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Influence of Poultry and Green Manures on the Productivity of Popcorn (*Zea mays var. everta* L.) in the Northern Guinea Savanna of Nigeria

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Abstract

Poor soil management practices in the savanna regions have resulted in decreased yield due to soil degradation expressed as a decline in organic matter content and fertility of the soil. These could however be remedied by adopting the use of manures to boost the soil organic matter content and consequently improve the nutrient status of the soil. A trial was therefore carried out at the Institute for Agricultural Research field, Samaru during the 2013 and 2014 rainy seasons to determine the effect of poultry and green manures on the productivity of popcorn. Treatments included four poultry manure rates (0, 2000, 4000 and 6000 kg ha^{-1}) and green manure from two types of cowpea; SAMPEA 6 which is an improved variety and a local cultivar Kanannado. The cowpea foliage was clipped 15 cm from the soil surface and incorporated into the soil at 2500 kg ha^{-1} 6 weeks after sowing (WAS) to serve as green manure. Significant increases on plant height, cob weight, 1000 grain weight and grain yield were recorded with application of 2000 kg ha^{-1} of poultry manure in addition to green manure from either type of cowpea. Soil sample analysis showed that organic carbon, total nitrogen and magnesium increased in the second year, while the soil pH and sodium content decreased. Based on the result of this trial, application of 2000 kg ha^{-1} of poultry manure in addition to 2500 kg ha^{-1} green manure from either type of cowpea can be recommended for good popcorn yields.

Keywords: Green manure, poultry manure, cowpea, organic matter, soil nutrient.

Influence de la Volaille et des Engrais Verts Sur la Productivite du Popcorn (*Zea mays Var. Everta* L.) Dans le Nord De la Guinee-savane, au Nigeria

Résumé

Les mauvaises pratiques de gestion des sols dans les régions de savane ont entraîné une baisse des rendements en raison de la dégradation des sols, exprimée par une diminution de la teneur en matière organique et de la fertilité des sols. On pourrait toutefois remédier à ces problèmes en utilisant du fumier pour augmenter la teneur en matière organique du sol et, partant, améliorer le statut nutritionnel du sol. Un essai a donc été effectué sur le terrain de l'institut de recherche agricole de Samaru pendant les saisons des pluies de 2013 et 2014 afin de déterminer l'effet de la volaille et des engrais verts sur la productivité du maïs soufflé. Les traitements comprenaient quatre taux de fumier de volaille (0, 2000, 4000 et 6000 kg ha-1) et du fumier vert provenant de deux types de niébé; SAMPEA 6, une variété améliorée et un cultivar local Kanannado. Le feuillage du niébé a été coupé à 15 cm de la surface du sol et incorporé dans le sol à raison de 2 500 kg / ha 6 semaines après semis (SAS) pour servir d'engrais vert. Des augmentations significatives de la hauteur de la

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plante, du poids des épis, du poids de 1000 grains et du rendement en grain ont été enregistrées avec l'application de 2 000 kg / ha-1 de fumier de volaille en plus du fumier vert de l'un ou l'autre type de niébé. L'analyse des échantillons de sol a montré que le carbone organique, l'azote total et le magnésium ont augmenté la deuxième année, alors que le pH et la teneur en sodium du sol ont diminué. D'après les résultats de cet essai, l'application de 2 000 kg / ha^{-1} de fumier de volaille en plus de 2 500 kg / ha^{-1} d'engrais vert de l'un ou l'autre type de niébé peut être recommandée pour de bons rendements en maïs soufflé.

Mots clés: Engrais vert, fumier de volaille, niébé, matière organique, élément nutritif du sol.

Introduction

Food production in many parts of Africa is limited primarily by nutrient deficiencies and soil degradation (Cassman, 1999; Pablo and Ken, 2013). Soil nutrient deficiency could be largely attributed to the decreased soil organic matter as most farmers fail to incorporate or allow their crop residues decompose and recycle nutrients back into the soil. Similarly, the use of low levels of nutrients by farmers leads to mining of the soil thus further decreasing the soil nutrient content. Loss of soil macronutrients in sub - Saharan Africa has been estimated at 10 to 70 kg N ha^{-1}, 2 to 10 kg P ha^{-1} and 8 to 50 kg K ha^{-1}(Stoorvogel and Smaling, 1998;, Zingore *et al*., 2015). This results in decreases in crop yields as reported by FAO (2010) and Zingore *et al*. (2015) that over the past five decades, yields of cereal crops in sub - Saharan Africa have stagnated at less than 1500 kg ha^{-1}, although the yield potential of most crop varieties exceeds 5000 kg ha^{-1}. The decline in crop yield has resulted in food insecurity manifested as starvation and malnutrition. In order to increase crop production, farmers adopt intensive agriculture of applying mineral fertilizers, and this is often associated with reduced yield with time, due to soil acidification and nutrients imbalance. This challenge could however, be reduced through the adoption of strategies for better soil management, e.g., use of manures as nutrient sources. Additionally, organic matter and soil nutrient status can be improved if only the grain is harvested and the straw left to be worked into the soil or spread in stables and returned to the fields as manure. The volumes that are taken from the system would be significantly lower (Johannes, 2013). Mulvaney *et al.* (2009) also reported that loss of organic nitrogen decreases soil productivity and agronomic efficiency of fertilizer N and that this has been implicated in the widespread reports of yield stagnation or even decline in grain production. The research was carried out to determine the influence of poultry and green manures on productivity of popcorn.

Materials and Methods

A trial was carried out at the Institute for Agricultural Research field, Samaru (11°11'N, 07°38'E and 686m above sea level) during the 2013 and 2014 rainy seasons.

Treatments included four poultry manure rates (0, 2000, 4000 and 6000ha^{-1}), two types of cowpea: SAMPEA 6 which is an improved variety and Kanannado a local cultivar, clipping practice (clipped and unclipped) and time of sowing cowpea (early, i.e. sowing at the same time with popcorn and late i.e. at four weeks after sowing popcorn) laid out in a split plot design replicated three times. Poultry manure and types of cowpea were in main plot while time of sowing and clipping were in the sub plot.

Cowpea was clipped using secateurs at 15cm from the soil surface at six weeks after sowing (WAS) about the period of peak lush plant material and dry matter accumulation. Clipped foliage (2500 kg ha^{-1}) was incorporated during earthening (remoulding) up at six weeks after sowing to serve as green manure. The same field and plots were used during the two years of experimentation. The soil of the experimental site was sampled before and after the trial to determine the physical and chemical properties. Soil particle size distribution was analysed using the hydrometer method (Gee and Or, 2002), pH using glass electrode pH meter (Agbenin, 1995), organic carbon by the dichromate wet oxidation method of Walkley and Black (Nelson and Sommer, 1986), total nitrogen by the kjeldahl method (Bremner and Mulvaney, 1982), available phosphorus using Bray 1 method (Bray and Kurtz, 1945), exchangeable bases were extracted using HCl as described by

Agbenin (1995), exchangeable potassium and sodium were read using a photometer, exchangeable calcium and magnesium concentration were determined using the atomic absorption spectrophotometer and cation exchange capacity was determined using ammonium acetate method (Thomas, 1982).

Poultry manure used was obtained from laying birds (layers) and was analysed to determine its nutrient composition. Foliage collected from the cowpeas used as green manure was also analysed to determine the nutrient composition. Data were collected on plant height, shoot dry weight, crop growth rate, cob weight, 1000 grain weight and grain yield. These were analyzed using analysis of variance as described by Snedecor and Cochran (1967), using the general linear model (GLM) procedure of the statistical analysis system (SAS) package (SAS, 1990). The treatment means were separated using Duncan Multiple Range Test (Duncan, 1955).

Results

The physical and chemical properties of the soil of the experimental site during the years of the experiment are shown in Table 1. The soil texture was clay loam with pH in H_2O slightly acidic, while pH in $CaCl_2$ was moderately acidic in the two years. A decline in the soil pH was however observed in 2014. Low values of soil organic carbon and the total nitrogen (N) were recorded in 2013, but increased in 2014. The exchangeable cations showed moderate amount of calcium (Ca) in the soil and the value was the same in both years of the trial. Soil magnesium (Mg) content was medium, although it increased in the second year. Potassium (K) content was high in 2013 and medium in 2014. The exchangeable sodium (Na) content in the soil was high in 2013, but decreased in 2014. Cation exchange capacity (CEC) recorded was medium in both years although a decline in the CEC value was observed in 2014.

Table 2 shows the nutrient composition of the cowpea foliage incorporated into the soil as green manure. Nitrogen content (%) of SAMPEA 6 tended to increase with increase in the rate of poultry manure applied, while with Kanannado, the reverse was observed. Organic carbon content was inconsistent and C:N ratio decreased with increase in poultry manure rate in SAMPEA 6, and the reverse was observed with Kanannado.

Table 1: Physical and Chemical Properties of the soil of the experimental site during 2013 and 2014 rainy seasons at 0-30cm depth

	2013	2014
Particle Size Distribution (g kg^{-1})		
Sand	370	366
Silt	358	360
Clay	272	274
Textural class	Clay loam	Clay loam
Chemical properties		
pH in H_2O	6.3	6.1
pH in 0.01M $CaCl_2$	5.9	5.8
Organic carbon(g kg^{-1})	0.5	1.3
Total N (g kg^{-1})	0.1	0.2
Available P(mg kg^{-1})	3.5	6.9
Exchangeable bases (cmolkg^{-1})		
Ca	3.4	3.4
Mg	0.6	0.7
K	0.4	0.1
Na	0.6	0.2
CEC	5.3	4.3

Soil samples were analyzed in the analytical laboratory of the Agronomy Department, Ahmadu Bello University Samaru, Zaria.

Table 2: Mean nutrient composition of the cowpeas incorporated as green manure at Samaru during the years of experiment

		Percentage (%)		Mg kg^{-1}			
Treatments	**N**	**P**	**K**	**OC**	**Calcium**	**Magnesium**	**C: N**
SAMPEA 6							
0 kg ha^{-1} Pm	1.40	0.370	1.53	44.89	2111.10	6734.50	32.06
2000 kg ha^{-1} Pm	2.10	0.455	2.50	33.58	1979.10	7808.44	15.99
4000 kg ha^{-1} Pm	4.73	0.436	1.96	42.46	2106.30	4789.55	8.98
6000 kg ha^{-1} Pm	3.71	0.394	1.42	37.11	1784.50	6347.42	10.00
Kanannado							
0 kg ha^{-1} Pm	4.10	0.443	1.71	52.34	2165.40	3846.33	12.77
2000 kg ha^{-1} Pm	4.87	0.374	1.56	47.52	1987.30	4983.72	9.760
4000 kg ha^{-1} Pm	2.63	0.483	1.28	45.88	2066.62	13572.21	17.44
6000 kg ha^{-1} Pm	1.75	0.284	1.18	55.20	2022.60	1368.46	31.54

Plant tissue analyzed at the analytical laboratory of the Soil Science Department, Ahmadu Bello University Samaru Zaria. Pm = Poultry manure, OC = Organic carbon.

Table 3: N, P and K contents of poultry manure used during the experiment in 2013 and 2014 rainy seasons

Nutrients (%)	2013	2014
Total N	1.70	1.74
Total P	1.59	1.32
Total K	0.63	0.89

Poultry manure analyzed in the analytical laboratory, Department of Agronomy, Ahmadu Bello University, Zaria.

The N, P and K contents of the poultry manure used during the experiment in 2013 and 2014 rainy seasons (Table 3) showed that the total N and total K content of the poultry manure used in the trial during 2014 rainy season were higher than that in 2013. While the total P content in the poultry manure was higher in 2013 than in 2014.

Result in (Table 4) shows that in both years poultry manure applied at 2000 kg ha^{-1} with the addition of 2500 kg ha^{-1} of green manure from SAMPEA 6 significantly increased height of the popcorn. Addition of higher poultry manure rates resulted in non-significant differences in the height of popcorn. This trend was also observed with addition of green manure from Kanannado in 2014. However, in 2013, the application of poultry manure from 0 to 4000 kg ha^{-1} resulted in significant increases in height of popcorn with addition of green manure from Kanannado. Further increase to 6000 kg ha^{-1} of poultry manure resulted in statistically similar increases.

Table 4: Effect of poultry manure and green manures on the plant height(cm) of popcorn at Samaru during 2013 and 2014 rainy seasons

	2013		2014	
Poultry manure (kg ha^{-1})	**SAMPEA 6**	**Kanannado**	**SAMPEA 6**	**Kanannado**
0	141.96c	152.58c	165.39c	186.08b
2000	184.96ab	176.92b	207.14a	202.67a
4000	188.50a	206.04a	210.81a	204.39a
6000	204.08a	195.50a	206.42a	199.08ab
	SE± 7.666		SE± 6.257	

Means followed by the same letter(s) within a treatment group are not significantly different at 0.05 level of probability using DMRT.

Table 5: Effect of poultry manure and green manures on the shoot dry weight (g) of popcorn at Samaru during 2013 and 2014 rainy seasons

	2013		2014	
Poultry manure (kg ha^{-1})	**SAMPEA 6**	**Kanannado**	**SAMPEA 6**	**Kanannado**
0	131.7b	108.9c	81.7b	92.8b
2000	136.8b	128.4bc	102.3ab	92.9b
4000	169.3ab	178.0a	104.7a	104.0a
6000	191.9a	188.1a	128.0a	108.4a
	SE± 15.67		SE± 9.68	

Means followed by the same letter(s) within a treatment group are not significantly different at 0.05 level of probability using DMRT

Table 5 shows that in 2013, a significant increase in shoot dry weight was recorded with increase in application of poultry manure up to 4000 kg ha^{-1} in addition to 2500 kg ha^{-1} green manure from either type of cowpea. Further increase to 6000 kg ha-^{1} of poultry manure resulted in similar increases. In 2014 however, significant increases in dry weight was recorded from 2000 kg ha^{-1} poultry manure, in addition to 2500 kg ha^{-1} green manure from SAMPEA 6. Significant increases were also recorded from 4000 kg ha^{-1} of poultry manure where Kanannado served as source of green manure".

The crop growth rates (Table 6) of the popcorn in both years were not significantly different at all for the poultry manure rates and green manures applied.

The effect of poultry and green manure on cob weight of popcorn (Table 7) showed that in 2013, application of poultry manure from 2000 – 6000 kg ha^{-1} with 2500 kg ha^{-1} green manure from SAMPEA 6 resulted in statistically similar increases in cob weight. Application of 4000 or 6000 kg ha^{-1} however significantly differed from the control. In 2014, fertilizing popcorn with 2500 kg ha^{-1} of green manure from SAMPEA 6 and poultry manure at 2000kg ha^{-1} significantly increased cob weight, but further increase to higher poultry manure rates resulted in statistically similar cob weights. Popcorn fertilized with green manure from Kanannado did not significantly differ in cob weight at all the poultry manure levels in both years.

Table 6: Effect of poultry manure and green manures on the crop growth rate (g wk^{-1}) of popcorn at Samaru during 2013 and 2014 rainy seasons

	2013		2014	
Poultry manure (kg ha^{-1})	**SAMPEA 6**	**Kanannado**	**SAMPEA 6**	**Kanannado**
0	17.09	17.51	17.91	17.04
2000	18.86	14.03	16.92	13.79
4000	12.41	15.69	13.33	17.18
6000	14.29	19.05	16.26	16.07
	SE±3.499		SE±2.036	

Means followed by the same letter(s) within a treatment group are not significantly different at 0.05 level of probability using DMRT.

Table 7: Effect of poultry manure and green manures on the cob weight(g) of popcorn at Samaru during 2013 and 2014 rainy seasons

	2013		2014	
Poultry manure (kg ha^{-1})	**SAMPEA 6**	**Kanannado**	**SAMPEA 6**	**Kanannado**
0	48.60bc	58.05ab	76.73b	109.95a
2000	70.80ab	77.02a	103.22a	105.38a
4000	84.27a	84.37a	108.86a	105.99a
6000	86.56a	87.28a	111.71a	101.30a
	6.090		6.702	

Means followed by the same letter(s) within a treatment group are not significantly different at 0.05 level of probability using DMRT.

Table 8: Effect of poultry manure and green manures on the 1000 grain weight(g) of popcorn at Samaru during 2013 and 2014 rainy seasons

	2013		2014	
Poultry manure (kg ha^{-1})	**SAMPEA 6**	**Kanannado**	**SAMPEA 6**	**Kanannado**
0	116.02b	110.76b	168.46a	168.18ab
2000	129.82a	129.65a	168.60a	167.34b
4000	129.57a	126.98a	169.26a	168.59a
6000	131.01a	128.58a	171.05a	166.18b
	SE± 1.986		SE±1.046	

Means followed by the same letter(s) within a treatment group are not significantly different at 0.05 level of probability using DMRT.

The study (Table 8) showed that 1000 grain weight of popcorn in 2013 significantly increased with application of 2000 kg ha^{-1} of poultry manure with the addition of 2500 kg ha^{-1} green manure from either type of cowpea. Increase in poultry manure to higher rates resulted in non-significant differences. In 2014, 1000 grain weight was not significantly different at all poultry manure rates with addition of green manure from SAMPEA 6. The application of 4000 kg ha^{-1} of poultry manure with the addition of 2500 kg ha^{-1} green manure from Kanannado however gave the highest 1000 grain weight than 2000 and 6000 kg ha^{-1} of poultry manure applied, but statistically similar with the 0 kg ha^{-1} of poultry manure.

Results in Table 9 showed that grain yield of popcorn increased at 2000 kg ha^{-1} of poultry manure with addition of 2500 kg ha^{-1} green manure from either type of cowpea. Application of higher poultry manure rates resulted in statistically similar grain yield increases. This trend was observed in 2014, although the yield increases were higher than the first year.

Discussion

The incorporation of poultry manure from 2000 kg ha^{-1} in addition to 2500 kg ha^{-1} of green manure from either type of cowpea into the soil resulted in increases in plant height, cob weight, 1000 grain weight and grain yield taken and this was evident especially in the second year of the trial. Increases being more evident in the second year of the trial could be associated with mineralization (a process whereby soil microbes and other organisms like earthworms decompose manure thus releasing organic matter and nutrients into the soil) of the manures which enhanced release of nutrients particularly nitrogen (N), phosphorus (P) and potassium (K) which were taken up and utilized by the popcorn (Johannes, 2013; Lomander *et al.*, 1998). Incorporation of poultry manure into the soil has been reported to build up soil organic matter which consequently raise the humus content of the soil as well as compensate for the continuous humus mineralization which in turn improves the soil's nutrient storage capacity and

Table 9: Effect of poultry manure and green manures on the grain yield (kg ha^{-1}) of popcorn at Samaru during 2013 and 2014 rainy season

	2013		2014	
Poultry manure (kg ha^{-1})	**SAMPEA 6**	**Kanannado**	**SAMPEA 6**	**Kanannado**
0	1077c	1325bc	1605c	1941b
2000	1668ab	1827a	2307a	2257a
4000	1916a	1889a	2390a	2298a
6000	1899a	1971a	2335a	2398a
	SE± 124.12		SE± 109.19	

Means followed by the same letter(s) within a treatment group are not significantly different at 0.05 level of probability using DMRT.

availability to plants (Johannes, 2013). Poultry manure helps in soil amendment (improves bulk density, aggregation, organic matter, water infiltration and retention), in addition to provision of nutrients to crops (Agbede *et al.,* 2013, 2014, 2017, Atakora *et al.*, 2014, Warren *et al*., 2006).

Addition of the green manure also could have contributed to the increases recorded on the popcorn as this could have improved the soil nutrient content through the process of mineralization. The process of mineralization is greatly influenced by the carbon: nitrogen (C:N) ratio. Research has shown that C: N ratio around 25 to 30 parts of carbon to 1 part of nitrogen hastens rate of decomposition (Anon, 2019). Foliage clippings or manures are within the same range and thus have a high rate of decomposition (Anon, 2019). Additionally, a report by Lomander *et al.* (1998) stated that decomposition and nitrogen release generally occur faster for organic materials with narrowed C: N ratio. Analysis of the clipped cowpea (Table 2) in this trial showed that C: N ratio of the cowpea varieties used was within the above mentioned range and thus enhanced mineralization and consequently nutrient release. Research has also shown that cowpea leaves take 32-40 days and the stems 43-53 days to decompose when buried in the soil (Sambo *et al*., 2009). It, therefore, means that the incorporated cowpea foliage clippings decomposed and improved the nutrient status of the soil alongside the poultry manure applied thus the increases recorded on the popcorn parameters taken, as well as the improvement in soil nutrient status especially in the second year of the trial.

The organic carbon, the total nitrogen (N) and magnesium (Mg) content of the soil of the experimental site was observed to increase in the second year compared to the first year. The increase in soil organic carbon was due to the incorporation of the poultry and green manure which also resulted in release of nutrients for plant growth as well as promotion of the structure, biological and physical health of the soil. Soil nitrogen levels might have increased because cowpea is a leguminous plant and leguminous green manures increase soil nitrogen levels through their association with nitrogen-fixing *Rhizobium* bacteria (Madge and Jaeger, 2003). Increase in organic matter level and biological activity of soil have also been reported with the addition of green manures (Madge and Jaeger, 2003). Similar findings were made by Sambo *et al.* (2009) where he recorded improvement in soil organic carbon by 18.4%, soil organic matter 19.6% and nitrogen 59.9%. The improvement in soil fertility due to the manures applied resulted in increased dry matter production of the popcorn which was consequently converted into increase in cob weight and the grain yield. A similar finding stated that if more residues are returned into the soil, lower rates of manure application will be sufficient to maintain or build up soil organic matter (Madge and Jaeger, 2003).

Organic matter serves as a store house for nutrients, improves nutrient recycling, builds soil structure, increases infiltration and water holding capacity, and serves as a buffer against rapid pH changes and energy source for micro-organisms (Perrings, 1999).This may imply that continuous application of organic manures to the soil will build up the organic matter content of the soil which could result in increase in soil fertility, and over time very little or no fertilizers may be required to be added to the soil to cultivate crops.

Soil pH `of the experimental site was however observed to decrease in the second year of the trial. This could be due to the release of organic acids from the manures (poultry and green manure) applied which in turn reduced soil pH by releasing hydrogen ions. Similar observation was also reported by Patil *et al*. (2003) where he recorded a decrease in soil pH with increase in farm yard manure rates which he attributed to organic acid production during decomposition. The soil sodium content was observed to decrease in the second year which could be due to the magnesium and calcium contained in the manure applied which might have produced a liming effect when added to the soil (Josh and John, 2019).

Conclusion and Recommendation

The result of the trial showed significant increases in grain yield of popcorn with application of 2000 kg ha^{-1} of poultry manure and 2500 kg ha^{-1} green manure from either type of cowpea. Therefore, this can be recommended to be adopted for optimum production of popcorn in the northern guinea savanna of Nigeria.

References

Agbede, T.M., Adekiya, A.O. and Ogeh, J.S. (2013). Effects of organic fertilizers on yam productivity and some soil properties of a nutrient depleted tropical alfisol. *Archives of Agronomy and Soil Science* 59 (4-6):803-822.

Agbede, T.M., Adekiya, A.O. and Ogeh, J.S. (2014). Response of Soil Properties and Yam Yield to *Chromolaena odorata* (Asteraceae) and *Titinia diversifolia* (Asteraceae) Mulches. *Archives of Agronomy and Soil Science* 60(2):209-224.

Agbede, T.M., Adekiya A.O. and Eifediyi, E.K. (2017). Impact of Poultry Manure and NPK Fertilizer on Soil Physical Properties and Growth and Yield of Carrot. *Journal of Horticultural Research.* Volume 25 (1): 81-88.

Agbenin, J.O. (1995). Laboratory manual for Soil Plant analysis. Department of Soil Science, Ahmadu Bello University, Zaria.

Anonymous (2019). Carbon- to- Nitrogen Ratios. www.planetneutral.com/composting101/making/c-n-ratio/

Atakora, K., Agyarko, K., and Aseidu, E.K. (2014). Influence of grass cutter, chicken manure and NPK fertilizer on the physical properties of Chromic Luvisol, growth and yield of Carrot (*Daucus carota*). *International Journal of Plant and Soil Science* 3(2): 197-204.

Bray, H. R. and Kurtz, L. T. (1945). Determination of organic and available forms of phosphorus in soils. *Journal of Soil Science*. 9: 39-46.

Bremner, J. M. and Mulvaney, C. S. (1982). Nitrogen-Total. In: Methods of Soil Analysis, Part 2. Chemical and Microbiological Properties, Page, A.L., R.H. Miller and D.R. Keeney (Eds.). ASA and SSSA, Madison, WI., USA., pp: 595-624.

Cassman, K.G. (1999). Ecological intensification of cereal production systems: Yield potential, soil quality and precision agriculture. *Proc. National Academic Science.* U.S.A.96: 5952-5959.

Duncan, D.B. (1955). Multiple ranges and Multiple 'F'test, *Biometrics*. 11-42.

Food and Agricultural Organization (FAO) (2010). Agricultural data. Agricultural Production. *http://faostat.fao.org/site* 567.

Gee, G.W. and Or, D. (2002). Particle size analysis. In: J.H. Dane and G.C. Topp (eds). Methods of soil analysis, Part 4. Physical methods. Soil Science Society of America. Book series. No. 5, America Society of Agronomy and Soil Science Society of America Madison, W1, pp 255-293.

Johannes Kotschi (2013). A soiled reputation: Adverse impacts of mineral fertilizers in Tropical Agriculture. Association for Agriculture and Ecology. Pp 13.

Josh, B.P and John L. (2019). Manure as a source of crop nutrients and soil amendment. Animal manure management.*lpelc.org/manure-as-a-source-of-crop-nutrients-and-soil-amendment.*

Lomander, A., Katterer, T. and Andren, O. (1998). Modelling the effects of temperature and moisture on CO_2 evolution from top and sub-soil using a multi-compartment approach. *Soil Biology and Biochemistry*. 39:2023-2030.

Madge, D. and Jaeger, C. (2003). Organic Farming: Green Manures for Vegetable Cropping. *Agriculture Notes*. AG1084.1-4.

Mulvaney, R.L., Khan S.A. and Ellsworth, T.R. (2009). Synthetic Nitrogen Fertilizers deplete soil nitrogen: A global dilemma for sustainable cereal production. *Journal of Environmental Quality* 38:2295.

Nelson, D.W. and Sommer, L.E.(1986). Total carbon organic carbon and organic matter. In A.L. Oage, R.H. Miller and D.R. Keeney (eds) Methods of soil analysis Page 2 Chemical and Mineralogical properties 2nd ed. *Agronomy* 9:539-579.

Pablo Tittonell and Ken E.Giller (2013). When yield gaps are poverty traps: The paradigm of ecological intensification in African smallholder agriculture. *Field Crops Research* 143: 76-90.

Patil, P.V., Chalwade, P. B., Solanke, A. S and Kulkarni, V. K. (2003). Effect of fly ash and FYM on physico-chemical properties of Vertisols. *Journal of Soils and Crops.* 13(1) : 59-64.

Perrings, C. (1999). The Economics of Biodiversity Loss and Agricultural Development in Low Income countries. University of York, UK. Pp1-26.

Sambo, B., Odion, E.C., Aliyu, L. and Labe, D.A. (2009). Estimation of time for fresh fodder decomposition under innovative clipping management for soil fertility conservation. Presented at the 1st African Organic Conference, Kampala, Uganda. Pp 52.

Snedecor, G.W. and Cochran, W.G. (1967). Statistical Method 6th Edition. Iowa State University Press. Ames Iowa, U.S.A. 607pp.

Statistical Analysis System (SAS) Institute (1990). The SAS Users Guide, version 9.1.3. SAS Institute, Cary NC.

Stoorvogel, J.J. and Smaling, E.M.A, (1998). Nutrient Cycle. *Agro-ecosystem*. 50:151-158.

Thomas, G.W. (1982) Exchangeable cations. In R.H. Miller and D.R. Keeney (eds) Methods of soil analysis Page 2 Chemical and Mineralogical properties 2nd ed. Agronomy 159-166.

Warren, J.G., Phillips, S.B., Mullins, G.L, Kealey, D. and

Penn, C.J. (2006). Environmental and production consequences of using alum amended poultry litter as a nutrient source for corn. *Journal of Environmental Quality*, 35:172-182.

Zingore, S., Mutegi, J., Agesa, B. Tamene L. and Kihara, J. (2015). Soil Degradation in Sub-Saharan Africa and Crop Production Options for Soil Rehabilitation. *Better Crops*. 99: 24-26.

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