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Effect of some organic, inorganic and foliar fertilizers on the growth of cocoa (*Theobroma cacao* L.) seedlings raised in soils of contrasting characteristics

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The establishment of cocoa farms has been popular with the use of nursed seedlings in polybags. Availability of fertile topsoil for nursing cocoa seedlings is becoming limited and poor seedling growth of cocoa in the nurseries has been ascribed to the use of unsuitable potting media. A search for an alternative means of raising healthy seedlings at the nursery that will accelerate seedling growth is what this trial investigates. The experiment was laid out in 2 x 5 factorial arranged in Completely Randomized Design with four replications. Two soils, 'Black soil' obtained from a refuse dump and topsoil of Wacri series, collected from an old cocoa farm were used. Five fertilizer sources, control, inorganic, organic and two foliar fertilizers were used. Seedlings were raised from mixed hybrid cocoa and assessed at bi-weekly intervals for 14 weeks for growth. Initial soil analyses showed that the Black soil was relatively fertile compared to the Wacri series. Percent seedling emergence was initially higher with the unfertilized soil than the fertilized. Dry matter yields of roots and leaves were significantly (p<0.05) affected by the fertilizer. Application of fertilizers had no significant (p>0.05) effect on stem dry matter yield. Finally, seedlings from the Black soil which had higher initial fertility status performed better than those of Wacri series. With the different fertilizers on the growth performance and dry matter production, foliar fertilizer treatments performed better compared with the organic and inorganic fertilizers. From the experiment, it is concluded that the well decomposed Black soil from the refuse dump remains the best medium for the nursery work, but in the absence of this medium, less fertile topsoil could be used for raising cocoa seedlings and the growth boosted with foliar fertilizers.

INTRODUCTION

Cocoa production in Ghana is limited by soil nutrient depletion after many years of cultivation. The establishment of cocoa farms normally begins with the raising of seedlings in nurseries using topsoil from refuse dumps known as ‘Black soil’. This type of soil cannot effectively support cocoa seedling growth in the nursery currently, because it is basically made up of non-degradable materials. An alternative attempt is to use topsoil but such soils are mostly deficient in P, K, Ca, Mg and ECEC (Rhodes, 1995). Poor growth of cocoa seedlings in the nursery has been ascribed to the use of unsuitable potting media and also the problem of getting adequate quantities of fertile topsoil for potting cocoa (Donkor *et al*., 1991; Ofori-Frimpong *et al*., 2006). Under the current cocoa rehabilitation programme in Ghana, most farmers who prepare nurseries from seed pods collected from the Seed Production Division of COCOBOD use different types of soils from their farms for filling the polybags because of scarcity of fertile topsoil. These soils differ in their fertility status, which also impact negatively on the growth of cocoa seedlings. There is, therefore, the need to look for ways of improving the growth of cocoa seedlings in the nursery, and young cocoa after transplanting in the field. One such way is to apply foliar fertilizers to seedlings in the nursery and after transplanting. Foliar fertilizers have multiple advantages. These include efficient and timely method of applying and enhanced nutrient utilization. Moreover, the application rates are low, and their effects are usually independent of soil conditions (Kolota and Osinska, 2001). Cocoa pod husk-based compost was used to raise cocoa seedlings at the nursery in Ghana (Ofori-Frimpong *et al*., 2010; Mensah-Brako, 2011) and Nigeria (Ayeni, 2008). The use of organic materials in potting media will not only improve the growth performance of cocoa seedlings but also improve the quality of soil used for raising the seedlings (Adejobi, *et al*., 2013). The use of inorganic fertilizers is the most effective and convenient way to improve the fertility of nutrients poor soils. Inorganic fertilizers are known to contain readily available plant nutrients which are released to plants rapidly after application. The work by Gockowski *et al*. (2004) indicated that cocoa seedlings need nitrogen, phosphorus, potassium and metabolites such as proteins, lipids, carbohydrates for their growth. Thus it is important that young nursery seedlings and transplanted seedlings are in optimal condition as far as their nutrient and energy status are concerned. Though, there are studies reported on utilization of organic fertilizers especially cocoa pod husk for raising cocoa seedlings (Odedina *et al*., 2007; Ayeni, 2008; Ofori-Frimpong *et al*., 2010) there is limited research information on how different fertilizers especially foliar fertilizers can effectively be utilized to boost the growth of cocoa seedlings in nutrients poor soils in Ghana (Oppong *et al*., 2008). The objective of this study was therefore, to determine the effect of different fertilizer sources on the growth performance of cocoa seedlings raised in soils of different fertility status in the nursery.

2.0 MATERIALS AND METHODS

2.1 Study site

The experiment was conducted at the main nursery of the Cocoa Research Institute of Ghana, New Tafo (latitude 6°13’ N, longitude 0°22’ W, altitude 222 m above sea level) with a total land area of 4,3027 km.

2.2 soil sampling analyses

Two soils of different fertility status were sampled and used for this investigation. Topsoil (0-15 cm depth) collected from an old cocoa plot (R5) and the other soil known as ‘Black soil’ collected from a refuse dump were used for the experiment. The soil from the old cocoa plot has been classified as Rhodic-Lixic Ferrasol (WRB, 2014) and belongs to the Wacri soil series according to the Ghanaian system of classification (Dwomo and Dedzoe, 2010). Samples of the soils were air-dried and sieved through a 2 mm mesh and stored for analysis of their chemical properties. Soil pH was determined using the glass electrode at soil: water ratio of 1:2.5 (McLean, 1982), organic carbon was by the Walkley and Black wet oxidation method (Nelson and Sommers, 1982) and total N by the Kjeldahl digestion and distillation method (Bremner and Mulvaney, 1982). Available phosphorus was determined by the Troug method (Troug, 1930). Exchangeable K, Ca and Mg were extracted with 1*N* ammonium acetate solution and the leachate analyzed by the Atomic Absorption Spectrophotometer (Thomas, 1982).

2.3 Nursery studies

Bulk soil samples were passed through 8 mm mesh. Sub samples of each soil type were used to fill the standard polybags with dimensions 18 cm x 25 cm (Ofori-Frimpong *et al*.,2006; Oppong *et al*.,2008) which had earlier been perforated at the bottom edges to enable perfect drainage of water. The soils were either mixed with organic or inorganic fertilizer. Samples of the soil-fertilizer mixtures were sent to the laboratory for analyses. The treatments tested were two soil types (Black soil and Wacri series) and five fertilizer sources (control, conventional NPK 3:5:5, Green grow organic compost, Foliar NPK 22:16:18+TE and Foliar NPK 15:8:33+TE). The compost was mixed with the soils at the ratio of 3:1 while the foliar fertilizers were applied at 12 g/ 15 litres of water. The inorganic fertilizer was applied at 33.5 g/ 3 kg soil. Mixed hybrid cocoa seeds were sown at a seeding rate of two per polybags which were thinned to one seedling per polybags one month after sowing. The foliar fertilizers were sprayed on the seedlings at bi-weekly interval using pneumatic knapsack sprayer. Each treatment had thirty seedlings and the experiment was laid out as a 2 x 5 factorial arranged in Completely Randomized Design (CRD) with four replications. Seedling girth, height and dry matter production were measured at bi-weekly intervals for 14 weeks.

2.4 Data analysis

Data collected were subjected to analysis of variance (ANOVA). Treatment means were compared using the least significant difference (LSD) at α = 0.05. All statistics were performed using GenStat Statistical Package (GenStat, 2008).

3.0 RESULTS

3.1 Initial properties of the soils and fertilizers

The Wacri soil series had a pH of 6.1 which is slightly acidic while the Black soil was slightly basic with pH of 7.8. Percent organic carbon in the Black soil (1.75%) was five times higher than the Wacri series (0.31 %). Nitrogen content in the Black soil (0.19%) was higher than the Wacri series (0.04%). The available phosphorus was higher in the Black soil than the Wacri series. The concentration of the available phosphorus in the Black soil was sixty-four times higher than the concentration in the Wacri series. Basal cations (K, Ca and Mg) were all higher in the Black soil than the Wacri series. The pH of Green grow (7.3) was neutral. Total N content was low (0.01%) but phosphorus (5380.7 mg kg^{-1}) and exchangeable Mg (6.56 cmol kg^{-1}) contents were very high. The two foliar fertilizers have high nitrogen, phosphorus and potassium contents (Table 1). In addition to the macro nutrient elements, boron, iron, manganese, molybdenum and zinc were trace elements included in the formulations. The inorganic (N:P:K 3:5:5) was formulated using the following primary fertilizers.; Sulphate of Ammonia, Triple Super phosphate and Muriate of potash.

Table 1: Some chemical properties of the soils and fertilizers used for the experiment

Soil type	pH	%OC	%N	P (mg kg^{-1})	K	Ca cmol kg^{-1}	Mg
Black soil	7.8	1.75	0.19	776.10	0.97	1.20	3.51
Wacri soil series	6.1	0.31	0.04	12.80	0.70	0.90	2.74
Inorganic fertilizer	-	-	3.00	5.00	5.00	-	-
Green grow compost	7.2	0.02	0.01	5380.70	17.2	0.11	6.56
Foliar fertilizer 1	4.9	-	22.00	16.00	18.00	-	-
Foliar fertilizer 2	5.4	-	15.00	8.00	33.00	-	-

3.2 Changes in soil chemical properties following the application of organic and inorganic fertilizers

There was reduction in the pH from 7.8 to 7.2 of Black soil following the addition of inorganic fertilizer while the application of Green grow did not change the pH of the soil. The pH of Wacri series also reduced from 6.1 to 5.9 with the application of inorganic fertilizer but Green grow increased the pH to 7.5. The additions of Green grow increased the percent carbon contents in both soil types. Green grow raised the nitrogen contents in the soils compared with the inorganic fertilizer treated soils. Again, available phosphorus in Green grow treated soils was higher compared with the inorganic fertilizer treated soils. This trend was similar for all the basal cations measured.

Table 2: Some chemical properties of the soils amended with organic and inorganic fertilizers

Soil type	pH	%OC	%N	P (mg kg^{-1})	K	Ca (cmol kg^{-1})	Mg
Black soil	7.8	1.75	0.19	776.10	0.97	1.20	3.51
Wacri series	6.1	0.31	0.04	12.80	0.70	0.90	2.74
Black soil + Inorganic	7.2	1.79	0.22	844.70	3.15	3.20	3.24
Black soil + Green grow	7.8	3.00	0.47	951.42	4.98	4.00	3.62
Wacri series + Inorganic	5.9	0.39	0.11	600.79	1.60	1.20	0.74
Wacri series + Green grow	7.5	2.67	0.47	1024.87	4.92	4.20	3.29

3.3 Seedling emergence

Seedling emergence was initially higher in the soil types alone and soils treated with Green grow. Poor seedling emergence was recorded in soils treated with inorganic fertilizer within the 14 days. There were 100% seedlings emergence at 21 days after sowing for the Black soil and its combination with Green grow or inorganic fertilizer and Wacri series alone. Twenty percent of seeds raised in the Wacri series treated with either Green grow or inorganic fertilizer were found dead in the soil after digging them up for usual observation.

Table 3: Percent seedling emergence in the different growth media at 14 and 21 days after sowing

Growth media	14 days after sowing	21 days after sowing
Black soil	100	100
Black soil + Green grow	90	100
Black soil + NPK	35	100
Wacri series	94	100
Wacri series + Green grow	17	80
Wacri series + NPK	29	80

3.4. Seedling girth and height

The mean girth of the cocoa seedlings was significantly ($p<0.05$) biggest in the Black soil and smallest in the Wacri series at the end of the 14th week. Application of fertilizers significantly ($p<0.05$) influenced seedling girth with the foliar NPK 15-8-33+TE recording the biggest stem and the Green grow compost treated seedlings the smallest. Similar to the seedling girth, plant height was significantly ($p<0.05$) tallest under the Black soil and shortest for the Wacri soil series. The unamended control and the foliar fertilizer treatments gave significantly ($p<0.05$) tallest plant height compared to the Green grow and the inorganic NPK fertilizer treatments.

Table 4: Mean girth and height of cocoa seedlings grown in different soil types and treated with various fertilizers at 14 weeks after sowing.

Soil type	Girth (mm)	Height (cm)
Black soil	6.30A	39.17A
Wacri series	5.79B	35.50B
Fertilizers		
Control	6.05A	42.48A
Foliar NPK 22-16-18	6.03A	40.21A
Foliar NPK 15-8-33	6.22A	42.31A
Green grow compost	5.86B	30.83B
Inorganic NPK (3:5:5)	6.08A	30.73B

Means in column followed by the same alphabet are not significantly different at $p<0.05$.

3.5 Dry matter production

The mean roots dry weights per seedling was significantly ($p<0.05$) highest under the Black soil treatment and lowest for the Wacri soil series. Cocoa seedlings treated with foliar fertilizers gave the highest root dry matter compared to the other fertilizer treatments (Table 5). Stem dry matter yield was not significantly ($p>0.05$) influenced by either soil types or fertilizers at the end of the study period. Considering leaf dry weights, seedlings raised in Black soil emerged the highest with the Wacri soil series the lowest. Seedlings sprayed with foliar fertilizers recorded significantly ($p<0.05$) the highest leaf dry weight with the Green grow and inorganic NPK fertilizers the lowest. Similar trend was recorded for the total dry matter production (Table 5).

Table 5: Dry matter production (g plant $^{-1}$) of cocoa seedlings grown in different soil types and treated with various fertilizers at 14 weeks after sowing

Soil type	Stem	Leaves	Root	Total
Black soil	1.47A	2.47A	0.68A	4.62A
Wacri series	1.33A	2.11B	0.48B	3.92B
Fertilizers				
Control	1.47A	2.33A	0.68A	4.48A
Foliar NPK 22-16-18	1.68A	2.75A	0.66A	5.09A
Foliar NPK 15-8-33	1.57A	2.54A	0.70A	4.81A
Green grow compost	1.48A	1.94B	0.37B	3.79B
Inorganic NPK (3:5:5)	1.23A	2.00B	0.50B	3.73B

Means in column followed by the same alphabet are not significantly different p<0.05

4.0 DISCUSSION

Proper seedling growth is usually dependent on the potting media in which the seedlings are raised. The organic carbon contents of the Black soil could be described as medium whilst that of the Wacri series as very low. This is because the values obtained were below the 3% considered adequate for good cocoa growth (Ahenkorah 1981). The low organic carbon of the Wacri series meant that nutrient supply to the seedlings would be difficult. Nitrogen content of the Wacri series was substantially lower than the critical level of 0.09 % required for cocoa cultivation (Ahenkorah, 1981; Egbe *et al*., 1989). Wacri soil series had the least mean available phosphorous concentration and was lower than the optimum level of above 20 ppm required for cocoa cultivation (Egbe *et al*., 1989; Ogunlade *et al*., 2006). Mechanical analyses indicated that the soils have high sand content and this has implication on their ability to retain moisture and the release of plant nutrients. The pH of the soils changed with the incorporation of the soil amendments. The addition of Green grow organic media improved the fertility status of the less fertile Wacri series. This finding was similar to that of Moyin-Jesu (2007) who reported the nutrient superiority of organically amended fertilizers compared to the ordinary forms of the materials. Arthur *et al*. (2019) also found an improvement in soil chemical properties following the application of Municipal Solid Waste compost to less fertile topsoil. Application of organic fertilizer mineralizes and releases nutrients to the soil. The reduction in soil pH following the application of the NPK fertilizer could be attributed to the acidifying effect of sulphate of ammonia in the formulation (McCauley *et al*., 2017).

The low initial seedling emergence recorded in the two soil types treated with NPK fertilizer could be ascribed to the acidic condition created by the sulphate of ammonia fertilizer in the formulation. Although Wacri soil series treated with Green grow gave very fertile medium, there was generation of heat in the growth medium and this affected the early seedling emergence. The rest of the treatments performed better because the conditions in the growth media were optimal for the seedlings to germinate and emerge. Considering the dry matter production, the greatest proportion was in the leaves, followed by the stem and then the roots. This is somehow contrary to the findings of Owusu-Aduomi and Frimpong (1985), who found the greatest dry matter yield in the stem followed by the leaves and then the roots. The differences in the dry matter yield distribution observed were attributed to the differences in the formulations of the foliar fertilizers. The foliar with high potassium concentration (NPK 15-8-33+TE) increased the root dry weights over the foliar with high nitrogen concentration (NPK 22-16-18+TE). As noted by (Egbe *et al.*, 1989) high potassium affects plant metabolism, carbohydrate formation and translocation of starch to all parts of the seedlings. Under water stress, K-treated plants had increased root and shoot biomass, higher leaf water content, higher chlorophyll fluorescence and reduced electrolyte leakage from leaves leading to improved vigour (Djan *et al*., 2017). On the contrary, foliar fertilizer with high nitrogen concentration increased the leaf dry weights of the seedlings. This is in line with the findings of Lockwood and Asomaning (1963), who also found increase leaf dry matter yield with the application of fertilizer with high nitrogen source. The very good performances of seedling growth recorded on soils with the foliar fertilizers may be due to the fact that the optimum soil conditions were supported with nutrients from the foliar fertilizers. With the addition of NPK fertilizer, the changes in the fertility status did not increase much but this soil performed worse than the soil without any fertilizer added. This may be attributed partly to the changes in pH. Similar observation was made by Ofori-Frimpong *et al*. (2010) who found a depressive effect of cocoa seedling growth following the application of inorganic NPK fertilizer. Although the incorporation of Green grow improved the initial fertility status of the soils, the C:N ratio narrowed to 3:1 which was not conducive for soil microbial activities.

5.0 CONCLUSION

It is concluded that, the soil from the refuse dump remains the best soil for the nursery work. This could be supported by the application of foliar fertilizers to boost the growth of seedlings and also reduce the time seedling spent in the nursery before they are planted out in the field. In the absence of soils from the refuse dump which is well decomposed, the surface soils from any secondary forest could be used and supplemented with foliar fertilizers to increase dry matter production and growth performance of cocoa seedlings. Soils with the incorporation of inorganic NPK or soil amendments like Green grow have depressive effects on the seedlings.

Competing interests

The authors have declared that no competing interests exist.

Authors' contributions

This work was carried out in collaboration among all authors. Author Alfred Arthur handled the data compilation, performed the statistical analysis, and wrote the final manuscript. Author Solomon Acquaye designed the experiment and wrote the first draft of the manuscript. Author Jerome Agbesi Dogbatse managed the literature search and read proof the final manuscript. Authors Alfred Arthur and Jerome Agbesi Dogbatse read and approved the final manuscript.

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