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Effect of Land Application of Dairy Effluent on Soil Physical and Chemical Properties.

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ABSTRACT

The effects of land application of dairy effluent on soil physical and chemical properties were assessed at two sites in Maizube farms that had received effluent irrigation for over 15 years. A comparison was made with another site within the farm without effluent application. Results showed that dairy effluent improved soil status in plant essential nutrients such as organic materials and potassium. No sodicity problems were observed due to significant ($p < 0.05$) increases in Mg and Cacations in the site treated with effluent which counteracted the dispersion effect of Na cation. Though the total nitrogen and available P were low in the effluent treated soil, the primary soil properties and qualities important in the design, construction, management, and performance of wastewater irrigation systems (SAR, permeability, salinity, bulk density and soil reaction) where positively achieved by the dairy effluent application to soil.
Keywords: Wastewater, soil quality, irrigation, soil water

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INTRODUCTION

The dairy industry represents an important component of the agricultural sector of the Nigerian economy. According to [1], over 183 thousand rural households derived income from the dairy industry in 1986. With increased access to modern technology made available by the Federal Ministry of Science and Technology, the number may have tripled by 2013.

A new impetus was added to the dairy industry in Nigeria with the emergence of large-scale mechanized farms. Associated with this, is the large production and discharge of dairy effluent.Maizube Farm is one of such farms. It has exotic cattle imported from South Africa which on individual basis yields at least 20 litres of milk per day. Maizube farms are reputed to be one of the largest single integrated dairy farms in Africa. Accordingly, it produces large quantities of dairy effluent. Farm Dairy Effluent (FDE) is the mixture of dairy cow faeces and urine deposited during milking and subsequently diluted with wash-down water during the cleaning of the milking area and the associated holding yards [2].

FDE is a veritable source of nutrient for crop production when properly managed and can reduce costs of chemical fertilizers. In addition, land application of dairy effluent can be a good and cheap wastewater disposal method. The organic matter in the effluent will improve soil water holding capacity, aeration and drainage, and make soil less prone to compaction and erosion. The water content is also beneficial if irrigated during the dry season [3].

Despite the numerous advantages associated with FDE, it is still prone to risk as there are environmental concerns surrounding its land application. These include the possibilities of leaching of nutrients to groundwater and accumulation of sodium in the soil [4]. Literatures indicate that there is limited research on the effect of FDE application on soil properties [2, 5-7]. The limited studies were undertaken in developed countries. Accordingly, [6] in their study on storage of farm dairy effluent quality in Maizube farms recommended investigating the effects of dairy waste water on soil properties. Thus, the objective of this study was to determine the effect of land application of farm dairy effluent on soil physical and chemical properties.

MATERIALS AND METHODS

Study site

The study site is Maizube farms located at km 26 Minna-Bida highway, Niger State, Nigeria. Maizube farms (latitude 9^o 37^{1}N and longitude 6^o 30^{1}E) is in the semi-arid climate with two distinct seasons. The wet season spans from May to October and the dry season from November to April. Average annual rainfall is about 1200 mm. Air temperature ranges from 19 ^{o}C (minimum) to 38 ^{o}C (maximum). The soil of the study sites is predominantly sandy clay (47 % sand, 12.5 % silt and 40.36 % clay) for the effluent irrigated site and (49.72 % sand, 10.20 % silt and 40.08 % clay) for the non-effluent treated site (control). The study was conducted during the dry season of 2011. The effluent irrigated site is used for banana plantation and had a known history of FDE irrigation of over 15 years. The non-effluent applied site was planted to maize. The two sites are at least 100 meters apart to minimize interference. The FDE was first stored in an oxidation pond and discharged to the field after attaining a certain level in the pond through outlet pipe.

Soil sampling and analysis

At each site, soil samples were randomly collected from three locations from 0- 0.4 m depth. The samples were bulked and thoroughly mixed, air dried and sieved (< 2 mm) for chemical analysis. The particle size analysis was done using the hydrometer method. Soil cores were taken for the determination of soil physical properties (moisture content, bulk density, particle density, porosity) using gravimetric method; and the hydraulic conductivity using constant head permeameter.

Electrical conductivity and pH were analysed in a 1:2 (v/v) water extract using glass electrodes. Available P was extracted using Olsen's procedure (0.5 M sodium bicarbonate, pH 8.5, 1:2 (v/v) soil extraction ratio, 30 minute extraction) and the extracted phosphate determined calorimetrically by a molybdenum blue procedure.

Cations (K, Ca, Mg, Na) were extracted using ammonium acelate (1.0M, pH 7, 1:2 (v/v) soil extraction ratio, 30 minutes extraction) using standard methods [8]. Organic C and total N content were measured by automated dry combustion using a Carlo Erba C, H, N analyser. The total C measured was converted to organic matter using the Van Bremmelen factor of 1.724. Sodium adsorption ration (SAR) was determined using equation 1 after converting the cations to miliequivalent.

$$\text{Sodium adsorption ratio (SAR)} = \frac{Na^{+}}{\frac{\sqrt{Ca^{2+} + Mg^{2+}}}{2}} \quad (1).$$

STATISTICAL ANALYSIS

Descriptive statistics was used to compute the mean, range and standard deviation among the various physico- chemical variables and student T-test was used to detect the level of significance at 5% probability level.

RESULTS AND DISCUSSION

Soil physical properties

The results of the soil physical properties are presented in Table 1. The results indicate that there is no significant difference between the soil physical properties of the effluent treated site and the control. However, there were appreciable increases in soil moisture content and porosity, and reduction in bulk density in the effluent treated soil compared to the control. This may be due to the increase in organic matter content. These results are in agreement with earlier findings [9, 10]. Although [11] noted an increase in hydraulic conductivity, most researchers have observed a decrease in hydraulic conductivity with effluent [12-14]. The effect of land application of FDE on the hydraulic conductivity of soil is not clearly understood. There are two mechanisms suggested for a decrease in hydraulic conductivity which are: biological clogging of soil pores by microbial growth and the production of extra-cellular carbohydrate [15]. If FDE application decreases hydraulic conductivity, this will affect the soil chemical properties and increase the potential for overland flow and erosion. The observed results indicate that the physical properties of the effluent irrigated site and the control site are similar. Therefore, any differences in their chemical properties are more likely due to the dairy effluent application than the soil physical differences.

Table 1: Soil Physical properties of soil treated with dairy effluent in relation to the control

Parameter	Soil without dairy effluent Mean Value±S.d	Soil with dairy effluent Mean Value±S.d	Sig. (2-tailed)
Moisture content (%)	25.54±5.798	37.80±9.961	0.122
Bulk density (g/cm^3)	1.52±0.115	1.30±0.164	0.081
Particle density (g/cm^3)	2.04±0.040	2.11±0.005	0.109
Porosity (%)	25.83±4.166	38.63±7.931	0.059
Hydraulic Conductivity (cm/min)	0.015±0.000	0.015±0.001	0.916

Soil chemical properties

Table 2 shows that there was a general decrease in pH both in water and in $CaCl_2$ in the effluent treated (irrigated) soil compared to the control. The pH in water of the soil irrigated effluent was slightly acidic (6.40), while that in $CaCl_2$ was moderately acidic (5.3) (Table 3). The decrease in pH of the effluent irrigated soil be attributed to cleansing agents used in washing milking parlour. pH is a very important chemical parameter for crop growth and development. It influences availability of plant nutrients, the solubility of toxic nutrients in the soil, soil microbial activity, physical breakdown of root cells and the cation exchange capacity in soils whose colloids are pH dependent. The relatively lower pH values observed in the dairy effluent irrigated soil compared to the control plot was favourable to the soil.This is because micronutrient deficiencies rarely occur when the soil pH is below 6.5 [16]. Results indicate that the dairy effluent induced higher organic materials (organic carbon and organic matter) in the effluent treated soil compared to the control (Table 2), though the difference was not significant. The increased organic materials will have stabilizing effect on the soil structure [17].

Table 2: Chemical properties of soil treated with dairy effluent in relation to the control

Parameter	Soil without dairy effluent Mean Value±S.d	Soil with dairy effluent Mean Value±S.d	Sig. (2-tailed)
pH in water	6.8±0.152	6.40±0.264	0.093
pH in $CaCl_2$	5.97±0.152	5.37±0.378	0.122
Organic carbon (%)	0.86±0.370	1.29±0.602	0.482
Organic matter (%)	1.47±0.640	2.04±1.295	0.637
Total Nitrogen	0.34±0.073	0.32±0.076	0.774
Sodium (CMol/kg)	0.63±0.180	0.63±0.020	0.575
Potassium (CMol/kg)	0.92±0.080	0.98±0.079	0.576
Magnesium (CMol/kg)	0.73±0.115	1.57±0.404	0.046*
Calcium (CMol/kg)	0.87±0.305	2.23±0.378	0.008*
Electrical conductivity (dS/m)	0.19±85.500	0.25±32.005	0.378
Available P (Mg/kg)	8.87±2.228	7.64±0.452	0.408
Zinc (Mg/kg)	8.53±1.464	7.64±0.452	0.691
Copper (Mg/kg)	3.13±1.933	2.31±0.937	0.478
Iron (Mg/kg)	19.90±2.137	25.60±7.470	0.277
SAR	0.011±0.045	0.08±0.010	0.289

** is significantly different at P<0.05*

Table 3: Soil pH ranges

	pH
Strongly acidic	< 5.1
Moderately acidic	5.2 – 6.0
Slightly acidic	6.1 – 6.5
Neutral	6.6 – 7.3
Moderately alkaline	7.4 – 8.4
Strongly alkaline	> 8.5

Source: Horneck et al. (2011)

Total nitrogen indicates N in organic and inorganic forms. There was a slight reduction of total N in the effluent treated soil in relation to the control. This is because effluent from food processing plants including dairy effluent is very low in nitrogenous matter[18]. Moreover, the control plot planted to maize may have been applied high dose of nitrogenous fertilizer. Sodium is not a plant nutrient and therefore is not necessary for plant growth. High levels of sodium are detrimental to soil structure, soil permeability, and plant growth. Results obtained indicate that there was no appreciable change in the level of sodium in the effluent irrigated soil compared to the control. Elevated sodium can also displace other cations such as Ca and Mg into soil solution and they can subsequently be leached down the soil profile [7].

Other cations (K, Mg, Ca) showed appreciable increase in the effluent treated soil with magnesium and calcium being significantly different ($p < 0.05$) with those of the control soil. This increase in Mg and Ca helped to counteract the effect of Na which will not cause any sodicity problem in the field. Thus, the dairy effluent proved to be a good neutralizer of sodium to the benefit of higher water intake rate and nutrient extraction by plant roots.

Electrical conductivity of dairy effluent is usually greater than that of the soil [5, 6]. Thus, the effluent irrigated soil had higher EC value in relation to the control, though the difference in the two sites was not significant. The values of EC recorded on both sites fall within the FAO accepted limit of 0.75 dS/m [19]. Therefore, the FDE does not pose any salinity problem to the soil.

Phosphorus soil test is an index of available P which may be low, medium, high or excess. Table 2 shows that available P was lower in the effluent treated soil than in the control with no significant differences. The low value implies that dairy effluent has a lower content of available P which is good for the soil and ecosystems. High phosphorus combined with P movement from soil into surface waters can cause excessive growth of vegetation, followed by a decrease in dissolved oxygen, thus damaging aquatic ecosystems [16].

The results of the analysis shows that there were no significant differences between the trace elements in the effluent treated soil and the control site. However, while Zn and Cu decreased in magnitude in effluent treated soil, Fe increased in magnitude. This could be attributed to the scraping and conveyance systems for the effluent, which are made of iron.
The tendency for sodium to increase its proportion on the cation exchange sites relative to calcium and magnesium cations is estimated by the sodium adsorption ratio (SAR). Table 2 indicates that the SAR values ranged from 0.07 – 0.09 on the effluent irrigated site. The mean values of SAR on both sites fall below FAO recommended guideline of < 10 meq/L

[19]. Thus, the dairy effluent does not pose any sodicity hazard to the soil. High sodium hazard indicates that sodium is disproportionally abundant and can cause soils to disperse reducing porosity and have a salt crust which impedes infiltration and making it difficult for roots to extract moisture.

CONCLUSIONS

The effect of farm dairy effluent on soil physical and chemical properties was investigated. The application of farm dairy effluent improved the nutrient status of the soil with increases in plant essential nutrients, especially organic materials and potassium. The dairy effluent did not negatively impact on the soil structure as no sodicity problems were observed due to significant ($p < 0.05$) increases in Mg and Cacations which counteracted the dispersion effects of the Na cation to achieve an acceptable level of sodium adsorption ratio. Thus, the application of dairy effluent achieved the primary soil physical and chemical properties and qualities important in the design, construction, management, and performance of wastewater irrigation systems.

REFERENCES

[1] FAO (Food and Agriculture Organization of the United Nations). Agricultural development in Nigeria 1965-80.FAO, Rome, Italy, 1988.
[2] Hawke RM. Summers SA. New Zealand J Agr Res 2006; 49:3, 307-320.
[3] Dexcel. A guide to managing Farm dairy effluent 2007,Version No. 2.
[4] Britz TJ, Vanschalkwky C, Hung Y. In Waste Treatment in the Food Industry. (Ed. LK. Wang Y Hung, HH Lo, C. Yapijakis)(Taylor and Francis, Boca Raton) 2006, pp.1-28
[5] Hawke RM. Summers SA. New Zealand J Agr Res 2003;46:339-346.
[6] Adeoye PA, Musa JJ, Olaleye AO. Assumption University J Technol 2009;12,2:175-181.
[7] Liu, Yen-Yiu Haynes R. 19th World Congress of Soil Science, Soil Solutions for a Changing World, Brisbane, Australia.Published on DVD, 2010.
[8] Blackemore LC, Searle PL, Daly BK. New Zealand, NZ DSIR. (NZ Soil Bureau Scientific Report 80)1987.
[9] Bernal MP, Roig A, Lax A, Navarro AF. Bioresource Technol 1992;42: 233-239.
[10] Sparling GP, Schipper LA, Russell JM. Australian J Soil Res 2001; 39: 505-518.
[11] Mathan KK. Bioresource Technol 1994, 48: 275–276.
[12] Clanton CJ, Slack DC. Trans American Soc Agr Eng 1987; 30: 683–687.
[13] Cook FJ, Kelliher FM, McMahon SD. J Environ Quality 1994; 23: 476–482.
[14] Magesan GN, Sparling GP. Williamson JC. Soil News 1998, 46: 105–107.
[15] Magesan GN, Williamson JC, Sparling GP, Schipper LA Lloyd-Jones A. Rh Australian J Soil Res 1999; 37: 391-402.
[16] Horneck DA, Sullivan DM, Owen JS, Hart JM. Oregon State University Extension Service, 2011.
[17] Cameron KC, Di HJ, Anwar MR. New Zealand J Agr Res 2003; 46, 147-154.
[18] USDA. Soil Interpretations Rating Guides Part, 1993; 620, pp 43-49.
[19] Ayers RS, Westcott DW. Rome 1985, ISBN 92-5-1022631.