPHC10	5.67	15.43	20.27	3.10	9.77	26.70	1.63	5.80	14.80	10.40	31.00	61.77
	Sawdust and sawdust Mixes											
SD100	2.00	1.70	6.50	2.07	3.27	8.03	1.90	3.40	10.07	5.97	8.37	24.60
SD75:RHB25	2.70	2.47	1.90	2.93	3.47	3.77	1.93	3.93	4.83	7.57	9.87	10.50
SD50:RHB50	2.40	1.97	3.47	2.33	3.57	3.30	1.73	3.40	3.83	6.47	8.94	10.60
SD25:RHB75	2.07	2.17	1.73	2.40	3.43	3.20	1.90	2.87	3.00	6.37	8.47	7.93
SD80:CPHC20	3.03	4.87	5.03	2.40	4.03	6.97	1.77	4.27	7.87	7.20	13.17	19.87
SD90:CPHC10	2.40	2.90	2.00	2.30	4.27	4.17	1.67	3.47	4.13	6.37	10.64	10.30
	Rice Husk and Rice husk Mixes											
RH100	1.63	1.57	1.83	1.23	2.10	3.10	1.30	2.70	3.33	4.16	6.37	8.26
RH75:RHB25	1.93	2.47	2.70	2.03	3.40	3.43	2.10	3.63	3.80	6.06	9.50	9.93
RH50:RHB50	1.83	2.17	2.63	2.27	3.20	3.87	1.80	3.53	5.10	5.90	8.90	11.60
RH25:RHB75	1.87	2.57	2.27	2.07	3.70	4.10	1.73	4.17	5.33	5.67	10.44	11.70
RH80:CPHC20	4.67	11.50	16.27	2.37	5.87	13.77	2.43	6.57	14.30	9.47	23.94	44.34
RH90:CPHC10	2.38	5.77	5.43	1.23	3.33	6.33	1.73	3.80	9.17	5.35	12.90	20.93
p-value (@ 5%)	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**0.08^{NS}**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**
LSD (@ 5%)	**1.745**	**3.488**	**5.515**	**0.805**	**1.765**	**4.185**	**0.646**	**1.518**	**3.829**	**2.357**	**6.201**	**11.184**
CV (%)	**29.80**	**28.9**	**34.3**	**19.70**	**19.1**	**22.5**	**21.10**	**19.6**	**24.2**	**18.1**	**21.4**	**22.1**

MAG=Months After Germination; TS =Topsoil, SD=Sawdust, RH=Rice husk, RHB=Rice husk Biochar, CPHC=Cocoa pod husk Compost

Nutrient uptake response of cocoa seedlings

Nitrogen uptake of seedlings raised in TS mixed treatments TS50:RHB50 (0.425 g plant^{-1}), TS90:CPHC10 (0.378 g plant^{-1}) and TS80:CPHC20 (0.373 g plant^{-1}) were significantly ($p<0.05$) higher than those raised in TS75:RHB25 (0.262 g plant^{-1}) (Table 8). Among the soilless media treatments, nitrogen uptake of seedlings raised in treatment RH80:CPHC20 (0.284 g plant^{-1}) was significantly ($p<0.05$) higher than those raised in other soilless media mixes (Table 8).

Phosphorus uptake of seedlings raised in the TS mixed treatment, TS90:CPHC10 (0.053 g plant^{-1}) was significantly ($p<0.05$) higher than that of seedlings raised in the TS100 (0.024 g plant^{-1}). Among seedlings raised in the soilless media treatments, phosphorus uptake of those in RH80:CPHC20 (0.047 g plant^{-1}) was significantly ($p<0.05$) higher than those raised in other soilless media treatments (Table 8)

Potassium uptake of seedlings raised in TS mixed treatment TS90:CPHC10 (0.445 g plant^{-1}) was significantly ($p<0.05$) higher than that of seedlings raised in the TS100 (0.216 g plant^{-1}). Among the soilless media treatments, potassium uptake of seedlings raised in RH80:CPHC20 (0.272 g plant^{-1}) was significantly ($p<0.05$) higher than that of seedlings raised in other soilless media treatments (Table 8).

Calcium uptake of seedlings raised in TS100 (0.269 g plant^{-1}) and TS mixed treatment TS90:CPHC10 (0.266 g plant^{-1}) were significantly ($p<0.05$) higher than those raised in treatments TS75:RHB25 (0.119 g plant^{-1}) and TS25:RHB75 (0.148 g plant^{-1}) (Table 8). Among the soilless media treatments, calcium uptake of seedlings raised in RH80:CPHC20 (0.171 g plant^{-1}) was significantly ($p<0.05$) higher than that of seedlings raised in other soilless media treatments except SD100 (0.109 g plant^{-1}) (Table 8).

Magnesium uptake of seedlings raised in TS100 (0.146 g plant^{-1}) and TS mixed treatment TS90:CPHC10 (0.150 g plant^{-1}) were significantly ($p>0.05$) higher than those raised in other TS mixed treatments TS75:RHB25 (0.081 g plant^{-1}) and TS25:RHB75 (0.070 g plant^{-1}) (Table 8).

Among the soilless media treatments, magnesium uptake of seedlings raised in treatment RH80:CPHC20 (0.126 g plant^{-1}) was significantly ($p<0.05$) higher than those raised in other soilless media treatments except those in treatment SD100 (0.079 g plant^{-1}) (Table 8).

Discussion

Properties of soil and organic materials

The texture of the soil was sandy clay loam. The soil was acidic in water and may be responsible for the low exchangeable potassium and calcium levels in the soil but ideal for cocoa growth. The ideal pH range of a good cocoa

TABLE 8

Effects of Treatments on Nutrient Uptake of cocoa seedlings at 6 MAG

Treatment	Nitrogen (N)	Phosphorus (P)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)
	------ (g plant^{-1}) ------				
	Topsoil and Topsoil Mixes				
TS100	0.340	0.024	0.216	0.269	0.146
TS75:RHB25	0.262	0.027	0.321	0.119	0.081
TS50:RHB50	0.425	0.037	0.413	0.202	0.126
TS25:RHB75	0.338	0.024	0.268	0.148	0.070
TS80:CPHC20	0.373	0.046	0.391	0.208	0.111
TS90:CPHC10	0.378	0.053	0.445	0.266	0.150
	Sawdust and sawdust Mixes				
SD100	0.089	0.008	0.080	0.109	0.079
SD75:RHB25	0.026	0.003	0.034	0.019	0.015
SD50:RHB50	0.061	0.007	0.065	0.053	0.025
SD25:RHB75	0.024	0.003	0.031	0.030	0.016
SD80:CPHC20	0.095	0.016	0.100	0.073	0.041
SD90:CPHC10	0.030	0.006	0.033	0.032	0.018
	Rice Husk and Rice husk Mixes				
RH100	0.024	0.002	0.017	0.032	0.016
RH75:RHB25	0.041	0.005	0.052	0.012	0.016
RH50:RHB50	0.036	0.004	0.043	0.021	0.015
RH25:RHB75	0.029	0.002	0.031	0.026	0.013
RH80:CPHC20	0.284	0.047	0.272	0.171	0.126
RH90:CPHC10	0.104	0.023	0.083	0.076	0.042
p-value (α = 5%)	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**
LSD (α = 5%)	**0.0925**	**0.0157**	**0.0944**	**0.0725**	**0.0498**
CV (%)	**33.9**	**50.6**	**35.4**	**42.2**	**48.9**

MAG=Months After Germination; TS =Topsoil, SD=Sawdust, RH=Rice husk, RHB=Rice husk Biochar, CPHC=Cocoa pod husk Compost soil is 5.6 to 7.5. The soil was low in electrical conductivity. The percent organic carbon of 0.47% was below the critical minimum of 3% found suitable for cocoa cultivation in Ghana (Ahenkorah, 1981). The soil had moderate level of nitrogen which is sufficient for cocoa growth. This is in agreement with Kongor et al., (2018) and Snoeck et al., (2010) who reported that a good cocoa soil should have at least 0.09%N. The results show that the soil is low in available P, exchangeable K and Ca than the critical minimum level considered adequate for cocoa production. Ahenkorah (1981) gave the critical minimum level of available P, K and Ca suitable for cocoa cultivation as 20 mg kg^{-1}, 0.25 cmolc kg^{-1} and 77.5 cmolc kg^{-1} respectively. The factors which account for low P availability in Sub Sahara Africa (SSA) soils include low inherent P content in the parent material from which the soils were derived, and/or depletion of soil reserve P through intensive cultivation, without adequate external P input additions. The soil's exchangeable magnesium was higher than the critical minimum level of 1.33 cmolc kg^{-1} required for cocoa cultivation as reported by Ahenkorah (1981). The low levels of organic carbon (OC), P, K, and Ca indicate that the soil was heavily leached and had low fertility; therefore, it would benefit from the addition of organic matter (OM) and some inorganic fertilizers.

The results of organic amendments indicated that rice husk biochar (RHB) was slightly acidic but its incorporation into soil has improve soil quality and productivity. This is in consonance with Ajema et al. (2018) who stated that biochar as a soil amendment improves soil fertility and soil quality by raising the pH of the soil, enhancing its capacity to hold onto moisture, luring more beneficial fungi and other microbes, enhancing the ability of cation exchange, and preserving the nutrients in the soil.

Rice husk has a high C:N ratio, which may be attributed to its tough outer layer composed mainly of cellulose and lignin, with high silica content but low levels of protein and nitrogen required for microbial decomposition. Cocoa pod husk compost has a low C:N ratio, and its application to soil or soilless potting media can enhance nitrogen availability to plants. Rice husk biochar had adequate amount of nutrients and can support growth performance of cocoa seedlings. Cocoa pod husk compost (CPHC) was high in electrical conductivity, total N, % P, % K, %Mg and %Ca and is adequate to support growth of cocoa seedlings. This is in consistent with Dogbatse et al. (2020) who reported that composts made from cocoa pod husks shown significantly different physical, chemical, and biological characteristics that are good for supporting plant growth.

Germination response of cocoa seeds

The result shows that cocoa seeds sown in 50% topsoil mixed with 50% rice husk biochar gave 100% germination at 14 days after sowing and seeds sown in 80% topsoil mixed with 20% cocoa pod husk base compost gave 100% germination at 17 days after sowing. The higher seed germination rate recorded in these soil base media mixes may be attributed to the availability of well decomposed organic matter which might have preserved soil humidity, improve soil structure, provided sufficient moisture, increased aeration, increase the water holding capacity of the growing substrate which tends to increase water absorption and maintains cell turgidity, cell elongation and increase respiration at optimum level leading to favourable seed sprouting. This is in consonance with Edwards and Hailu (2011), who reported that compost enhances soil aeration for seed germination, maintain soil tilth, increases soil nutrient availability and soil water holding capacity.

Seeds sown in soilless media such as sawdust only, 25% sawdust mixed with 75% rice husk biochar, 80% sawdust mixed with 20% cocoa pod husk base compost, 75% rice husk mixed with 25% rice husk biochar and 50% rice husk mixed with 50% rice husk biochar recorded significantly higher (100%) germination than those sown in top soil only. This can be attributed to the physical properties of the organic materials such as low bulk density, biodegradability and high-water content which result in imbibition of water by the seed coat, respiration and synthesis of enzymes, cell elongation and emergence of radicle hence seed germination. This assertion confirms findings of Sholes et al. (1994) who reported that organic materials increase pores, which increases water retention and affects water availability, Steinbrecher et al. (2017) stated that germination involves four main processes: imbibition, enzyme system formation, beginning of organ formation, and formation of shoot to emerge from the soil surface.

Growth performance of cocoa seedlings

Soil base media mix produced the tallest plant, a greater number of leaves, bigger stem diameter and larger leaf area of cocoa seedlings as compared to the top soil only and soilless media mixes. The addition of rice husk biochar or cocoa pod husk compost to soil enhance adequate growth of cocoa seedlings. The availability of water and nutrient in the organic materials (Rice husk biochar and Cocoa pod husk compost) may be responsible for the observed significant increase in growth parameters (plant height, number of leaves, stem diameter and leaf area) of cocoa seedlings in the present study. Higher seedling growth observed in seedling height, stem diameter, number of leaves, leaf area and tap root length and chlorophyll content may all be due to the fact that organic materials (rice husk biochar and cocoa pod husk compost) mixed with the soil provided ideal environmental conditions such as suitable pH and electrical conductivity to support seedling growth and development. The application of organic wastes improves soil structure and soil fertility which provides favourable conditions for plant performance. Organic materials (Rice husk biochar and cocoa pod husk compost) added to top soil provided nutrient and also enhanced the organic matter content and improved the physical and chemical properties of the media mix for effective seedling growth and performance. This assertion is in agreement with Abdul-Razak et al. (2020), who observed that adding biochar and compost, either separately or together, significantly increased the growth response metrics (plant height, number of leaves, stem girth, and leaf area) of cocoa seedlings.

The bioavailability of essential nutrients in the compost may be responsible for the reported significant impacts of compost on the growth of cocoa seedlings in this study. This agrees with Ofori-Frimpong et al. (2010), who reported that cocoa seedling growth was enhanced when cocoa pod husk compost was used as a potting media or soil enhancer. This also corroborate with observation by Quaye et al. (2017), who stated that cocoa seedlings grown in rice husk media combined with compost were significantly taller, bigger and had large leaf area. The addition of rice husk biochar to soil produced longer tap roots. This emphasizes the importance of biochar in the soil by decreasing soil bulk density which loosened the soil and thereby increasing the air space of the media for effective root proliferation. This assertion is in agreement with the observation by Bruun et al., (2014) that adding biochar to soil increases pore spaces and promotes deeper root penetration and greater root branching.

Dry matter yield

Incorporation of organic amendments (Rice husk biochar and cocoa pod husk compost) in soil increased the physical and chemical properties of the soil for better cocoa seedling growth performance. The observed increase in biomass of cocoa seedlings in this present study can be ascribed to the fact that, adding cocoa pod husks and rice husk biochar to the soil appears to improve growth media nutrition and creating a better environment for robust seedlings growth and development. This assertion confirms findings of El Sharkawi et al. (2006), who reported that organic matter enhances soil physical properties by improving aggregation, aeration, and water-holding capacity.

The addition of rice husk biochar to the soil was associated with higher seedling vegetative growth and this suggests increased seedling dry matter partitioning to the plant components. This is also in agreement with findings of Sosu (2014) who noted rise in dry matter weight of cocoa seedlings grown in carbonated rice husk mixed with top soil.

Plant nutrient uptake

The high nitrogen (N) uptake by cocoa seedlings raised in 50% top soil and 50% biochar media mix can be attributed to the fact that soil nutrient availability increases due to the addition of biochar resulting in high nitrogen (N) uptake. The high nitrogen (N) uptake by seedlings grown in 50% top soil and 50% biochar resulted in vigorous vegetative growth of cocoa seedlings in the media. This observation corroborates with the findings of DeLuca et al. (2015) who documented that the application of biochar boosts plants N uptake. Cocoa seedlings raised in 90% top soil mixed with 10% cocoa pod husk base compost recorded significantly higher potassium, magnesium and phosphorus uptake than those raised in top soil only and other media mixes. The high uptake of K in 90% top soil mixed with 10% cocoa pod husk base compost media can be attributed to the high levels of K in the cocoa pod husk used for the production of the compost and this is in consonance with the observations made by Adu-Dapaah et al. (1994) that CPH contains high K.

The high phosphorus (P) uptake in 90% top soil mixed with 10% cocoa pod husk base compost media can be attributed to P level in poultry manure used in the compost preparation. This confirms findings of Ch'ng et al. (2013) which stated that poultry manure is a P- rich source and is frequently utilized to increase the P content of composts. High Mg and Ca uptake by cocoa seedlings raised in 90% top soil mixed with 10% cocoa pod husk base compost media may reflect initial high Mg and Ca in the soil and compost used. Among the soilless media mix, cocoa seedlings grown in 80% rice husk mixed with 20% cocoa pod husk base compost recorded high nitrogen (N), potassium (K), calcium (Ca), Magnesium (Mg) and phosphorus (P) uptake respectively than those raised in other soilless media mix. This is as a result of high nutrient composition of cocoa pod husk compost making nutrient available for seedlings uptake. This is in line with observation made by Quaye et al (2017) that rice husk mixed with compost significantly improved foliar nutrient (NPK) uptake of cocoa seedlings.

Conclusion

The present study evaluated the effect of biochar and compost amendment with soil, rice husk and sawdust on cocoa seedling growth and nutrient uptake. The study has demonstrated that addition of rice husk biochar and cocoa pod husk compost to soil produce significant effect on cocoa seedling growth and development than the sole use of top soil. 50% top soil mixed with 50% rice husk biochar, sawdust and sawdust mixtures significantly supported better seed germination. Soil base media mix (50% top soil mix with 50% rice husk biochar and 90% top soil mixed with 10% cocoa pod husk base compost) significantly supported better growth performance of cocoa seedlings. Among the soilless media mix, 80% rice husk mixed with 20% cocoa pod husk base compost significantly supported better cocoa seedling growth performance than the use of sawdust and rice husk only and sawdust and rice husk combinations. Higher plant nitrogen (N) uptake was observed in cocoa seedlings raised in 50% top soil mixed with 50% rice husk biochar media mix. The high K, Mg and P uptake by seedlings raised in 90% top soil and 10% cocoa pod husk base compost media mix resulted in better growth of cocoa seedlings. Among the soilless media mix, cocoa seedlings leaf N, K, Ca, Mg and P uptake were significantly higher in 80% rice husk mixed with 20% cocoa pod husk base compost. This resulted in adequate seedling growth and performance of cocoa seedlings.

Recommendation

Fifty percent (50%) top soil mixed with 50% rice husk biochar is recommended as the best soil base growth media and 80% rice husk mixed with 20% cocoa pod husk compost is recommended the best soilless growth media.

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Competing interest

The authors have declared that no competing interest exist.

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