

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°13' N and 00°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: Significant 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. Significantly higher shoot:root ratio of cocoa seedlings were observed in Compost 1 than the others. 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.

21 **1. INTRODUCTION**

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

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34 Good composts from organic materials which are often regarded as waste and not utilized
35 are a source of macro and micronutrients to plants. They also provide a stabilized form of
36 organic matter that imparts longer lasting residual effects to soil [3]. Organic materials have
37 been recommended for use as renewable resources in pot media production [4]. Poultry
38 manure (PM) is considered a valuable organic resource for providing nutrients to crops [5,
39 6]. It has a higher fertilizing value than other livestock manure because it is richer in nitrogen
40 [7] and helps build soil organic matter and improves structural stability by improving the soil
41 characteristics such as aeration, water holding capacity, bulk density, aggregation, cation
42 exchange capacity and activity of beneficial microflora [8, 9, 10]. Likewise, *Panicum*
43 *maximum* (*Pmax*), a high biomass-producing plant considered weeds on most farmers in
44 Ghana could provide the soil with needed macro elements and trace elements when
45 composted and applied to the soil [11]. In Ghana, cocoa pod husk (CPH) which decomposes
46 readily, releasing plant nutrients, is also readily available in large quantities. It is estimated
47 that about 595,000 tonnes of dry CPH residue was generated in Ghana in 2008 [12].

48

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

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63 **2. MATERIAL AND METHODS**

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65 **2.1 Study area**

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

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74 **2.2 Soil and compost production**

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

85

86 **Table 1. Quantity of raw materials used for compost production**

Compost type	Ratio	Quantity (kg)		
		CPH	PM	<i>Pmax</i>
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

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

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90 The weighed composting materials were composted in pits 1.2 m deep, 0.9 m wide and 3.2
91 m long covered with polythene sheets. At maturity, five subsamples each were taken from
92 five different points at the top, middle (60 cm depth) lower bottom (85 cm depth) and base
93 (110 cm from the bottom of the pile) for each type of compost. The subsamples were
94 thoroughly mixed together, placed in polyethylene bags for subsequent chemical analysis.

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96 **2.3 Laboratory analyses**

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

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108 **2.4 Nursery studies**

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110 Polythene bags (17.5 x 25 cm) perforated at the bottom were filled with 4 kg of these soil-
111 compost mixtures. The experiment was laid out in a Complete Randomized Design with four
112 replications. The treatments were four different soil-compost mixtures, a control (soil alone)

113 and soil + standard foliar fertilizer (Table 2). Each of the four compost types was used for
114 Treatment 3 (T3) to Treatment 6 (T6).

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116 **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)

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119 The standard foliar fertilizer (NPK 10:10:10) was applied to the seedlings at a rate of 10 mL
120 per 11 L of water at bimonthly intervals using a pneumatic knapsack sprayer. All the
121 polythene bags were then arranged on thick polythene sheet to prevent the growth of the
122 roots into the ground for possible uptake of nutrients. Each polythene bag was sown with two
123 mixed hybrid cocoa seeds which were thinned out to one seedling per polythene bag at 20
124 days after sowing. There were 30 seedlings per treatment. The seedlings were kept under a
125 shade and watered as and when necessary to keep the moisture content of the soil at field
126 capacity. Weeds were removed by hand picking. Confidor 200 O-TEQ, a systemic
127 insecticide was applied quarterly to the seedlings at a rate of 30 mL in 15 L of water using a
128 pneumatic knapsack sprayer to prevent damage by insect pests. Sampling started one
129 month after seedling emergence and continued at monthly interval for 6 months. Seedling
130 height and stem diameter were taken with the aid of a standard metre ruler and digital
131 calipers respectively. At each sampling, three seedlings with the roots intact in each
132 treatment were thoroughly washed with distilled water, partitioned into shoots and roots and
133 their fresh weights determined. The plant parts were dried to a constant weight at 80°C for
134 48 hours and dry weights determined. Absolute growth rate (AGR) for dry matter variable
135 was determined according to [23]:

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137
$$\text{AGR (g day}^{-1}\text{)} = \frac{W_2 - W_1}{t_2 - t_1}$$

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139 Where: W1 and W2 refer to dry weight of plant at sampling time t1 and t2 respectively.

140 Shoot-root ratio and root-shoot ratio were calculated from the dry weight of shoots and roots.

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142 **2.5 Data analysis**

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

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150 **3. RESULTS AND DISCUSSION**

151

152 **3.1 Properties of soil, raw materials and compost**

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

157

158 **Table 3: Chemical properties of soil and raw materials**

Properties (%)	Soil	Raw materials		
		CPH	PM	<i>Pmax</i>
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

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161 The pH of the soil was 5.5, indicating slight acidity typical of a WACRI Series or Forest
162 Ochrosols or Ferric Lixisols and may be responsible for the low exchangeable cations level
163 in the soil. The percent carbon content of 0.43 % was below the critical minimum of 3 %
164 found suitable for cocoa cultivation in Ghana [26]. This suggests the need to increase the
165 soil organic matter content to give opportunity for optimal growth of cocoa on the soil. Total
166 nitrogen of 0.06 % was below the critical minimum of 0.09% required for cocoa cultivation
167 reported by [26]. As regards the available phosphorus (AP), the value for the soil was found
168 to be higher than the critical value of 20 mg kg⁻¹ considered suitable for cocoa cultivation
169 [26]. The soil has exchangeable potassium that was higher than the critical value of 0.25
170 cmol kg⁻¹ considered ideal for cocoa cultivation [26]. The potassium content was probably
171 due to the high levels of kaolinitic clay minerals in the soil. Exchangeable Ca and Mg
172 contents of the soil were below the range suitable for the growth of cocoa [26]. These low
173 levels of organic carbon, N, Ca and Mg show that the soil used was intensely leached and of
174 low fertility, hence, the soil would benefit positively from organic materials addition.

175

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

182
 183 The pH of the different composts ranged from 7.1 to 8.3 (Table 4). The soil used for the
 184 experiment is acidic, therefore the addition of these composts with high pH will have a
 185 positive effect on the soil, that is moderate the acidity of the soil. Apart from CMPT2, the pH
 186 of CMPT1, CMPT3 and CMPT4 were within the recommended level of 5.5 to 8.0 for
 187 compost [33, 34].

188
 189 **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

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 191
 192 The optimum value of OC in compost has been reported be higher than 10% [34]. However,
 193 in this study, the OC in the different composts were generally low (ranging between 3.74 and
 194 3.83%) but greater than the critical value of 3% reported to be ideal in soils for cocoa
 195 cultivation in Ghana [26]. The low OC observed also indicates that, part of the carbon in the
 196 decomposing residues was either probably assimilated by the microbial biomass [35, 36] or
 197 lost as carbon dioxide (Table 4).

198
 199 Total nitrogen of the compost samples varied from 0.65 to 0.67% (Table 4) and was within
 200 the range of 0.5 to 2.7% reported by [37]. The C/N ratio is an important parameter that
 201 determines the extent of composting and degree of compost maturity. Ideal ready-to use
 202 compost has a C/N ratio range of 15:1 to 20:1 [38]. However, the C:N ratio values obtained
 203 in this study were generally greater than 30:1 with the exception of CMPT1. This implies that

204 there is a possibility of initial nitrogen immobilization when these composts are applied to the
205 soil.

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

214

215 For the exchangeable bases, K concentration ranged from a low value of 0.89% on CMPT1
216 to a highest of 1.06% for CMPT4 (Table 4). Calcium and Mg concentrations of the compost
217 samples were generally low, and ranged from 0.19% to 0.33% while Mg level ranged from
218 0.17 to 0.27%. The recommended levels of Ca and Mg for optimum plant growth is 1.0 to
219 4.0% and 0.2 to 0.4% respectively [40]. This implies the composts are not supplying
220 adequate exchangeable bases for the plants.

221

222 **3.2 Growth parameters**

223

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

234

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

247

248 **Table 5: Compost and compost-soil mixtures effect on height and stem diameter of**
 249 **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 †

250 * 12 reps † 54 reps

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254 **3.3 Dry matter production and distribution**

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256 Dry matter yield (DMY) of the cocoa seedlings generally increased with time (Fig. 1).
 257 Significant ($P = .05$) interaction effect was observed between composts and compost-soil
 258 ratio on DMY of cocoa seedlings (Table 6). Dry matter yield of cocoa seedlings in T4, T5 and
 259 T6 were significantly ($P = .05$) higher than T3 for CMPT1 but not significant for CMPT2 and
 260 CMPT4 (Table 6).

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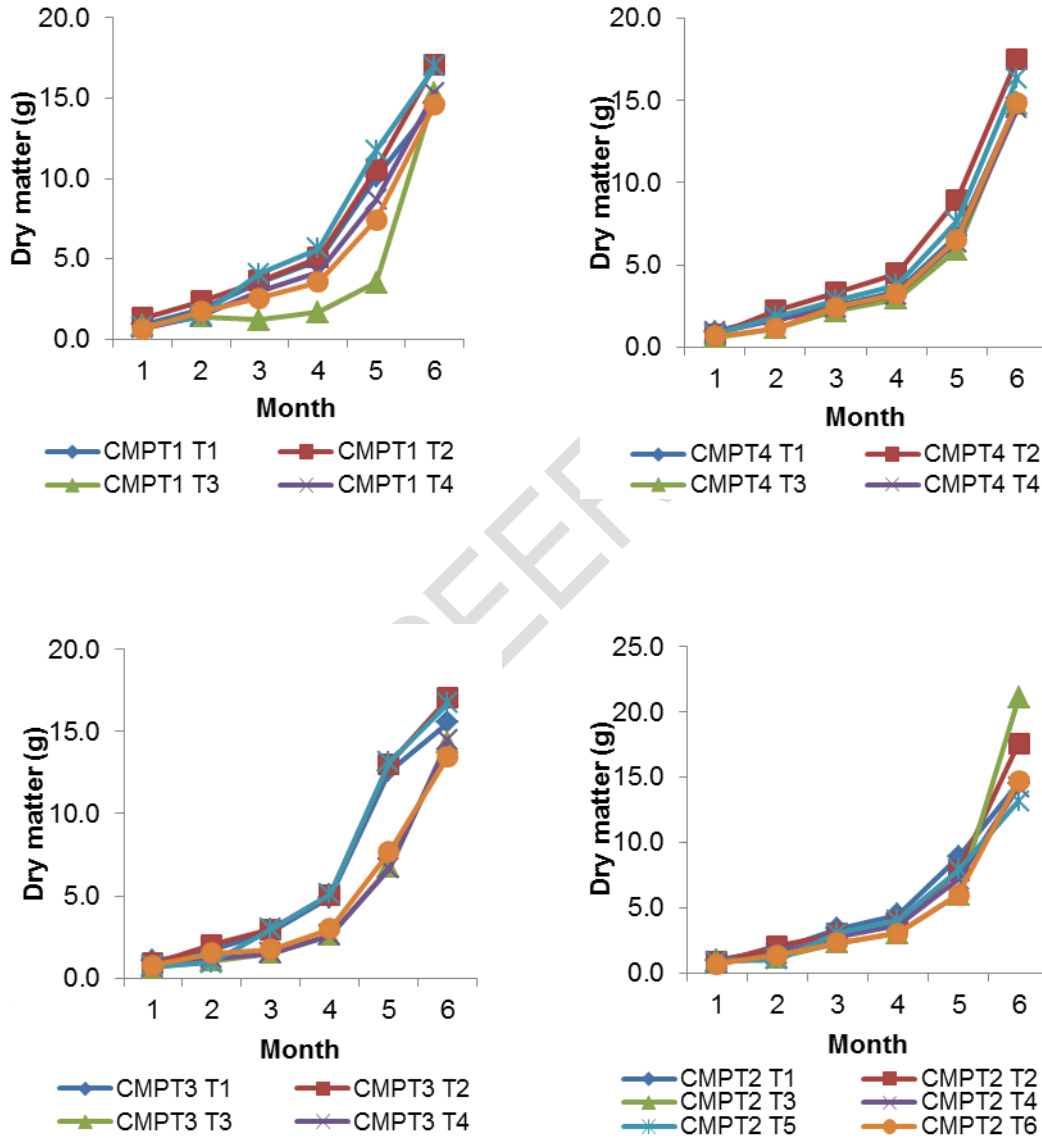
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301 **Fig. 1. Total dry matter of cocoa seedlings grown in different compost-soil**
 302 **mixtures at 6 months after planting**

305 For CMPT2, T6 had the lowest DMY. CMPT1 had the highest DMY in T4, T5 and T6. Dry
 306 matter yield of T5 in CMPT1 and CMPT3 was higher than standard (T2). However, T5 of

307 CMPT1 had the highest DMY among all the treatments in the various compost-soil
 308 mixtures.

309
 310 **Table 6: Compost and compost-soil mixtures effect on dry matter yield of cocoa**
 311 **seedlings at 6 months after planting**

Factor	Compost-soil ratio †					
	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				

312 * 12 reps † 54 reps

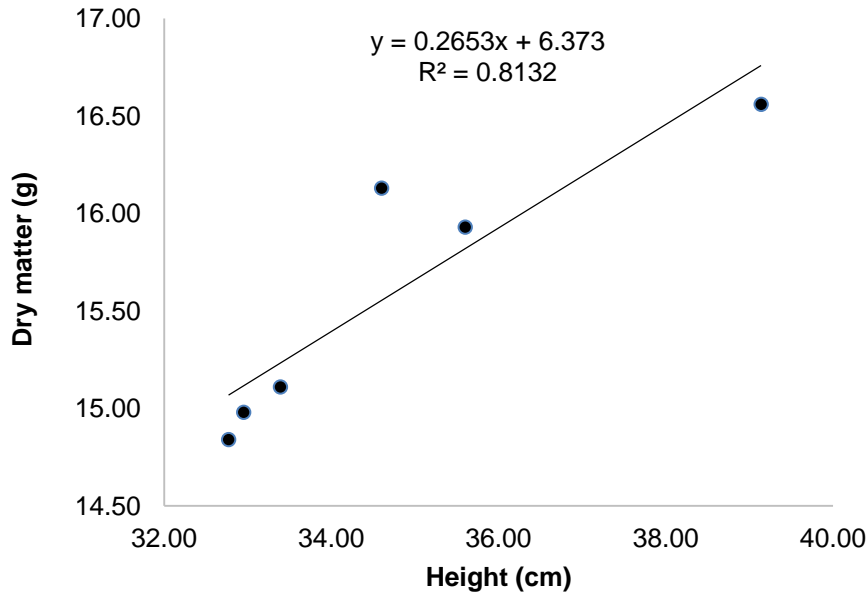
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315 Generally, T3 and T6 which had higher levels of compost in the various compost-soil
 316 mixtures depressed growth of cocoa seedlings compared to T4 and T5 which had lower
 317 compost levels. The depression in growth of cocoa seedlings might be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

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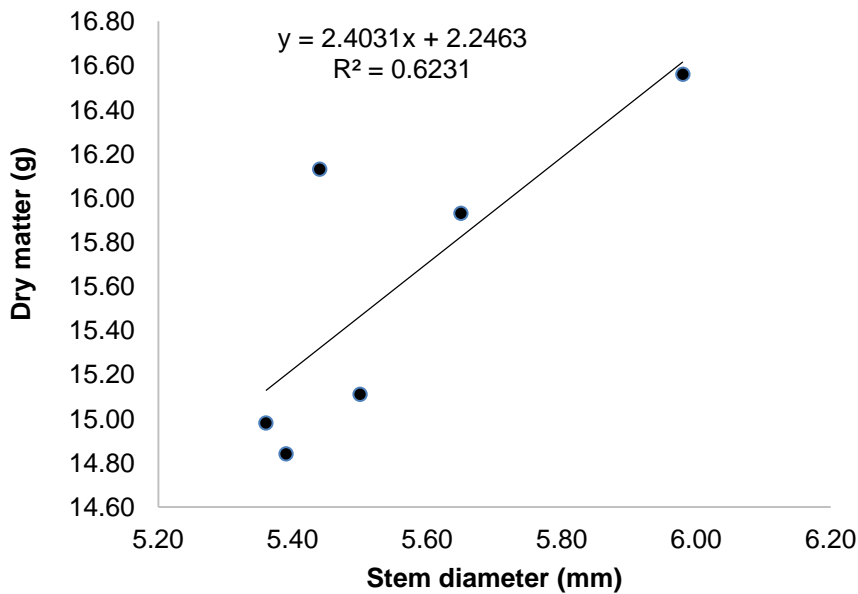
325 There was a positive linear relationship between height and dry matter production under
 326 conditions of varied combinations of compost and soil mixtures in the nursery (Fig. 2). Stem
 327 diameters of seedlings also had strong linear and positive relationship with dry matter (Fig.
 328 3). This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

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



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Fig. 3. 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 significantly ($P = .05$) 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

348 photosynthate to the roots for better growth and the need to exploit larger volumes of the
 349 potting media for N. It has also been reported that plants growing in N deficient medium
 350 diverts more photosynthate to the roots, thus, greater root development [45]. Deficiencies of
 351 mineral elements can strongly decrease the shoot:root ratio (SRR) of plants [44]. The higher
 352 SRR obtained for the standard was as a result of its high N content compared to the other
 353 treatments. High N supply increases the SRR owing to increasing shoot growth with only
 354 small differences in root growth at the same time [44]. These results imply that the composts
 355 did change the proportion of shoot to the root in the treatments. The interaction effects of
 356 compost and compost-soil mixtures on SRR of cocoa seedlings were not significantly
 357 different (Table 7).

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

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

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 362
 363 The total dry matter accumulation per cocoa seedling per day was very slow (Table 8) during
 364 0-30 days after sowing (DAS). With the exception of 0-30 DAS, the growth rate of cocoa
 365 seedlings at the various periods showed significant ($P = .05$) differences among the
 366 composts and compost-soil mixtures (Table 8). Generally, the minimum and maximum
 367 growth rates were observed on the control and standard treatments respectively. Thus, foliar

368 fertilizer added to the soil in the standard treatment had a profound effect on increasing plant
 369 growth than the control (soil alone treatment).

370

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

372 **treatments**

Factor	Days after sowing					
	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}						

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3.4 Nutrient uptake

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The nutrient concentrations were higher in the shoots than in the roots (Figure 4). 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 (Figure 4). However, T5 of CMPT4 had the highest P concentration. Potassium concentration was highest in T6 of CMPT3. The uptake of K was significantly ($P = .05$) higher for seedlings of compost-soil mixtures of CMPT4 than for those of the standard (T2) and control (T1).

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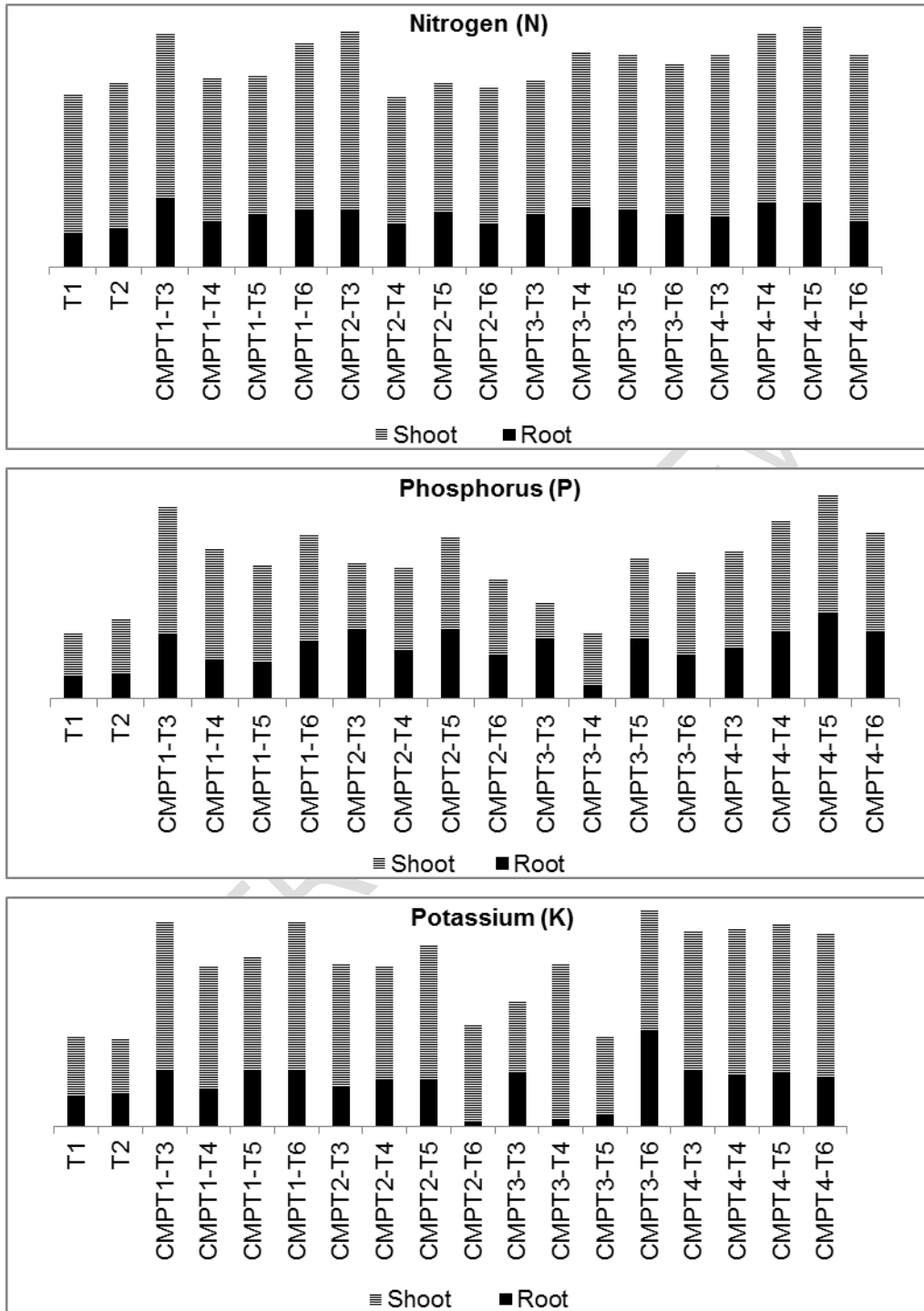


Fig. 4. Nutrient element concentrations in the cocoa seedlings at 6 months after planting

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

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448 **4. CONCLUSION**

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

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466 **COMPETING INTERESTS**

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468 Authors have declared that no competing interests exist.

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471 **AUTHORS' CONTRIBUTIONS**

472

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

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