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EVALUATION OF CACAO (*THEOBROMA CACAO* L.) GROWING SOIL AND NUTRIENT AMENDMENT ON SEEDLING GERMINATION AND GROWTH

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ABSTRACT

To increase production capacity of cocoa in Nigeria, the Federal Government distributed improved cocoa varieties to farmers for raising seedlings. Farmers used soils from various cocoa plantations and the resultant seedlings were of reduced and varied growth. A screen-house experiment was conducted at FUNAAB to determine the suitability or otherwise of top-soils collected from some cocoa plantations amended with nutrient elements for raising cocoa seedlings in Nigeria. A 6 x 9 factorial experiment was conducted using six growth media: top soils collected from major cocoa growing regions (Etung-A, Etung-B, Idanre, Atakumosa, Abeokuta) and Sawdust. Each medium was amended with a combination of seven nutrient elements (N, P, K, Ca, Mg, Zn, B) essential for cocoa production in Nigeria. Using nutrient omission technique, N, P, K, Ca, Mg, Zn, B (Complete) were combined by omitting each of the nutrients: (Complete minus B, Zn, Mg, Ca, K, P or N) and Control, giving eight nutrient combinations and control. In all, there were (9x6)=54 treatment combinations in split plot arrangement in completely randomised design, replicated three times. Growth media and soil amendment were allotted to main and sub plots, respectively. Data collected on germination percentage and plant height were subjected to analysis of variance and means were separated using standard error of the difference (sed). Plant height of seedlings raised on soils from Idanre amended with Complete-B was 40.3 cm compared to Control (32.03 cm). Height of seedlings raised on Atakumosa soil amended with Complete was 35.27cm while the control seedlings had 24.87cm. Height of seedlings raised on Etung-A soil amended with Complete-Zn was 32.73 cm which was higher than its unamended treatment with 25.30 cm. Height of seedlings raised on Etung-B soil amended with Complete-Zn (with 31.43 cm) was equally higher than its control plant (with 24.57cm) while seedlings raised on soils from Abeokuta plantations, amended with Complete-Zn was 41.93 cm in height. This was higher than its control seedlings with 36.5cm height. Height of seedlings raised on Sawdust amended with Complete-B was 40.67cm while its control treatment was 18.83 cm. The differences were all significant. This implies that soils from Abeokuta, Idanre, Etung-B and Etung-A plantations require an amendment with Complete-Zn while soils from Atakumosa require amendment with Complete nutrient for improved growth vigour of cocoa seedlings. These results have implications on rehabilitation operations of cocoa plantations through total replanting method.

Keywords: Cocoa, Seedling Growth, Growth media, Nutrient amendment

INTRODUCTION

Cocoa (*Theobroma cacao* Linn.) is one of the most important commodity tree crops traded across the international boundaries. Cocoa

has been re-classified into a member of the family *Malvaceae* (Alvenson, *et al*., 1999) *and* genus *Theobromae*. According to cocoa production statistics of the International Cocoa Conference Organisation, the estimated world production as at 2018 stands at 4,649,000 MT. Out of which Nigeria produces 255,000 MT (5.48%) of dried cocoa beans to become third largest producer behind Côte d'Ivoire (42.25%) and Ghana (19.47%) ICCO, 2018. After petroleum, cocoa is the Nigeria's most important export commodity, being produced from 14 out of the 36 states of the country from on a total landed area of 1,363.60 hectares (NBS *et al.,* 2013). The producing states include, Oyo, Ondo, Ogun, Osun, Ekiti, Edo, Delta, Akwa Ibom, Cross river, Kwara, Kogi, Taraba, Abia and Adamawa.
Theobroma cacao is cauliflorous and semi-deciduous. It flourishes in rainforest ecology with low-attitude of about 700 metres above sea level and rainfall of between 700–2500 mm well distributed in a year and sandy loam to loamy soils (Sanusi and Oluyole, 2005; Opeke, 2005; Ajiboye *et al.,* 2015).

In Nigeria, most of the cocoa plantations are old, less productive and the cacao are moribund. The soil chemical fertility has become low and soils are heavily leached and the nutrients are heavily mined through crop harvest compared to soils under forests (Ayoola, 2002; Hartemink, 2003; Wessel and Quist-Wessel, 2015). Wessel (1971) and Opeke, (2005) observed N, P, K, Ca, Mg, Mn and Zn to be steadily declining with increasing age of cocoa plantations. Olaiya (2006) reported that Boron is also a limiting nutrient element in old cocoa plantations. Omotoso (1975), Ogunlade (2009) blamed the declining soil and nutrient facilities on crop harvests: for every 1000kg dry cocoa beans, about 20kgN, 41kgP, 10kgK are removed from the soil. The situation becomes pronounced by the gross inadequate fertilizer use in cocoa cultivation in Nigeria (Okuneye, 2003). These limiting nutrient elements coupled with inadequate fertilizer use and nutrient erosion occasioned by crop harvests have led to declining cocoa production in Nigeria.

To meet up with the projected cocoa production of 1,000,000 tonnes of Cocoa Transformation Action Plan of the Federal Government of Nigeria, cocoa farmers were freely given pods of improved varieties of cocoa to raise seedlings on their plantations for replanting operations of the moribund cacao. The farmers made use of the depleted soils from their cocoa plantations for raising the seedlings. Most of the ultimate seedlings were therefore of reduced growth vigour. The genetic superiority of the genotypes could not be fully expressed. This experiment was therefore conducted to examine the suitability or otherwise of soils from selected cocoa plantations for raising seedlings and the amendments that may be needed for improved growth vigour of the seedlings.

MATERIALS AND METHODS

The experiment was carried out in a screen house of the Horticultural Nursery of the Federal University of Agriculture Abeokuta (FUNAAB) - Latitude 7°10'N and Longitude 3° 2' E, Ogun State, Nigeria.

Polythene bags (2 litres capacity) were filled with six growth media which consisted of five types of top soils and saw dust as a control growth medium. The five soil samples were collected from the largest cocoa producing plantations in Nigeria. These included: Etung-A and Etung-B (Cross-River State), Idanre (Ondo State), Atakumosa west

(Osun State) and Abeokuta (FUNAAB farm site) (Ogun State) while Sawdust was used as an alternative medium. Variety F_3 Amazon of cocoa was used for the study. The experiment was 6 x 9 factorial laid out in completely randomized design with three replications. Factor-1 was growth media collected from the five locations and Sawdust while factor-2 consisted of nutrient elements at 9 levels: N+P+K+Ca+Mg+Zn+B. It was the combinations of 5g of Urea + 12.5g of Abeokuta rock phosphate + 2g of Muriate of potash + 1g of Calcium oxide + 1g of Magnesium oxide + 0.5 g of Zinc oxide and 0.5 g of Sodium tetraborate per bag of 2kg soils were added based on the calculations indicated by Aduayi *et al.,* (2002). The addition of the nutrient amendments was carried out at 6 WAS. Using nutrient omission technique, the 9 levels were obtained: [(Complete (denoted as 'C')], C-B (Boron deficient), C-Zn (Zinc deficient), C-Mg (Magnesium deficient), C-Ca (Calcium deficient), C-K (Potassium deficient), C-P (Phosphorus deficient), C-N (Nitrogen deficient), Control (wherein no nutrient was applied). Cocoa pods of F_3 Amazon were obtained from Cocoa Research Institute of Nigeria (CRIN), the beans were extracted and sown immediately after extraction at seeding rate of two per bag which were later thinned to one seedling per bag. Germination rates were monitored for 4 Weeks After Sowing (WAS). Quantitative observations began at 8 WAS and continued till 18 WAS, at 2 weekly intervals.

Prior to commencement of the experiment, representative soil samples were taken randomly, using soil auger at depth of 0-30 cm, from the experimental site. The soil samples were bulked, oven-dried, gently crushed to pass through 2mm sieve and 0.5mm sieve for routine analysis. The processed soil was used for determination of both physical and chemical properties by standard method. The parameters determined included, Particle size analysis, Soil pH, Soil organic carbon, Soil organic matter, Total nitrogen, Available phosphorus and Total exchangeable bases.

Data were taken on percentage seed germination, plant height (cm), stem girth (cm), and number of leaves of the seedlings until optimum growth (uniform growth capacity of the rhizosphere) obtained at 18 Weeks After Sowing (WAS). The data were subjected to analysis of variance and treatment means compared with Standard error of the difference as well as Duncan multiple range test at $P<0.05$.

RESULTS

Physico-chemical properties of the growth media

Most of the growth media used were acidic (pH between 4.78 and 5.86) except soil from Abeokuta plantations which was near neutral of 6.8. The organic matter content was generally low with the exception of sawdust which had a high content of 5.38 (Table 1). Nitrogen content and available phosphorus of all the media were generally low; the highest value was from Abeokuta soil with 0.29 g/kg and 4.77 mg/kg, respectively. The zinc content was adequate in all the media. With respect to soil texture, Etung-A, Idanre and Atakumosa soils were clayey loam while Etung-B and Abeokuta soils were sandy loam (Table 1).

Table 1: Physico-chemical properties of the growth media

Parameters	Etung-A	Etung-B	Idanre	Atakumosa	Abeokuta	Sawdust
Sand (%)	54.61	72.66	64.55	64.20	73.00	-
Silt (%)	11.36	6.66	8.73	8.22	8.80	-
Clay (%)	34.03	20.68	26.88	27.58	18.2	-
Textural Class	Sandy clay loam	Sandy loam	Sandy clay loam	Sandy clay loam	Sandy loam	-
pH (H_2O)	4.80	4.78	5.86	5.49	6.80	5.00
OC (g/kg)	1.42	0.93	1.14	1.24	1.60	5.38
Total N (g/kg)	0.07	0.06	0.07	0.07	0.17	0.09
Avail-P (mg/kg)	3.23	2.95	1.76	3.70	1.69	4.77
K (mg/kg)	0.15	0.18	0.15	0.15	0.79	0.99
Ca (mg/kg)	1.68	2.17	5.65	6.40	1.99	5.32
Mg (mg/kg)	0.59	0.42	0.72	0.68	1.93	0.22
Na (mg/kg)	0.27	0.32	0.28	0.32	0.68	0.14
Fe (cmol/kg)	398.08	175.13	149.00	226.92	164.30	203.80
Mn (cmol/kg)	388.12	26.18	427.65	473.43	479.20	255.00
Cu (cmol/kg)	7.31	0.77	13.34	14.10	1.08	9.00
Zn (cmol/kg)	3.89	8.33	3.79	5.33	-	8.00
B (cmol/kg)	1.07	1.46	1.36	1.07	-	-

Germination percentage of cocoa seeds as affected by growth media and nutrient amendments

The growth media exerted significant differences on seed germination rate. At 2 WAS, cocoa seeds sown in Etung-A had higher germination of 45.5% compared to others that had between 7.4% (sawdust) and 37.5% (Etung-B). At 3 WAS, cocoa seeds sown in soil of Abeokuta had highest germination of 71.6% closely followed by those of Etung-A and Etung-B with 69.7% and 70.0% while 46.9% of seeds sown in sawdust germinated. At 4 WAS when germination was complete (beyond which no germination was observed), soils from Abeokuta plantation supported 78.4% germination of cocoa seeds. Those sown in sawdust had least germination of 56.8%. Cocoa seeds sown in all other growth media had germination of between 69.1 and 70.0% (Figure 1).

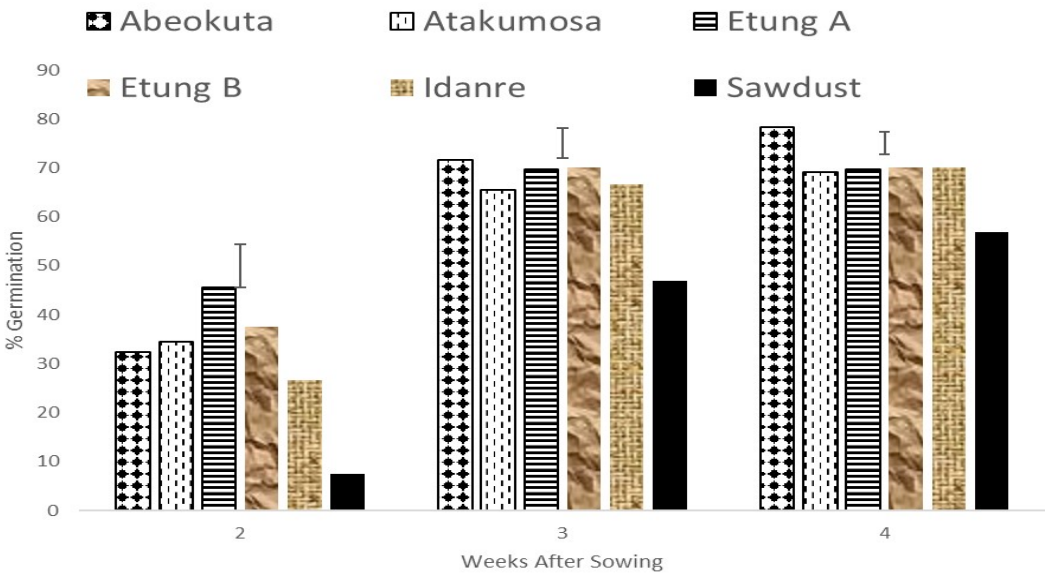

Figure 1: Germination percentage of cocoa seeds as affected by growth medium (soils from cocoa plantations)

Growth of cocoa seedlings as affected by soils from cocoa plantation and nutrient amendment Plant height (cm)

At the earliest period of 12 WAS when cocoa seedlings were fit for transplanting, seedlings raised on soils from Idanre and Abeokuta plantations had improved plant height of 25.2 cm and 24.5 cm, respectively (Table 2). These were followed by those of Atakumosa (22.6 cm), Etung-B (21.7 cm) and Etung-A (21.3 cm). Seedlings raised on sawdust had reduced height of 20.7 cm. However, at the latest period (18 WAS), cocoa seedlings raised on soils from Idanre, Abeokuta and Atakumosa plantations had improved plant height of 31.6 cm, 30.3 cm and 28.5 cm, respectively. These were followed by seedlings raised on soils from Etung-B and Etung-A with 25.0 cm and 24.3 cm height values, respectively. Cocoa seedlings raised on sawdust had reduced height of 23.9 cm (Table2).

With respect to amending the soils with nutrient formulations (amendment), non-inclusion of Zn (C-Zn) in the nutrient formulations, improved height of the cocoa seedlings at both 12 and 18 WAS. At 12 WAS, cocoa seedlings raised from Zn-deficient (C-Zn) growth media had height of 25.0 cm followed by C-Mg (23.5 cm) and C-P (22.8 cm) while in unamended medium (control), the seedling height was 23.9 cm. Compared to the above, in all other growth media the nutrient amendments resulted in reduced heights of the cocoa seedlings (between 20.7 cm and 22.7 cm). These observations in height almost continued till 18 WAS when seedlings raised on C-Zn media, had a height of 31.6 cm followed by C-B media with 29.4 cm. However, cocoa seedlings raised on N-, P-, K-, and Ca-deficient growth media had retarded plant height of between 24.1 cm and 25.5 cm compared to the plant height of the seedlings raised on unamended control with 27.0 cm (Table 2).

With respect to the interactions between the soils from cocoa plantations and nutrient amendments on plant height of cocoa seedlings, seedlings grown on soils from Abeokuta amended with Zn-deficient nutrient formulations and unamended control had plant height of 29.3 cm and 28.1 cm, respectively at 12 WAS (Table 3). These were followed by seedlings grown on same soils amended with N-deficient nutrient formulations with 27.0 cm. All other treated cocoa seedlings on soils from Abeokuta had reduced plant height of between 20.3 cm and 23.8 cm. Cocoa seedlings grown on soils from Atakumosa plantations, amended with C-P, C-K and C-Ca had plant height values ranging between 24.3 cm and 25.8 cm. However, the seedlings had retarded plant height values of 17.8 cm and 19.1 cm on same soils amended with C-Zn and C-B. Seedlings grown on other nutrient amendment of same soils, were taller, with heights ranging between 23.9 cm (in C-Ca) and 21.8 cm (in C-N). On soils from Etung-B plantations, cocoa seedlings grown on C-Zn amendments had height of 25.9 cm followed by those grown on C-Mg with 24.3 cm and C-P with 23.4 cm. Cocoa seedlings grown on all other amendments of soils from Etung-B plantations, were shorter with height values of between 22.9 cm (on unamended control) and 18.8 cm (on C-K amended soils). However, cocoa seedlings grown on Etung-A soils amended with C-Zn recorded improved height of 28.0 cm followed by seedlings grown on unamended control with 23.8 cm. Those seedlings grown on other Etung-A treated soils recorded height values of between 21.5 cm (on C-P amended soils) and 16.7 cm (on C-Mg amended soils). On Idanre soils, cocoa seedlings grown on C-Zn amended soils recorded improved height of 31.0 cm followed by those grown on unamended control with 28.0 cm, C-P amendment with 26.2 cm and C amendment with 26.0 cm. Cocoa seedlings grown on all other nutrient amendments of Idanre plantation soils recorded heights of between 25.7 cm (on C-K amendment) and 19.4 cm (on C-B amendment). On sawdust, cocoa seedlings grown on C-B amendment recorded improved height of 32.5 cm. On all other amendments, cocoa seedling heights were between 25.2 cm (on C -Mg amendment) and 17.3 cm (on C-N amendment)-Table 3.

At 18 WAS, cocoa seedlings grown on soils from Abeokuta cocoa plantations amended with C-Zn recorded improved height of 41.9 cm followed by the unamended control with 36.5 cm and C-B amendment with 31.4 cm (Table 3). Seedlings grown on Soils from Abeokuta amended with all other nutrient formulations recorded heights of between 30.5 cm (in C-N amendment) and 22.8 cm (in C-Ca amendment). With respect to soils from Atakumosa cocoa plantations, seedlings grown with C amendment recorded improved height of 35.3 cm followed by seedlings grown on C-Ca amendment with 34.0 cm. Seedlings grown on other amendments recorded heights of between 31.8 cm (in C-Mg amendment) and 21.6 cm (in C-Zn amendment). Cocoa seedlings grown on Etung-B soils recorded improved height of 31.4 cm on C-Zn amendment, followed by seedlings with heights 27.5 cm and 26.0 cm on C-Mg and C nutrient amendments, respectively. Heights of seedlings on other amendments were between 24.6 cm and 21.8 cm. When soils from Etung-A cocoa plantations were amended with C-Zn, the cocoa seedlings had improved height of 32.7 cm, followed by seedlings grown on C-B amendment (with 26.6 cm), 25.3 cm in unamended control and 24.5 cm in C amendment while

seedlings grown on C-Ca amendment had reduced height of 20.2 cm. On soils from Idanre cocoa plantations, cocoa seedlings grown on C-Zn amendment had improved height of 40.3 cm followed by seedlings grown on C-Ca amendment (with 33.0 cm), unamended control (with 32.0 cm), C-K amendment (with 31.5 cm), C-Mg & C amendments (with 30.9 cm each) and C-P amendment with 30.2 cm while seedlings grown on C-N amendment had reduced height of 26.0 cm. With respect to sawdust, on C-B amendment, cocoa seedlings had improved height of 40.7 cm followed by seedlings grown on C-Mg amendment with 30.7 cm. Seedlings grown on all other nutrient amendments of sawdust had reduced heights of between 21.5 cm (on C-Zn amendment) and 18.8 cm (on unamended control)-Table 3.

Table 2: Plant height (cm) of cocoa seedlings as affected by soils of cocoa plantations and nutrient amendments

Treatments	12 WAS	14 WAS	16 WAS	18 WAS
Medium:				
FUNAAB	24.5	25.6	28.3	30.3
Atakumosa	22.6	23.9	26.0	28.5
Etung A	21.3	22.1	23.4	24.3
Etung B	21.7	22.8	23.6	25.0
Idanre	25.2	27.6	29.5	31.6
Sawdust	20.7	22.0	23.1	23.9
$Sed_{0.05}$	0.81	0.99	1.23	1.48
CV (%)	8.0	9.3	10.7	12.1
Amendment:				
C	22.1	24.6	26.1	27.4
C-B	22.7	24.5	26.7	29.4
C-Zn	25.0	27.9	29.7	31.6
C-Mg	23.5	25.2	26.8	28.4
C-Ca	20.7	21.0	23.7	25.5
C-K	22.4	23.3	24.0	25.3
C-P	22.8	23.9	25.0	26.3
C-N	20.9	22.0	22.7	24.1
Control	23.9	24.7	26.3	27.0
$Sed_{0.05}$	0.48	0.70	0.74	0.82
CV (%)	6.0	8.2	8.1	8.5

Medium = Soils from cocoa plantations
C = Medium amended with complete nutrients of N, P, K, Ca, Mg, Zn & B
C-B = Medium amended with all nutrients except Boron (B)
C-Zn = Medium amended with all nutrients except Zinc (Zn)
C-Mg = Medium amended with all nutrients except Magnesium (Mg)
C-Ca = Medium amended with all nutrient except Calcium (Ca)
C-K = Medium amended with all nutrients except Potassium (K)
C-P = Medium amended with all nutrients except Phosphorus (P)
C-N = Medium amended with all nutrients except Nitrogen (N)
Control = Unamended medium from each of the cocoa plantations

Table 3: Height/plant (cm) of cocoa seedlings as affected by interaction of growth medium and nutrient amendment

Growth medium	Nutrient Amendment										
	C	C-B	C-Zn	C-Mg	C-Ca	C-K	C-P	C-N	Control	$SED_{0.05}$	CV (%)
12 WAS											
Abeokuta	23.0	23.8	29.3	23.3	20.3	22.6	23.5	27.0	28.1	1.04	11.9
Atakumosa	23.8	19.1	17.8	23.6	23.9	24.3	25.8	21.8	23.0	0.91	11.4
Etung-B	21.9	19.9	25.9	24.3	20.2	18.8	23.4	19.3	22.9	0.87	11.3
Etung-A	19.3	21.3	28.0	16.7	17.4	21.1	21.5	19.3	23.8	1.22	16.4
Idanre	26.0	19.4	31.0	24.8	25.3	25.7	26.2	20.9	28.0	1.22	13.7
Sawdust	18.6	32.5	17.9	25.2	17.6	21.8	17.4	17.3	17.7	1.83	25.0
14 WAS											
Abeokuta	26.1	25.2	36.1	24.2	16.0	22.2	24.9	27.3	28.6	1.89	20.9
Atakumosa	25.7	19.8	19.0	25.3	25.3	25.5	27.9	22.9	23.7	1.03	17.2
Etung-B	22.9	20.6	27.6	25.9	21.0	19.4	23.0	20.3	24.0	0.97	12.1
Etung-A	20.3	22.5	29.0	20.9	18.3	21.4	22.2	20.1	24.4	1.10	14.0
Idanre	27.1	23.3	36.6	27.1	27.2	28.4	27.1	22.8	29.2	1.41	14.4
Sawdust	19.7	35.5	19.4	27.6	18.3	22.8	18.1	18.6	18.2	2.10	26.9
16 WAS											
Abeokuta	27.7	26.9	39.2	25.5	22.2	22.4	27.9	28.3	34.6	1.94	19.4
Atakumosa	31.3	21.5	20.2	29.1	29.5	25.6	28.9	23.2	24.2	1.39	15.1
Etung-B	24.5	21.5	29.5	27.0	21.8	20.1	23.5	20.8	24.1	1.08	13.0
Etung-A	23.7	24.1	31.0	21.7	19.4	22.0	22.9	20.3	25.2	1.20	14.5
Idanre	28.9	27.6	37.7	28.1	30.4	30.2	28.2	24.0	30.8	1.30	12.4
Sawdust	20.1	38.7	20.4	29.5	18.9	23.7	18.8	19.4	18.7	2.41	29.4
18 WAS											
Abeokuta	30.0	31.4	41.9	26.7	22.8	22.9	30.2	30.5	36.5	2.61	20.1
Atakumosa	35.3	23.7	21.6	31.8	34.0	30.0	30.1	24.8	24.9	1.72	17.1
Etung-B	26.0	24.2	31.4	27.5	23.7	21.8	24.6	22.5	24.6	1.02	11.5
Etung-A	24.5	26.6	32.7	22.6	20.2	22.3	23.3	21.0	25.3	1.33	15.5
Idanre	30.9	29.8	40.3	30.9	33.0	31.5	30.2	26.0	32.0	1.34	12.0
Sawdust	20.6	40.7	21.5	30.7	19.7	24.0	19.2	19.9	18.8	2.58	30.6

Growth medium = Soils from cocoa plantations and control (sawdust)
C = Growth medium amended with complete nutrients of N, P, K, Ca, Mg, Zn & B
C-B = Growth medium amended with all nutrients except Boron (B)
C-Zn = Growth medium amended with all nutrients except Zinc (Zn)
C-Mg = Growth medium amended with all nutrients except Magnesium (Mg)
C-Ca = Growth medium amended with all nutrient except Calcium (Ca)
C-K = Growth medium amended with all nutrients except Potassium (K)
C-P = Growth medium amended with all nutrients except Phosphorus (P)
C-N = Growth medium amended with all nutrients except Nitrogen (N)
Control = Unamended growth medium from each of the cocoa plantations

Stem Girth (mm)

At 18 WAS, plants grown on Idanre, Abeokuta, Etung-B and Atakumosa media had significantly higher values of stem girth, between 6.3 and 6.7 mm, compared to plants grown on other media. Stem girth values of plants grown on Idanre medium were 16.42% higher than those grown on sawdust Table 4. With respect to nutrient amendment at 18 WAS, values of stem girth of plants amended with C-Zn (7.2 mm) and C-B (6.7 mm) were highest while least values were obtained on plants amended with C-N (5.7 mm) and C-P (5.8 mm) (Table 4). At

the same period of 18 WAS, seedlings grown on soils from Abeokuta amended with C-Zn had highest stem girth value of 10.0 mm which was 47 % higher than that of seedlings raised on sawdust amended with C-Ca (5.3 mm) and 37 % higher than that of the unamended control (6.3 mm). All growth media amended with C-K, C-Ca and C-P were between 48 % and 56 % lower in stem girth values compared to seedlings grown on Abeokuta medium amended with C-Zn (Table 5). However, seedlings raised on Atakumosa medium amended with C, had optimum girth value of 7.3 mm which was 19.18 % higher than seedlings raised from the control treatment and 26.02 % higher than seedlings raised on same medium amended with C-Zn (Table 5). Seedlings raised on Etung-B soils amended with C-Zn had optimum girth of 7.6 mm which was 14.47% higher than from control treatment and 27.63 % higher than seedlings raised on same soil amended with C-P (5.5 mm). Also, seedlings raised on soils from Idanre plantations, amended with C-Zn had stem girth value of 8.5 mm which was 28.23 % higher than that of same medium but amended with C-N. However, cocoa seedlings grown on sawdust amended with C-B had girth value of 7.8 mm which was 42.31 % higher than that grown on same medium amended with C-Ca (4.5 mm). Seedlings raised on soils from Etung A plantations, amended with C-Zn had girth value of 6.9 mm and this was 24.64% higher than that of the control (5.2 mm) and 31.88 % higher than that of same medium amended with C-Ca (Table 5).

Average Number of Leaves

The leaf production of cocoa seedlings, at 18 WAS varied. Seedlings grown on soils from Etung-A plantations, were very prolific in leaf production with 13.4 average number of leaves (Table 6). This was followed by seedlings grown on Abeokuta medium with 12.3 average number of leaves while seedlings grown on sawdust and Etung-B media produced least average number of leaves of 9.9 each. However, the variability in leaf production as a result of nutrient amendment of growth medium was minimal (7.18 %). Cocoa seedlings grown on C-Zn amendment produced highest average number of leaves of 12.7 closely followed by seedlings grown on C-B with 11.7 and seedlings grown on Complete amendment with 11.4 average number of leaves. All other nutrient amendments resulted in leaf production of between 10.2 and 10.9 leaves on the average (Table 6).

Interactions of the growth medium and nutrient amendment resulted in moderately large variability of between 15.1 and 24.4 % in leaf production at 18 WAS (Table 6). Cocoa seedlings grown on Abeokuta medium amended with C-Zn had improved leaf production of 16.7 on the average, followed by seedlings grown on same medium amended with C-B and C with 14.3 and 14.0 average leaves, respectively. The seedlings grown on unamended control treatment of same medium produced 12.7 mean leaves while those amended with C-K and C-Ca produced of leaves of 9.7 and 9.0 leaves, respectively. On Atakumosa medium, seedlings grown with C -K amendment had highest average number of leaves with 14.7 followed by the control treatment with 11.0 average leaves, while seedlings grown on same medium but amended with C-Zn, C-B and C-N had least average of 7.0, 8.3 and 8.7 leaves, respectively. Seedlings on Etung-B medium amended with C-Zn had highest average leaf production with 12.3 leaves followed by those with C amendment with 11.7 and those with C-Mg with 11.0 average leaves. All other treat-

ed seedlings of same medium produced between 5.3 and 10.7 average leaves. However, seedlings on Etung-A medium amended with C-Zn were very prolific in leaf production with 19.0 leaves, which was followed by seedlings amended with C-Ca, C-P with 15 leaves each and C-K with 14.7 leaves. All other treated seedlings of same medium produced average leaves of between 9.7 (control treatment) and 13 (C treated seedlings). On Idanre medium, cocoa seedlings treated with C-Zn amendment produced highest number of leaves of 14.0 on the average, followed by seedlings grown on same medium but amended with C-B and C-N with 11.0 average leaves each. Other treated cocoa seedlings of same medium had between 9.0 and 10.7 leaves. Cocoa seedlings grown on sawdust amended with C-B had highest average number of leaves with 15.7 followed by seedlings, on same medium, amended with C-Mg and C with 11.0 and 10.0 average leaves, respectively. Other treated cocoa seedlings grown on sawdust had between 7.3 and 9.3 leaves on the average (Table 7).

Table 4: Stem girth (mm) of cocoa seedlings as affected by soils of cocoa plantations and nutrient amendment at transplanting periods

	Weeks After Sowing			
Treatments	**12**	**14**	**16**	**18**
Growth medium:				
Abeokuta	5.0	5.5	5.3	6.6
Atakumosa	5.1	5.6	5.9	6.3
Etung-B	5.0	5.6	6.0	6.4
Etung-A	5.0	5.3	5.5	5.8
Idanre	5.2	5.8	6.3	6.7
Sawdust	4.6	5.0	5.3	5.6
$Sed_{0.05}$	0.09	0.13	0.18	0.20
Cv (%)	0.68	0.86	1.20	1.18
Amendments:				
C	5.0	5.4	5.9	6.5
C-B	5.1	5.6	6.2	6.7
C-Zn	5.3	6.1	6.7	7.2
C-Mg	5.1	5.5	5.9	6.4
C-Ca	4.5	4.9	5.3	5.7
C-K	4.9	5.4	5.7	6.0
C-P	4.8	5.1	5.5	5.8
C-N	4.8	5.1	5.3	5.7
Control	5.3	5.7	5.9	6.1
$Sed_{0.05}$	0.09	0.13	0.16	0.18
Cv	0.58	0.74	0.85	0.91

Note: Growth medium = Soils from cocoa plantations and control (sawdust)
C = Growth medium amended with complete nutrients of N, P, K, Ca, Mg, Zn & B
C-B = Growth medium amended with all nutrients except Boron (B)
C-Zn = Growth medium amended with all nutrients except Zinc (Zn)
C-Mg = Growth medium amended with all nutrients except Magnesium (Mg)
C-Ca = Growth medium amended with all nutrient except Calcium (Ca)
C-K = Growth medium amended with all nutrients except Potassium (K)
C-P = Growth medium amended with all nutrients except Phosphorus (P)
C-N = Growth medium amended with all nutrients except Nitrogen (N)
Control = Unamended growth medium from each of the cocoa plantations

Table 5: Stem girth (mm) of cocoa seedlings as affected by interactions of growth medium and nutrient amendment at transplanting periods

Growth medium	Nutrient amendment										
	C	C-B	C-Zn	C-Mg	C-Ca	C-K	C-P	C-N	Control	$SED_{0.05}$	CV (%)
12 WAS											
Abeokuta	4.6	4.3	6.0	5.2	4.7	4.4	4.7	5.3	5.4	0.20	11.20
Atakumosa	5.7	4.5	4.7	5.0	5.2	4.9	4.7	5.5	5.3	0.14	7.90
Etung-B	5.3	5.5	6.0	5.5	4.4	4.1	4.5	4.7	5.3	0.22	12.52
Etung-A	4.7	5.4	5.6	4.9	4.0	5.8	5.5	4.3	4.7	0.22	12.45
Idanre	5.3	4.9	5.8	5.1	5.0	5.2	5.1	4.9	5.7	0.12	6.25
Sawdust	4.4	6.0	3.9	5.0	3.5	5.2	4.1	4.1	5.2	0.28	17.33
14 WAS											
Abeokuta	4.9	4.6	7.7	5.6	5.0	4.5	5.3	5.4	6.9	0.38	19.41
Atakumosa	6.3	5.0	5.1	5.4	5.8	5.8	5.2	5.9	5.5	0.15	7.70
Etung-B	5.8	6.1	6.6	5.9	4.9	4.7	4.8	5.2	6.0	0.24	12.11
Etung-A	4.9	6.2	6.1	5.3	4.3	6.0	5.7	4.5	4.9	0.25	13.38
Idanre	5.8	5.4	7.1	5.6	5.7	5.7	5.4	5.2	6.1	0.20	9.71
Sawdust	4.9	6.6	4.1	5.3	3.8	5.5	4.4	4.4	5.5	0.31	17.66
16 WAS											
Abeokuta	5.3	5.6	9.0	6.0	5.2	4.7	5.5	5.6	6.1	0.44	21.04
Atakumosa	6.9	5.4	5.2	5.9	6.3	6.2	5.6	6.2	5.7	0.19	8.83
Etung-B	6.3	6.7	7.1	6.3	5.5	5.0	5.2	5.4	6.3	0.26	12.15
Etung-A	5.1	6.4	6.5	5.7	4.5	6.0	6.0	4.6	5.0	0.27	13.65
Idanre	6.2	5.8	7.9	6.1	6.3	6.3	5.9	5.6	6.5	0.24	10.59
Sawdust	5.5	7.3	4.5	5.6	4.1	5.7	4.7	4.6	5.8	0.34	18.19
18 WAS											
Abeokuta	7.0	6.7	10.0	7.1	5.3	5.2	5.6	6.1	6.3	0.52	22.10
Atakumosa	7.3	5.7	5.4	6.3	6.8	6.4	5.9	6.6	5.9	0.21	9.50
Etung-B	6.9	7.1	7.6	6.6	6.1	5.6	5.5	5.9	6.5	0.25	11.03
Etung-A	5.3	6.6	6.9	6.0	4.7	6.2	6.3	4.8	5.2	0.28	13.85
Idanre	6.9	6.3	8.5	6.3	6.7	6.7	6.2	6.1	6.9	0.26	10.81
Sawdust	5.8	7.8	4.7	6.0	4.5	5.9	5.1	4.8	6.0	0.36	18.00

Note: Growth medium = Soils from cocoa plantations and control (sawdust)
C = Growth medium amended with complete nutrients of N, P, K, Ca, Mg, Zn & B
C-B = Growth medium amended with all nutrients except Boron (B)
C-Zn = Growth medium amended with all nutrients except Zinc (Zn)
C-Mg = Growth medium amended with all nutrients except Magnesium (Mg)
C-Ca = Growth medium amended with all nutrient except Calcium (Ca)
C-K = Growth medium amended with all nutrients except Potassium (K)
C-P = Growth medium amended with all nutrients except Phosphorus (P)
C-N = Growth medium amended with all nutrients except Nitrogen (N)
Control = Unamended growth medium from each of the cocoa plantations

Table 6: Average number of leaves of cocoa seedlings as affected by growth medium and nutrient amendment at transplanting periods

Treatments	Weeks After Sowing			
	12	14	16	18
Growth medium:				
Abeokuta	8.9	9.7	10.9	12.3
Atakumosa	7.7	8.4	9.1	10.1
Etung-B	7.5	8.3	9.2	9.9
Etung-A	8.9	10.4	11.7	13.4
Idanre	7.4	8.5	9.5	10.4
Sawdust	7.4	8.3	8.9	9.9
$SED_{0.05}$	0.33	0.40	0.51	0.67
Cv (%)	9.16	10.08	11.54	13.55
Amendments:				
C	7.9	9.3	10.6	11.4
C-B	8.2	9.1	10.4	11.7
C-Zn	8.9	10.3	11.4	12.7
C-Mg	7.9	8.4	9.3	10.6
C-Ca	7.8	8.7	9.2	10.6
C-K	7.6	8.7	9.3	10.9
C-P	7.6	8.6	9.5	10.6
C-N	7.6	8.3	9.4	10.2
Control	8.3	9.0	9.7	10.4
$SED_{0.05}$	0.19	0.27	0.34	0.35
Cv (%)	5.39	6.83	7.70	7.18

Note: Growth medium = Soils from cocoa plantations and control (sawdust)
C = Growth medium amended with complete nutrients of N, P, K, Ca, Mg, Zn & B
C-B = Growth medium amended with all nutrients except Boron (B)
C-Zn = Growth medium amended with all nutrients except Zinc (Zn)
C-Mg = Growth medium amended with all nutrients except Magnesium (Mg)
C-Ca = Growth medium amended with all nutrient except Calcium (Ca)
C-K = Growth medium amended with all nutrients except Potassium (K)
C-P = Growth medium amended with all nutrients except Phosphorus (P)
C-N = Growth medium amended with all nutrients except Nitrogen (N)
Control = Unamended growth medium from each of the cocoa plantations
SED—Standard Error of Difference

Table 7: Average number of leaves of cocoa seedlings as affected by interactions of growth medium and nutrient amendment at transplanting periods

Growth medium	Nutrient amendment										
	C	**C-B**	**C-Zn**	**C-Mg**	**C-Ca**	**C-K**	**C-P**	**C-N**	**Control**	**$SED_{0.05}$**	**CV (%)**
12 WAS											
Abeokuta	9.7	9.3	10.7	8.3	7.3	7.2	7.3	10.0	10.3	0.50	15.8
Atakumosa	6.7	5.7	5.3	8.0	8.3	10.7	8.3	8.3	8.3	0.58	21.1
Etung-B	7.7	7.7	8.3	8.0	8.7	6.7	7.0	5.7	7.7	0.32	12.1
Etung-A	8.7	8.7	13.7	8.0	8.0	8.0	8.7	8.3	8.0	0.65	20.6
Idanre	7.0	7.3	9.0	6.7	6.7	6.3	8.0	6.7	9.3	0.38	14.5
Sawdust	8.0	10.7	6.3	8.7	8.0	6.7	6.0	6.3	6.0	0.56	21.6
14 WAS											
Abeokuta	11.3	11.0	13.0	8.7	7.7	7.3	7.7	10.3	10.3	0.69	20.2
Atakumosa	8.7	5.7	5.3	8.3	9.0	11.3	9.3	8.7	9.7	0.67	22.3
Etung-B	8.7	7.7	10.0	8.0	9.0	7.7	8.0	6.7	9.0	0.34	11.7
Etung-A	10.7	8.7	14.7	8.7	10.7	10.7	10.7	10.0	9.7	0.63	16.8
Idanre	7.7	8.7	12.3	7.7	7.3	7.3	8.7	7.0	6.3	0.62	21.6
Sawdust	9.0	12.7	6.7	9.3	8.7	7.7	7.0	7.0	9.0	0.65	21.5
16 WAS											
Abeokuta	12.3	12.0	15.0	9.0	8.0	8.3	10.0	11.7	11.3	0.80	20.8
Atakumosa	9.0	7.0	6.0	9.7	9.3	12.0	10.0	8.7	10.0	0.62	19.3
Etung-B	10.7	9.0	11.3	9.3	9.3	8.0	8.3	7.3	9.0	0.44	13.7
Etung-A	13.0	10.7	17.0	9.0	11.7	11.7	12.0	10.7	9.7	0.82	19.8
Idanre	8.7	9.7	12.7	9.0	8.3	7.3	9.7	9.7	10.3	0.53	15.9
Sawdust	9.7	14.0	6.7	10.0	8.7	8.3	7.0	8.3	7.7	0.77	24.5
18 WAS											
Abeokuta	14.0	14.3	16.7	10.0	9.0	9.7	11.3	13.0	12.7	0.89	20.5
Atakumosa	10.3	8.3	7.0	10.3	10.3	14.7	10.3	8.7	11.0	0.76	21.3
Etung-B	11.7	9.3	12.3	11.0	10.7	8.0	9.0	8.0	5.3	0.78	23.2
Etung-A	13.0	11.3	19.0	11.7	15.0	14.7	15.0	11.3	9.7	1.00	21.0
Idanre	9.3	11.0	14.0	9.3	9.3	9.0	9.7	11.0	10.7	0.56	15.1
Sawdust	10.0	15.7	7.3	11.0	9.3	9.3	8.3	9.0	9.0	0.85	24.4

Note: Growth medium = Soils from cocoa plantations and control (sawdust)
C = Growth medium amended with complete nutrients of N, P, K, Ca, Mg, Zn & B
C-B = Growth medium amended with all nutrients except Boron (B)
C-Zn = Growth medium amended with all nutrients except Zinc (Zn)
C-Mg = Growth medium amended with all nutrients except Magnesium (Mg)
C-Ca = Growth medium amended with all nutrient except Calcium (Ca)
C-K = Growth medium amended with all nutrients except Potassium (K)
C-P = Growth medium amended with all nutrients except Phosphorus (P)
C-N = Growth medium amended with all nutrients except Nitrogen (N)
Control = Unamended growth medium from each of the cocoa plantations
D—Standard Error of Difference

Average Dry Matter Yield (g/plant)

Cocoa seedlings grown soils from Atakumosa plantations had dry matter yield of 6.3 g/plant. These were followed by seedlings grown on soils from Abeokuta, sawdust. Idanre and Etung-A with 5.8, 5.5, 5.3 and 4.9 g/plant, respectively. The seedlings grown on soils from Etung-B had least dry matter yield of 4.6 g/plant. The differences were significant at $P \leq 0.05$ (Figure 2).

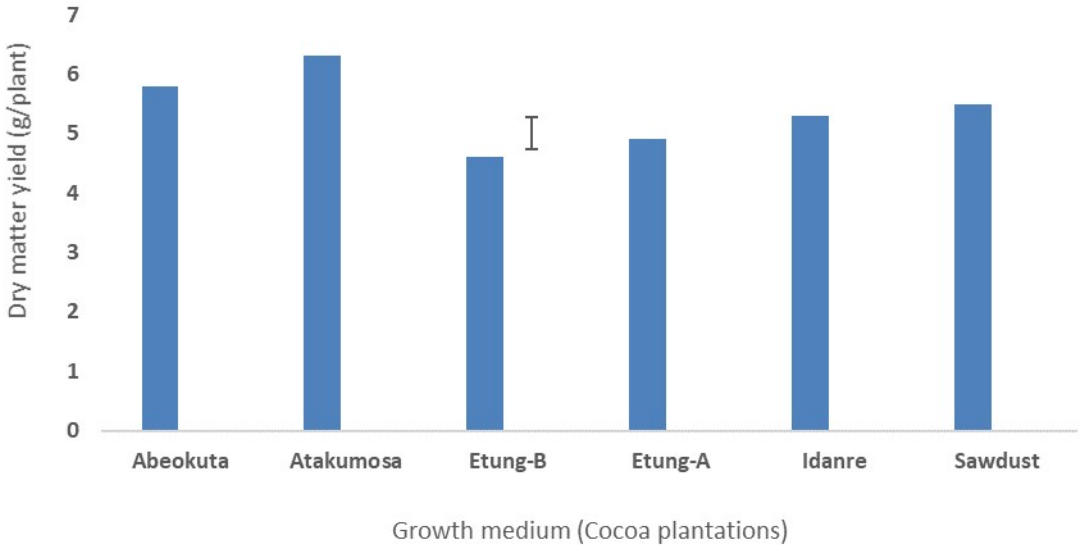

Figure 2: Dry matter yield (g/plant) of cocoa seedlings as affectd by growth medium (soils from cocoa plantations) at 18 WAS

Note: Growth medium = Soils from cocoa plantations and control (sawdust)

However, the seedlings grown on these soils amended with complete nutrient elements minus Zinc had highest dry matter yield of 7.9 g/plant followed by seedlings that received complete nutrient elements, complete nutrients minus Boron and complete nutrient minus Phosphorus with 7.0, 6.9 and 6.3 g/plant, respectively. The seedlings that received complete nutrients minus Nitrogen and complete minus Magnesium had least dry matter yield of 2.9 and 3.1 g/plant, respectively which were lower than dry matter yield of seedlings grown on unamended control that had 4.3 g/plant. The differences were significant at $P < 0.05$ (Figure 3).

With respect to interaction between growth medium and nutrient amendment, cocoa seedlings grown on soils from Abeokuta amended with complete minus Phosphorus had highest dry matter yield of 8.91 g/plant followed by that of seedling grown on unamended control with 7.56 g/plant. Seedlings grown on all other nutrient amendment of soils from Abeokuta had dry matter yield of between 4.52 and 6.94 g/plant and the differences were significant at $P < 0.05$ (Figure 4). The seedlings grown on soils from Ata-

kumosa amended with complete nutrients minus Phosphorus and complete nutrient minus Calcium had highest dry matter yield of 10.1 and 8.22 g/plant, respectively. The seedlings grown on unamended control had reduced dry matter yield of 5.9 g/plant, while seedlings grown on all other amendments of this soil had dry matter yield of between 3.5 and 4.77 g/plant ($P < 0.05$). The dry matter yield of cocoa seedlings grown on soils from Etung-B amended with complete nutrient minus Boron was highest with 7.03 g/plant followed by those grown on same soils amended with complete nutrients (5.57 g/plant) and unamended control (5.54 g/plant) and complete nutrient minus Zinc (5.20 g/plant). The seedlings grown on soils from Etung-A amended with complete nutrient minus Boron had highest dry matter yield of 6.12 g/plant. This was followed by those grown on unamended control (5.60 g/plant) and complete nutrient minus Zinc amendment (5.57 g/plant). The differences were significant at $P \leq 0.05$ (Figure 4).

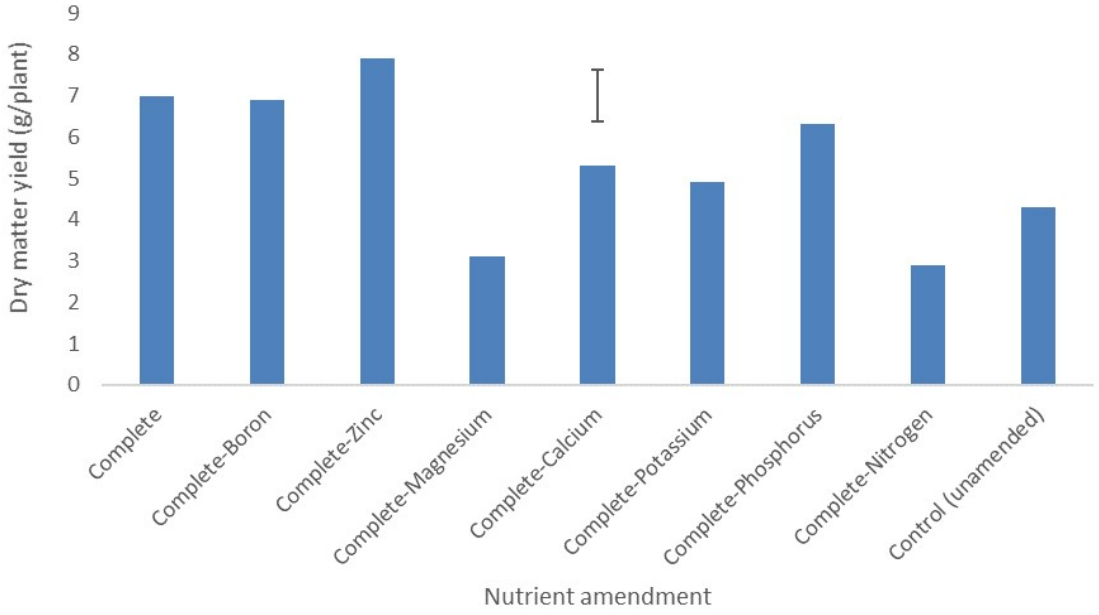

Figure 3: Dry matter yield (g/plant) of cocoa seedlings as affected by nutrient amendment

Legend:

Complete = Growth medium amended with complete nutrients of N, P, K, Ca, Mg, Zn & B
Complete – Boron = Growth medium amended with all nutrients except Boron (B)
Complete – Zinc = Growth medium amended with all nutrients except Zinc (Zn)
Complete – Magnesium = Growth medium amended with all nutrients except Magnesium (Mg)
Complete – Calcium = Growth medium amended with all nutrient except Calcium (Ca)
Complete – Potassium = Growth medium amended with all nutrients except Potassium (K)
Complete – Phosphorus = Growth medium amended with all nutrients except Phosphorus (P)
Complete – Nitrogen = Growth medium amended with all nutrients except Nitrogen (N)
Control = Unamended growth medium from each of the cocoa plantations

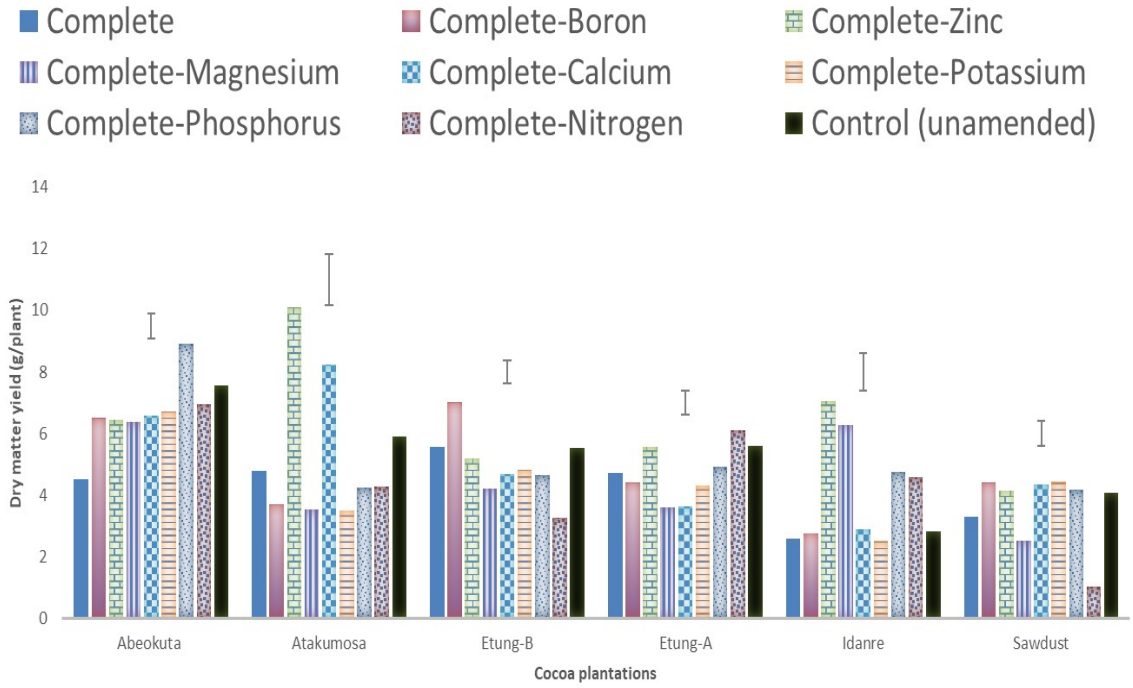

FIGURE 4: DRY MATTER YIELD OF COCOA SEEDLINGS AS AFFECTED BY SOILF OF COCOA PLANTATIONS AND NUTRIENT AMENDMENT

However, on soils from Idanre, cocoa seedlings that received complete nutrient minus Zinc as well as complete nutrient minus Magnesium, had highest dry matter yield of 7.04 and 6.28 g/plant, respectively. These were different ($P \leq 0.05$) from dry matter yield of cocoa seedling grown on all other amendments of the soils which were between 2.52 and 4.76 g/plant. On sawdust, cocoa seedlings that received complete nutrient minus Boron, complete nutrient minus Zinc, complete nutrient minus Calcium, complete nutrient m,inus Potassium, complete nutrient minus Phosphorus as well as seedling grown on unamended control had similar dry matter yield of between 4.13 and 4.46 g/plant. The dry matter yields of the seedlings grown on same sawdust amended with all other nutrient amendments were between 1.02 and 3.29 g/plant and the differences were significant at $P \leq 0.05$ (Figure 4).

DISCUSSION

The six growing media used in this experiment displayed a wide range of physico-chemical properties. The soils from Etung - A, Etung-B, Atakumosa cocoa plantations as well as sawdust were slightly acidic (pH in water) in nature while, the soil from Idanre cocoa plantations was moderately acidic and that of Abeokuta cocoa plantations was neutral (pH in water). The acidic nature of cocoa plantations was supported by the reports of Eneje *et. al.* (2011) who reported similar results in Abia State on soils under cocoa plantations. Adewole *et. al.* (2010) equally reported lower soil pH in soils that had been under cocoa cultivation for about 150 years. This relatively reduced pH of the soils under co-

coa cultivation is attributable to the relative poor drainage condition of the soils in addition to the release of organic acids from slow decomposition of organic materials as cited by Olatunde *et. al.,* (2013). The available nutrients elements in all the growth media (except that of Abeokuta and sawdust) that were mostly lower than their respective critical values were as a results of continuous mining of these nutrients (both major and trace nutrients) by crop harvests over the years without any programmed replenishment except a fraction returned by leaf litters (Egbe *et. al.* 1989; Aikpokpodion, 2010; Illoyanomon, 2011). This confirms the reports of Wessel (1971) that there is a steady decline in fertility status of cocoa soils with length of cultivation due to soil nutrient mining. Omotosho (1975) similarly reported that a crop of 1000kg dry cocoa beans removed about 20kg N, 4kg P and 10kg of K from the soils; and where the method of harvesting (as the case in Nigeria) involves the removal of pod husk from the field, the amount of K removed is increased more than five-fold. The presumed good agricultural practices of the University farms might have contributed to the higher nutrient status of soils from Abeokuta, while sawdust on the other hand, is a plant product and thus organic in nature. The sawdust might have mineralized between the periods of sowing and growth observations (18 weeks) and thus, its nutrient content become available for cocoa seedling growth.

With respect to germination and growth of the seedlings, the improved germination of cocoa seedlings in all growth media (especially, with sandy soils from Abeokuta plantations), was supported by the reports of Brady and Weil (1999) that the rapid warming up of sandy soils, results in increased biochemical activities in the seeds which translate into increased germination. This was equally supported by the findings of Tinsdale and Nelson, (1975) that ambient temperature directly affects the plant functions of photosynthesis, respiration, enzyme activities and protein coagulation. This was equally in line with reports of Okunomo *et al.,*(2004; 2009) who obtained a higher germination percentage in topsoil with *Dacroydes edulis* and *Persea americana* citing the presence of adequate nutrient for germination in topsoil.

The morphological growth parameters of cocoa seedlings that were observed to be improved (or otherwise) by growth media and nutrient amendment provide indications that nutrient amendments will differ and more importantly, would be location specific as the soils were not similar in Physicochemical properties.

CONCLUSION

This study shows that all the growth media examined were suitable for germination and growth of cocoa seedlings in the nursery. However, each cocoa plantation requires different nutrient amendment for vigorous growth of the seedlings: amendment of soils from Abeokuta, Etung-B, Idanre and Etung-A, with C-Zn (complete nutrient minus Zinc) promotes vigorous growth of cocoa seedlings while soils from Atakumosa amended with C (Complete nutrients) and sawdust amended with C-B (Complete nutrient minus Boron) promotes growth of cocoa seedlings in the nursery. It is highly recommended that supply of pods of improved cocoa varieties to resource-poor farmers for the purpose of raising cocoa seedlings inside the plantations, to replace the old varieties with the newly bred varieties, should be accompanied with supply of required nutrient

elements for proper soil amendment without which the expected traits of the new varieties may not be expressed.

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