Original Research Article

Growth response of cocoa (*Theobroma cacao* L.) seedlings to application of cocoa pod husk-based compost

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ABSTRACT

Aim: To study the effects of cocoa pod husk based compost: soil mixtures on growth of cocoa (*Theobroma cacao* L.) seedlings.

Study design: The experiment was laid out in a Complete Randomized Design with four replications.

Place and Duration of Study: The experiment was conducted at the main nursery of Cocoa Research Institute of Ghana at New Tafo - Akim (06^{o}13’ N and 00^{o}22’ W) in the Eastern Region of Ghana, between November, 2016 and December 2017.

Methodology: Surface soil classified as Ferric Lixisols together with four compost types produced from cocoa pod husk, poultry manure and *Panicum maximum* was used to fill polythene bags. A Soil alone (T1) and Soil + standard foliar fertilizer (T2) with a four compost:soil mixture treatments namely T3 - 1:1 w/w, T4 - 1:2 w/w, T5 -1:3 w/w and T6 - 2:1 w/w were tested. Each of the four compost types was used for T3 to T6. Surface soil, poultry manure, compost and compost-soil mixtures were carried out using standard laboratory procedures. Mixed hybrid cocoa seedlings were raised and growth evaluated monthly.

Results: Interaction effect was observed between compost types and compost-soil mixtures on dry matter yield of cocoa seedlings. Cocoa seedlings grown in T5 of compost 1 had the highest dry matter yield. Higher shoot: root ratio of cocoa seedlings were observed in compost 1. The order of desirability for the four compost types in terms of compost-soil mixtures was compost:soil (1:3 w/w) > compost:soil (1:2 w/w) > compost:soil (2:1 w/w) > compost:soil (1:1 w/w). CMPT1 will ensure more vigorous cocoa seedlings growth after transplanting and subsequently, higher establishment rate.

Conclusion: The optimum mixture of compost and soil for growing cocoa seedlings under limited availability of fertile surface soil is compost 1 mixed with surface soil at the ratio of 1:3.

Keywords: cocoa pod husk; Theobroma cacao; poultry manure; compost.

1. INTRODUCTION

The ability of surface soils to provide adequate and balanced amounts of nutrients is essential for optimum growth and development of seedlings at the nursery. However, surface soil of good fertility status is not readily available due to over exploitation of these soils for nursery activities [1]. At the Cocoa Research Institute of Ghana (CRIG), surface soils used for raising seedlings are usually of low fertility and are often amended with inorganic fertilizer. Amending the surface soil nutrient with inorganic fertilizer is limited by the high cost of fertilizers [2] and also adds to the cost of seedling production due to the additional resources required to apply these fertilizers. Thus, the use of inexpensive potting media, by the use of nutrient-rich surface compost:soil mixtures would possibly result in reducing the amount of supplementary fertilizer application.

Good composts from organic materials which are often regarded as waste and not utilized are a source of macro and micronutrients to plants. They also provide a stabilized form of organic matter that imparts longer lasting residual effects to soil [3]. Organic materials have been recommended for use as renewable resources in growth media production [4]. Poultry manure (PM) is considered a valuable organic resource for providing nutrients to crops [5, 6]. It has a higher fertilizing value than other livestock manure, because it is richer in nitrogen [7], 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 [8, 9, 10]. Likewise, *Panicum maximum* (*Pmax*), a high biomass-producing plant considered weeds on most farmers in Ghana could provide the soil with needed macro and micronutrients when composted and applied to the soil [11]. In Ghana, cocoa pod husk (CPH) which decomposes readily, releasing plant nutrients, is also readily available in large quantities. It is estimated that about 595,000 tonnes of dry CPH residue was generated in Ghana in 2008 [12].

CPH on cocoa farms may serve as abode for insect pests and disease causing organisms. However, composting CPH destroys most of these insect pests and disease causing organisms. In developing a method of composting CPH, [13] found out that increasing the duration of decomposition of compost affected the incidence of *Phytophthora* and other soil microbial population. The utilization of CPH for cocoa production was first reported by [14] and for growing of cocoa seedlings by [13]. However, the extent to which CPH based compost could be fully utilized on a large scale as potting media for growing cocoa seedlings has not received much attention in Ghana [13]. There is therefore the potential for the use of CPH and other agricultural wastes to produce compost which together with surface soil can form a good alternative potting medium to the use of sole surface soil for raising cocoa. The objective of this research was to study the effects of cocoa pod husk based compost:soil mixtures on growth of cocoa (*Theobroma cacao* L.) seedlings.

2. MATERIAL AND METHODS

2.1 Study area

The experiment was conducted in the main nursery at the CRIG at New Tafo - Akim (06^{o}13’ N and 00^{o}22’ W) in the Eastern Region of Ghana. The area is characterized by double 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 to 1,750 mm.

2.2 Soil and compost production

Surface soil (0 - 15 cm) was collected from a 25-year old cocoa farm at CRIG. The soil belongs to the WACRI series [15], which is a typical Forest Ochrosols under Ghanaian system [15] or Ferric Lixisols [16]. Old CPH and fresh *Pmax* were obtained from the CRIG. Poultry manure was collected from a poultry farm at Bunso in Eastern Region. Cocoa pod husk and *Pmax* were shredded into tiny pieces. Using a weighing scale, approximately 1,454 to 1,938 kg of waste mixtures were prepared separately by mixing the shredded cocoa pod husk, poultry manure and chopped *Pmax* grass in ratios of 3:1:2, 3:1:1, 3:½:1, 3:1:½ to produce four different types of composts (Compost 1, Compost 2, Compost 3 and Compost 4) (Table 1).

Table 1. Quantity of raw materials used for compost production

		Quantity (kg)		
Compost type	**Ratio**	**CPH**	**PM**	***Pmax***
CMPT1	3: 1: 2	969	323	646
CMPT2	3: 1: 1	969	323	323
CMPT3	3: ½ :1	969	162	323
CMPT4	3: 1: ½	969	323	162

CMPT1 = Compost 1, CMPT2 = Compost 2, CMPT3 = Compost 3 and CMPT4 = Compost 4

The weighed composting materials were composted in pits 1.2 m deep, 0.9 m wide and 3.2 m long covered with polythene sheets. At maturity, five subsamples each were taken from five different points at the top, middle (60 cm depth) lower bottom (85 cm depth) and base (110 cm from the bottom of the pile) for each type of compost. The subsamples were thoroughly mixed together, placed in polyethylene bags for subsequent chemical analysis.

2.3 Laboratory analyses

Samples of surface soil, poultry manure, compost and compost-soil mixtures were air-dried and sieved to pass through a 2 mm sieve for analysis. Chemical analyses were done on the samples. pH was determined electrometrically in distilled water at 1:2.5 [17]. Organic carbon (OC) was determined using the wet combustion method of [18]. Total nitrogen (TN) was determined using the Kjeldahl method [19]. Available phosphorus (AP) was determined using the Troug method [20] and colorimetrically on Spectrophotometer. Exchangeable basic cations (K, Ca and Mg) were extracted with 1 M neutral ammonium acetate solution and filtrate analyzed by the atomic absorption spectrophotometer [21]. Particle size analysis was determined by the method of [22].

2.4 Nursery studies

Polythene bags (17.5 x 25 cm) perforated at the bottom were filled with 4 kg of these soil-compost mixtures. The experiment was laid out in a Complete Randomized Design with four replications. The treatments were four different soil-compost mixtures, a control (soil alone) and soil + standard foliar fertilizer (Table 2). Each of the four compost types was used for Treatment 3 (T3) to Treatment 6 (T6).

Table 2: Treatment combinations used in the study

Treatment	Description
T1	Soil alone (Control)
T2	Soil + Standard foliar fertilizer
T3	Compost : Soil (1:1 w/w)
T4	Compost : Soil (1:2 w/w)
T5	Compost : Soil (1:3 w/w)
T6	Compost : Soil (2:1 w/w)

The standard foliar fertilizer (NPK 10:10:10) was applied to the seedlings at a rate of 10 mL per 11 L of water at bimonthly intervals using a pneumatic knapsack sprayer. All the polythene bags were then arranged on thick polythene sheet to prevent the growth of the roots into the ground for possible uptake of nutrients. Each polythene bag was sown with two mixed hybrid cocoa seeds which were thinned out to one seedling per polythene bag at 20 days after sowing. There were 30 seedlings per treatment. The seedlings were kept under a shade and watered as and when necessary to keep the moisture content of the soil at field capacity. Weeds were removed by hand picking. 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 damage by insect pests. Sampling started one month after seedling emergence and continued at monthly interval for 6 months. Seedling height and stem diameter were taken with the aid of a standard meter ruler and digital calipers respectively. At each sampling, three seedlings with the roots intact in each treatment were thoroughly washed with distilled water, partitioned into shoots and roots and their fresh weights determined. The plant parts were dried to a constant weight at 80^{o}C for 48 hours and dry weights determined. Absolute growth rate (AGR) for dry matter variable was determined according to [23]:

$$\text{AGR (g day}^{-1}\text{)} = \frac{W2-W1}{t2-t1}$$

Where: W1 and W2 refer to dry weight of plant at sampling time t1 and t2, respectively.
Shoot-root ratio and root-shoot ratio were calculated from the dry weight of shoots and roots.

2.5 Data analysis

Data collected were subjected to analysis of variance. Treatment means were compared using the standard error of difference (SED). All statistics were performed using GenStat statistical package [24].

3. RESULTS AND DISCUSSION

3.1 Properties of soil, raw materials and compost

The texture of the soil was sandy clay loam with 63.2, 12.0, and 24.8 % of sand, silt and clay, respectively (Table 3). The silt and clay contents of the soil were found to be adequate to hold sufficient soil moisture for cocoa seedling growth. The ratio of silt to clay was wide indicating that, the soil was highly weathered [25].

Table 3: Chemical properties of soil and raw materials

		Raw materials		
Properties (%)	**Soil**	**CPH**	**PM**	***Pmax***
Organic carbon	0.43	2.75	2.77	1.08
Total nitrogen	0.06	1.99	2.68	1.90
Available phosphorus	22.05	0.05	0.05	0.03
Potassium	0.29	3.49	2.74	0.89
Calcium	3.00	0.11	0.20	0.03
Magnesium	0.92	0.16	0.15	0.08
pH	5.50			
Sand	63.20			
Silt	12.00			
Clay	24.80			
Carbon/Nitrogen ratio		1.38	1.03	0.57

The pH of the soil was 5.5, indicating slight acidity typical of a WACRI Series or Forest Ochrosols or Ferric Lixisols and may be responsible for the low exchangeable cations (EC) level in the soil. The percent carbon content of 0.43 % was below the critical minimum of 3 % found suitable for cocoa cultivation in Ghana [26]. This suggests the need to increase the soil organic matter (SOM) content to give opportunity for optimal growth of cocoa on the soil. Total nitrogen (TN) of 0.06 % was below the critical minimum of 0.09% required for cocoa cultivation reported by [26]. As regards the available phosphorus (AP), the value for the soil was found to be higher than the critical value of 20 mg kg^{-1} considered suitable for cocoa cultivation [26]. The soil has exchangeable potassium (EK) that was higher than the critical value of 0.25 cmol kg^{-1} considered ideal for cocoa cultivation [26]. The K content was probably due to the high levels of kaolinitic clay minerals in the soil. Exchangeable Ca and Mg contents of the soil were below the range suitable for the growth of cocoa [26]. These low levels of organic carbon (OC), N, Ca and Mg show that the soil used was intensely leached and of low fertility, hence, the soil would benefit positively from OM addition.

Cocoa pod husk had the highest K content and C/N ratio compared to PM and *Pmax* (Table 3). The high K content of CPH was consistent with the observations made by [27] and [28], that CPH contains high K. The poultry manure used in the study had properties similar to those obtained from other countries [29, 30, 31, 32]. The levels of the major nutrients were generally high. The nutrient content of *Pmax* especially K, Ca and Mg were lower than that of PM and CPH.

The pH of the different composts ranged from 7.1 to 8.3 (Table 4). Apart from CMPT2, the pH of CMPT1, CMPT3 and CMPT4 were within the recommended level of 5.5 to 8.0 for compost [33, 34].

Table 4: Chemical properties of the compost types

Property	Compost types			
	CMPT1	**CMPT2**	**CMPT3**	**CMPT4**
pH	7.45	8.28	7.59	7.11
Organic carbon (%)	3.74	3.80	3.81	3.83
Total nitrogen (%)	0.67	0.67	0.65	0.66
Available phosphorus (%)	0.23	0.22	0.24	0.24
Total phosphorus (%)	0.41	0.45	0.38	0.47
Potassium (%)	0.89	0.96	0.93	1.06
Calcium (%)	0.33	0.19	0.25	0.26
Magnesium (%)	0.27	0.17	0.20	0.23
C/N ratio	5.58	5.67	5.86	5.80
C/P ratio	9.12	8.44	10.03	8.15

The optimum value of OC in compost has been reported be higher than 10% [34]. However, in this study, the OC in the different composts were generally low (ranging between 3.74 and 3.83%) but greater than the critical value of 3% reported to be ideal in soils for cocoa cultivation in Ghana [26]. The low OC observed also indicates that, part of the carbon in the decomposing residues was either probably assimilated by the microbial biomass [35, 36] or lost as carbon dioxide (Table 4).

TN of the compost samples varied from 0.65 to 0.67% (Table 4) and was within the range of 0.5 to 2.7% reported by [37]. The C/N ratio is an important parameter that determines the extent of composting and degree of compost maturity. Ideal ready-to use compost has a C/N ratio range of 15:1 to 20:1 [38]. However, the C:N ratio values obtained in this study were generally greater than 30:1 with the exception of CMPT1. This implies that there is a possibility of initial N immobilization when these composts are applied to the soil.

Available P concentration ranged from 0.22% for CMPT2 to 0.24% for both CMPT3 and CMPT4 (Table 4). The addition of composts resulting in initial immobilization of soil P has been shown to depend on the carbon:phosphorous ratio (C/P) of the OM added. Immobilization is likely to occur with a C/P ratio of >200 [39]. The C/P ratio varied from 8.15 to 10.03 for the different compost types, suggesting that none of the composts used would immobilize P, but rather, P would be released for the growth of the cocoa seedlings. On this basis, maximum P availability is likely to be from CMPT3 treatment.

For the exchangeable bases, K concentration ranged from a low value of 0.89% on CMPT1 to a highest of 1.06% for CMPT4 (Table 4). Calcium and Mg concentrations of the compost samples were generally low, and ranged from 0.19% to 0.33% while Mg level ranged from 0.17 to 0.27%. The recommended levels of Ca and Mg for optimum plant growth is 1 .0 to 4.0% and 0.2 to 0.4% respectively [40]. This implies the composts are not supplying adequate concentration of exchangeable bases for the plants.

3.2 Growth parameters

In table 5, the standard treatment plants were (*P* = .05) taller than those of the control and the compost-soil mixtures. This indicates that, the foliar fertilizer addition did satisfy the nutritional demands of the seedlings, and therefore, supported their optimal growth. However, cocoa seedlings in the compost-soil mixtures were taller than the control treatment. The main effect of compost showed that, CMPT1 had the greatest influence on height increase of cocoa seedlings leading to taller plants. Higher exchangeable bases required for good seedling growth present in CMPT1 compared to the other composts might have been responsible for the tall plants. T5 supported the tallest plants among the compost-soil mixtures, while T3 failed to support height gain, leading to shortest plants. CMPT2 was the worst performing compost treatment.

The main effect of compost indicated that, CMPT1 recorded stem diameter increase (Table 5). Stem diameter increase of cocoa seedlings in the standard was (*P* = .05) higher than the increase in the control and the compost-soil mixtures. The increases in height and stem diameter of cocoa seedlings raised under compost-soil mixtures compared to the control could be attributed to the fact that the composts provided the plants more nutrients which supported seedling growth. This agrees with the earlier results of [41] and [42] which stated that the addition of organic materials such as cocoa pod husk as nutrient sources supports crop performance. Plant growth generally tended to be better in CMPT1 than in the other compost types and the control. This trend may be attributed to differences in the nutrient status of the compost types and the soil. However, the interaction effects of compost and compost-soil mixtures on growth rates of cocoa seedlings were not different (Table 5).

Table 5: Compost and compost-soil mixtures effect on height and stem diameter of cocoa seedlings at 6 months after planting

Factor		Height (cm)	Stem diameter (mm)
Control		32.60	5.25
Standard		39.14	5.98
Compost-soil ratio		33.43	5.42
Compost *			
	CMPT1	37.33	5.90
	CMPT2	29.75	5.00
	CMPT3	32.56	5.33
	CMPT4	34.08	5.50
Compost-soil ratio †			
	T3	32.77	5.39
	T4	33.39	5.50
	T5	34.60	5.44
	T6	32.95	5.36
SED	min rep	1.78 *	0.20 *
	max-min	1.41	0.16
	max rep	0.89 †	0.10 †

** 12 reps* *† 54 reps*

SED = Standard errors of differences of means

3.3 Dry matter production and distribution

Dry matter yield (DMY) of the cocoa seedlings generally increased with time. Interaction (*P* = .05) effect was observed between composts and compost-soil ratio on DMY of cocoa seedlings (Table 6). Dry matter yield of cocoa seedlings in T4, T5 and T6 were (*P* = .05) higher than T3 for CMPT1 but not for CMPT2 and CMPT4 (Table 6). For CMPT2, T6 had the lowest DMY. CMPT1 had the highest DMY in T4, T5 and T6. Dry matter yield of T5 in CMPT1 and CMPT3 was higher than standard (T2). However, T5 of CMPT1 had the highest DMY among all the treatments in the various compost-soil mixtures.

Table 6: Compost and compost-soil mixtures effect on dry matter yield of cocoa seedlings at 6 months after planting

		Compost-soil ratio †					
Factor		**T1**	**T2**	**T3**	**T4**	**T5**	**T6**
Control		14.63					
Standard			16.56				
Compost *****							
	CMPT1			14.13	15.67	16.93	15.27
	CMPT2			15.90	15.13	15.17	14.83
	CMPT3			14.60	14.67	16.77	14.83
	CMPT4			14.73	14.97	15.67	14.97
SED	0.53 *	min rep					
	0.42	max-min					
	0.27 †	max rep					

** 12 reps* *† 54 reps*
SED = Standard errors of differences of means

Generally, T3 and T6 which had higher levels of compost in the various compost-soil mixtures depressed growth of cocoa seedlings compared to T4 and T5 which had lower compost levels. The depression in growth of cocoa seedlings might be due to the fact that some of the nutrients in the compost applied to the soil for these treatments (T3 and T6) were immobilized by soil microorganisms, their high SOM and other edaphic factors thereby making these nutrients unavailable to the cocoa seedlings. This observation is consistent with the findings of [43] Ibiremo *et al*., (2012) and [41] Akanbi *et al*., (2013) who observed a depression in the growth of cocoa seedlings when organic fertilizer material such as cocoa pod husk ash was used on cocoa seedlings.

There was a positive linear relationship between height and dry matter production under conditions of varied combinations of compost and soil mixtures in the nursery (Fig. 1). Stem diameters of seedlings also had strong linear and positive relationship with dry matter (Fig. 2). This relationship explained dry matter yield up to 62 per cent (R^2 = 0.6231). This relationship emphasizes a disproportionate allocation of dry matter to vegetative growth at this stage of the seedling growth.

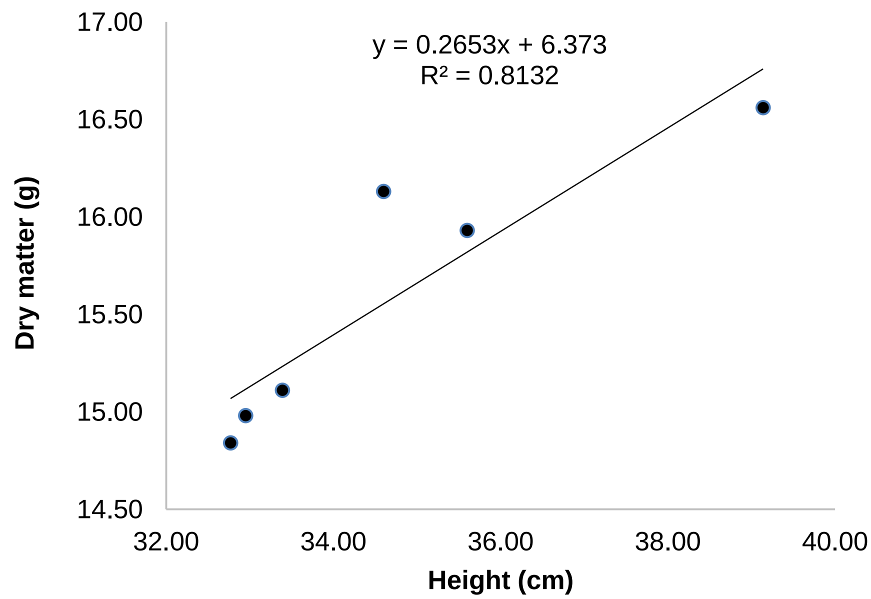

Fig. 1. Relationship between height and dry matter of 6 months old cocoa seedlings under different compost-soil mixtures

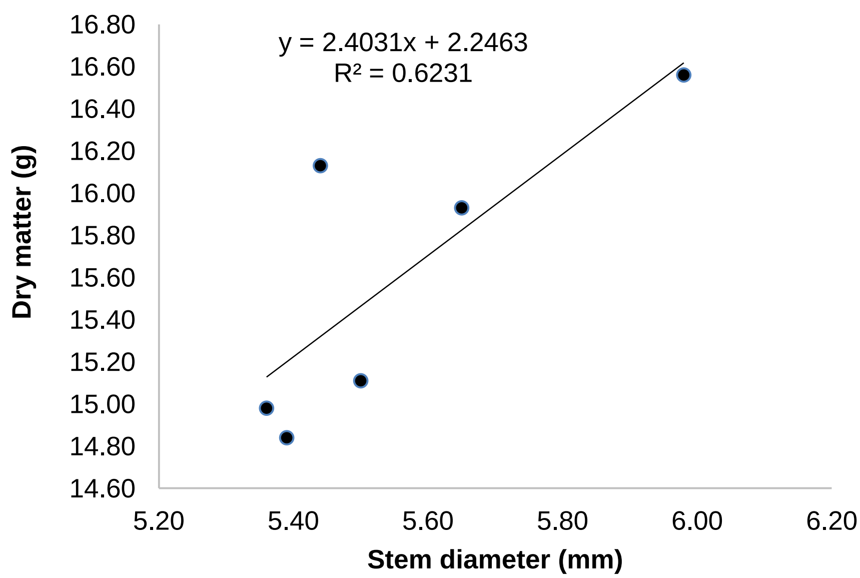

Fig. 2. Relationship between stem diameter and dry matter of 6 months old cocoa seedlings under different compost-soil mixtures

The balance between carbohydrates and mineral nutrients in plant tissues plays a key role in determining the magnitude of above and below ground growth according to [44]. The effect of compost application on SRR of cocoa grown in CMPT1 and the standard was (*P* = .05) higher than those grown in CMPT3 (Table 7). This may be due to the low level of N and P content of CMPT3, therefore, cocoa grown in CMPT3 may have diverted more photosynthate to the roots for better growth and the need to exploit larger volumes of the potting media for N. It has also been reported that plants growing in N deficient medium diverts more photosynthate to the roots, thus, greater root development [45]. Deficiencies of mineral elements can decrease the shoot:root ratio (SRR) of plants [44]. The higher SRR obtained for the standard was as a result of its high N content compared to the other treatments. High N supply increases the SRR owing to increasing shoot growth with only small differences in root growth at the same time [44]. These results imply that the composts did change the proportion of shoot to the root in the treatments. The interaction effects of compost and compost-soil mixtures on SRR of cocoa seedlings were not different (Table 7).

Table 7: Compost application on Shoot:Root ratio of cocoa seedlings 6 months after planting

Factor		**Shoot:Root ratio**
Control		2.74
Standard		3.25
Compost		
	CMPT1	3.23
	CMPT2	2.69
	CMPT3	2.14
	CMPT4	2.52
SED		*0.50*
Compost-soil ratio		
	T3	2.29
	T4	2.37
	T5	2.48
	T6	2.76
SED		*0.62*

SED = Standard errors of differences of means

The total dry matter accumulation per cocoa seedling per day was very slow (Table 8) during 0-30 days after sowing (DAS). With the exception of 0-30 DAS, the growth rate of cocoa seedlings at the various periods showed (*P* = .05) differences among the composts and compost-soil mixtures (Table 8). Generally, the minimum and maximum growth rates were observed on the control and standard treatments respectively. Thus, foliar fertilizer added to the soil in the standard treatment had a profound effect on increasing plant growth than the control (soil alone treatment).

Table 8: Absolute growth rate based on dry matter as influenced by different treatments

		Days after sowing					
Factor		**0-30**	**30-60**	**60-90**	**90-120**	**120-150**	**150-180**
Control		0.030	0.028	0.043	0.120	0.213	0.268
Standard		0.033	0.043	0.035	0.123	0.225	0.430
Compost							
	CMPT1	0.028	0.028	0.053	0.120	0.190	0.310
	CMPT2	0.027	0.022	0.043	0.120	0.265	0.312
	CMPT3	0.025	0.025	0.025	0.135	0.237	0.345
	CMPT4	0.027	0.032	0.032	0.122	0.260	0.302
Compost-soil ratio							
	T3	0.025	0.0150	0.038	0.120	0.250	0.300
	T4	0.023	0.0250	0.030	0.128	0.258	0.285
	T5	0.028	0.0250	0.058	0.120	0.228	0.375
	T6	0.023	0.0250	0.028	0.135	0.255	0.245
SED $_{df = 48}$							

SED = Standard errors of differences of means

3.4 Nutrient uptake

The nutrient concentrations were higher in the shoots than in the roots (Fig.3). The concentrations of N in the seedlings were similar, with T3 of CMPT2 recording the highest N concentration compared to the other treatments. A similar trend was observed for P (Fig.3). However, T5 of CMPT4 had the highest P concentration. Potassium concentration was highest in T6 of CMPT3. The uptake of K was (*P* = .05) higher for seedlings of compost:soil mixtures of CMPT4 than for those of the standard (T2) and control (T1).

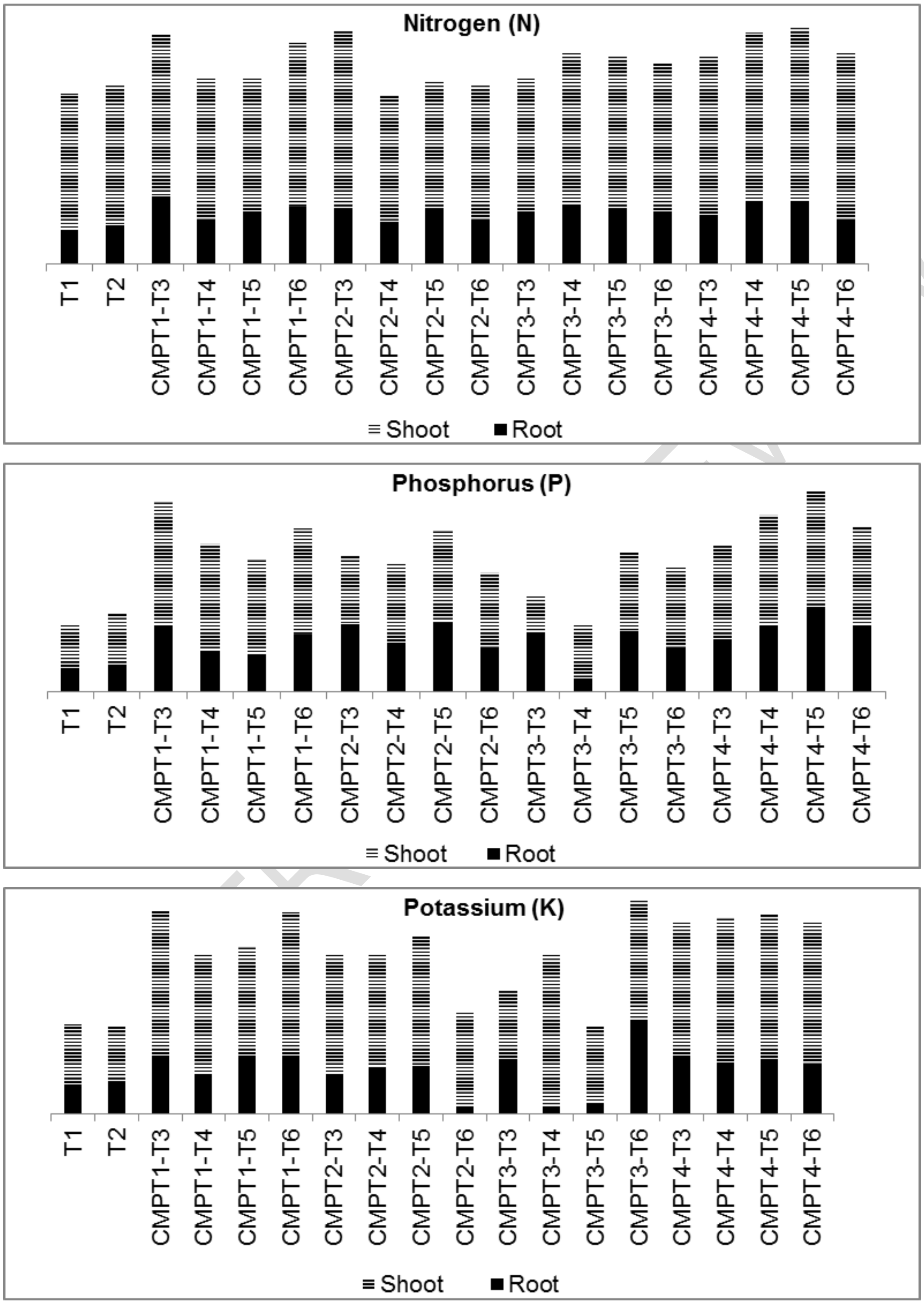

Fig. 3. Nutrient element concentrations in the cocoa seedlings at 6 months after planting

A possible reason for this trend may be the K content of CMPT4, which was the highest. The uptake of nutrients by the cocoa seedlings was highest for K, followed by N and P in that order (Table 9). The high uptake of K can be attributed to the high levels of K in the cocoa pod husk used for the production of the composts. The low uptake of P was due to the low P content of the compost types. Although P uptake by the crop was lowest in relation to the other major plant nutrient elements, it’s the most important nutrient element limiting cocoa production in Ghana [46] (Smith and Acquaye, 1963).

Table 9: Total nutrient uptake (%) by cocoa seedlings at 6 months after planting

Treatment	N	P	K
Control - T1	4.61	0.53	4.75
Standard - T2	4.89	0.63	4.67
CMPT1 - T3	6.20	1.51	10.84
CMPT1 - T4	5.05	1.18	8.51
CMPT1 - T5	5.08	1.05	8.96
CMPT1 - T6	5.98	1.30	10.78
CMPT2 - T3	6.27	1.08	8.57
CMPT2 - T4	4.57	1.03	8.44
CMPT2 - T5	4.94	1.28	9.51
CMPT2 - T6	4.81	0.95	5.43
CMPT3 - T3	5.01	0.76	6.57
CMPT3 - T4	5.71	0.52	8.60
CMPT3 - T5	5.67	1.11	4.72
CMPT3 - T6	5.43	1.00	11.37
CMPT4 - T3	5.66	1.16	10.26
CMPT4 - T4	6.24	1.40	10.41
CMPT4 - T5	6.42	1.60	10.71
CMPT4 - T6	5.69	1.30	10.21
SED	0.49	0.20	0.30

SED = Standard errors of differences of means

4. CONCLUSION

The addition of CPH based compost as nutrient sources to surface soil produced promising effects on cocoa seedlings comparable to standard treatment. There were differences among the composts and compost-soil mixtures with regards to the growth rate of cocoa seedlings at 6 months after planting. The order of desirability in terms of compost-soil mixtures was compost:soil (1:3 w/w) > compost:soil (1:2 w/w) > compost:soil (2:1 w/w) > compost:soil (1:1 w/w). In the case of DMY, cocoa seedlings grown in T5 of CMPT1 were the best compared to the other compost-soil mixtures, standard and control treatments. From its superiority over the other composts, CMPT1 may ensure more vigorous growth of the cocoa seedlings after transplanting. Nevertheless, the optimum mixture of CPH based compost and soil recommended for growing cocoa seedlings under limited availability of fertile surface soil is CMPT1 mixed with surface soil at the ratio of 1:3 (T5).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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