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Response of Maize (*Zea mays L*) and Soil Properties to Oil Mill Effluents in Ultisol of Emerging Biotechnology in Nigeria.

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Abstract

The effects of oil mill effluents on Maize performance and selected properties of ultisol in Ihiagwa, Southeastern Nigeria were studied in 2013. The response of Maize to (0.0,2.0, 2.5,3.0, 3.5 and 4.0 m^3 per hectare) of oil mill effluents application was evaluated using complete randomize design (CRD).Every treatment was replicated 3 times, thus total of experiment was 18units. Soil samples were taken at a depth of 0 – 20cm, air-dried, and sieved with a 2-mm mesh for laboratory analysis. Maize grain yield, plant height, dry matter weight and soil residual physico-chemical properties were evaluated. The results showed that application of palm oil mill effluents (POME) had significant effect on Maize performance and some soil physico-chemical characteristics. Maize grain yield, dry matter weight, N,P,K contents and residual organic C, and Soil pH were improved. Exchangeable Al in soil of the studied area decreased with increasing levels of palm oil mill effluents and the growth of maize generally. The research demonstrated thatthe treated soils with fermented POME significantly produced higher grain yield, dry matter, and favourable soil properties tested than plots that received sustainable agriculture. The best maize performance and soil propertieswas in 3.5 m^3/ha of palm oil mill effluents.

Keywords: palm oil effluent, ultisol, fermentation, sustainability.

INTRODUCTION

Oil palm is widely cultivated in Nigeria and has risen from 8.2 million tons in 1990 to 9 million tons in 2001 (FAO, 2002). Oil palm effluent (POME) is one of the by-products released from palm oil mills. Large quantities of water are used during the extraction of crude palm oil from the fresh fruits and about 50% of the water results in palm oil mill effluent. It is estimated that for each 1 ton of crude palm oil produced, 5-7.5% tons of water will end up as palm oil mill effluent (Ahmad et al, 2003). Palm oil mill effluent contains relatively high amount of plant nutrients particularly potassium, nitrogen, magnesium and calcium (Lum et al., 1993). The separated waste water sludge commonly referred to as POME, is a brown slurry which is composed of 4-5% solids (mainly organic), 0.5-1% residual oil and about 95% water and high concentration of organic nitrogen (Onyia et al., 2001). This effluent is a serious land and aquatic pollutant when discharged immediately into the environment. This residue among others will continue to accumulate with increasing production. Efforts are geared towards converting these waste materials into useful products in energy production, livestock feed formulation and organic fertilizer. This is turn has an economic prospect to increase income of farmers and to generate national revenue. It is a brownish oily liquid obtained after extraction of palm oil.

However, ultisols are acidic and are widely distributed in the southern parts of Nigeria. Ultisols provide a potential opportunity to increase food crop production; however the main constraints of ultisols for crop production are low soil fertility due to low availability of essential macronutrients for plant growth, low soil organic matter content, low pH and high aluminum content (Hardijowigeno, 1995; Budianta, 1999).

Maize (*Zea mays L*) used as a test crop in this experiment, is one of the mainstay crop of Nigeria, because the yield from this crop has an economic prospect to increase income of farmers. To succeed the growth of maize, is by applying organic fertilizers. One of the organic fertilizers that can supply nutrients is Palm Oil Mill Effluent (POME). The POME and other by products of palm oil mills processing has good potential to improve soil physical, chemical and soil biology (Zaharah and Lim 2000; Sutarta et al., 2002; Lum and Zaharah, 2002). The POME can be incorporated to the

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soil with low content of organic material. From this point of view, this organic material will reduce the application of chemical fertilizers (Sutarta et al., 2002) which are relatively scarce, costly and may increase soil acidity. Palm oil mill effluent and related products in Nigeria can be used as a source of organic matter in improving the fertility of ultisols (Adeoluwa and Adeoye, 2008). Palm oil mills release POME in tremendous volumes with its attendant polluting potential. Therefore POME requires proper management and handling strategies by the industries and government authorities. Proper management of POME has been poorly practiced in Nigeria as many oil mills dispose their POME within their vicinity or dump them in special pits that could later drain to soil surface and ground waters.

Efficient utilization of POME will be helpful in boosting soil fertility status of ultisol and in the environmental management. This research work was therefore conducted to evaluate the fertilizer value of fermented POME in a field trial experiment using maize (*Zea mays L*) as a test crop

Materials and Methods

A pot experiment was conducted in the Federal University of Technology, Owerri (FUTO) agricultural farm during 2013 cropping season. The university is situated between latitudes $5^0 29^1$N and longitudes $7^0 02^1$E within the Nigeria rainforest zone. The experiment was led out in a Completely Randomized Design (CRD) with 3 replications. The experiment area was 46.02m^2. Composite soil samples (ultisol) weighing 10kg in each of the pots were laid out in the field. Six (6) treatments replicated three times hence given a total of eighteen (18) samples were at a spacing of 75 x 25cm and 1.5m between each row. Two seeds of maize grain (Oba supper) were planted per pot and later thinned down to 1 plant per stand at 3weeks after planting achieving a density of 53000 plants/ha. The fermented POME was applied at rates of O.0 m^{3}ha^{-1} (control), 2.0 m^{3}ha^{-1}, 2.5 m^{3}ha^{-1}, 3.0 m^{3}ha^{-1}, 3.5 m^{3}ha^{-1} and 4.0 m^{3}ha^{-1}. POME was applied 3 weeks after planting (WAP) into the pots on each maize stand except in the control. Data on maize growth and grain yields were collected at harvest.

Pre-soil analysis was based on composite samples, subsample and analyzed for parameters such as soil pH, organic matter, total nitrogen, available P, exchangeable calcium and magnesium, sodium, potassium and total exchangeable acidity. pH was determined using glass electrode pH meter (Hendershot et al., 1993). Organic carbon was determined by Walkey – black method (Nelson and Sommers, 1996) and multiplying it by 1.724 for Organic Carbon. Available phosphorus was measured using Bray II method (Nelson and Sommers, 1996). Exchangeable acidity was determined by leading the soil with 1NkCl and titrating with 0.05N NaoH (Agbenin, 1995). Some physical properties were also determined. Particle size distribution was determined by hydrometer method described by Gee and Or (2002). Bulk density was measured by the core method (Grossman and Renisch, 2002).

Post-soil analysis was also conducted to evaluate the current residual effects of POME on soil properties.

POME Fermentation

POME fermentation involved the use of 6 plastic bowls of 80 litres in volume and diameter 0.5m. The plastics were fed each with fresh POME + 0.8 g/L of urea to enhance microbial activities. Temperature was maintained at 30^{0}C, pH 8.5 using 2NaoH. This mixture was allowed to ferment for 15,20 and 25 days respectively. The content stirred at least once each day to aid aeration.

Statistical Analysis

Analysis of variance (ANOVA) and least significance difference (5%) comparison procedure were carried out using statistical software Genstat discovery edition 3. Regression analysis was used as appropriate.

Results and Discussion

High values of BOD, COD and TSS observed in POME (Table 1) suggest that it could be a serious aquatic pollutant. This observation is in agreement with the works of Onyia et al., (2001), Kittikun et al., (2000) on POME. High acidity observed in POME could be as a result of presence of phenolic acids and oxidation of other organic acid compounds in the POME. This is in line with the findings of MdDin et al (2006). The pre-planting soil physico-chemical analysis (Table 1) revealed the acidic nature of the soil, low N, and organic matter hence low fertility status of the soil (ultisol).

However, presence of organic N, Mg, K, P, organic matter in POME (Table 1) point to its possibility for use as organic amendment to improve soil fertility. Organic matter mineralization in wastewater such as POME may be enhanced by providing favourable conditions for microbial and enzymatic activity. Reduced C:N ratio, soil aeration, optimum pH and favourable temperature put together are likely essential factors in organic matter mineralization (Pascual et al., 2007, Piotrowska et al., 2006).

At physiological maturity, varied results emerged from the different treatments. There were significant differences in maize height as influenced by Dferm and rates of POME application. $Dferm_{25}$ improved maize performance (Table 3). From the results, there were up to 1.03, 1.08 folds maize height increases as Dferm increased 15-20.

Similar results were obtained in dry water weight and grain yield. The result is in agreement with the report of Orhue et al., 2005 who reported a positive growth response in maize as influenced by brewery effluent application.

Regression equations revealed a strong positive relationship between Dferm, POME application rates and maize performance in this experiment (Table 5). Increased maize performance (growth and yield parameters recorded in Dferm25 may be as a result of longer period, provided enough time for microbial activity and enhanced mineralization of macronutrients for maize growth. Cereti et al., (2004) reported that Olive mill waste gave a beneficial effect on prolonged fermentation. Cordovil et al., (2005) reported that increasing the quantity of waste materials applied to soils always lead to high potential available N.

The results generally showed that the soils treated with the application of POME resulted in an improved maize performance compared to the control. Application rate of $3.5m^3ha^{-1}$ gave the highest maize height of 95.6 cm, dry matter weight of 1.74 t/ha^{-1}, grain yield of 3.50 t/ha-1 respectively (Table 3). This application rate may have provided sufficient hydraulic load for effective soil reactions for optimum crop performance. Consequently, it should be noted that the excess application of POME to agricultural soils could result to undesirable effects: oxygen depletion (anaerobic condition), nutrient loss due to immobilization, denitrification and leaching (Searl et al., 1981).

However, low maize performance observed in the control plots could be attributed to poor nutrient availability and other soil characteristics. Generally, maize growth and grain yield as affected by Dferm increased in the order of $Dferm_{25}$>$Dferm_{20}$>$Dferm_{15}$. Similarly, maize growth and grain yield increase as affected by different rate of POME application in the order of O.0 m^3ha^{-1}<2.0 m^3ha^{-1}<2.5 m^3 ha^{-1}<3.0 m^3ha^{-1}<4.0 m^3ha^{-1}.

It is obvious therefore that the enhanced maize performance recorded in POME amended plots were direct consequences of the provision of sufficient quantity of organic nutrients as well as sound agronomic management practices.

Authors such as Paredes, et al., (2005), Zhou et al., (2000) warman and Termer (2005) all reported high yields in crops following adequate fermentation of waste application. The high yield response may be predicted based on prolonged days of POME fermentation which perhaps provided enough period of microbial activity which cumulated into nutrient mineralization. POME amendment may have provided the needed microbes and nitrates that stimulated soil organic matter (SOM) degradation (Douglas et al., 2003). This study therefore revealed that fermented POME could improve the performance of maize and soil productivity.

Table 1: Physicochemical Characteristics of the native soil (0-20cm) and POME

Soil Parameters		Fresh POME Parameter	Mean of three determination std deviation
Sand (%)	79.0	BOD mg/L	16504.3±13.9
Silt (%)	4.2	COD mg/L	14305.0±5.2
Clay (%)	16.8	TSS mg/L	10878.4±2.8
pH (H_20)	4.2	Total N (mg/L)	786.7±1.5
Org. M (%)	3.0	Mg (mg/L)	218.4±0.8
Total N (%)	0.15	P (mg/L)	251.7±0.9
Avail P. (mg/kg)	8.5	pH	4.1±1.7
ECEC (cmol/kg)	12.6		

Table 2: Selected nutrient content of fermented POME prior to application

POME (Nutrient Content)	Duration of fermentation	Mg/L
N	$Dferm_{15}$	41.3±2.0
	$Dferm_{20}$	94.2±1.6
	$Dferm_{25}$	130.1±1.3
P	$Dferm_{15}$	39.7±2.4
	$Dferm_{20}$	44.6±1.8
	$Dferm_{25}$	48.2±3.2
K	$Dferm_{15}$	37.8±2.3
	$Dferm_{20}$	43.2±1.7
	$Dferm_{25}$	45.5±2.2

Dferm = Duration of POME fermentation

Table 3: Mean growth and yield of maize as affected by POME

Treatment	Plant height	Dry matter weight	Grain yield
Dferm (D)	Cm	t/ha^{-1}	t/ha^{-1}
15	81.1	1.59	3.21
20	89.3	1.75	3.47
25	90.4	1.94	4.00
LSD	7.29	0.16	0.15
Rate of application (R) of POME (m^{3}ha^{-1})			
0.0	66.3	1.10	2.15
2.0	86.8	1.54	2.70
2.5	89.0	1.66	3.17
3.0	92.1	1.68	3.20
3.5	95.6	1.74	3.50
4.0	93.4	1.67	3.40
$LSD_{0.05}$	9.41	0.21	0.19
D x R	ns	ns	ns

Dferm = Duration of POME fermentation, ns=Non-significant

Table 4: Mean Post-harvest soil chemical properties as affected by POME application

Treatment Dferm(D)	%Org. N	%Org.C	Av.P(cmop/kg)	pH(H_20)
15	0.03	0.93	4.29	5.8
20	0.03	0.03	4.47	6.0
25	0.04	1.16	4.43	6.0
$LSD_{0.05}$	0.004	0.07	0.26	0.12
Rate of application (R) of POME (m^{3}ha^{-1})				
0.0	0.03	0.83	3.44	5.6
2.0	0.03	0.87	4.24	5.9
2.5	0.03	0.03	4.36	5.9
3.0	0.03	1.22	4.51	6.0
3.5	0.03	1.60	4.88	6.1
4.0	0.03	1.91	5.13	6.1
$LSD_{0.05}$	0.005	0.69	0.33	0.11

Table 5: Coefficient of determination and Simple linear regression equation for plant height, dry matter weight and grain yield as affected by rates of application of POMAE and duration of POME fermentation.

Parameters	Coefficient of determination (r^2)	Linear regression equation
a. Plant ht as affected by rate of application	0.7827	Y = 7.099 x + 59.1
b. Plant ht as affected by duration of POME fermentation	0.9726	Y = 7.855 x + 65.5
c. Dry matter wt as affected by rate of application	0.7517	Y = 0.2627 x + 0.88
d. Dry matter wt as affected by duration of POME fermentation	0.8899	Y = 0.1715 x + 1.27
e. Grain yield as affected by rate of application	0.7677	Y = 0.4272 x + 1.55
f. Grain yield as affected by duration of POME fermentation	0.9998	Y = 0.2385 x + 2.26

References

1. **Adeoluwa O.O., Adeoye G.O.** (2008). Potential of oil palm empty fruit bunches as fertilizer (*Elaiseguinensis L. Jacq*) nurseries. In "Proceeding of second scientific conference of the ISOFAR, held at the 16th organic world congress in cooperation with the International Federation of organic Agriculture Movements (IFOAM) and the ConsorzioModenabio, 18-20 June, 2008 in Modena, Italy".

2. **Agbenin J.O.** (1995). Laboratory manual for soil and plant analysis (Selected methods and data analysis Faculty of Agricultural Research

3. **Ahmad A., Ismail S. and Bhatia S.** (2003). Water recycling from palm oil mill effluent (POME) using membrane technology. Desalination, 157 (1-3): 87 – 95.

4. **Budianta D.** (1999).Reclamation of an ultisol from South Sumatra using mucuna L. and Lime.Ph.D Thesis, University of Ghent, Belgium.

5. **Cereti E.F., Rossini F., Federici F., Quaratino D., Vassiler N., and Femice M.** (2004). Reuse of microbially treated olive mill waste water as fertilizer for wheat (TriticumcurumDesf). Biorescourcetechn. 91:35-140.

6. **Cordoril CMDS, Coutinho J, Goss M. and Cabral F.** (2005). Potentially mineralizable nitrogen from organic material applied to a sandy soil: fitting the one-pool exponential model. Soil use and management 21:65 – 72.

7. **Douglas J.T., Aitkin M.N. and Smith C.A** (2003).Effects of five non-agriculture organic waste on soil composition, and on the yield and nitrogen recovery of Italian rye grass. Soil use and management 19:135-138.

8. **FAO (2002).FAO** stat.Site. Retrieved July (2003) from www.fao.org.

9. **Gee G.W. and Or D.** (2002). Particle size analysis. In: Dane, J.H and G.C. Topps (eds). Methods of soil analysis, Part 4.physical methods. Soil Sci. Soc. Am. book series No.5, ASA and SSSA, Madison, W.I. pp.255-293.

10. **Grossman R. B., Reinsch T,G.** (2002). Bulk density. In: Dane, J.H. Topp, G.C. (eds) methods of Soil analysis, physical methods 201-228. Soil Science Society of America Book Series, ASA and ASSA, Madison WI.

11. **Hardjowigeno S.** (1995). "Genesis danKlasifikasi Tanah (IPB.: Bogor).

12. **Hendershot W.H., Lalande H. and Duquette** (1993). Soil reaction and exchangeable acidity in carter, M.R. (ed). Soil sampling and methods of analysis Can. Soc. Soil Sci., Lewis Pub. London. pp 141-145.

13. **Kittikun A.H., Prasertsan P., Srisuwan G. and Krause A.** (2000). Environmental management for palm oil mill material flow analysis of integrated biosystems P.11 retrieved May, 23 from http://ias.unu.edu/processings/ic.mfa/kittikum/paper.html.

14. **Lim C.H, PNG T.C, Chan K.W and Ychooi S.** (1993).land application of digested palm oil mill Effluent (POME) by sprinkle system.

15. **Lim KC and ZAharah AR** (2002). The effects of oil palm empty fruit bunches on oil palm nutrition and yield, and soil chemical properties. J. oil palm Res. 14(2): 1 – 9.

16. **MdDin M.F. Ujang Z, MuhdYunus S, Van Loosdrecht MCM** (2006). Storage of polyhydroxyalkanoates (PHA) in fed-batch mixed culture using palm oil mill effluent (POME). 4th seminar on water management (JSPS-VCC).Johor; p.119-27.

17. **Nelson D.W. and Somners L.E.** (1996).Total carbon, organic carbon and organic matter. In Sparks, D.L. (ed). Methods of soil analysis, part 3. Book series 5.SSSA,Madison, W.I. 961-101.

18. **Onyia C.O., Uyub A.M., Akuma J.C., Norulaini N.A., O,arAkm** (2001). Increasing the fertilizer value of palm oil mill sludge: bioaugumentation in nitrification. Water science and technology: 44(10) 157-162.

19. **Orhue E.R., Osaigbovo A. U., Vwioko D.E.** (2005). Growth of maize (Zea mays L) and changes in some chemical properties of an ultisol amended with brewery effluent. African J. Biotech 4(9) 973-978)

Paredes C., Cegarra J., Bernal M.P., Roig A.

(2005). Influence of olive mill waste water in composting and impact of the compost on a swiss chard and soil properties. Environmental International 31:305-312.

20. **Pascual I. Antolin A.C., Garcia C., Polo A., Sancheziaz M.** (2007). Effect of water deficit on microbial characteristics in soil amended with sewage sludge or inorganic fertilizer under laboratory conditions. Bioresource Technology. 98:29-37.

21. **Piotrowska A., Iamarino G., Rao M.A., Gianfreda L.** (2006). Short-term effects of olive mill waste water (OMW) on chemical and biochemical properties of a semi-arid Mediterranean soil. Soil biology and biochemistry. 38:600-610.

22. **Searle PGE, Comudom Y., Shedden D.C. Nance R.A.** (1981). Effect of maize/legume intercropping systems and fertilizer nitrogen on crop yields and residual nitrogen. Field crops Res. 4: 133-145.

23. **Sutarta, ES Rahutomo, Darmosarkoro W. and Winarna** (2002).PerananUnsar Hara danSumber Hara pada Pemupukan TanamanKelapa Sawit. Laporan Penelitian. PusatPenelitiankelapaSawit (PPKS).

24. **Warman P.R. and Termeer W.C.** (2005). Evaluation sewage sludge, septic waste and sludge compost applications to corn and forage: yield and N, P and K content of crops and soils. Bioresource technology. 96: 955-961).

25. **Zaharah AR and Lin KC** (2000). Oil palm empty fruit bunch as nutrients and soil ameliorant in oil palm plantation. Malay J. Soil Sci 4: 51 – 66.

26. **Zhou X., Madramootoo C.A., Mackenzie A.F., Kaluli J.W., Smith D.L.** (2000). Corn yield and fertilizer N recovery in water-table controlled corn-rye grass systems. Eur J. Agron, 12:83-92.