MAIZE ROOT CHARACTERIZATION USING IMAGE ANALYSIS AS AFFECTED BY TOPSOIL REMOVAL AND SOIL STRENGTH

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Abstract:

A study was carried out in 2005 to investigate the effect of artificial de-surfacing on maize root growth in relation to the application of nutrient amendments on an Alfisol topo-sequence in Abeokuta, Southwestern Nigeria and to analyze and compare the root system of maize after topsoil removal using image analysis.

Soil was artificially desurfaced to depths of 0, 15 and 25 cm at two slope positions (upper and lower). Root samples were characterized for root length density, root mass density. Root samples were analyzed using the image analysis method. Penetrometer resistance measurements using (the CP20, a self-recording instrument manufactured by Agri RIMIK, Toowoombola, Australia) were carried out on plots artificially de-surfaced and readings were used to quantify soil resistance to root penetration.

Root biomass production from upslope and lower slopes were 0.32 and 0.21 t ha^{-1}; respectively. For poultry manure it was 0.40 t ha^{-1}; 0.32 t ha^{-1} for NPK+Urea and 0.08 t ha^{-1} for no amendment. Topsoil removals to 0, 15 and 25 cm yielded biomass values of 0.31, 0.26 and 0.23 t ha^{-1} respectively.

Keywords: root growth, pixels, artificial desurfacing, slope position,

Introduction

The root system plays important role in plant adaptation to soil limitations such as availability of water, low nutrient and level of degradation or erosion (Araujo et al., 2004)
Roots can be affected adversely by the effects of compaction, topsoil removal, soil strength and lack of or limited amount of nutrients for development. It can be affected adversely by increase in the concentration of gravel in the soil.

Fulton et al. (1996) stated that increase soil bulk density and soil strength which indicates that a soil is compacted will result in adverse effects on root growth. The root system can be affected by high soil strength, soil compaction, hardsetting soils and gravel concentration in soil.(Panayiotopoulos et al. 1994, Salako et al., 2002,).

Several methods have been used to estimate root length, many of which are the line-intersect method first proposed by Newman (1966) and modified by Tennant (1975). The line intersect method also has it own drawbacks in that it assumes a random root distribution, so errors in the estimation of root length can arise when this assumption is ignored.
Computer assisted electronic image analysis has made root analysis less time consuming and more accurate root characterizing can be done with the method Carlos et al., 2000).

The objective of this study was to analyze and compare the root system of maize after topsoil removal using image analysis.

2. Materials and Methods

Study site description

The study site was located in the University of Agriculture, Abeokuta. (Latitude 7°14′ N and longitude 3°21′ E). The annual rainfall is 1200 mm. The vegetation is mainly secondary forest The slope steepness of the toposequence was 5%. Plots were established by manually removing topsoil with a shovel in two slope positions to stimulate artificial erosion.

3. Experimental Design

A factorial experiment in a randomized complete block design with three replications was set up. There were three factors: topsoil removal, nutrient amendment and slope position. The topsoils were removed to 15 and 25 cm depths while non-removal (0 cm depth) served as control for this factor. Plot size was 4m x 3m. There were 54 plots altogether made up of 27 at upslope and 27 at lower slope position. For nutrient amendment, poultry manure was applied at a rate of 10 t ha^{-1} while NPK (15:15:15) + Urea was applied to supply 60 kg ha^{-1} N, 30 kg ha^{-1} P_2O_5, 30 kg ha^{-1} K_2O; the control was no nutrient amendment (0 kg ha^{-1}). Thus, there were 3 levels of topsoil removal and 3 levels of nutrient amendments on two slope positions (upper and lower slopes). Poultry manure was collected from a poultry farm near the University main campus. The test crop was maize (DMR-LSY) which reached maturity in 90 days and the maize crop was planted at distance 0.75 m within rows and 0.25 m across rows.

4. Root sampling and measurements

Excavation (destructive) sampling method was used to study roots (Anderson and Ingram, 1993). Roots were excavated from a soil volume of 20 cm diameter x 20 cm depth, using a shovel at 6 and 12 weeks after planting around the maize stem. Prior to weighing, the roots were stored in 98% ethanol and put in a refrigerator to ensure its freshness if weighing was to be delayed for more than 12 hours. The roots were air-dried first before oven drying at a temperature of 60^0C to a constant weight.

Root mass density (g/cm^3) was calculated as the fresh weight of the roots excavated to the volume of excavated soil.

Root samples were scanned at 300 dots per inch (dpi) for image analysis; color images (red, green, blue (RGB) format) were used. The software used for analysis was GIMP version 1.2.5. (www.gimp.org). which shows information about the statistical distribution of color values of the image that is currently active. A range of intensity levels from 0 to 255 was used, such that a black pixel was encoded by 0 and a white pixel was encoded by 255. In simple term, a pure black image had zero value a pure white image had 255 as its scale. The mean pixels obtained from image analysis were subtracted from 255 to obtain the portion of the analysis covered by the roots (dark area). Thus, in order to normalize the values from 0-1, the proportion of the dark area pixels to maximum intensity of 255 (degree of blackness) was obtained. These proportions were further divided by the mass of roots sampled for image analyses to obtain the proportion of darkness per gram of root. The closer this value was to zero, the darker the root color and the closer it is to 1, the brighter. This was used as an index of root responses to treatments.

5 *Data Analysis*

All the data were subjected to analysis of variance using SAS (Littel et al., 1996). The Proc Mixed option of the statistical software was used. This allowed for paired comparison of all the means including the interactions of the various factors. All possible combinations of the interactions were considered. In presenting the data, the observed least significant difference (LSD) which was at $P \leq 0.05$ was indicated.

6. *Results and Discussion*

6.1 Root growth

The highest root mass density was at the upper slope under the application of poultry manure while the least was observed where there was no amendment at the lower slope position (Table 1). The upper slope had a significantly higher mean root mass density than the lower slope with values of 1.2 kgm^{-3} and 0.7 kgm^{-3} respectively. Root mass density also significantly decreased with increase in the depth of topsoil removed though the effects of topsoil removal depths were not significantly different (Table 2) Poultry manure was a better amendment than NPK+ Urea with a root mass density of 1.5 kgm^{-3} compared to NPK+Urea with 1.2 kgm^{-3}. No amendment had a root mass density of 0.3 kgm^{-3}.

Furthermore from table 2, slope position affected the root mass density significantly and amendment of soil also had a significant effect on root mass density. Root biomass production from upslope and lower slopes were 0.32 and 0.21 t ha^{-1}; respectively. For poultry manure it was 0.40 t ha^{-1}; 0.32 t ha^{-1} for NPK+Urea and 0.08 t ha^{-1} for no amendment. Topsoil removals to 0, 15 and 25 cm yielded biomass values of 0.31, 0.26 and 0.23 t ha^{-1} respectively.

Plates 1-6 show the image analysis of some scanned roots. Non-removal of topsoil enhanced the development of the root system while high bulk density and 25 cm removal of topsoil caused maize root to thicken at the upper slope position. The effect of no amendment on maize roots, low density of fine roots with 25 cm removal (plate 3) greatly affected the root development negatively but with non-removal of topsoil and poultry manure application (plate 4), improved maize root system development was observed.

Root production was better in the upper slope than lower slope, mainly because the soil had more clay content to retain nutrients and water than the lower slope. Addition of organic and inorganic amendments enhanced root development. The root growth pattern of maize was that it responded to increased soil strength due to topsoil removal (stress) and increased bulk density as a result of reduction in soil pores by thickening of maize roots leading to less development of fine and medium size roots, which would have enhanced nutrient uptake through high surface density and penetration of soil fine pores. (Table 1) The darkest color of roots in the images was associated with nutrient amendment and non-removal of topsoil, thereby, corroborating the quantitative data.

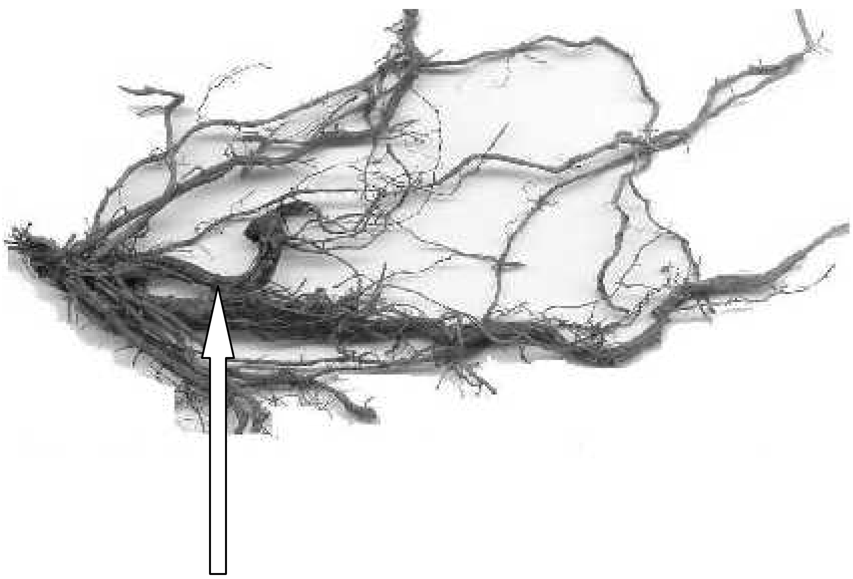

Plate 1: Maize root thickening due to rigidity of pores and high bulk density with 25 cm topsoil removal (+ NPK and urea) in the upper slope

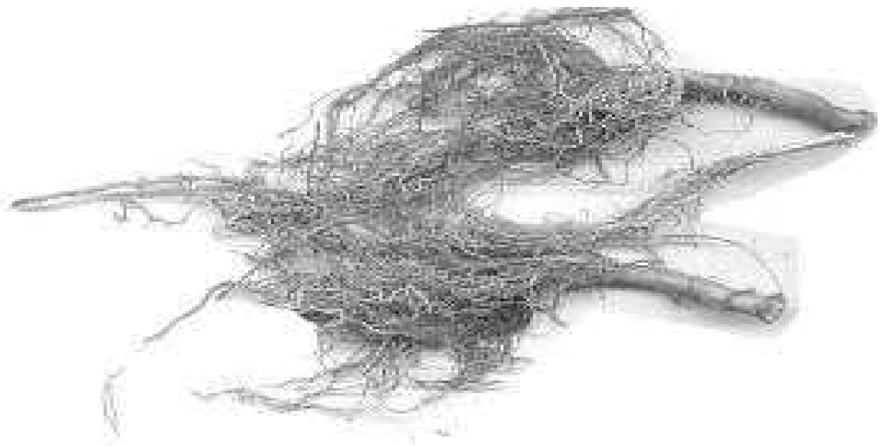

Plate 2: Normal root system development due to non-removal of topsoil with application of NPK + urea in the lower slope

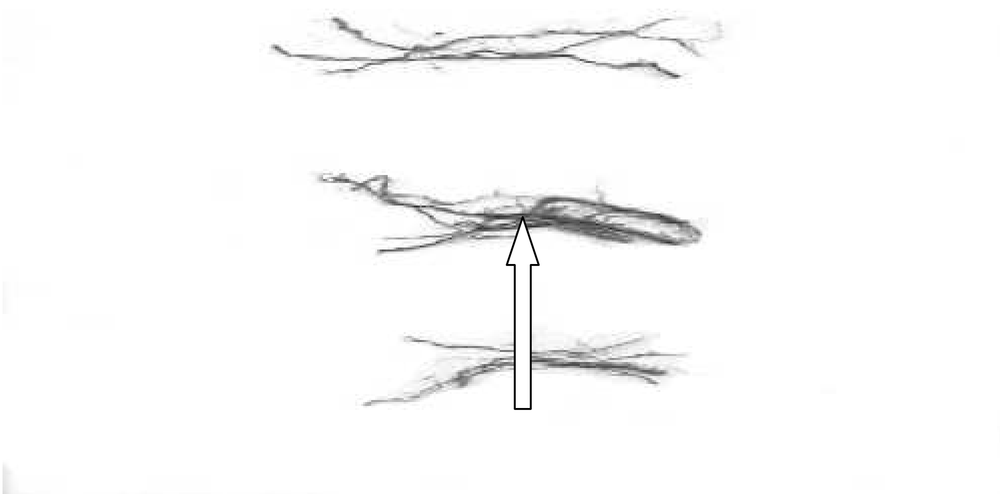

Plate 3: Poor maize root growth of 3 plots (D19-D21), with low density of fine roots with 25 cm topsoil removal and no nutrient amendment in the lower slope

Plate 4: Improved maize root system development of 3 plots (D22-D24) with non-removal of topsoil and poultry manure application.

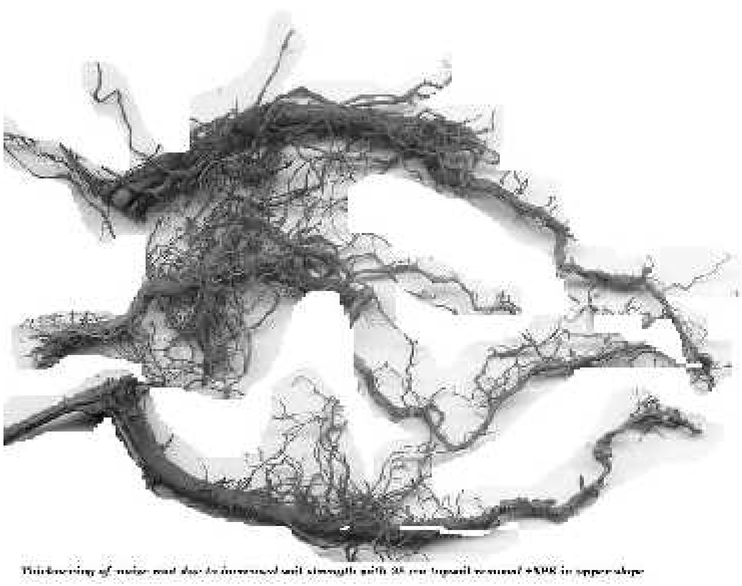

Plate 5. Upper slope, plot 3 at 25 cm topsoil removal + NPK/Urea.

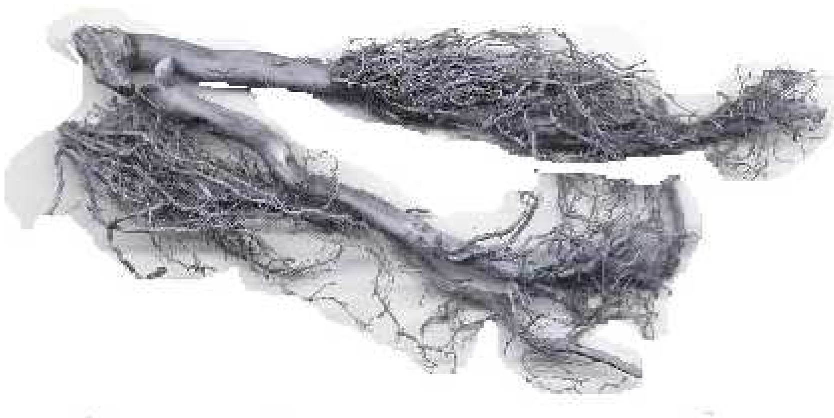

Plate 6: U14: Upper slope, poultry manure, 25 cm topsoil removal

Addition of NPK+ Urea at the 0 cm (Non removal of topsoil) produced the lowest pixel of 0.005 followed by poultry manure, 0 cm removal with a value of 0.008 pixels. (Table 1)The highest pixel value was at the 15 cm topsoil removal under the application of NPK+ urea. On the whole, poultry manure application collectively produced the lowest degree of darkness while no amendment produced the highest.

6.2 Penetrometer resistance

At 6 days before planting , overall means of penetrometer resistance for topsoil removal was 2641 kPa for 0 cm topsoil removal, 3344 kPa for 15 cm topsoil removal and 3159 kPa for 25 cm soil depth removal. (Figure 1) Penetrometer resistance for both slope positions increased with increase in topsoil depth removed. Penetrometer resistance was high at the topsoil but decreased significantly to less than 2500kPa and 1500kPa for upper slope positions respectively at the 10 cm depth. From the 10 cm to the 50 cm depth, penetrometer resistance increased significantly with the upper slope position having higher penetrometer compared to the lower slope.

At 9 weeks after planting maize, the overall means were 1750 kPa for lower slope and 2688 kPa for upper slope. Penetrometer resistance increased from 1637 kPa at the 0 cm topsoil depth removal to 2578 kPa at the 15 cm topsoil removal depth but decreased to 2443 kPa at the

25 cm topsoil depth removal, though there was no significant difference between the 15 cm and 25 cm depth removal.

Furthermore, slope position, topsoil removal and their interactions all had significant effects on penetrometer resistance but nutrient amendment did not have a significant effect on penetrometer resistance. (Table 3).

Conclusion

- Topsoil removal increased soil strength above a threshold value of 2000 kPa considered as a limit for adequate growth of roots of cereals. Thus, the soils are considered to have a zero soil loss tolerance to prevent the subsoil from constituting an impediment to root growth, hence sustainable crop production.

- Nutrient amendment and non-removal of topsoil promoted root growth of maize and these ensure availability of more root residues for organic matter addition through decomposition.

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Table 1. Ranking according to degree of darkness of scanned maize roots through image analysis for lower slope position.

Topsoil removal (cm)	Amendment	Pixels (%)/gram of scanned roots	Rank according to degree of darkness	Classification
0	No amendment	0.118	3	darkest
15		0.225	8	dark
25		0.153	6	Darker
0	NPK + Urea	0.005	1	darkest
15		0.230	9	dark
25		0.158	7	dark
0	Poultry manure	0.008	2	darkest
15		0.132	4	darker
25		0.137	5	darker

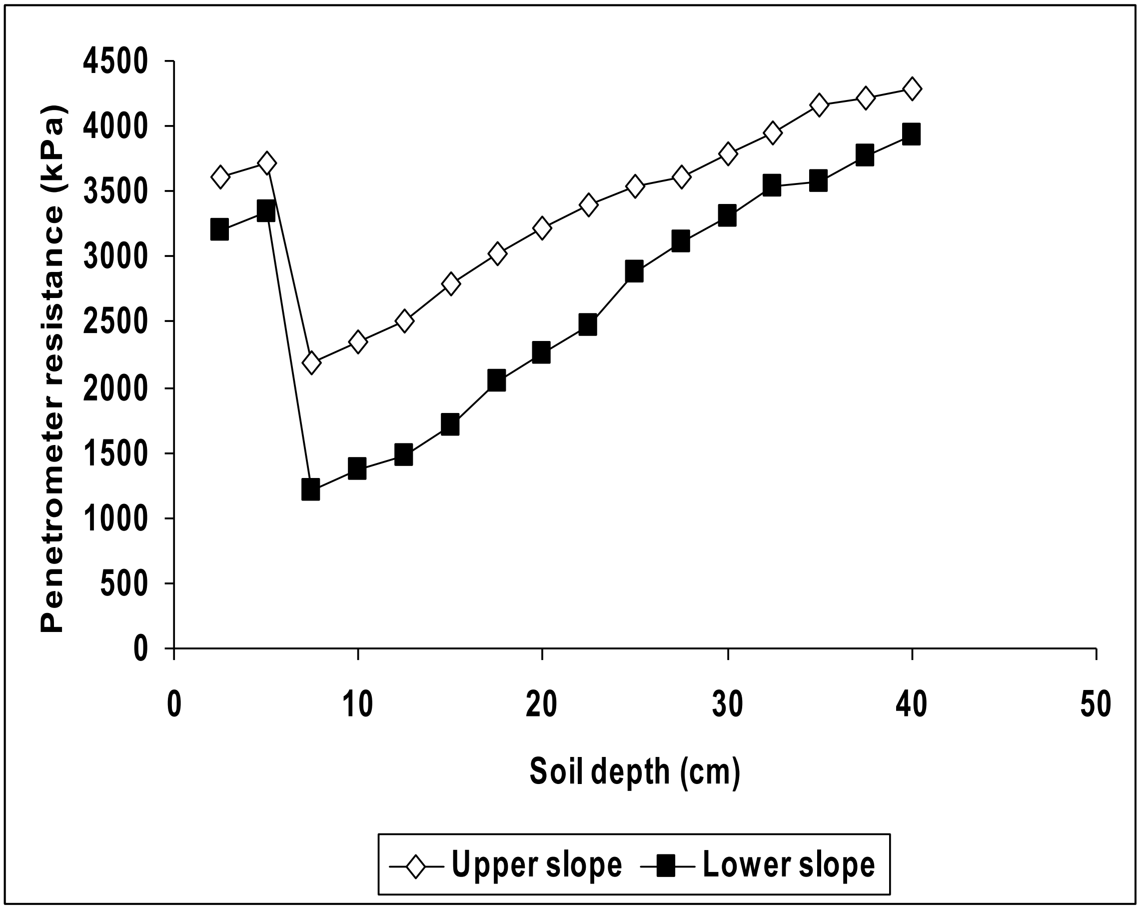

Figure 1: Changes in penetrometer resistance with soil depth after topsoil removal, 6 days before planting maize in August 2005.

Table 2: Root mass density (kg m^{-3}) of maize as affected by slope position, topsoil removal and nutrient amendment at 88 DAP.

Slope position	Nutrient amendment	Topsoil removal (cm)	Root mass density (kgm^{-3})
	No amendment	0	0.5
		15	0.1
		25	0.1
Lower slope	NPK+ Urea	0	1.8
		15	0.7
		25	0.6

	Poultry manure	0	0.7
		15	1.1
		25	0.9
	No amendment	0	0.5
		15	0.2
		25	0.2
Upper slope	NPK+ Urea	0	1.8
		15	1.3
		25	0.9
	Poultry manure	0	1.8
		15	2.6
		25	2.0
LSD P≤0.05			
Slope position			0.5
Topsoil removal			NS
Nutrient amendment			0.9
Slope x amendment			0.7
Slope x topsoil removal			0.7
Slope x amendment x topsoil removal			1.1

Table 3: Penetrometer Resistance (0-25 cm) depth at 9 weeks after planting maize as affected by slope position, topsoil removal and nutrient amendment.

Slope position	Nutrient amendment	Topsoil removal (cm)	Penetrometer resistance (kPa)
	No amendment	0	1245
		15	2475
		25	2339
Lower slope	NPK+ Urea	0	1891
		15	1833

		25	1564
	Poultry manure	0	1164
		15	1465
		25	1778
	No amendment	0	2101
		15	2977
		25	2621
Upper slope	NPK+ Urea	0	1805
		15	3550
		25	3953
	Poultry manure	0	1618
		15	3165
		25	2404
LSD P≤0.05			
Slope position			938
Topsoil removal			500
Nutrient amendment			NS
Slope x amendment			1068
Slope x topsoil removal			633
Slope x amendment x topsoil removal			1057