

Effect of media type and compost mixtures on nutrient uptake and growth of cocoa (*Theobroma cacao* L.) seedling in the nursery

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Abstract

This experiment investigated the effect 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 (133.2 cm²) than in TS (98.1 cm²). 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 grown 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). Seedling height and girth as well as shoot and root biomass were higher with higher 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). The residual nutrients were significantly ($p < 0.05$) higher with higher compost rate. The combined effect of RH with Comp3 significantly ($p < 0.05$) increased pH and available P of the potting media. The results showed that rice husk biochar mixed with either 400g or 600g of the compost was the most suitable medium for raising cocoa seedlings as it produced seedlings with adequate foliar and residual nutrients which could support vigorous growth and plant survival after transplanting. 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, coco peat, rice husk biochar, cocoa

Introduction

The production of cocoa in Ghana is threatened by unproductive trees in over-aged farms. Rehabilitating these old farms will require raising millions of seedlings for transplanting and this will also require large quantities of topsoil for the nursery works. The use of topsoil only as potting medium will destroy the ecosystem of the areas where the topsoil is collected (Siregar *et al.*, 2002). The use topsoil alone will also require additional inorganic fertilizers 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 successfully used as alternatives to topsoil as potting media (Anda *et al.*, 2010; 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 environmental problems associated with 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 nurseries in Ghana. The objective of the study was to investigate the effect of four media types, viz: Sawdust (SD), Cocopeat (CP), Rice husk biochar (RH) and Topsoil (TS) used alone or in a mixture with four rates of compost on nutrient uptake and growth of cocoa seedlings under nursery conditions.

Materials and Methods

The experiment was carried out at Kade (6 °.0854'N and longitude 0° 5400W) in the deciduous forest agro-ecological zone of Ghana. The soil at the experimental site has been classified as Udisols in Soil Taxonomy (Soil Survey Staff, 1998). The weight of the four media types per polybag were; 0.60 Kg, for SD, 0.86 Kg, for CP, 0.87 Kg, for Rice husk RH biochar and 2.70 Kg for Topsoil TS. Four rates of municipal solid waste (MSW) compost, viz: 0g (Comp0), 200g (Comp1), 400g (Comp2) and 600g (Comp3) were mixed with each of the media types. The formulated media were used to fill nursery polybags measuring 17.3cm in diameter and 23.3cm in length (Ofori-Frimpong *et al.*, 2007). The various media were watered thoroughly and allowed for 72 hours to stabilize before sowing the cocoa seeds. Hybrid cocoa seeds were sown at a seeding rate of two per polybag which were later thinned to one seedling per polybag. The treatments were arranged in a complete randomized design with four replications and 20 plants per experimental unit.

At 42 weeks after sowing (WAS), stem height and girth were measured and height:diameter ratio was calculated. Leaf area was measured with a leaf area meter (YMJ-A). Seedlings were then harvested for the determination of shoot, root and leaf biomass. Shoot: root ratio was calculated as dry weight of leaves plus stem divided by the dry weight of root (g/g). Nutrient contents of the leaves and in the potting media were also determined at the end of the experiment.

Statistical analyses were done using Statistical Analysis System 9.2 (SAS 2002). All the data collected were subjected to analysis of variance (ANOVA) followed by Fisher's protected least significant difference test.

Results

Chemical properties of potting media

The results of the analysis indicated that the soil at experimental site was slightly acidic with moderate level 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: 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 ⁻¹	Mg Cmol ₍₊₎ kg ⁻¹
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	1.4
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	2.20	0.75	55.5	11.7

Media and compost effect on cocoa seedling growth

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 were higher in media with higher compost rates. Height: diameter ratio was not affected by compost rates but height and diameter and their ratio were higher with higher 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).

Media and compost effect on biomass production of cocoa seedlings

Leaf 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 leaf biomass were found between seedlings grown in TS and those in RH (Table 4). The N, P and K contents in the leaves of the seedlings grown in RH and TS were significantly ($p < 0.05$) higher than those grown in CP and SD (Table 4). Generally, leaf biomass of the seedlings treated with Comp3 was significantly ($p < 0.05$) higher than those

treated with all other compost rates (Table 3). The N and K contents in plants grown with Comp3 was significantly ($p<0.05$) higher than those in other compost rates. Leaf P content in Comp3 was significantly ($p<0.001$) higher than the other treatments (Table 3).

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

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

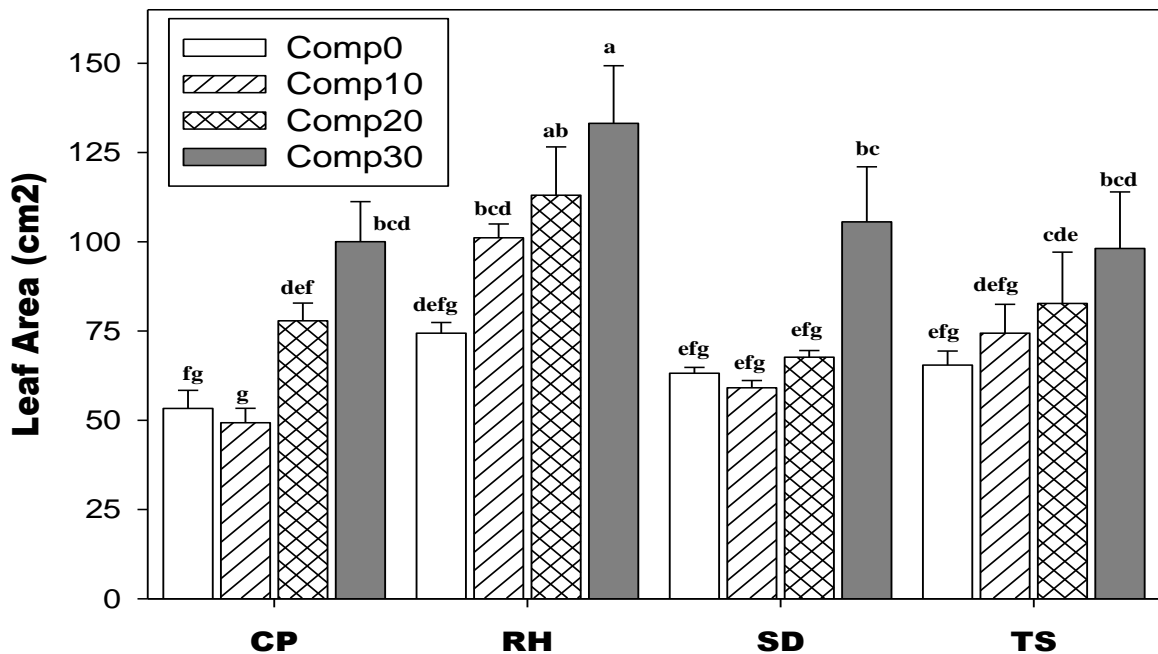


Figure 1: Effects of media types and compost rates on leaf area of cocoa seedlings at 42 weeks after sowing (Bars indicate standard errors)

Shoot and root biomass of seedlings grown in TS and RH were 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 raised with Comp3 was significantly higher than those treated with Comp1 and Comp0. Root biomass of seedlings raised 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 3: Leaf biomass and nutrient content (g plant⁻¹) of cocoa seedlings grown with different media types and compost rates

	Leaf biomass	Nitrogen	Phosphorus	Potassium
Media type				
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

Table4: Shoot and root biomass and shoot-root ratio of cocoa seedlings grown in different media and compost rates at 42 weeks after sowing

Media Types	Shoot weight (g plant ⁻¹)	Root weight (g plant ⁻¹)	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 nutrients in the amended media

Residual nitrogen in CP and RH were significantly ($p < 0.02$) higher than those in SD and TS (Table 5). Residual N of potting media which contained Comp3 was significantly ($p < 0.03$) higher than those supplied with Comp1 and Comp0 Whiles

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, Exchangeable Mg and Ca of the potting mixtures as influenced by the media type and compost rates after 42 weeks of cocoa seedlings growth

Media type	TN (g Kg ⁻¹)	Mg (Cmol ₍₊₎ Kg ⁻¹)	Ca (Cmol ₍₊₎ Kg ⁻¹)
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 the other media combinations. Potting media which contained SD with Comp0 and Comp1 were significantly ($p<0.05$) higher in pH than those which contained TS and CP with same compost combinations (Figure 2A). Residual available P in RH with Comp3 was significantly ($p<0.05$) higher than the other treatments (Figure 2B). Residual K was significantly ($p<0.03$) higher in potting media which contained 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 the other three media types with the same compost rates (Figure 2C).

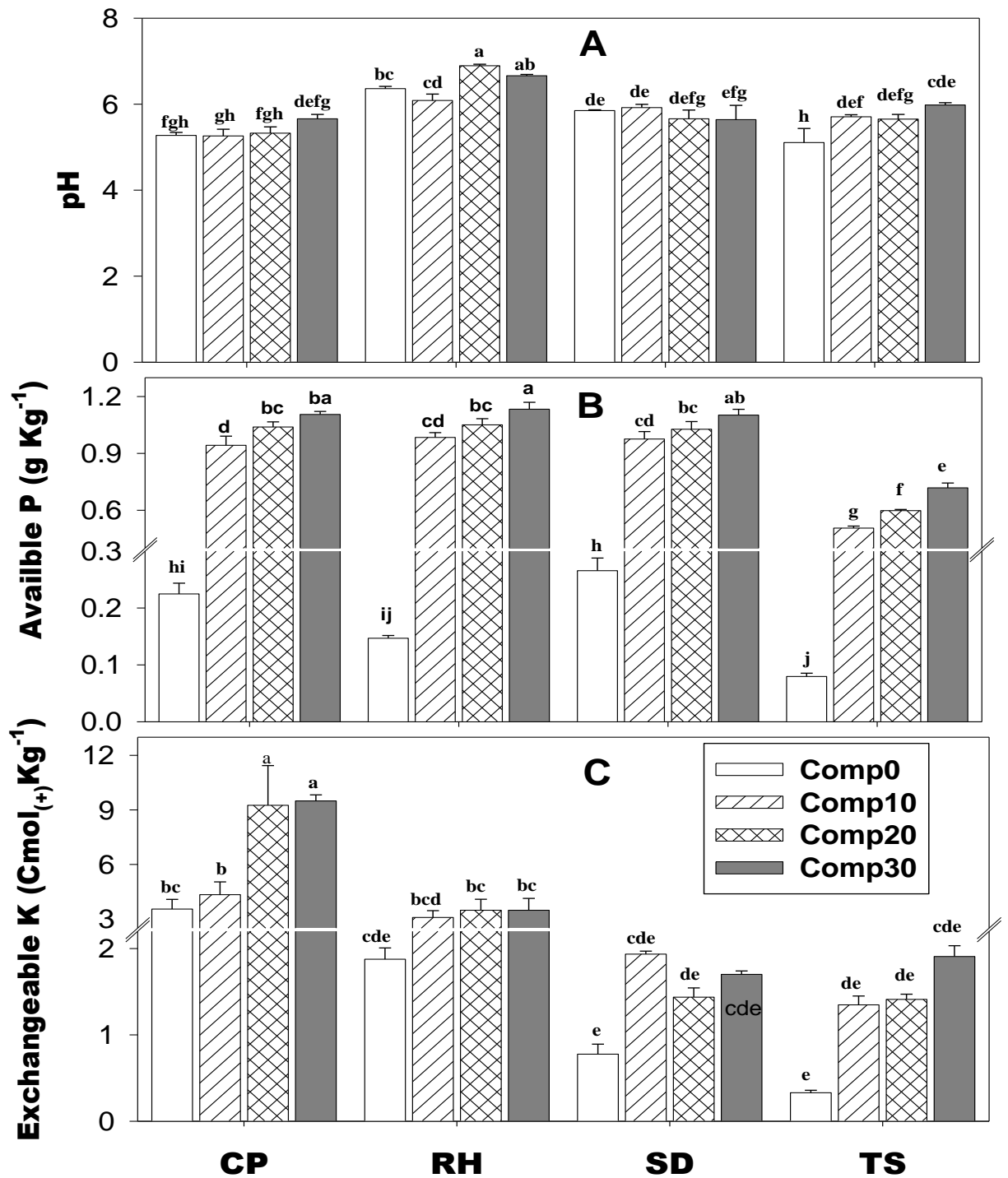


Figure 2: pH (A) and residual levels of P (B) and K (C) in the different media and compost mixtures used for raising cocoa seedlings at the nursery for 42 weeks

Discussions

The use of agricultural wastes in the preparation of potting media can support seedlings growth in the nursery and their survival after transplanting (Moyin-Jesu, 2008; 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; Ofofu, 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 positive effects of RH and compost on the growth (Diameter and height) and biomass production (Shoot and root) of cocoa seedlings observed in this 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 also indicated that the seedlings that were raised in RH with the compost rates improved the growth of the seedlings. The results of this study is similar to earlier findings on cocoa seedlings (Sosu, 2014), oil palm seedlings (Ofofu, 2014), *Terminalia ivorensis* (Omokhua *et al.*, 2015) and plantain (Kumah, 2012).

Shoot: root ratio is a measure of robustness or balance between the shoot and the 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 have better survival rates after transplanting (Haase, 2007). Though the addition of higher rates of compost significantly increased shoot and root biomass, shoot: root ratio was not affected by the compost addition. This indicates that the seedlings were robust and had a good balance between the shoot and the root and therefore had higher survival potential after transplanting. It was observed that the leaf area of cocoa seedlings increased with higher compost rates. This shows the importance of compost in providing nutrient for the growth of the cocoa seedlings (Sosu, 2014). Ofori-Frimpong *et al.* (2010) found improved growth of cocoa seedlings with the use of compost developed from cocoa pod husk. The high leaf biomass and nutrients contents of cocoa seedlings in RH with Comp3 could be attributed to the chemical composition of the compost and the ability of biochar 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 provided favorable rhizosphere condition for root development and seedling 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 to enhancement of their degradation rate by the compost and the lower C/N ratio of the RH and CP compared SD.

Conclusion

The amended rice husk biochar and coco peat with compost improved the growth and biomass production of cocoa seedlings in the nursery. They also retained sufficient residual nutrient which could support seedling survival and establishment in the field after transplanting. The use of rice husk biochar and coco peat amended

with compost is therefore recommended as a suitable potting media for raising cocoa seedlings in Ghana. Further evaluation of different combinations of biochar, coco peat and compost at different rates as potting media for raising cocoa seedling is suggested.

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References:

- Adejoko, 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.
- Haase, D L. (2007) *Morphological and Physiological Evaluations of Seedling Quality In: Riley, L. E.; Dumroese, R. K.; Landis, T. D., tech. coords. 2007. National proceedings: Forest and Conservation Nursery Associations—2006. Proc. RMRS-P-50. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.*
- 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.
- Ofori, 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.