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Growth of maize in a simulated degraded soil under the influence of organomineral fertilizer and sawdust application

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ABSTRACT

A greenhouse investigation was conducted using simulated degraded soil and a completely randomized design with three factors and three replicates. The factors investigated were organomineral fertilizer application – two levels (with and without); soil amendment with sawdust – two levels (amended and non-amended) and method of application of fertilizer – three levels (ring, sub-surface, and completely mixed with soil). Data collected include plant height, stem girth, leaf area, number of leaves, dry weight of stem, leaf root, cob, total biomass, above ground biomass and mycorrhizal colonization. Data were analysed using ANOVA and means separated by Duncan's multiple range test. The simulated degraded soil was high in clay and deficient in essential minerals. Growth of maize in non-amended soil was significantly ($p<0.05$) higher compared to the amended soil with or without application of organomineral fertilizer. The least plant height under non-amended soil with organomineral fertilizer application was 72.0% higher than the highest height in the amended soil with fertilizer application. There was no significant increase in the vegetative growth of maize under the application of organomineral fertilizer in the amended soil, whereas, in the non-amended soil, organomineral fertilizer application significantly ($p<0.05$) increased the yield of maize. Method of application of organomineral fertilizer did not significantly affect the growth of maize. Application of sawdust to amend an already degraded soil will not support good growth of maize even with the application of organomineral fertilizer, but yield of maize in degraded soil can be significantly increased with the application of organomineral fertilizer, particularly with reference to above ground biomass.

INTRODUCTION

Land degradation renders soil agriculturally unproductive and results in depletion of nutrients, organic matter, reduction of water holding capacity and reduces release of nutrients (Agboola, 1987; Sanchez and Logan, 1992; Akinbola, 1989). The Global Assessment of Soil Degradation (GLASOD, 1990) has estimated that nearly 2 billions hectares worldwide or 22% of all cropland, pasture, forest and woodland have been degraded since 1945. About 5.10 millions arable land is loss annually to land degradation (Scherr, 1999). Furthermore, poor structure, poor water retention capacity, depletion of nutrient reserves, soil acidification combined with aluminum toxicity, phosphate fixation, salinization, and soil erosion, are other effects of soil degradation. Soil degradation factors can be recognized as socio-economic, chemical, biological and physical (Boel *et al.*, 1982; Oldeman, 1993; LEISA, 2003).

Rehabilitation of degraded soil whose topsoil has been eroded takes a lot of effort. Conservation technology used in the control of run-off and erosion is the cross slope, such as live barrier, rock walls, infiltration ditches, terraces and earth bunds (Hellin and Schrader, 2003). Agroforestry system characterized by three layers of vegetation, mulch, crops and dispersed shrubs trees and planting of cover crops are effective means used to reduce soil degradation (Hellin and Haigh, 2002). The use of organic waste such as crop residues, live mulch and sawdust improves the physiochemical properties of the soil (Larson *et al.*, 1978; Balasubramanian and Nnadi, 1980; Wei *et al*., 1985; Warman, 1986). Darra *et al.,* (1968) found that incorporation of organic waste were more effective than surface application in increasing the water holding capacity and in reducing bulk density. There is beneficial effect of combining organic manure and mineral fertilizer (organomineral) over mineral fertilizer alone. It is more economical and simpler way of achieving the same effect of ploughing crop residues and applying chemical fertilizer separately (Akpomudjere and Omueti, 1991; Adeoye *et al.,* 1998).

Will the incorporation of sawdust and organomineral fertilizer improve maize growth and yield in a degraded soil? It is therefore the objective of this study to assess the growth and yield of maize as influenced by sawdust and organomineral fertilizer under different application methods.

MATERIALS AND METHODS

It was a green house experiment with the following condition: average day /night temperature 36/25± 2^0C, and relative humidity (uncontrolled) ranging between 45% and 75% during the day.

Soil sample (sub-soil, 30-70cm) was collected from Parry road, University of Ibadan experimental site, air dried, and sieved using a 2mm sieve to remove large stones. Soil sample were analyzed for physical and chemical properties.

Experimental design was a completely randomized design with three replicates and a factorial combination of organomineral fertilizer - two levels (with and without), soil amendment with sawdust –two levels (amended and non-amended) and organomineral fertilizer application methods - three levels (ring, sub-surface and mixed). All experimental units were replicated three times. Amended soil was on 1:1 soil to sawdust by volume. Each pot contained approximately 10 L volume (soil or soil/sawdust). Three maize seeds were planted per pot and thinned to one per pot, ten days after planting. Application of organomineral fertilizer was by the three methods already mentioned. NPK 15-15-15 was applied at the rate of 5 g/pot as top dressing. Growth parameters; height, girth, leaf area and number of leaves were taken while dry weight of stem, leaf, root, cob, total biomass, above ground biomass and mycorrhizal root colonization were taken at the end of the experiment. Mycorrhizal staining was according to the method of Philip and Hayman (1970) while quantitation was by the grid - line intersect method (Giovannette and Mosse, 1980).

Data were analyzed using ANOVA (SAS, 1995) and the means separated by Duncan's multiple range tests.

RESULTS

Soil analyses

The soil was very high in clay and deficient in essential minerals, particularly nitrogen, phosphorus and potassium that are below the critical level (Table 1). The pH was moderately acidic.

Table 1: Pre-planting chemical and physical properties of soil.

Parameters	Values
pH (H_2O; 1:2)	5.2
Total organic carbon (g/kg)	10.9
Total nitrogen (g/kg)	0.13
Available phosphorus (mg/kg)	1.52
Exchangeable cations (Cmol/kg)	
Ca	0.05
Mg	0.04
K	0.04
Particle component (g/kg)	
Sand	704
Silt	98
Clay	211
Textural class: Sandy clay loam	

Vegetative growth of maize

Generally, the height and girth of maize in the non-amended soil with organomineral fertilizer application was significantly ($p<0.05$) higher compared to those of soil amended with sawdust with or without organomineral fertilizer application irrespective of method of application (Table 2).

Table 2: Vegetative growth of maize as affected by soil amendment, fertilizer application and application methods under greenhouse conditions

Soil	Fertilizer application	Fertilizer application method	Height (cm)	Girth (cm)	Leaf area (cm^2)	Number of leaves
Amended	With	Ring	35.2d	3.5c	244.7bc	11.7ab
"	"	Sub-surface	37.5d	3.6c	241.1bc	10.3b
"	"	Mixed	38.1d	3.8bc	316.2b	10.0bc
"	Without	Ring	37.5d	3.4c	226.5bc	10.0bc
"	"	Sub-surface	34.5d	3.8bc	233.6bc	10.7b
"	"	Mixed	32.0d	3.3cd	219.5c	9.7c
Non-amended	With	Ring	65.6b	4.7a	311.8b	13.3a
"	"	Sub-surface	68.4b	5.1a	354.0a	12.7a
"	"	Mixed	91.3a	4.9a	296.5b	13.0a
"	Without	Ring	57.2c	4.4b	271.5b	12.0ab
"	"	Sub-surface	55.4c	4.2b	297.1b	11.0b
"	"	Mixed	37.4d	4.1b	255.4bc	10.7b
		ANOVA				
		Soil (S)	***	***	***	***
		Fertilizer (F)	***	NS	NS	*
		Methods (M)	***	NS	NS	NS
		Interactions				
		S*F	***	NS	NS	NS
		S*M	**	NS	NS	NS
		F*M	NS	NS	NS	NS
		S*F*M	NS	NS	NS	NS

Values followed by different letters under the same column are significantly different according to Duncan's multiple range test.
*, **, *** - Significant at 0.05, 0.01 and 0.001 respectively. NS – Not significant.

The least height under non-amended soil with organomineral fertilizer application was 72.0 % higher than the highest in the amended soil with fertilizer application. In the non-amended soil, organomineral fertilizer application significantly ($p<0.05$) increased the height and girth of maize plants, whereas, in the amended soil, effect of organomineral fertilizer application on the two variables was not significant. The organomineral fertilizer application method was not significantly different in terms of height, girth, leaf area and number of leaves except for height where mixed method of application was significantly higher compared to other treatments. Furthermore, with reference to leaf area, sub-surface buried method was also significantly higher compared to other methods (Table 2).

Above Ground Biomass

The total biomass of maize was significantly ($p<0.05$) higher in non-amended soil with organomineral fertilizer application (Figure 1). Ring method of organomineral fertilizer application method has the higher biomass. The amended soil with and without organomineral fertilizer application was approximately 50% lower than the non-amended soil with organomineral fertilizer application. The highest above ground biomass yield in the non-amended soil was 100% higher compared to the yield in the soil amended with sawdust.

Mycorrhizal Colonization.

Natural mycorrhizal colonization was observed with maize even at subsoil level though very low. Mycorrhizal colonization count was significantly ($p<0.05$) higher in the amended soil with sawdust with and without organomineral fertilizer application when compared to the non- amended soil. However, amended soil with sawdust without organomineral fertilizer application had the highest AM fungi colonization (Figure 2). Non – amended soil with organomineral fertilizer had the lowest AM colonization irrespective of the organomineral fertilizer application methods.

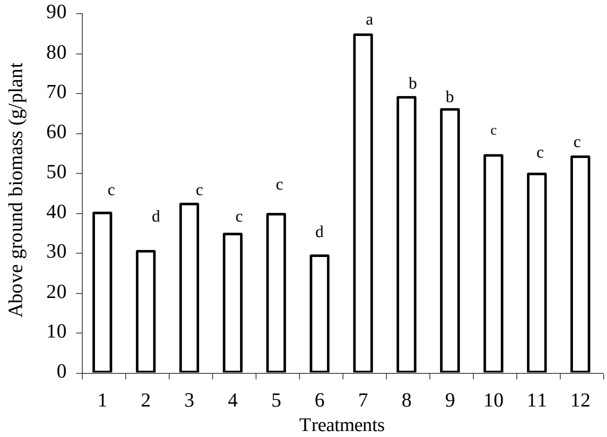

Fig.1. Above ground biomass (g/plant) of maize as affected by soil amendment, fertilizer application and application methods in a simulated degraded soil

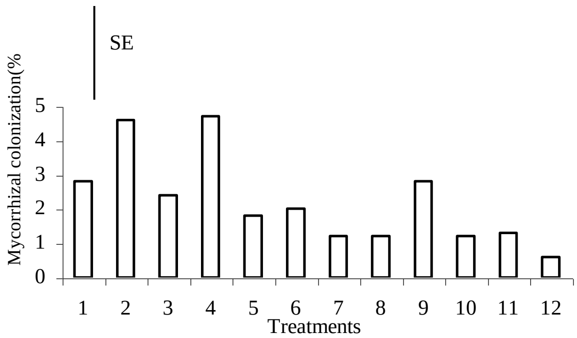

Fig.2. Mycorrhizal colonization (%) of maize as influenced by soil amendment, fertilizer application and methods

Legend:

Treatments:

1. Soil amended with sawdust and ring application of organomineral fertilizer.
2. Soil amended with sawdust and sub-surface application of organomineral fertilizer.
3. Soil amended with sawdust and mixed application of organomineral fertilizer.
4. Soil amended with sawdust and without application of organomineral fertilizer (ring).
5. Soil amended with sawdust and without application of organomineral fertilizer (sub-surface).
6. Soil amended with sawdust and without application of organomineral fertilizer (mixed).
7. Non-ammended soil and ring application of organomneral fertilizer.
8. Non-ammended soil and sub-surface application of organomneral fertilizer.
9. Non-ammended soil and mixed application of organomneral fertilizer.
10. Non-ammended soil without application of organomneral fertilizer (ring).
11. Non-ammended soil without application of organomneral fertilizer (sub-surface).
12. Non-ammended soil and ring application of organomneral fertilizer (mixed).

Bars followed by different letters in Figure 1 are significantly different ($p<0.05$) according to Duncan's multiple range test.

SE – Standard error (in Figure 2).

Component Yield of Maize

The dry matter yield of maize stem, leaf, and height in non-amended soil with organomineral fertilizer application was significantly higher than those of other treatments (Table 3). The highest yield in the soil amended with sawdust with and without organomineral fertilizer application was approximately 50% of the highest yield of the non- amended soil with organomineral fertilizer application. Under different organomineral fertilizer application methods, the ring method of application showed significant increase in stem and leaf dry matter weight. Irrespective of the organomineral fertilizer application methods, the cob yield was significantly ($p<0.05$) higher in non-amended soil with organomineral fertilizer. Also Cob yield was significantly ($p<0.05$) higher in non-amended soil compared to the amended soils. There was no significant difference in the yield of maize on the amended soil with sawdust irrespective of the organomineral fertilizer application methods. Highest cob weight in non-amended soil was 155.0% higher compared to the smallest cob weight under amended soil. Application of organomineral fertilizer was more effective on the non-amended soil compared to the amended soil with respect to cob weight.

DISCUSSION

Generally, sub-soil is very high in clay content and the nutrients are below critical level yet it can sustain crops to some extent (Adeoye, 1986; Enwenzor *et al*., 1989). Among other environmental factors, the type of soil used in cultivation has either a negative or positive effects on maize (Dowswell *et al*., 1996). The pH of the soil was lower than the near neutral alfisols that are commonly reported.

Organic waste such as sawdust can be a source of nutrient that will improve the physical and chemical properties of the soil (Larson *et al*., 1978; Wei *et al*., 1985; Warman, 1986). In addition, the incorporation of sawdust in the soil is a way of reducing environmental pollution.

The reduction of the growth and yield of maize in the soil amended with sawdust resulted from the direct incorporation of sawdust with high lignin content (C:N ratio, 560:1), this causes N- immobilization (Yoneyama and Yishida, 1977; Olayinka and Adebayo, 1989). The plant height, stem girth, dry matter yield of stem, root, leaf and cobs were significantly ($p<0.05$) higher in non- amended soil compared to the amended soil. The organomineral fertilizer application was more effective in non-amended soil compared to soil amended with sawdust. There was significant ($p< 0.05$) increase in the above ground biomass in non-amended with organomineral fertilizer application under different application methods compared to other treatments. Under different application methods, ring method of organomineral fertilizer application was significantly higher in terms of above ground biomass, so ring method is more effective way of organomineral fertilizer application.

Arbuscular mycorrhizal fungi constitute an important component of microbial soil community and it has considerable positive and negative impact on plant health and growth (Dehne, 1982; Azcon- Aguilar *et al*., 1996; Taylor and Harrier, 2000; Reqiuena *et al*., 2001). From this study, natural mycorrhizal colonization was low in degraded soil. Organic matter content has a high correlation with AM fungi propagule density, hence the soil amended with sawdust has higher mycorrhizal counts than non-amended; this confirmed the work done by Toro and Sieverding (1986).

The application of organomineral fertilizer and different application methods significantly ($p<0.05$) increase the growth of maize. Therefore, organomineral fertilizer (organomineral fertilizer) can be used to improve the yield of crops in degraded soil where the topsoil has been eroded. Amendment of degraded soil with sawdust, a highly lignified plant material can be detrimental to the growth of crops like maize. Nevertheless, the long-term effect of such amendment is a subject of further investigation.

Table 3: Yield component of maize as affected by soil amendment, fertilizer application and application methods under greenhouse conditions.

Soil	Fertilizer application	Fertilizer application method				Root	Stem	Leaf	Cob
Amended	With	Ring	3.1de	17.1cd	8.3c	14.2d	17.1cd	8.3c	14.2d
“	“	Sub-surface	4.7cde	10.2e	5.0f	15.0c	10.2e	5.0f	15.0c
“	“	Mixed	2.9e	17.7cd	6.9de	17.5c	17.7cd	6.9de	17.5c
“	Without	Ring	4.0de	13.6de	7.7cd	13.3d	13.6de	7.7cd	13.3d
“	“	Sub-surface	5.0cd	18.8cd	6.1e	14.6c	18.8cd	6.1e	14.6c
“	“	Mixed	4.1cde	8.9e	4.2f	16.0c	8.9e	4.2f	16.0c
Non-amended	With	Ring	10.2a	36.1a	14.3a	34.0a	36.1a	14.3a	34.0a
“	“	Sub-surface	7.3b	25.2b	11.2b	32.2a	25.2b	11.2b	32.2a
“	“	Mixed	10.1a	20.4bc	13.1b	32.2a	20.4bc	13.1b	32.2a
“	Without	Ring	7.3b	15.1cd	8.7c	30.4b	15.1cd	8.7c	30.4b
“	“	Sub-surface	6.1bc	12.7de	7.3d	29.6b	12.7de	7.3d	29.6b
“	“	Mixed	4.1cde	15.7cd	8.7c	29.5b	15.7cd	8.7c	29.5b
		ANOVA							
		Soil (S)	*	*	NS	***	*	NS	***
		Fertilizer (F)	NS	*	NS	NS	*	NS	NS
		Methods (M)	NS	NS	NS	NS	NS	NS	NS
		Interactions							
		S*F	NS	NS	NS	NS	NS	NS	NS
		S*M	NS	NS	NS	NS	NS	NS	NS
		F*M	NS	NS	NS	NS	NS	NS	NS
		S*F*M	NS	NS	NS	NS	NS	NS	NS

Values followed by different letters under the same column are significantly different according to Duncan's multiple range test.
*, *** - Significant at 0.05 and 0.001 respectively. NS – Not significant.

REFERENCES

Adeoye, G. O (1986). Comparative studies of Ammonium bifloride chelate extractants and some conventional extractants for sedimentary soil of southwestern Nigeria. Ph.D Thesis, University of Ibadan. Ibadan, Nigeria.

Adeoye G. O., Shridar, M.KC and Fidelis, A. (1998) Analysis of the chemical composition of two strains of *Pleurotus* sp. Unpulished dissertation. 56 pp

Agboola, A. A. (1987). Farming system in Nigeria. In: Land development and management of arid soils in Africa. II. IBSRAM Proc. No7 pp67-81.

Akinbola, G. E. (1999), Environmental impact assessment (soil studies) of the phase II gas projects. Shell Nigeria Gas Limited, Port Harcourt, Nigeria 32 p.

Akpomudjere, E. and Omueti, J.A.I. (1991). Effect of NPK fertilizer and farmyard manure or growth and yield of upland rice (*Oryza sativa* (L). Proceedings of the 19th Annual Conference of the Soil Science Society of Nigeria, Ile-Ife. Nigeria.

Azcon-Aguilar, C., Berea J. M., Azon R. and Diaz – Rodriguez, R. M. (1996). Assessment of field situations for the feasibility of vesicular – arbuscular mycorrhizal inoculums, using a forage legume as test plant. Agriculture Ecosystems and Environment 15: 241- 252.

Balasubramarian, V. and Nnadi, C. A. (1980). Crop residue management and soil productivity in savanna areas of Nigeria. In organic recycling in Africa. FAO soil bulletin pp. 106-120.

Boel, D, Dankis D. B. and Johnson, A. E. (1982). Soil degradation Balkema, Rotterdam, Netherlands, 280 pp.

Darra, B.L., Jan. S.V., and Ussaman. O. (1968). The influence of different green manure crops on soil structure and wheat yield. Indian Journal of Agronomy 13; 162-164.

Dehne H. W. (1986). VAM and plant health. In: Abstracts 2nd European symposium on mycorrhizae 26-27. Institute of Landscape Ecology, Prague.

Dowswell, C. D; Patiwal, R. L. and Cantrell, R. P. (1996). Maize in the third World. Boulder, CO, USA, Westview Press.

Enwenzor, W. O. E., Udo, J., Udoroh, N. J., Ayolade, R. A., Adepetu, J. A., Chude, V. O. and Udegbe, U. I. (1989). Fertilizer use and management for crops in Nigeria series No. 2. 163pp.

Giovanetti, M. and Mosse, B. (1980). An evaluation of techniques for measuring vesicular arbuscular mycorrhizal infection in roots. New Phytologist 84:489-500.

GLASOD (1990). Global Assessment of soil degradation world maps, Wageningen, Netherlands, ISRIC and PNUE.

Hellin, J and Haigh, M. J. (2002). Better land husbandry in Honduras: towards the new paradigm in conserving soil, water and productivity. Land Degradation and Development 13: 233-250.

Hellin, J and Schrader, K. (2003). The case against direct incentives and the search for alternative approaches to better land management in Central America. Agriculture Ecosystems and Environment 99: 61-81.

Larson, W. E., Holt, R.F. and Carlson, C. W. (1978). Residues for soil conservation. In: Crop Residues Management Systems. Oschwald, W. R.(ed). America Society of Agromony. Madison WI.

LEISA Magazine (2003) December 2003, Vol. 19. No. 4. P4.

Olayinka, A. and Adebayo. A. (1989). Effect of pre-incubated sawdust based cowdung on growth and nutrient uptake of *Zea mays* (L) and on soil chemical properties. Biology and Fertility of Soils 7: 176-179.

Philip, J.M. and Hayman, D.S. (1970). Improved procedure for clearing roots and staining parasitic and vesicular arbuscular mycorrhizal fungi for rapid assessment of infection. Transaction of British Mycological Society 54:53-63.

Reqiuena, N, Perez-Solis, E., Azcon-Aguilar, C., Jeffries, P. and Barea J. M. (2001). Management of indigenous plant microbe symbioses aids restoration of desertified ecosystems. Applied and Environmental Microbiology 67:495-498.

Sanchez, P.A. and Logan, T.J. (1992). Myths and science about the chemistry and science of soil of the tropics. SSSA special publication N 0.29. Soil society of America. America Society of Agronomy, Madison, USA pp 35-46.

SAS (1985) SAS users guide. Statistical Analysis System, Carry, NC, USA 957P.

Scherr, S. J. (1999). Global estimates of land degradation by region and land use. VII 63p.

Taylor, J., and Harrier, L. (2000). A comparison of nine species of arbuscular mycorrhizal fungi on the development and nutrition of micro propagated *Rubus idacus* (l) cv. *Culen prosen* (Red Raspberry). Plant and Soil 225:53-61.

Toro, T. S. and Sieverding, E. (1986). Evalucion cuantitiva de hongos formadores de micorriza vesicule arbuscular enla region de Mondomo, Colombia. Suclos Ecuatoriales 16 : 122-129.

Warman, P. R. (1986). Effect of fertilizer, pig manure and sewage sludge on timothy and soil. Journal of Environmental Quality 15: 95-100.

Wei, Q. F., Lowery, B. and Peterson A. E. (1985). Effect of sludge application on physical properties of a silty clay loam soils. Journal of Environmental Quality 14:178-180.

Yoneyama, T. and Yoshida, T. (1977). Decomposition of rice residue in tropical soils: III. N mineralization and immobilization of rice residue during its decomposition in soil. Soil Science and Plant Nutrition 23:175-183.