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Comparative Growth Response of Maize on Amended Sediment from the Odaw River and Cultivated Soil

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Abstract Pot experiment to determine the agronomic performance of maize was carried out in a randomized complete block with nine pots per block and three replicates using sediment from Odaw River and soil from cultivated field in Ghana. The sediment only (BS), soil only (S) and soil-sediment composite (S+BS) were each amended with poultry manure (PM), cow dung (CD) and biochar (BC), then maize (*Obatanpa* variety) grown for 45 days. Plant height, leaf length, girth and width were measured weekly. The dredged sediment from the Odaw River was found to be good and quite similar to the soil from the cultivated field in terms of organic matter, organic carbon and macro nutrients. For the sediment, the heavy metals comprising of Fe, Pb, Zn, Cu and Cd had concentrations (mg/l) 3.48, <0.005, 0.073, 0.010 and <0.002 respectively. For the soil only the heavy metal concentration of Fe, Pb, Zn, Cu and Cd had concentrations (mg/l) 7.13, <0.005, 0.348, 0.067 and <0.002 respectively. Maize performed well on the amended soil than the amended sediment from the Odaw River. The fresh shoot weight of maize grown on the cultivated soil at the end of the 45 days period was between 101.8 g and 182.3 g and that of the sediment was 56.0 g and 131.0 g, respectively. The soil-sediment amended treatment showed an enhanced growth but slightly lower than the soil amended treatments at the end of the growth period. Individual growth parameters measured at the end of the experiment also showed growth pattern which followed the overall growth order. Heavy metal concentrations in both the sediment and the cultivated soil were within tolerable limits, though the soil from the cultivated field had higher concentrations.

Keywords: *Odaw river, maize, sediment, amendments, cultivated soil*

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1. Introduction

Sedimentation in lakes and streams is a major problem worldwide. Significant amounts of eroded sediments can be stored in channel beds and flood-plains before suspended sediments are routed to the watershed outlet [1]. One obvious alternative to get sediments out of riverbed is underwater dredging or excavation of the deposited material. Dredged sediment had traditionally been considered as a waste material to be disposed of as cheaply as possible. The basic chemical and physical properties of these dredged sediments vary widely based on their depositional environment and watershed characteristics. The age of the dredged sediments is also important on the suitability of the sediment to be used for agriculture. It had been observed by [2] that, exposure and weathering of highly sulfidic dredged sediments produce extremely acid soil conditions with mineral release, while materials dredged from marine or brackish environments would necessarily contain entrained salts and sodium that will need to be leached before conversion into viable top soil material.

Eroded soil particles are influenced by many factors in water environment that may change their quality especially from the viewpoint of elements and substances [3]. The sediments may also serve as the sink for the deposition of pollutants in river basins [4]. It may be loaded with potentially toxic substances in situations where it is connected with the presence of polluting sources like industrial, urban zones and waste outputs. Sediments that are loaded with potentially toxic substances leads to the difficulty of using the sediment in the same way as sewage sludge and other organically rich materials [5] since plants have the potential to take up pollutants from the soil. The potential contamination of the sediments by a wide spectrum of hazardous substances cannot be overlooked. In recent years however, dredged sediments have been shown to have potential use as soil for agricultural purposes [6,7]. Once sediments are dewatered they may have a wide range of uses such as agriculture, landscaping, construction and other beneficial purposes. The accumulation of nutrients and organic matter especially in ponds and downstream sediments provides good reason for the application of sediment in agriculture. Such uses would only apply based on facts that recovered sediment does not pose significant risks to human or ecological receptors.

The Odaw River in Ghana receives over 60% of Accra's untreated grey-water in addition to solid waste. Sediment from the Odaw River is loaded with excreta, refuse and effluent from both industries and domestic sources [8]. Squatters who live along the banks use this river as a dumping place for waste including human excreta thus, the Odaw River has high content of organic material. Section of the river was dredged in 2012 to remove the large amount of sediment that had been deposited due to both natural and anthropogenic factors and to reduce periodic flooding of parts of Accra. Initial analyses of the sediment from the Odaw River revealed its suitability for crop cultivation in terms of its limited heavy metal load. An experiment was therefore set up to compare the growth of maize (*Obatanpa* variety) on the sediment to soil from cultivated field which belongs to *Oyarifa series* (FAO classification, Haplic Lixisols and USDA Classification, Typic Rhodudalf) [29].

2. Materials and Methods

2.1, Soil and Sediment Sampling and Analyses

The pot experiment was conducted at the premises of the Soil Research Institute Accra Center, Ghana under field conditions. Soil samples were taken from the top 0-15 cm and 15-30 cm and homogenized. Dredged sediment was taken from three different locations along the Odaw River and sun dried for one week. The dried dredged sediment was crushed and all foreign material removed. The sediment was then sieved using a 2 mm sieve and mixed thoroughly. Portions of both the soil from cultivated field and the sediment were used for the determination of physical and chemical parameters (Table 1 and Table 2). Soil particle size analysis was determined by the pipette method as described by [9].

Table 1. Physical Analysis of Samples

Sample	Sand %	Silt %	Clay %	Texture
Oyarifa series	59	34	7	Sandy Loam
Sediment	30	65	5	Silt Loam

Table 2. Chemical Analysis of Samples

Parameters		Oyarifa series	Sediment
Depth		0-30	-
pH($H_2$0) (1:2.5)		6.11	6.80
Elect. Condt (dS/m)		0.12	0.28
Total N (%)		0.09	0.12
Avail. Phos. (mg/kg)		5.54	8.70
Avail. Potas. (mg/kg)		6.80	10.67
O/C (%)		0.81	1.44
O/M (%)		1.76	2.48
Exchangeable Cation (cmol(+)/kg	K	0.45	0.17
	Na	0.73	0.75
	Ca	1.40	2.32
	Mg	0.82	1.12
TEB		3.40	2.36
Exch. Acidity (Cmol(+)/kg) (Al+H)		0.08	0.20
ECEC (Cmol(+)/kg) (pH7)		3.51	2.56

The chemical analyses were determined as follow; Electrical conductivity (EC) and soil reaction (pH) were measured in 1:2.5 soil: water suspension. Total nitrogen was determined by the modified Kjeldahl method [10]. Available phosphorus and potassium contents in soils were extracted by Bray's P1 solution and measured by a spectro-photometer [11]. Organic Carbon was determined by the wet oxidation method of [12]. Exchangeable Bases were extracted with 1.0 M ammonium acetate solution at pH 7.0.

The sodium and potassium contents in the extracts were measured by flame photometry while calcium and magnesium in the same extract were determined by EDTA titration [13]. Thomas [14] method was used for the determination of Exchangeable Acidity. Effective cation exchange capacity (ECEC) was calculated as the summation of the various exchangeable cations and total acidity (exchangeable Al^{3+} + H^{+}). Atomic Absorption Spectroscopy (AAS) was used to determine the heavy metals concentrations in both the sediment and the cultivated soil after digestion [15] (Table 3).

Table 3. Heavy Metal Levels in Sediment and Cultivated Soil

Parameters (mg/l)	Fresh sediment	SE	Fresh Soil	SE
Fe	3.48	±0.1311	7.13	± 0.0265
Pb	<0.005	±0.0002	<0.005	±0.0001
Zn	0.073	±0.0072	0.348	±0.0026
Cu	<0.010	± 0.0020	0.067	±0.0010
Cd	<0.002	± 0.0003	<0.002	±0.0000

2.2. Experimental Setup

The experiment was carried out in pots of radius 14 cm and 29 cm height. The pots were filled each with soil from cultivated field (*Oyarifa* series), sediment and soil-sediment mixture leaving space on top. Nine pots were filled with 6 kg of soil only, another nine pots were filled with 6 kg sediment only and the remaining nine pots were filled with 2 kg sediment and 4 kg soil mixture. Three amendments of 2 t/ha of biochar, 6 t/ha of poultry and 6 t/ha of cow manure were added to the soil, soil-sediment and sediment only separately and mixed thoroughly with three replicates. The pots were initially irrigated to field capacity and allowed to drain overnight into a receptacle before planting. The drained water from the various treatments were recycled to prevent leaching. Three viable maize seeds (*Obatanpa* variety) were planted in each pot and thinned to two after germination. Watering was done every other day after germination. The plant height, leaf length, leaf width and girth were recorded weekly for six weeks as growth indices.

3. Results and Discussion

Proper growth of plants is related to the properties of the soil in which they grow since it is the source of water and mineral nutrients essential for growth. It also constitutes the medium for growth of the roots necessary for anchorage and for absorption of water and minerals used in growth which depends largely on soil texture and structure. The dredged sediment from the Odaw River was found to be good and fairly similar to the soil from cultivated field in terms of organic matter, organic carbon and most other soil chemical properties (Table 2). The soil from cultivated field was slightly acidic than that from the sediment, but available P, K and organic matter in the sediment were higher than that from the soil from the cultivated field. Both the sediment and the soil from cultivated field samples were not saline. The high amount of silt in the sediment will have significant reduction effect on the drainage as compared to the soil from cultivated field which will have good drainage (Table 1).

The heavy metal presence in both the sediment and the soil from cultivated field were within essential limits and below toxic levels (Table 3). The metals (copper, iron and zinc) were higher in the soil from cultivated field than in the sediment, this could adversely affect the normal growth of plants on the sediment. Copper is essential for plants particularly for photosynthesis [16,17]. Zinc is also contained in several enzymes such as carbonic anhydrase, alcohol dehydrogenase, superoxide dismutase and RNA polymerase. Iron plays a significant role in energy transfer, respiration and plant metabolism.

Table 4. Growth Indices of Maize

Amendment	Treatments	LL (cm)	LW (cm)	G (cm)	H (cm)
Control	BS	30.74	2.6	5.92	29.88
	S	43.14	3.82	7.99	36.71
	BS+S	38.01	3.29	7.29	33.40
Poultry manure (PM)	BS	38.33	3.26	6.52	36.05
	S	56.13	5.15	12.12	58.29
	BS+S	45.34	3.98	9.00	40.48
Cow dung (CD)	BS	33.47	2.55	5.27	26.18
	S	54.48	4.91	11.7	56.74
	BS+S	42.02	3.35	8.70	33.87
Biochar (BC)	BS	33.86	2.16	5.70	26.02
	S	57.56	4.87	13.56	59.12
	BS+S	48.28	3.6	10.26	43.2

LL=Leaf length, LW=Leaf width, G=Plant Girth, H=Plant height

Table 5. Fresh and Dry Weight of Root and Shoot

Amendment	Treatments	DwR (g)	FwR (g)	FwSh(g)	DwSh (g)	%R Wl	% Sh Wl
Control	BS	15.3	25.6	56.3	23.3	40	59
	S	21.8	117.6	101.8	41.4	81	59
	BS+S	64.9	113.3	112.4	44.6	43	60
Poultry manure (PM)	BS	46.4	89.5	131.3	53.2	48	59
	S	127.8	260.3	182.1	68.3	51	62
	BS+S	68.1	216.8	155.3	58.6	69	62
Cow dung (CD)	BS	67.3	122.6	124.4	47.8	45	62
	S	74.8	166.0	164.3	64.2	55	61
	BS+S	72.7	145.4	119.4	47.4	40	60
Biochar (BC)	BS	66.4	119.2	103.7	41.3	44	60
	S	105.5	229.0	172.4	64.7	53	62
	BS+S	112.5	190.4	180.2	64.0	41	64

D=Dry, w=Weight (g), R=Root, Sh=Shoot, Wl=Water loss, F=Fresh

Generally, sediment only showed poor maize growth as compared with soil only and soil-sediment mixture. Soil only and sediment-soil mixture amended samples showed enhanced growth than sediment amended samples except cow dung. Soil only amended samples showed improved growth than the soil-sediment amended samples. Treatments with poultry manure also showed enhanced growth than cow dung and biochar for both sediment and soil from cultivated field except sediment-soil mixture amended with biochar. The dry biomass of maize from cultivated field and soil-sediment each amended with poultry manure, cow dung and biochar were heavier than sediment only amendments by a factor of 1.28, 1.34 and 1.57 for cultivated filed and 1.10, 0.99 and 1.55 for soil-sediment respectively as in Table 4 and Table 5.

Poultry manure has been reported as better organic manure than other sources [18]. The nutrient levels in poultry manure might surpass that of cow dung leading to more enhanced plant growth in treatments with poultry manure. Agyenim-Boateng *et al.* [19] and Olubunmi *et al.* [20] also found significant growth in crops cultivated on soils amended with poultry manure. Soil amended with biochar had a better growth than cow dung while the sediment showed a vice versa scenario. Biochar can hold up to three times its own weight in moisture [21]. Ash of biochar consists of small amount of nitrogen with other essential plant nutrients [22]. According to [23], when biochar is applied to sandy soil, it improves soil water holding capacity. The observed trend agrees with [24] and observed that biochar applied to clay or silty soils has been found to have no significant effect on water holding capacity. The soil-sediment composite indicated that biochar amendment showed the most shoot growth followed by poultry manure and then cow dung. Maize performed better on soil only than sediment only but soil-sediment mixture showed an improved growth than soil only and sediment only which could be due to improved water holding capacity. Sediment mixed with soil showed an improved growth especially with biochar and poultry manure. It showed an enhanced growth but slightly lower than soil amended treatments. The poor growth of maize on the sediment could be attributed to the silt loam texture. Water composed of 81% of the root weight of maize grown on soil only while water formed 40% of root weight on sediment only (Table 5). Sediment is a less favorable medium for proper root growth and functioning compared with the soil which is sandy loam. This could be attributed to the poor drainage. This implies that the root system of maize grown on soil was able to take up more water than that of the sediment. The difference in water loss between oven dry weights of the root and the fresh root of soil amended treatment is more than 50% and that of the sediment is less than 50%. The least weight of fresh shoot system for soil at the end of the six week period is 101.8 g and highest is 182.1 g and that of the sediment is 56 g and 131 g respectively (Table 5).

Table 4 indicates that individual growth index also followed the same growth pattern. Amended soil showed enhanced growth indices than the sediment amended treatment and also sediment-soil amendment. Soil amended with biochar showed an enhanced leaf length, girth and plant height slightly than soil amended with poultry manure. Sediment only performed poorly compared with sediment-soil mixture and soil only.

Figure 1 shows a strong correlation 0.81 between fresh root weight and growth. Generally as root weight increases, growth also increases under all treatments with the exception of the sediment which showed slightly increased growth at decreased root weight.

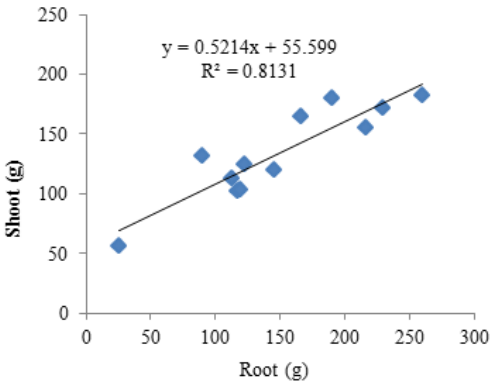

Figure 1. Fresh weight of root and shoot

Water limitations are commonly thought to trigger an adaptive response in plants to avoid water stress with relative greater carbon allocation to root which ultimately would result in higher root growth and greater capacity to absorb water [25]. It had also been shown by [26] a shift in allocation of growth toward shoot for many woody plant species under good irrigation regimes would result in consistently high relative water contents of the plant. However, [27] observed growth towards root system under limited water supply and vice versa. The sediment which is silt loam holds more water than the soil which is sandy loam and this may account for the slightly increased shoot growth at decreased root weight.

Figure 2 and Figure 3 indicate that individual growth indices also showed a very good correlation with root weight. As root weight increases there is a corresponding increase in fresh leaf length and plant height.

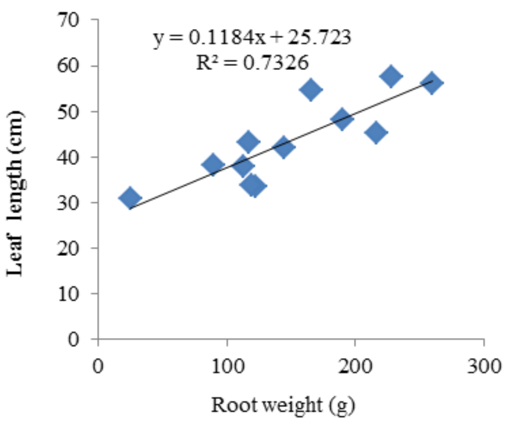

Figure 2. Fresh root weight and leaf lengh

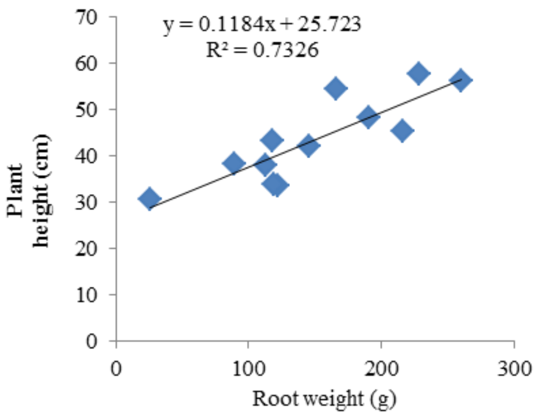

Figure 3. Relationship between plant height and root weight

The trend observed agrees with the intensive studies of selected plants by [28] which suggest that there is a persistent tendency of a positive correlation between roots and shoots, increase in size of above ground shoot being accompanied by increase in size of roots. Plant is a biological unit; the root system absorbs water and nutrients for the stem and leaves which in turn manufacture food for the maintenance of the root system.

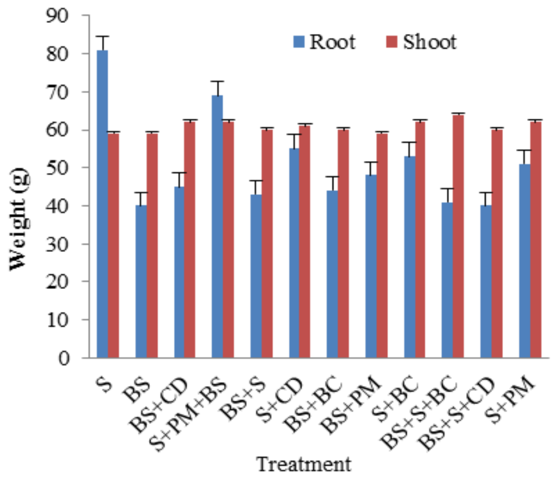

Figure 4. Percentage water loss

The percentage water loss from the shoot is fairly constant for all the treatments (Figure 4). The dry root weight of sediment only and sediment-soil mixture amended with cow dung is 40g half the weight of Soil only which showed the most dry root weight. Water formed about 60% of the shoot system; however the root showed varied weights due to the different drainage potential of soil and sediment. Plant adjustments to water availability include changes in morphological and anatomical features and shifts in the allocation of resources between roots and shoots [25].Variations in soil water content potentially could trigger an adaptive response in plants to avoid water stress with adaptive response more tilted towards the root depending on duration and stress level.

4. Conclusion

The riverbed sediment from the Odaw performed poorly because it is poorly drained and aerated. It is a less favorable medium for root growth and functioning though they store more water and minerals compared with *Oyarifa series* which is sandy clay loam. The amount of soil water available to plants is very important to their success and it varies widely between sands and silt during the growing season. The soil water content which was expressed as a percentage of dry weight of oven-dried samples indicated that the shoot system of the Obatanpa maize composed of about 60% of water indicating that water is important for plant growth. The heavy metal contained in both the sediment and the soil indicated that they are not significantly polluted. Using sediment from the Odaw for the cultivation of crops will not be important as it did not show marked improvement in growth. There are other sources of nutrient rich soils that can be used for agricultural production.

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