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Media type and compost mixtures effect on growth and nutrient uptake of cocoa seedling at the nursery in Ghana

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Abstract

Efforts at improving cocoa (*Theobroma cacao* (L.) production in Ghana have been targeted at increasing yield with little attention to the production of quality seedlings and subsequent survival and field establishment. This experiment investigated the effectiveness of four media types, viz: Sawdust (SD), Cocopeat (CP), Rice husk biochar (RH) and Topsoil (TS) and four rates of compost; viz: 0g (Comp0), 200g (Comp1), 400g (Comp2) and 600g (Comp3) polybag^{-1} on nutrient uptake and growth of cocoa seedlings. The treatments were arranged in a completely randomized design with four replicates. Foliar and residual nutrients were analyzed as well as growth and biomass production at 42 weeks after sowing. Results indicated that leaf area was significantly ($p<0.05$) higher in RH (74.4 cm^2 to 133.2 cm^2) than in TS (65.5 cm^2 to 98.1 cm^2) across the compost rates. Seedlings foliar biomass was significantly ($p>0.05$) higher in RH (6.4 g) than in SD. Plant nutrients uptake (NPK), was significantly ($p>0.05$) higher in RH (10.0, 8.7 and 22.8 g plant^{-1}) than in SD (4.0, 3.3 and 8.5 g plant^{-1}). Seedlings raised in RH were significantly taller (38.5 cm) and bigger (6.6mm) than those raised in SD. Shoot and root biomass of seedlings in RH (9.3g and 3.5g) were higher than those in SD (4.2g and 2.3g). With respect to compost effects, foliar biomass and nutrient content increased with increasing rate of compost. Seedling height and girth as well as Shoot and root biomass all increased with increasing rates of compost. Residual N, Mg and Ca in the potting media were highest in CP (5.5 g Kg^{-1}, 12.8 Cmol$_{(+)}$ Kg^{-1} and 28.5 Cmol$_{(+)}$ Kg^{-1}) and lowest in TS (2.3 g Kg^{-1}, 3.3 Cmol$_{(+)}$ Kg^{-1} and 19.9 Cmol$_{(+)}$ Kg^{-1} respectively). These residual nutrients increased significantly ($p<0.05$) with increasing compost rate. The combined effect of RH with Comp3 significantly ($p>0.05$) increased pH and available P of the potting media. Residual K was highest in CP with Comp3 (9.49 g Kg^{-1}) and lowest in TS with Comp0 (0.33 g Kg^{-1}). Rice husk biochar mixed with 400g and 600g of compost was the best potting media and produced robust seedlings with adequate foliar and residual nutrients which can support vigorous growth and survival in the field after planting out. Further evaluation of mixing TS, RH and compost at different ratios as a suitable potting media for raising cocoa seedling is recommended.

Key words: compost, media type, cocopeat, rice husk biochar, cocoa

1.0. Introduction

The potential production of cocoa in Ghana is threatened by over-aged and unproductive trees. Rehabilitating these aged farms will require raising millions of seedlings for transplanting. Large quantities of topsoil will be required for these nursery works. The use of topsoil only as potting media will destroy the ecosystem of the areas where the topsoil is collected (Siregar *et al*., 2002). Its use will also require additional inorganic fertilizer to supplement the seedlings nutrient demand. The compactness of topsoil restricts seedlings root growth and makes nursery polybags too heavy for conveyance over long distances for field transplanting.

The use of agro-industrial waste materials such as sawdust, rice husk and coconut fibre have been justifiably considered as better alternative to topsoil as potting media (Anda *et al.,* 2010 and Adejobi *et al.,* 2013). The use of these organic materials as potting media provide environmental benefits as ecosystem damage caused by soil extraction can be avoided and the environmental problems associated their disposal is mitigated. However, the use of these agricultural residues alone or in combination with compost has not been evaluated in the context of producing healthy cocoa seedlings at the nursery in Ghana. The objective of the study therefore was to investigate the effectiveness of four media types, viz: Sawdust, Cocopeat, Rice husk biochar and Topsoil (TS) used alone or amended with four rates of compost on nutrient uptake and growth of cocoa seedlings at the nursery.

2.0. Materials and Methods

The experiment was carried out at Kade (60.0854‘N and longitude 0o 5400W) in the deciduous forest agro-ecological zone of Ghana. The soil at the experimental site has been classified as Utisols in Soil Taxonomy (Soil Survey Staff, 1998). The four media types, viz: 0.60 Kg of Sawdust (SD), 0.86 Kg of Cocopeat (CP), 0.87 Kg of Rice husk biochar (RH) and 2.70 Kg of Topsoil (TS) were amended with four rates of municipal solid waste (MSW) compost, viz: 0g (Comp0), 200g (Comp1), 400g (Comp2) and 600g (Comp3). The respective materials were thoroughly and filled in nursery polybag measuring 17.3cm x 23.3cm (Ofori-Frimpong *et al*., 2007). The setup was watered to stabilize for 72 hours before sowing of the cocoa seeds. Hybrid cocoa seeds were sown at a seeding rate of two per polybag which were thinned to one seedling per polybag. The treatments were arranged in a complete randomized design with four (4) replications.

At 42 weeks after sowing (WAS), stem height (cm) and girth (mm) were measured and height: diameter ratio was calculated. Leaf area (cm2) was measured with a leaf area meter (YMJ-A). Seedlings were then harvested for the determination of biomass production (Shoot, root and leaf). Shoot: root ratio was calculated as dry weight of leaves plus stem divided by the dry weight of root (g/g). Nutrient uptake and residual nutrients in the potting media were also determined. These measurements were done to depict the status of the seedlings at the stage of transplanting.

Statistical analyses were done using Statistical Analysis System9.2 (SAS 2002). All data collected in these experiments were subjected to analysis of variance (ANOVA) followed by Fisher’s protected least significant difference test.

3. 0. Results

Results of the initial analysis indicate that the soil at experimental site is slightly acidic with moderate levels of N but low in exchangeable K, Mg and Ca. Results of the organic materials show that they were slightly alkaline. The results also showed that the organic materials used as potting media were relatively higher in nutrients than the soil (Table 1).

Table 1: Selected chemical properties of topsoil and organic materials used as potting media for raising cocoa seedlings.

Growing Media	pH	EC ds/cm	%N	%P	%K	Ca cmol/kg	Mg cmol/kg
Topsoil	5.9	300	0.92	0.33	0.4	2.1	1.5
Rice husk biochar	9.5	480	0.84	0.12	2.6	0.4 1	1.4
Cocopeat	6.2	3000	1.06	0.22	4.4	2.5	6.4
Sawdust	9.6	740	1.06	0.06	2.6	8.8	9.0
Compost	8.5	2700	1.97	2.2	0.75	55.5	11.7

There was no significant interaction effect of the media types and compost rates on height and diameter of the cocoa seedling. Seedlings in RH and TS were significantly ($p<0.05$) taller and bigger than those in SD and CP. Seedling sturdiness (height: diameter ratio) was not significantly affected by the differences in the media type however, seedlings in RH appeared to be slightly spindlier with higher sturdiness quotients than in the other media types (Table 2). Height and stem diameter increased with increasing compost rates. Height: diameter ratio was not affected by compost rates, however height, diameter and their ratio increased with increasing compost rates (Table 2).

Seedlings in Comp1 had significantly ($p<0.05$) smaller leaf area than those in Comp0. Seedlings grown in SD had smaller leaf area irrespective of compost rate. Leaf area of seedlings in SD with Comp3 were significantly ($p<0.05$) higher and comparable with those in RH with Comp2 and Comp3, CP with Comp3 and TS with Comp2. Mean leaf area of seedlings grown in RH with Comp3 were significantly ($p<0.05$) the largest (Figure 1).

Foliar biomass of seedlings grown in TS and RH were significantly ($p<0.05$) higher than those grown in SD and CP. No significant differences in foliar biomass existed between seedlings grown in TS and those in RH (Table 4). Foliar N, P and K contents of seedlings grown in RH and TS were significantly ($p<0.05$) higher than those grown in CP and SD (Table 4). Generally, foliar biomass and nutrient contents of the cocoa seedlings increased with increasing compost rate. Foliar biomass of seedlings treated with Comp3 was significantly ($p<0.05$) higher than those treated with all other compost rates (Table 3). Foliar N and K contents in Comp3 was significantly ($p<0.05$) higher than those in other compost rates. Foliar P content in Comp3 were significantly ($p<0.001$) higher (Table 3).

Table 2: Effect of different potting media and rates of compost application on cocoa seedling growth.

Media types	Height (cm)	Girth (mm)	Height: Girth
CP	35.0(1.9)AB	6.0(0.3)AB	57.7(1.9)A
RH	38.5(1.4)A	6.5(0.2)A	59.7(2.7)A
SD	31.4(1.2)B	5.4(0.2)B	57.9(1.7)A
TS	37.1(2.2)A	6.6(0.4)A	57.1(1.8)A
Compost Rates			
Comp0	29.9(1.7)B	5.4(0.4)B	55.6(1.6)A
Comp1	35.7(1.4)A	6.3(0.2)A	57.4(2.3)A
Comp2	37.0(1.2)A	6.3(0.2)A	58.7(1.7)A
Comp3	39.4(1.9)A	6.5(0.3)A	60.6(2.3)A

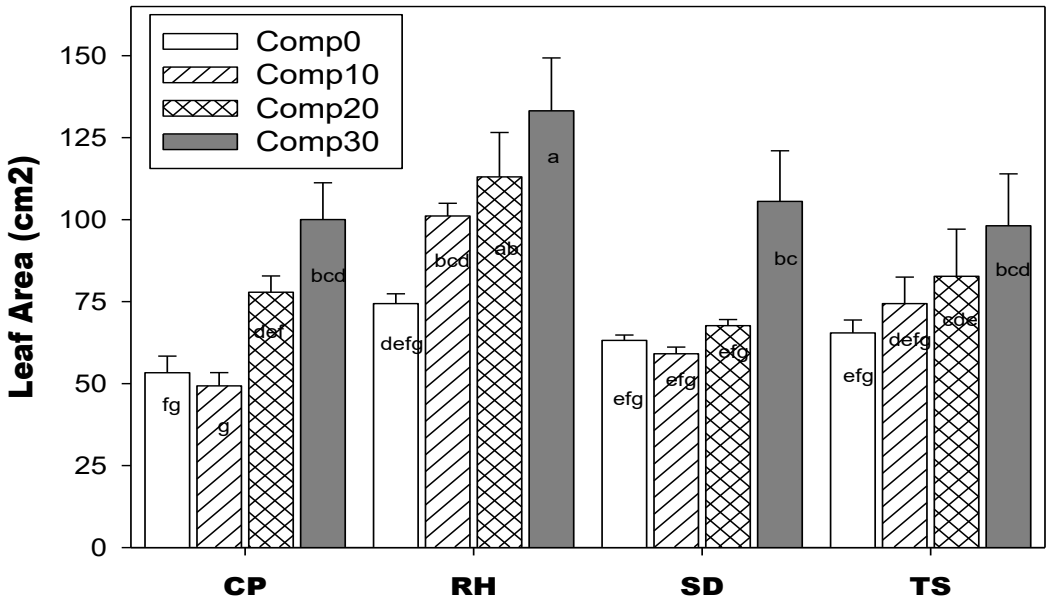

Figure 1: Interaction effects of different media types and compost rates on leaf area of cocoa seedlings at 42 weeks after sowing.

Table 3: Foliar biomass and nutrient uptake (g plant^{-1}) of cocoa seedlings grown with different media types and compost rates.

Media type	Biomass	Nitrogen	Phosphorus	Potassium
CCP	3.1(0.5)B	5.1(1.0)B	4.5(0.8)B	13.1(2.4)B
RH	6.4(0.7)A	10.0(1.1)A	8.7(1.6)A	22.8(3.1)A
SD	2.6(0.3)B	4.0(0.5)B	3.3(0.3)B	8.5(1.3)B
TS	6.1(0.6)A	10.3(1.0)A	9.2(1.3)A	20.1(2.2)A
Compost rates				
Comp0	3.0(0.5)C	5.1(1.0)C	4.9(1.0)B	9.6(2.3)C
Comp1	4.2(0.8)BC	6.8(1.2)BC	5.0(1.0)B	13.6(2.0)BC
Comp2	4.6(0.6)B	7.4(1.2)B	6.9(1.5)AB	17.7(2.5)B
Comp3	6.4(0.7)A	10.1(1.2)A	8.8(1.5)A	23.6(2.9)A

Shoot and root biomass of seedlings grown in TS and RH was significantly ($p<0.05$) higher than those grown in SD and CP. Shoot: root ratio of seedlings followed the same statistical pattern among the different media types (Table 4). Shoot biomass of seedlings treated with Comp3 were significantly higher than those treated with Comp1 and Comp0. Root biomass of seedlings treated with Comp3 was also significantly ($p<0.001$) higher. The ratio of shoot to root of seedlings was not significantly ($p<0.05$) influenced by the different compost rates (Table 4).

Table 4: Shoot and root biomass production (g plant^{-1}) and their ratio of cocoa seedlings grown in different media and compost rates for six months

Media Types	Shoot	Root	Shoot: Root
CP	4.9(0.7)B	3.2(0.5)AB	1.6(0.1)B
RH	9.3(0.9)A	3.5(0.3)A	2.8(0.3)A
SD	4.2(0.3)B	2.3(0.2)B	2.0(0.2)B
TS	9.1(0.9)A	2.7(0.3)AB	3.5(0.3)A
Compost Rates			
comp0	4.6(0.7)C	2.3(0.2)B	2.0(0.2)A
comp1	6.4(0.7)B	2.5(0.2)B	2.7(0.4)A
comp2	7.3(1.0)AB	2.9(0.3)B	2.7(0.4)A
comp3	9.1(1.1)A	3.9(0.5)A	2.5(0.3)A

Residual nitrogen in CP and RH were significantly ($p<0.02$) higher than in SD and TS (Table 5). Residual N of potting media containing Comp3 was significantly ($p<0.03$) higher than those containing Comp1 and Comp0. Residual Mg and Ca were significantly ($p<0.05$) higher in Comp3. Residual Mg in Comp0 and Comp1 were significantly lower than in Comp2 (Table 5).

Table 5: Residual N (g Kg^{-1}), Exchangeable Mg and Ca ($Cmol_{(+)}Kg^{-1}$) of the potting mixtures as influenced by the media type and compost rates after 6 months of growing cocoa seedlings at the nursery.

Media type	TN	Mg	Ca
CCP	5.5(0.5)a	12.8(0.8)a	28.5(3.2)a
RH	4.9(0.1)a	10.3(0.4)b	28.1(3.0)a
SD	4.1(0.2)b	11.7(0.6)a	28.5(2.2)a
TS	2.3(0.2)c	3.3(0.5)c	19.9(2.9)b
Compost rates			
Comp0	3.2(0.4)c	7.8(1.3)c	14.6(2.7)c
Comp10	4.0(0.4)b	8.8(1.1)c	25.8(2.3)b
Comp20	4.7(0.5)a	10.1(1.2)b	29.9(1.5)b
Comp30	4.7(0.5)a	11.3(1.2)a	34.7(1.6)a

The RH with Comp3 potting media had significantly ($p<0.05$) higher pH than in the other media combinations. Potting media containing SD with Comp0 and Comp1 were significantly ($p<0.05$) higher pH than in those containing TS and CP with same compost combinations (Figure 2a). Residual available P in RH with Comp3 was significantly ($p<0.05$) higher than in all the other treatments (Figure 2b). Residual K was significantly ($p=0.03$) higher in potting media continuing CP without compost than in the other media types (Figure 2c). Residual K of CP with the compost rates was significantly ($p<0.04$) higher than in the other three media types with the same compost rates (Figure 2c).

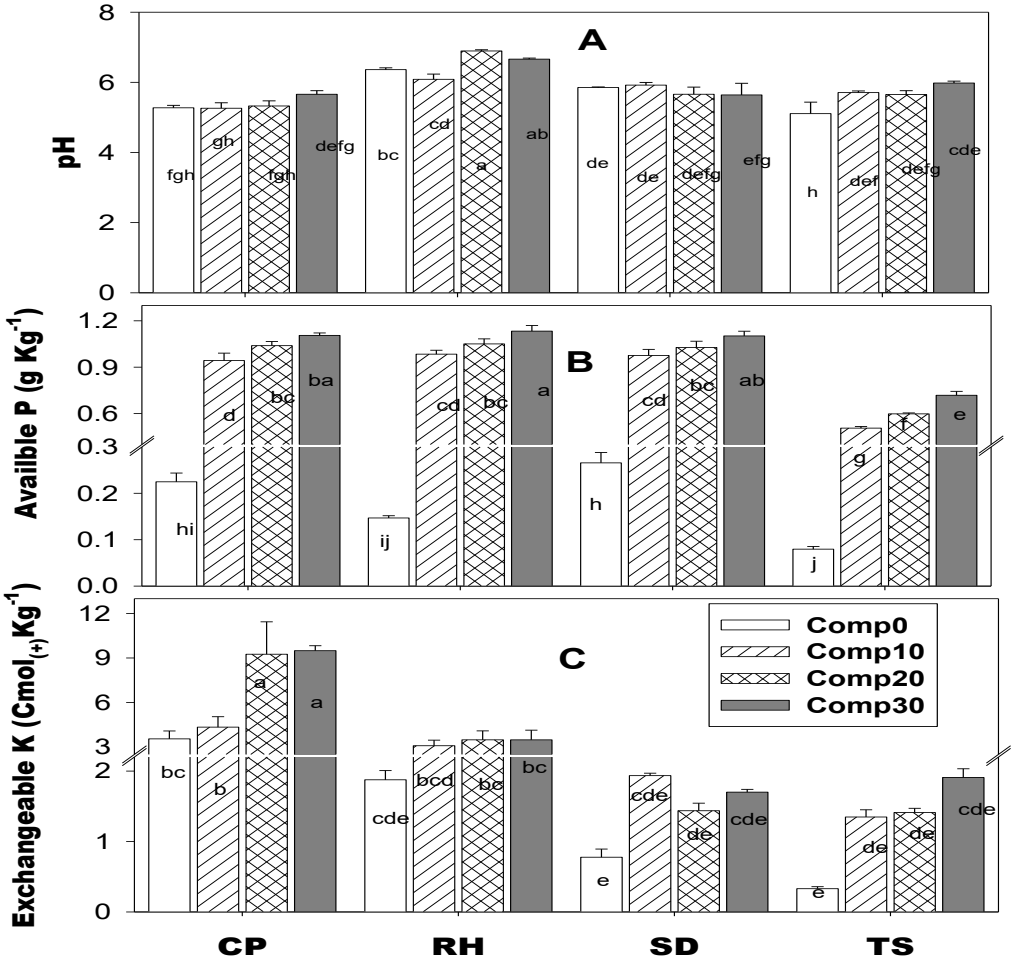

Figure 2: pH (A) and residual levels of P (B) and K (C) in the different media and compost mixtures used for raising cocoa seedlings at the nursery for 42 weeks.

4.0. DISCUSSIONS

The use of agricultural wastes as potting media can support seedlings growth in the nursery and field performance after transplanting (Moyin- Jesu, 2008, and Adejobi *et al.,* 2013). The positive impacts of media types and or their combinations with compost on the growth and nutrient uptake of cocoa seedlings in this current study confirms the observations made in other studies (Sosu 2014, Ofosu, 2014). The superiority of Rice husk biochar in improving seedling growth is attributable to the availability of nutrient through microbial utilization of labile carbon component of the biochar (Nesbitt, 1997). The weights of media in the nursery polybags were over 50% less the weight of topsoil. This lightweight material allows for ease of conveyance of large number of seedlings over long distances for field transplanting.

The observed significant effects of RH and compost on the growth (Diameter and height) and biomass production (Shoot and root) of cocoa seedlings in this current study could be attributed to the bioavailability of vital nutrients in the compost and the biochar. Adejobi *et al.,* (2013), reported similar effect of compost on the growth of cocoa seedlings. This result indicates that the seedlings that were raised in RH with the compost rates are of higher growth quality and would have higher survival and growth rates after field transplanting than those raised in CP and SD and without compost. The observations made in this current study confirm earlier findings on seedlings of cocoa (Sosu, 2014), oil palm (Ofosu, 2014), *Terminalia Ivorensis* (Omokhua *et al.,* 2015) and plantain (Kumah, 2012).

Shoot: root ratio is a measure of robustness or balance between the transpirational area (shoot) and the water absorbing area (root) of the seedlings. It is therefore a good indicator of internal water stress because shoot and root sizes directly affects water loss and uptake. Seedlings with lower shoot: root ratio is able to survive better. Though the higher rates of compost addition increased shoot and root biomass production significantly, shoot: root ratio was not affected by the compost addition. This indicates that the seedlings were robust and had a good balance between the transpirational area and water absorbing area and therefore had higher survival potential after transplanting.

It is observed in this study that cocoa seedlings leaf area increased with increasing compost rate. This emphasizes the importance of the compost in providing nutrient for the growth of the cocoa seedlings (Sosu, 2014). Ofori-Frimpong *et al.,* (2010), reported better cocoa seedlings growth with the use of compost developed from cocoa pod husk as potting medium. However, on the contrary, they observed that potting media with fertilizer additions significantly produced narrower leaves. The high leaf biomass production and nutrients content of cocoa seedlings in RH with Comp3 could be attributed to the chemical composition of the compost and biochar and ability to retain and release nutrients for plant uptake.

Compost addition improved the chemical properties of the different media types by enhancing efficient nutrient utilization and thereby increased growth of seedlings (Shamshuddin *et al.,* 2004). The addition of compost to the organic media also created favourable environment for plant and root growth. The observed increase in chemical composition of the growing media and the growth performances of the cocoa seedlings in the organic residues and compost combinations compared to their sole use could be attributed possibly to enhancement of their degradation rate by the compost and the lower C/N ratio of the RH and CP compared SD.

5.0. CONCLUSION

The agricultural wastes are effective sources of nutrients because their use as potting media with compost enhanced the growth and nutrient uptake of cocoa seedlings. Saw dust was the least effective while the amended RH and CP with compost improved their effects on these above-mentioned parameters for cocoa seedlings. It is therefore recommended that agricultural residues these agricultural residues with compost fertilizer are useful potting media for improving the nutrient availability and ensuring sustainable production of cocoa seedlings on lowly fertile soil in humid tropics. Evaluation of different combinations of Rice husk biochar and cocopeat with compost should be further investigated to as the main soilless media for raising cocoa seedlings in Ghana.

7.0. References:

Adejobo KB, Famaye AO, Akanbi OSO, Adeosun SA, Nduka AB, Adeniyi DO. 2013. Potentials of cocoa pod husk ash as fertilizer and liming materials on nutrient uptake and growth performance of cocoa. *Research Journal of Agriculture and Environment Management* 2 (2): 243-251.

Anda M, Shamshuddin J, Fauziah CI, Syed-Omar SR. 2010. Increasing the organic matter content of an Oxisol using rice husk compost: Changes in the composition and its chemistry. *Soil Science American Journal* 74: 1167-1180.

Kumah KH. 2012. Effect of type of initiation and growing media on growth and nutrient uptake of plantain (*Musa* aab) at the nursery stage. Mphil. Thesis University of Ghana, Legon.

Moyin-Jesu EI. 2008. Comparative evaluation of different organic fertilizers on the soil fertility, leaf mineral composition and growth of Dike Nut (*Irvingia gabonensis*). *Emirates Journal of Food and Agriculture* 20 (2):1-9.

Nesbitt HJ. 1997. Rice production in Cambodia; Ed.; International Rice Research Institute: Manilla, Philippines, 1997; pp. 15–29.

Ofori-Frimpong K, Afrifa AA, Acquaye S. 2010. Relative efficacy of cocoa pod husk-based compost on growth and nutrient uptake of cocoa seedlings in the nursery. *Ghana Journal of Agricultural Science* 43: 1

Ofori-Frimpong K, Afrifa AA, Akrofi AY, Sarfo JE. 2007. Development of cocoa pod husk-based compost for nursing cocoa seedlings. In: Proceedings, 15th International Cocoa Research Conference, San Jose, Costa Rica.;pp 1635-1644.

Ofosu AKB. 2014. Response of Oil Palm (*Elaeis Guineensis Jacq*) seedlings to different growing media and fertilizer rates at the nursery stage. A Thesis Submitted to the University of Ghana, Legon in Partial Fulfillment of the Requirements for the Award of Master of Philosophy, Crop Science Degree

Omokhua GE, Ogu A, Oyebade BA. 2015. Effects of different sowing media on germination and early seedling growth of *Terminalia ivorensis* (A.Chev.). International journal of scientific and technology research. 4: 03

SAS .2002. SAS Institute Inc. Statistical Analysis System. Cary NC, USA. 2002-2008

Shamshuddin J, Muhrizal S, Fauziah I, Husni MHA. 2004. Effects of adding organic materials to an acid sulphate soil on the growth of Cocoa *(Theobroma cacao* L.) seedlings. *Science of the Total Environment* 323: 33-45.

Siregar CA. 2007. Effect of charcoal application on the early growth stage of *Acacia mangium* and *Michelia montana. Journal of Forest Research* 4 (1): 19–30.

Soil Survey Staff. 1999. Soil Taxonomy. A Basic System for Soil Classification for Making and Interpreting Soil Surveys.USDA. Handbook. № 436, Washington D.C.

Sosu, G. 2014. Growth of cocoa seedlings as affected by different growth media and different polybag sizes. A Thesis Submitted to the University of Ghana, Legon in Partial Fulfillment of the Requirements for the Award of Mphil (Crop Science) Degree.