Original Research Article

Residual Effects of Abattoir Effluent on Soil Microbiological Composition, and Yield of Maize

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Abstract

The residual effects of abattoir effluent (ABAE) on soil microbiological composition and yield of maize were investigated in the Teaching and Research Farm of Ambrose Alli University, Ekpoma, Edo State, Nigeria. ABAE with treatment rates of 0, 2.025, 4.050, 8.100 and 12.150 L/ha were fitted into a completely randomized design with three replicates. The physical and chemical properties of the soil as well as the chemical properties of the effluent were determined before the experiment. The abattoir effluent and the soil were also analyzed for their microbiological properties (bacteria and fungi). Maize variety, Suwan-1, was used as a test crop and sown twice. Results obtained showed that the initial effect of abattoir effluent was significant on grain yield with the highest value of 6.82 tons/ha obtained at 4.050 L/ha. Residually, abattoir effluent had no significant influence on the yield of maize. However, the highest residual yield of1.39 tons/ha was obtained at 8.100L/ha of ABAE. The number of bacteria and fungi species in soil increased with increased rate of the effluent application. Total bacterial and fungal counts were higher in the initial effluent-affected soils than that of the residual. However, Bacillus and Aspergillus species were present at the initial stage while Bacillus and Candida species were present at the residual stage. It was concluded that abattoir effluent is a good source of organic manure which also contains microorganisms that assist in boosting the fertility of the soil for crop production.

Keywords: abattoir effluent, initial effects, residual effects, physico-chemical properties, microbiological properties

Introduction

The pride of a nation resides in her ability to feed herself (The Nation, 2017). In Nigeria, the population growth is so high that improved technologies especially fertilizers should be employed to meet the food requirements of the people (Nelly *et al*., 2003). Although a major increase in the use of artificial fertilizers will be necessary on a global scale, this will not be an option for large numbers of farmers due to poverty. Instead, they rely on recycling of nutrients from animal and vegetable composts and urban wastes (David *et al*., 2010). In many countries, pollution arises from activities of meat production as a result of failure in adhering to good management and hygienic practices leading to contamination of the soils. Tortora *et al.* (2007) noticed that following the discharge of untreated abattoir wastewater into the soil, certain elements such as Fe, Pb, P, Ca and Zn which were previously absent or present in minute quantities led to the increase of these elements thus altering the physico-chemical nature of the soil. Titiloye *et al.* (1985) used different organic wastes or manures, sewage, poultry droppings, cocoa husk and sawdust in Nigeria to grow maize and they reported significant effect on yield. The major constraint they observed as regards the utilization of animal manure appears to be the high quantities required to make any significant impact on crop yields. Joshua (1990) asserted that higher grain yields of maize were obtained by the cultivation of hybrids in preference to open pollinated. However, production of hybrid maize appeared to always demand very high N-doses. Adediran and Banjoko (1995) reported that the yield of maize varies from variety to variety, location to location and also depends on the availability of essential factors such as soil nutrient status and application of fertilizers. Akintunde *et al.* (2000) concluded that N input should be soil- and location-specific. Average grain yields of 4.9 and 5.2 tons/ha were obtained in Samaru and Mokwa respectively, while Ibadan and Ikenne locations had 3.5 and 3.6 t/ha respectively.

The soil is the final recipient of all forms of environmental pollutants and such pollutants have significant effects on soil microbial populations, soil properties, nutrients uptake and crop yield (Ogboghodo *et al.,* 2001). Toxic effects on soil micro-organisms is evident in soils with heavy metal accumulation despite the decrease of global deposition of Cadmium (Cd), Lead (Pb) and Zinc (Zn) over the past few decades (Pawloweska and Charvat, 2004). Heavy metal load in the soil reduces the functioning of soil biota resulting in reduced microbial activity (Kandiler, 1996). When Cadmium, Zinc, Lead, Mercury, Arsenic, Copper, Chromium, Nikel and Manganese accumulate in soil over long time, they reduce food quality and quantity. Isirimah (2002) stated that high levels of organic pollutants cause microorganisms responsible for the oxidation processes, to consume all the dissolved oxygen. The oxygen deficiency created in the effluent causes anaerobic condition, which is highly undesirable. Adesemoye *et al.* (2006) studied wastewater samples from two abattoirs and noticed that the mean bacterial counts were 3.32×10^7 cfu/ml and 2.7×10^7 cfu/ml respectively. They also noted that the mean fungal populations were 1.6×10^5 and 1.2×10^5 cfu/ml respectively. In the polluted soil sample, mean bacterial count was 3.36×10^7 cfu/ml when compared to the 1.74×10^6 cfu/ml of the control.

Rabah *et al.* (2010) reported a higher mean count for bacteria and fungi in soils contaminated with abattoir effluent than the control. It was observed that *Escherichia coli* had the highest frequency of occurrence followed by *Bacillus sabtilis* and *Staphylococcus aureus* and, finally, *Bacillus anthracis* and *Bacillus polymyxa*. In terms of fungal isolates, *Aspergillus niger* had the highest frequency followed by *Fusarium sporotrichoides* and *Mucor pusillus*. Atlas and Bartha (2007) stated that the presence and abundance of various species of Bacillus observed in the contaminated soil revealed that they were indigenous to soil environment hence, persisted in such environment.

Materials and Methods

Experimental site

A field experiment was conducted in 2009 at the Teaching and Research Farm of Ambrose Alli University, Ekpoma, Edo State between April and October under rain-fed conditions. Ekpoma is situated at about 85km North of Benin City and South of Auchi in Edo State. It is located between latitude $6^{0}41^{1}$N and $6^{0}49^{1}$N, and longitude $6^{0}00^{1}$E and $6^{0}14^{1}$E. The study area was rainforest/savanna transition zone with mean annual rainfall of 125.617mm and mean temperature of 32^{o}c. Soils of the area were classified as Typic Hapludult (Isitekhale, 1997).

Sources of samples

Abattoir effluent (ABAE) was collected from a slaughter house along Benin-Auchi Express Road, Ekpoma, while maize seeds (Suwan-l) were collected from ADP, Benin–City, Nigeria

Experimental Method

Five levels of abattoir effluent were applied at treatment rates of 0, 2.025, 4.050, 8.100 and 12.150 L/ha to five plots each measuring 2.25m^2 in a randomized complete block experiment with two replicates. Application of the effluent was done by spreading it uniformly on plot surfaces. Plots were left for 3 weeks before planting. Maize seeds were sown at a spacing of 75 cm x 25 cm between and within rows. At silking, two or three ear-leaves were sampled from the middle rows. The ear-leaves were oven-dried at 70^{0}C for 48 hours and then weighed. Also at maturity, only the cobs in the middle rows were harvested from each plot and weighed. The maize grains were shelled from the cobs and dried to 12% moisture content and weighed for determination of grain yield.

Soil sample collected was analyzed for its physical and chemical properties. The sample was air-dried at room temperature, mixed and crushed to fine size particles. The sample was then passed through a 2 mm sieve and analyses were done using standard laboratory procedures. Particle size was determined by the hydrometer method (Bouyoucos, 1981). Organic carbon was determined by Nelson and Sommers (1975) method. Total N was determined by Bray P-1 method (Anderson and Ingram, 1989). Soil pH was determined by a glass electrode pH method (IITA, 1979). Exchangeable cations were extracted with 1NH_4OAC at pH7. Calcium and Magnesium were determined by titrimetric method (Jackson, 1982) while Na and K were read on flame photometer (Oshome, 1973). Exchangeable acidity was determined by titration method (Anderson and Ingram, 1993). Effective Cation Exchange Capacity was determined by summation of exchangeable bases and exchangeable acidity. Micro-nutrients (Zn, Fe, Mn and Cu) and Heavy Metals (Pb, Cr, Ni and Cd) were determined using the method of Novosamsky *et al.* (1983). The abattoir effluent was also analyzed for its chemical and microbiological properties (bacteria and fungi) using standard laboratory procedures (Rhoades, 1982; Anderson and Ingram, 1989; Robert *et al*., 2004; Cheesebrough, 2006). The parameters analyzed included pH, organic carbon, total nitrogen (Total N), available phosphorous (Av. P) exchangeable cations (Ca, K, Mg and Na), Mn, Fe, Cu, Cr, Ni and Cd. The residual effects of the effluent on maize yield and microbiological composition were also considered.

Results and Discussion

The physical and chemical properties of the soil before application are shown in Table 1. The soil was acidic in nature which could be attributed to the nature of the parent material. Organic carbon and available phosphorus were high when compared with the critical levels of 10 g/kg and 15 mg/kg respectively given by Adeoye and Agboola (1985), and by Agboola and Ayodele (1987).

Total nitrogen content in the soil was low when compared with the critical level of 1.5 g/kg given by Sobulo and Osiname (1981). Exchangeable Calcium in the soil was above the critical level of 3.8 cmol/kg given by Agboola and Ayodele (1987). Exchangeable Magnesium was adequate when compared with the critical level of 1.92 cmol/kg given by Agboola and Ayodele (1987). Exchangeable Potassium appeared low when compared with the critical level of 0.2 cmol/kg given by Agboola and Ayodele (1987).

The value of ECEC was low. The soil was sandy which could be related to the parent material. Akamigbo and Asadu (1983) asserted that soil texture is related to the parent material.

Table 1: Physico-chemical properties of the soil used for the experiment before application

Parameters	Value
pH	4.77
Organic carbon (g/kg)	12.32
Organic matter (g/kg)	21.24
Total Nitrogen (g/kg)	0.93
C:N	13.1
Available P (mg/kg)	60.72
Exchange cations (cmol/kg)	
Exchangeable Ca	4.32
Exchangeable Mg	1.92
Exchangeable K	0.18
Exchangeable Na	0.40
Exchangeable acidity (cmol/kg)	
Hydrogen (H^+)	1.10
Aluminum (Al^{3+})	0.40
ECEC (cmol/kg)	8.32
Available micronutrients and heavy metals(mg/kg)	
Fe	3.26
Zn	31.60
Cu	1.59
Pb	0.09
Ni	0.48
Cr	4.36
Mn	0.98
Cd	0.99
Particle size (g/kg)	
Sand	908.00
Silt	66.00
Clay	26.00
Textural class	Sand

The chemical properties of abattoir effluent (Table 2) showed that the effluent was slightly alkaline (pH 7.60). The heavy metals concentrations in the effluent were within the permissible ranges, given by the European Community Regulation (Lacatusu *et al.*, 2011).

Initial effects of abattoir effluent on mean ear-leaf dry matter and grain yields of maize are shown in Table 3. There was no significant response of ear-leaf dry matter yield to different levels of ABAE application. The highest ear-leaf dry matter yield of 7.06 kg/ha was obtained from the application of 12.150 L/ha ABAE. There was a significant response of maize grain yield to different levels of ABAE application. The highest grain yield of 6.82 tons/ha was obtained from the application of 4.050 L/ha ABAE. This value was significantly different from what was obtained from the application of 2.025 L/ha ABAE but not significantly different from what was obtained from the control and other treatments. This finding was in agreement with what was earlier reported by Osemwota *et al*. (2012).

Table 2: Chemical properties of Abattoir effluent used for the experiment

Parameters	Abattoir Effluent (ABAE)
pH	7.60
Ava. P (mg/L)	112.00
Total N (mg/L)	0.56
Exchangeable cations (mg/kg)	
Ca	947.00
Mg	317.00
K	250.00
Na	659.15
Mn	338.55
Fe	215.50
Zn	96.65
Cu	28.11
Pb	1.10
Ni	2.98
Cr	2.35
Cd	0.08

Table 3: Initial effects of abattoir effluent (ABAE) on mean ear-leaf dry matter and grain yields of maize

Treatment ABAE (L/ha)	Ear-leaf Dry Matter Yield (kg/ha)	Grain Yield (tons/ha)
0	6.31	5.48^{ab}
2. 025	5.16	4.28^{b}
4.050	7.03	6.82^{a}
8.100	6.66	6.49^{ab}
12.150	7.06	6.69^{a}
LSD (P<0.05)	**NS**	**2.53**

NS: Not Significant

The residual effects of abattoir effluent had no significant influence on the grain and ear-leaf dry matter yields of maize (Table 4). However, the highest grain yield of 1.39 tons/ha was obtained from the residual effects of the application of 8.100L/ha ABAE. The highest ear-leaf dry matter yield of 7.77 kg/ha was obtained from the applications of 4.050 and 12.150 L/ha ABAE.

Means within the same vertical column followed by the same letter(s) are not significantly different at 5% level.

The result of the analysis of the effluent used for the experiment revealed that abattoir effluent had bacterial and fungal populations of 18×10^4 cfu/ml and 48×10^7 cfu/ml respectively (Table 5).

Table 4: Residual effects of abattoir effluent (ABAE) on mean ear-leaf dry matter and grain yields of maize

Treatment ABAE (L/ha)	Ear-leaf Dry Matter Yield (kg/ha)	Grain Yield (tons/ha)
0	9.21	0.98
2. 025	6.14	0.91
4.050	7.77	1.29
8.100	7.33	1.39
12.150	7.77	0.96
LSD (P<0.05)	**NS**	**NS**

NS: Not Significant

Table 5: Bacteria and fungi populations/identification on effluent and soil before application

Types of Sample	Bacteria population (cfu/ml)	Bacteria Identification	Fungi population (cfu/ml)	Fungi Identification
ABAE	$18x10^4$	*Pseudomonas* spp *Proteus vulgaris* *Staphylococcus* spp	$48x10^7$	*Candida* spp
Soil	(cfu/g) $31x10^3$	*Baccillus* spp *Clostridium* spp *Pseudomonas* spp *Staphylococcus* spp *Micrococcus* spp	$21x10^7$	*Candida* spp *Penicillium* spp

However, the soil had less populations of bacteria and fungi of $31x10^3$ cfu/g and $21x10^7$ cfu/g respectively, before the application of effluent. The population of microorganisms in the soil, affected with abattoir effluent was relatively high when compared to the control soil (Table 6). The highest level of the effluent applied at 12.150 L/ha gave the highest bacterial and fungal counts of $14x10^5$ cfu/g and $58x10^6$ cfu/g as against the controls of $31x10^3$ cfu/g and $21x10^7$cfu/g, respectively. The high counts of these organisms could be attributed to the high population of these organism in the effluents applied. The presence and abundance of *Bacillus* species observed in the polluted soil may not be surprising as these organisms are indigenous to soil environment, and are known to persist in such environment (Atlas and Bartha, 2007). The residual effect of the abattoir effluent further reduced the bacterial and fungal populations.

Table 6: Initial effects of abattoir effluent (ABAE) on bacteria and fungi populations/identification

Treatment ABAE (L/ha)	Bacteria Population (cfu/g)	Bacteria Identification	Fungi Population (cfu/g)	Fungi Identification
0	$28x10^{3}$	*Bacillus subtilis*	$19x10^{6}$	*Aspergillus niger*
2. 025	$58x10^{3}$	*Bacillus subtilis*	$22x10^{6}$	*Penicillium notatum*
4.050	$84x10^{3}$	*Bacillus subtilis*	$3x10^{7}$	*Rhizopus oryzea*
8.100	$11x10^{5}$	*Bacillus subtilis*	$42x10^{6}$	*Aspergillus niger*
12.150	$14x10^{5}$	*Bacillus subtilis* *Bacillus cereus*	$58x10^{6}$	*Aspergillus niger*

The highest counts of $48x10^6$ and $3x10^7$ cfu/g were observed at 12.150 L/ha ABAE when compared to the control (Table 7). Rabah *et al.* (2010) also reported a higher mean count for bacteria and fungi in soils to which abattoir effluent was added, than the control. *Bacillus subtilis* was the most abundant bacterial isolate followed by P*seudomonas* species. In terms of fungi isolates, *Candida albicans* had the highest occurrence followed by *Aspergillus flavus*.

Table 7: Residual effects of abattoir effluent (ABAE) on bacteria and fungi populations/identification

Treatment ABAE (L/ha)	Bacteria Population (cfu/g)	Bacteria Identification	Fungi Population (cfu/g)	Fungi Identification
0	$22x10^6$	*Bacillus subtilis* *Pseudomonas* spp	$16x10^6$	*Aspergillus flavus* *Microsporium equinum* *Candida* spp
$40x10^3$	$28x10^6$	*Bacillus subtilis* *Pseudomonas* spp	$14x10^6$	*Candida* spp
$80 x10^3$	$35x10^6$	*Bacillus subtilis*	$18x10^6$	*Aspergillus flavus*
$160 x10^3$	$36x10^6$	*Bacillus subtilis*	$2x10^7$	*Candida* spp
$240 x10^3$	$48x10^6$	*Pseudomonas pyocyanea*	$3x10^7$	*Candida* spp

Conclusion

The highest grain yield of 6.82 tons/ha was obtained from the application of 4.050 L/ha of abattoir effluent while the highest residual yield of 1.39 tons/ha resulted from 8.100 L/ha. Total bacteria and fungi counts were higher in the effluent-affected soils even as the level of application increased. At the initial stage, *Bacillus and Aspergillus* species predominated. Residually, *Bacillus* and *Candida* species predominated.

Abattoir effluent is a good source of organic manure which also contains microorganisms that assist in boosting the fertility of the soil for crop production.

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