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Artificial Topsoil Removal Effect on Some Arable Crops Performance in Ogbomoso, Nigeria

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Abstract: *The artificial topsoil removal can help in assessing the on-site effects of soil erosion while simulating the natural field condition. Therefore, an experiment involving three topsoil depths (0-10 cm, 10-20 cm and 20-30 cm) and four crops (okra, maize, cowpea and tomato) replicated four times with randomized complete block design was conducted in a screen house. Soil samples were analysed for both physical and chemical properties. Plant heights were measured at 2- 10 weeks after planting (WAP) and crop yields were determined at 10 WAP.The result indicated that macroporosity was significantly ($p<0.05$) affected by topsoil removal with a range of 50.15 % at 0-10 cm to 46.8 % at 20-30 cm depth. OrgC, N, P, Ca, and Mg significantly increased by 47.4%, 94.8%, 43.4% and 34.0%, respectively, at 0-10 cmcompared with 20-30 cm depth. Plant heights for all crops were significantly higher on 0-10 cm depth compared with other depths. R^2 values for depths of topsoil removal and crop yield for maize, okra, cowpea and tomato were 0.92, 0.99, 0.56 and 0.85 respectively, indicating that increases in topsoil depths removal resulted to decrease in crop yield.*
Keywords:*Soil erosion, Topsoil depth, Arable crops, Crop yield, Nigeria.*

I. Introduction

Soil erosion is a geomorphic process comprising of the detachment, entrainment, transport and deposition of soil particles (Srinivasan et al., 2012). It causes physical loss of topsoil with its constituent nutrients and soil organic matter exposing the less fertile subsoil of a low structural stability and productivity.

The global rate of soil erosion is approximately 75 million Mg yr^{-1} (Pimentel et al., 1995) with an average erosion rate of 100 $Mgha^{-1}$ on severely eroded soils (Lal, 2003). Intensive tillage, residue removal and burning accelerate erosion and exerbate soil degradation (Montgomery, 2007). Accelerated erosion adversely impacts ecosystem functions, soil quality and soil organic carbon (SOC) concentration.

Erosion by water is a major cause of soil degradation in the humid tropics. Damages from water erosion include the physical loss of topsoil materials with its constituent's nutrients, exposure of less fertile subsoil, loss of organic matter, reduction in root depth, reduction of soil available water holding capacity, reduction of soil structural stability, surface sealing, and reduced infiltration rate (National Soil Erosion – Soil Productivity Committee, 1981). Collectively, these factors often result in the eventual reduction of soil productivity. Erosion by water is probably the greatest factor that limits soil productivity in the humid tropics

In the past, a range of indirect methods have been used to quantify the effects of erosion on productivity including those involving the effects of past erosion on yield compared with productivity of \uneroded areas (Lal, 1981, 1998; Fahnestock et al., 1996), pot experiment with soils from different depths (Mielke and Schepers, 1986; Mbagwu, 1988), models to simulate the effects of erosion (Pierce et al., 1983), and artificial removal of topsoil to incremental depth (TSD) to simulate erosion and deposition at field levels (Larney et al., 2000; Oyedele and Aina, 2006; Jagadamma et al., 2009).

Minimizing the disturbance of the topsoil decreases soil organic carbon and other nutrients depletion in the soil. This enhances aggregate formation and stabilization. In contrast, intense tillage exacerbates the depletion of soil organic carbon (Bajracharya, 2001). The impact of soil erosion on crop yields among others are reduction in soil depth and potential rooting depth, reduction in soil organic matter content; non-uniform subsoil of poorer physical, biological and chemicals properties, changes in soil physical properties (Lal and Stewart, 1990; Cleveland, 1995; Loch and Silburn, 1997). The changes in the physical, chemical and biological qualities of soil are often the primary reason for monitoring soil erosion, as they affect soil productivity.

An understanding of the relationships between erosion severity and changes in soil properties on one hand and the influence of both on crop yield on the other hand, is required for sustainable soil management in southern guinea savannah of Nigeria. Thus, the present study was conducted with the objective of evaluating effect of artificial topsoil removal on soil properties and maize, okra, cowpea and tomato performance in southern guinea savannah of Nigeria.

II. Materials and Methods

2.1 Soil sampling

Soil samples were collected under a secondary forest planted with *Gmelina alborea* trees. The samples were taken at different depths of 0-10 cm, 10-20cm and 20-30 cm. An undisturbed triplicate core samples were taken with a cylindrical core sampler (5.0 cm – height and inner diameter) from different depths to determine soil physical properties. Bulk soils sample were collected at the same depths and sieved with 2 mm diameter mesh size. Sub-sample was taken from the sieved soil and taken to the laboratory for analyses of both soil chemical properties and particle size distribution. Twelve buckets (7 litres each) were filled with 10 kg of sieved soil collected from different depths. This was replicated at four different locations under the trees.

2.2. Laboratory analyses

Bulk density was estimated as described by (Grossman and Reinsch, 2002). Saturated hydraulic conductivity was determined as described by (Reynolds et al., 2002). Pore size distribution was calculated using the water retention data and capillary rise equation as described by (Flint and Flint, 2002). Macropores (pores > 30 µm), taken as drain pores were estimated at 10 kpa matric potential. Soil pH was determined using glass electrode pH meter in water, in the ratio of 1: 25 (Mclean, 1982). Organic carbon was determined by the Walkey- Black procedure described by (Nelson and Sommers, 1982). Exchangeable cations were determined according to the procedure described by (Tel and Roa, 1982). Available phosphorus was determined using Bray II method, (Bray and Kurtz, 1945) while Total nitrogen was determined by Macro-Kjeldahl method (Bremner, 1965).

2.3 Sowing, growth and crop yields determination

Okra, maize and cowpea seeds were sown at the rate of 3 seeds per pot filled with soil from different depths. However, tomato seeds were sown in the nursery, and transplanted into the pots 2 weeks after sowing. Seeds sown were later thinned to two plants per pot; two seedlings were maintained in the pot. The rationale behind this was to guide against damage by insect pests. Data were collected on plant height of okra, maize and cowpea at 2, 4 , 6, 8 and 10weeks after planting (WAP) except for cowpea that was stopped at 8WAP as a result of pod formation. However, data on tomato plant height were collected at 2, 4, 6, 8 and 10 weeks after transplanting (WAT). Maize stover was harvested at 10WAP and weighed as biomass because no cob was produced. Okra fruits were harvested at five days interval and weighed. The mean was calculated in gramme per plant. Cowpea yield were harvested and weighed and average yield were determined as weight of pod per plant. Tomato yield was determined as biomass harvested and weighed in gramme per plant becausetomato plant did not produce fruit at 10WAP.

2.4 Statistical Analysis

All data obtained were fitted into general linear model (GLM PROC) of the SAS statistical software (SAS Institute, 2002). The treatment effects were compared using analysis of variance (ANOVA), significant differences between individual means were tested using the least significant difference (LSD) test at $p = 0.05$ unless otherwise stated. Simple regression analysis was run between depths of topsoil removal and yield of crops, selected soil properties and crop yield.

III. Results And Discussions

3.1 Soil physical properties

Physical properties of the soil used for the experiment are presented in (Table 1).The textural class of the soil for all the depths is loamy sand. Particle size distribution (sand, silt and clay content) was not significantly different with various depths. Similarly, bulk density and saturated hydraulic conductivity were not affected by depths of topsoil removal. Although, bulk density increased with depth of topsoil removal from a mean of value of 1.36 g cm^{-3} under control to 1.41 g cm^{-3} at 20-30 cm. Saturated hydraulic conductivity decreased from 1.77 cm hr^{-1} at 0-10 cm depth of topsoil removal to 1.31 cm hr^{-1}at 20-30 cm depth. However, macroporosity under control significantly increased over 20-30 cm depth of topsoil removal by 6.58 %. Oyedele and Aina (2006) also observed that bulk density increased with depth of topsoil removal from a mean value of 1.38 g cm^{-3} under control to 1.55 g cm^{-3} at 20 cm depth of removal.

3.2 Soil chemical properties

Chemical properties of the soil used for the experiment are shown in (Table 2). All the chemical properties (Org carbon, nitrogen, phosphorus, calcium and magnesium) except pH and potassium were significantly ($p<0.05$) lower at 20-30 cm soil depth when compared with 0-10 cm soil depth. Organic carbon was lower at 20-30 cm soil depth than the control (0-10 cm). This corroborates the fact that soil erosion causes reduction in organic matter content (Loch and Silburn, 1997). The percentage reduction for all other soil chemical properties at 20-

30 cm soil depth when compared with the 0-10 cm depth of topsoil removal are , N-94 %, P-74%, Ca-43% and Mg - 33%. These results revealed the preliminary effects of topsoil loss associated with the exposure of the lower horizon organic matter content is one of the properties mainly affected by erosion because the concentration of organic carbon is consistently higher in the first 15 cm of the profile (Baver and Black, 1994). The reduction in organic matter due topsoil removal and its impact on crop productivity has been documented in other studies (Izuarralde et al, 2006; Oyedele and Aina, 2006).The strong decrease of N and P contents at 10-20 and 20-30 cm depths is an indicator of nutrient depletion at these depths. The results are similar to Rasran et al. (2007) who reported that topsoil removal is based on removing nutrients rich topsoil (mostly the Ap horizon) leaving the nutrient poor sandy subsoil containing far lower N and P levels.

3.3 Crop plant heights as influenced by depth of topsoil removal

Maize

Artificial topsoil removal had no significant effect on maize plant height across the weeks after planting (Fig.1a). However, the tallest plants were recorded at 0-10 cm depths of topsoil removal when compared with 10-20 cm and 20-30 cm depths of topsoil removal. Higher plant height can be attributed to higher nutrients status of the soil which supports the growth of the plant at 0-10 cm than other depths of topsoil removal because analysis of the soil revealed that 0-10 cm had higher nutrients status compared to other depthsTheresult of chemical analysis of the soil revealed higher nutrients at 0-10 cm which supported growth of maize to produce taller plants. Ossom and Rhykerd (2007) also found that soil chemical properties influenced plant growth, and development, as well as the concentration of various minerals nutrients at the end of cropping season.

Okra

Topsoil removal depths had no significant effect on okra plant height at 2, 4 and 6WAP(Fig.1b). However,at 8WAP and 10WAP, topsoil depths had significant ($p<0.05$) higher okra plant height. Okra plant height on 0-10 cm was significantly ($p<0.05$) higher than at 10-20 cm and 20-30 cm depths of topsoil removal by 40.8 % and 41.5 %, respectively, at 8WAP and 45.7 % and 41.5 %, respectively at 10WAP. The decrease in organic carbon and all other nutrients with depths of topsoil removal could be attributed to shorter plant at such depths. The observation is in agreement with Kalisz (1990) who reported that organic carbon contents play a crucial role in sustaining soil fertility, crop production and plant root growth. .

Cowpea

Cowpea plant height was significantly influenced by simulated soil erosion at 2, 4, 6 and 8WAP(Fig.1c). At 2WAP, cowpea plant height decreased significantly ($p<0.05$) from 18.00 cm on soil at 0-10 cm depth to 10.58 cm where 20- 30 cm topsoil was removed. However, topsoil removal at 0-10 cm only produced significantly higher cowpea plant height than at 20-30 cm topsoil depth by 43.1 %, 54.6 % and 30.9 %, respectively, at 4, 6 and 8WAP. The result revealed the superiority of the plant height on control soil than other treatments.Results on the productivity performance of cowpea showed that the 0-10 cm depth of topsoil removal produced significantly taller plants than other depths (Table 1). This could be attributed to higher soil fertility at this depth that supported better growth. The result agrees with Nyabenda(2005) who reported that the production of grain legumes had been low due to declining soil fertility as a result of soil impoverish organic matter.

Tomato

Artificial soil erosion did not significantly influenced tomato plant height at 2, 4 6and 8 weeks after transplanting [WAT] (Fig.1d). However, at 10WAT, tomato plant height was significantly higher on 0-10 cm soil than on 20-30 cm depth of topsoil removal by 32.7 %. The result followed similar trend of other crops that showed higher growth on control soils. The higher nitrogen content at 0-10 cm soil depth could have been responsible for the taller plant when compared to other depths. High rate of nitrogen induce vigorous vegetative growth to the detriment of fruit production.

3.4 Total biomass and crop yield (g/plant)

Maize (biomass)

Maize biomass yield was significantly influenced by depths of topsoil removal at 10 weeks after planting (Table 3). Maize yield had significant ($p<0.05$) greater yield on 0-10 cm depth of soil than 10-20 cm and 20-30 cm depth of soils removal by 54.4 % and 71.6 %, respectively. Inability of maize to produce cob may be due to insufficient volume of soil to provide enough nutrient up to maturity stage. This stemmed from the fact that maize demand high nutrient for its proper growth. The result could be corroborated by Oyedele and

Aina (2006) reported that maize yield decreased exponentially with increase in depth of topsoil removal (r^2 = 0.99, p< 0.01) with an average of 55% yield loss on the removal of just 5 cm topsoil. The result was also similar to Izaurralde et al., (2000) who demonstrated marked effects on total dry matter yield according to simulated erosion levels.

Cowpea (pod yield)

Topsoil removal had significant (p<0.05) influence on cowpea pod weight (Table 3). Cowpea yield decreased significantly (p<0.05) from 9.75 g /plant at 0-10 cm depth of topsoil removal to 3.00 g / plant where 20-30 cm topsoil was removed. The removal of 30 cm topsoil reduced cowpea pod yield by 69 % as compared with 10 cm soil depth. Despite the fact that cowpea plant can fix nitrogen, the result still revealed that topsoil removal at 0-10 cm depth had higher nutrient status which has marked effect on the yield when compared with other depths.The observation is in line with (Nyabenda, 2005) who reported that the production of grain legumes had been low due to declining soil fertility as a result of soil impoverishes organic matter content.

Okra (fruit yield)

Okra yield varied considerably with depths of topsoil removal (Table 3). For this reason topsoil removal depths had no significant effect on okra yield average. However, the 0-10 cm depth of topsoil removal had the greatest average yield of 8.45 g/plant, followed by 20-30 cm and 10-20 cm topsoil removal with respective average yield of 5.28 and 4.45 g/plant, suggesting a decreasing trend of fruit yield with increasing depths of topsoil removal. The pod yield obtained is a reflection of nutrient depletion from other depths apart from 0-10 cm. The observed differences among the depths though statistically similar, could be related to nutrient availability to okra plants as the plants have to rely on the native fertility of the soil.

Tomato (biomass)

Topsoil removal had similar effect on total dry biomass yield of tomato at 10 weeks after transplanting (Table 3). However, tomato yield was greater on 0-10 cm topsoil removal than 10-20 cm and 20-30 cm depth of topsoil removal respectively by 48.2 % and 55.6 %.This depicted that topsoil removal at 0-10 cm had higher nutrient as revealed by the soil analyses which influenced the growth of tomato. The effect of soil loss may be explained with changes in the chemical and physical characteristics of the soil and by its interactions that impact productivity (Izaurralde et al, 2006).

The result of simple regression analysis of crop yield with depths of topsoil removal showed negative relationship (Fig. 2). Maize, okra, cowpea and tomato yield linearly decreased with increase in depth of topsoil removal with respective R^2 values of 0.92, 0.99, 0.56 and 0.85 at (p< 0.05). Data revealed that nutrient loss due to soil erosionis one of the major causes of soil fertility depletion which can tremendously affect crop yield. In addition, the relationship of some selected soil properties that are significant with depthsof topsoil removal revealed that variation in yield of maize, cowpea and tomato accounted for by organic carbon are (94 %, 99 % and 88 %), bulk density (97%,98%,and 92 %), and macroporosity (73%, 95%, and 63%), respectively(Fig. 3a & b). Soil organic carbon and macroporosity have positive relationship with crop yield. The observation revealed thatthe contribution of organic carbon that improves macroporosity provideda better condition for plant growth in terms of aeration, moisture and drainage which translates to better yield. However, bulk density was negatively related to crop yields suggesting that increase in bulk density will hinder crop growth and eventually affects yield of crops.

IV. Conclusion

In this study, plant heights and the yield of maize, okra, cowpea and tomato had a proportional decreasing trend with respect to the depths of topsoil removal. Removal of soils up to 20-30 cm resulted in the loss of a fertile layer within the soil profile which was reflected by 53 % reduction in organic carbon content when compared to 0-10 cm depth of soil removal.

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References

[1]. Srinivasan, V., Maheswarappa, H. P., Lal, R., 2012. Long term effect of topsoil depth and amendments on particulate and non-particulate carbon fractions in a Miamian Soil of Central Ohio. Soil Tillage Research 121, 10-17.

[2]. Pimentel, D., Harvey, C., Resosudamo, P., Sinchair, K., Kurz, D., McNair, M., 1995. Environmental and economic costs of soil erosion and conservation benefits science 267, 1117-1123.
[3]. Lal, R., 2003. Soil erosion and the global carbon budget. Environ. Int. 29, 437-450.
[4]. Montgomery, D. R., 2007. Soil erosion and agricultural sustainability. PNAS 104, 13268-13272.
[5]. National Sol Erosion- Soil Productivity Committee, 1981
[6]. Lal, R. 1981. Soil erosion problems on an Alfisol in Western Nigeria. VI. Effects of erosion on experimental plots. Geoderma 25, 215-23.
[7]. Lal, R. 1998. Soil erosion impact on agronomic productivity and environmental quality. Crit. Rev. Plant Sci. 17(4), 319-404.
[8]. Fahnestock, P., Lal, R., Hall, G. F., 1996. Land use and erosional effects on two Ohio Alfisol. 11. Crop yields. J. Sust. Agric. 7, 85-100.
[9]. Mielke, L. N., Schepers, J. S., 1986. Plant response to topsoil thickness on an eroded loess soil. J. Soil Water Conserv. 41 (1), 59-63.
[10]. Mbagwu, J. S. C., 1988. Physico-chemical properties of an ultisol in Nigeria as affected by long term erosion. Pedology 38, 137-154.
[11]. Pierce, F. J., Larson, W.E., Dowdy, R. H., Graham, W. A. P., 1983. Productivity of soils: assessing long term changes due to erosion. J. Soil Water Conserv. 38 (1), 39-44.
[12]. Larney, F. J., Olson, B. M., Janzen, H.H., Lindwall, C.W., 2000. Early impacts of topsoil removal and soil amendments on crop productivity. Agron. J. 92 (5), 948-956.
[13]. Oyedele, D. J., Aina, P. O., 2006. Response of soil properties and maize yield to simulated erosion by artificial topsoil removal. Plant Soil 284, 375-384.

[14]. Jagadamma, S., Lal. R., Rimal, B. K., 2009. Effects of topsoil depth and soil amendments on corn yield and properties of two Alfisols in central Ohio. J. Soil Water Conserv. 64(1), 70-80.
[15]. Lal, R., Stewart, B. A. 1990. "Soil degradation: Advances in soil science 11". Sprinyer-Verlag New York.
[16]. Clevland, C. J. 1995. Resource degradation, technical change, and the productivity of energy use in U.S. agriculture. Ecol. Econ. 13, 185-201.
[17]. Loch, R. J., and Silburn, D. M., 1997. Soil erosion: In "sustainable crop production in the subtropics: An Australian perspective" (A. L. Clarke and P. B. Wylie, Eds.) pp27-63. Department of primary industries, Brisbane, Qld.
[18]. Grossman, R.B., Reinsch, T.G., 2002. Bulk density and extensibility: Core method. In: Dane, J.H., Topp, G.C. (Eds.). Methods of Soil Analysis, Part 4. Physical Methods. SSSA, Inc., Madison, WI. Pp. 208-228.
[19]. Reynolds, W. D., Elrick, D. E., Young's, E. G., Bobolink, H. W. G., Bouma, J., 2002. Soil water content: In: Dane, J.H, Topp, G.C.(Eds.).Methods of Soil Analysis, Part 4.Physical methods. SSSA, Inc., Madison, WI, pp. 802-817.
[20]. Flint, L.E., Flint, A. L., 2002. Porosity. In: Dane, J.H., Topp, G.C. (Eds.). Methods of Soil Analysis, Part 4. Physical Methods. SSSA, Inc., Madison, WI. Pp.241-254.
[21]. Mclean, E.D., 1982. Soil pH and lime requirements. In: Page, A.L.(Ed.). Method of Soil Analysis: Chemical Methods, Part 3, SSSA, Madison, WI, pp. 199-234.
[22]. Nelson, D.W., Sommers, L.E., 1996. Total carbon, organic carbon and organic matter. In: Sparks, D.L. (Ed.), Method of Soil Analysis: Chemical Methods, Part 3, SSSA, Madison, WI, pp. 61-1010.
[23]. Tel, D., Rao, F., 1982. Animated and semi- automated methods for soil and plant analysis, pp.201- 270
[24]. Bray R.H., Kurtz, I.T., 1945. Determination of total and available forms of phosphorus in soils. Soil Science 59: 45-49.
[25]. Bremner, J.N., Mulvary, C.S., 1965. Total nitrogen. In: Sparks, D.L. (Ed.), Method of Soil Analysis: Chemical Methods, Part 3, SSSA, Madison, WI, pp. 599-622.
[26]. SAS institute, 2002. SAS/STAT User's Guide In: Version 8.2, SAS Institute Cary, NC..
[27] Rasran, L., Vogt, K., Jenson, K., 2007. Effects of topsoil removal, seed transfer with plant material and moderate grazing on restoration of riparian fen grasslands. Applied Vegetation Science 10, 451-460.
[28] Ossom, E. M., Rhykerd, R.L. 2007. Effects of Corn (Zea mays L.) and grain legume associations on soil mineral nutrient concentration, soil temperature, crop yield, land equivalent ratio and gross income in Swaziland. In Kazem ZA, Mahmoud MAH, Shalabi SL , El-Morsi EMA, Hamady AMI (eds.).Proceedings of the 8th Afr. Crop Sci. Conf. 27-31 Oct. 2007, El-Minia, Egypt.
[29] Izaurralde, R.C., Malhi, S.S., Nyborg, M., Solberg, E.D., Quiroga, M.C., 2006.Crop performance and soil properties in two artificially eroded soil in North-Central Alberta. Agron. J. 98, 1298-1311.
[30] Bauer, A., Black, A., 1994. Quantification of the effect of soil organic matter content on soil productivity. Soc. Am. J. 58, 185-193.

Table 1: Physical properties of the soil used for the experiment at different depths of soil removal

Depth of soil removal (cm)	Sand (g/kg)	Silt (g/kg)	Clay (g/kg)	Bulk density (Mg/m^3)	Saturatedhydraulic conductivity (cm/hr)	Macroporosity (%)
0-10	845.00	75.00	80.00	1.36	1.77	50.15
10-20	845.00	70.00	85.00	1.39	1.63	49.25
20-30	840.00	75.00	85.00	1.41	1.31	46.85
LSD $_{(0.05)}$	ns	ns	ns	ns	ns	2.52

ns- No significant difference at 5 % probability level

Table 2: Chemical properties of the soil used for the experiment at different depths of soil removal.

Depths of soil (cm)	pH	Organic Carbon (%)	Nitrogen (%)	Av. P (g/kg)	K (cmol/kg)	Ca (cmol/kg)	Mg (cmol/kg)
0-10	7.53	0.78	0.77	6.41	0.27	4.59	0.53
10-20	7.63	0.58	0.06	7.21	0.24	3.64	0.42
20-30	7.50	0.41	0.04	1.69	0.31	2.60	0.35
$LSD_{(0.05)}$	ns	0.16	0.02	5.97	ns	1.27	0.16

ns – No significant difference at 5% probability level

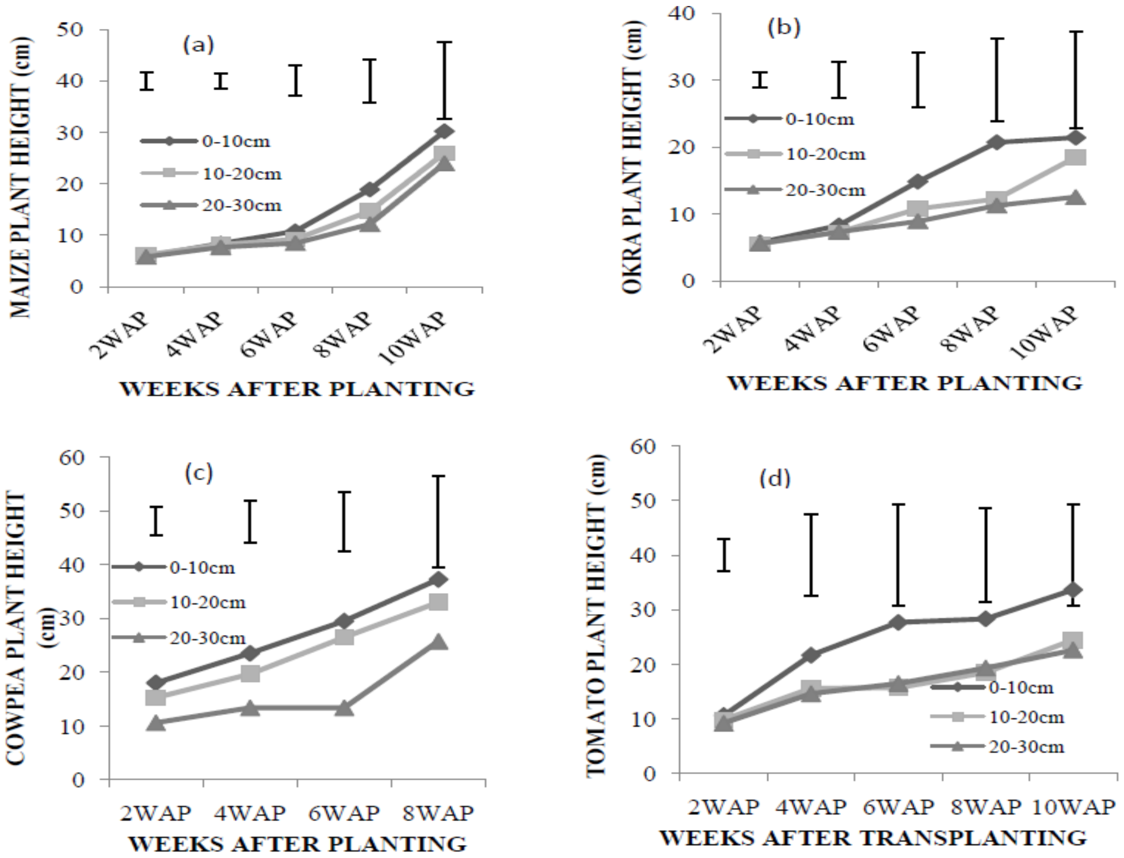

Fig. 1: Effect of depths of topsoil removal on plant heights of (a) Maize (b) Okra (c) Cowpea and (d) Tomato.

Table 3: Effect of depths of topsoil removal on total biomass and yield (g/plant) of selected arable crop

Depths of topsoil removal (cm)	Maize (stover)	Okra (fresh pod weight)(g/plant)	Cowpea (pod weight)	Tomato (total biomass)
0-10	15.88	8.45	9.75	6.75
10-20	7.25	4.45	6.25	3.50
20-30	4.50	5.28	3.00	3.00
$LSD_{(0.05)}$	3.97	Ns	1.98	2.59

ns – No significant difference at 5% probability level.

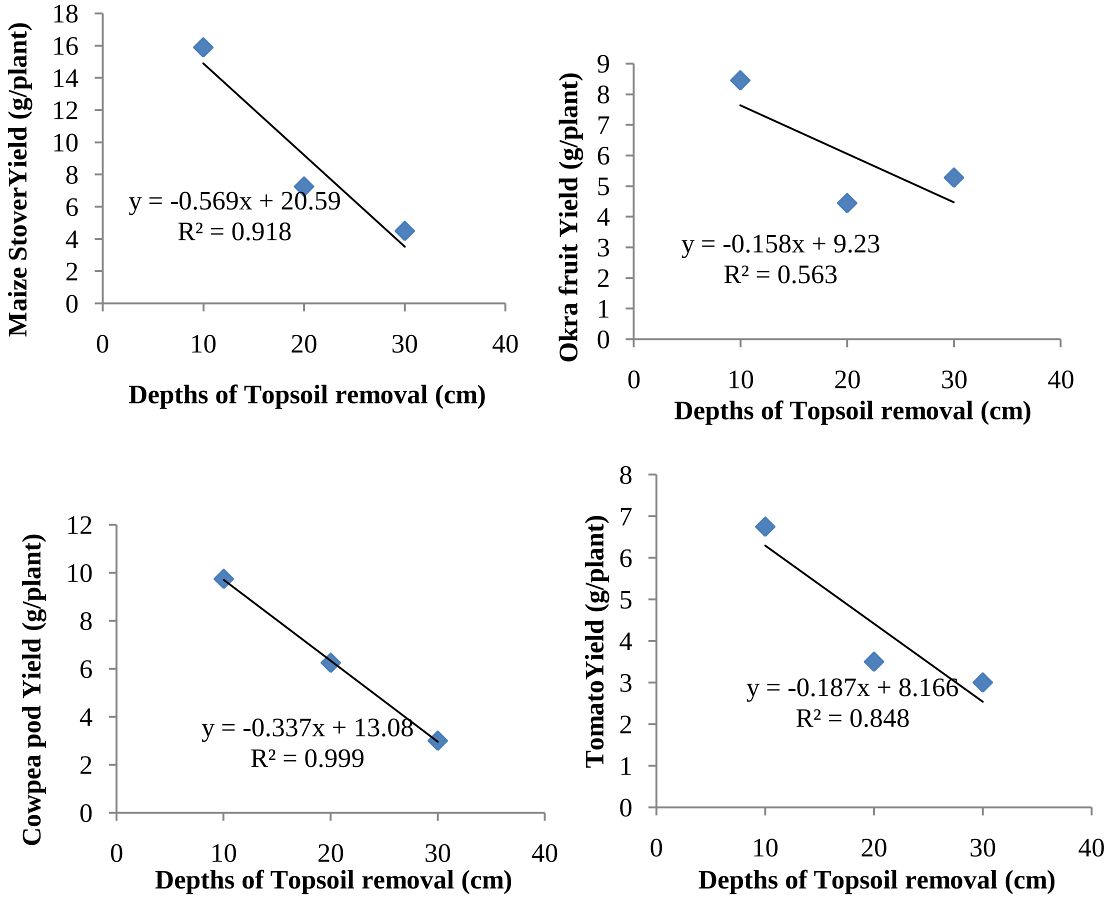

Fig. 2: Relationship between depths of topsoil removal and crop yield (a) Maize (b) Okra (c) Cowpea and (d) Tomato

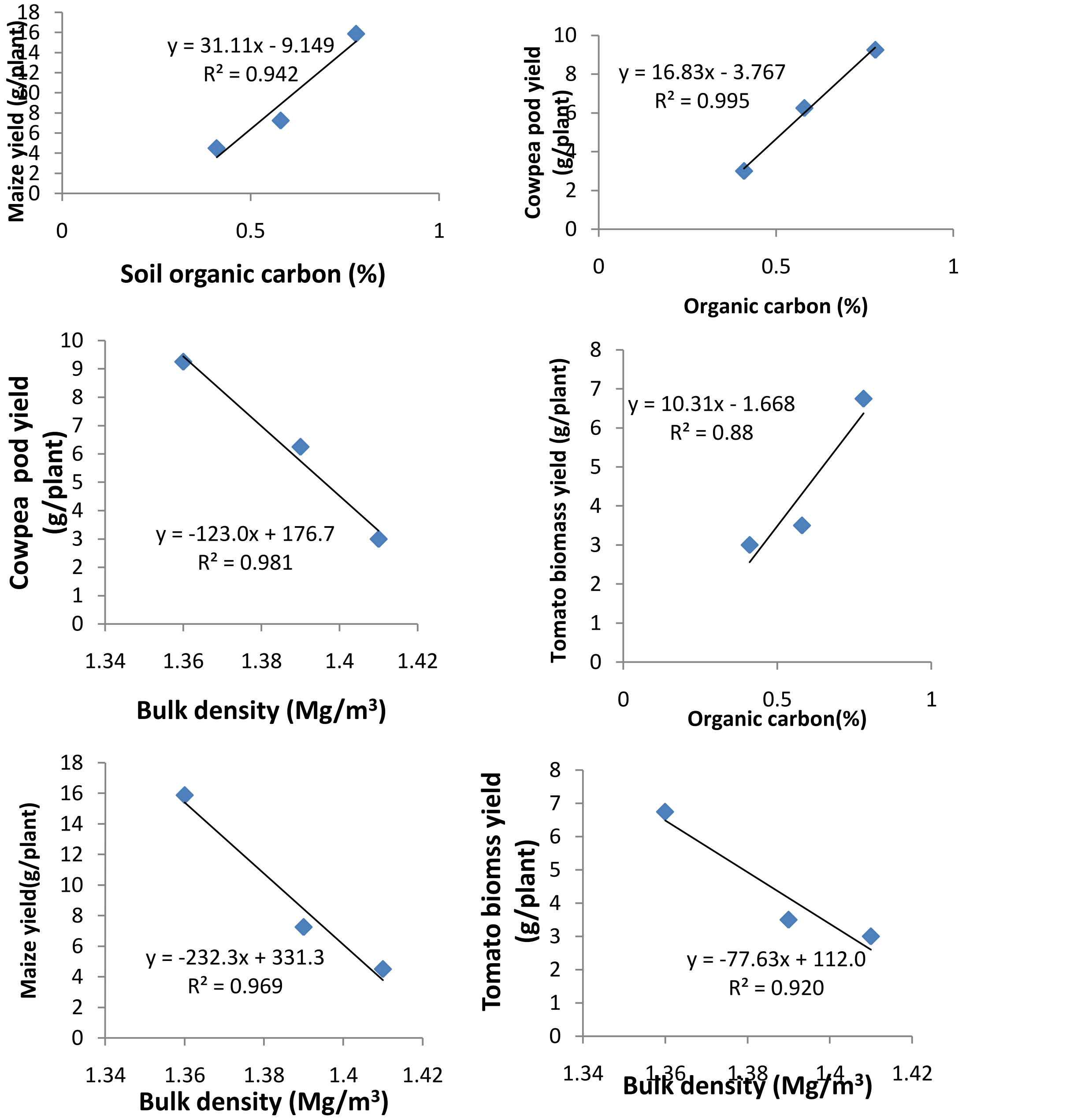

Fig. 3a: Relationship between soil organic carbon, bulk density and crop yields at different depths of topsoil removal.

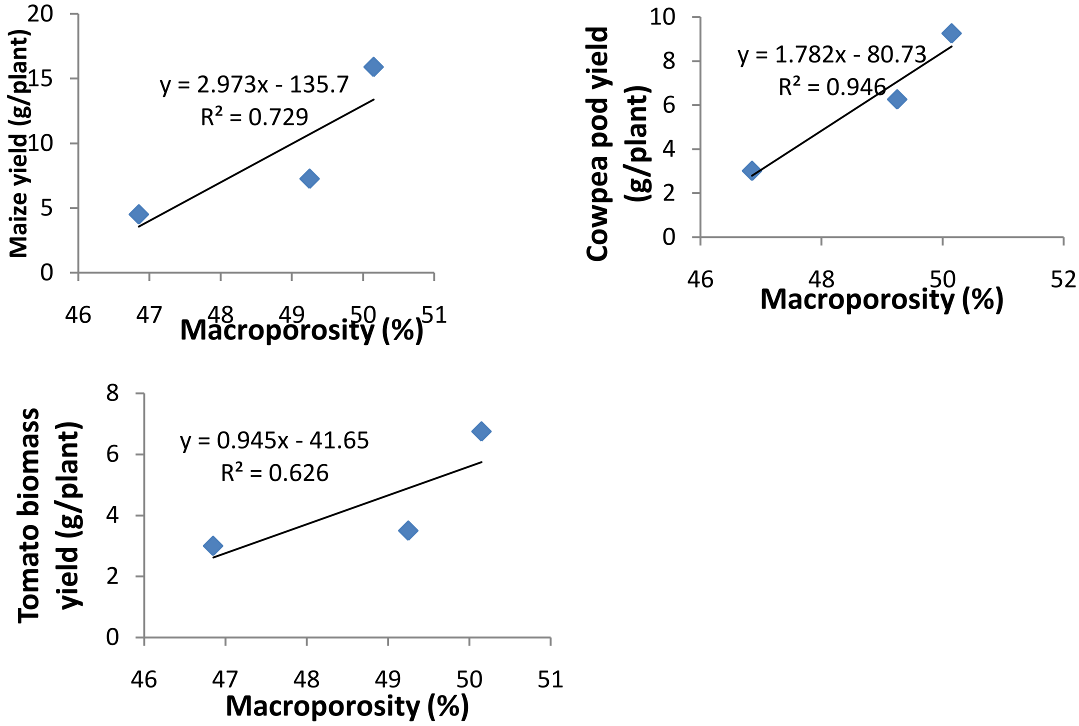

Fig.3b: Relationship between macroporosity and crop yieldsat different depths of topsoil removal.