Organic amendment in urban and periurban agriculture: Biochemical composition and mineralization in different types of soil

Mame Farma Ndiaye[1,P], Ndéye Yacine Badiane Ndour[1], Moussa Ndiénor[3], Aïssatou Diouf[1], Ndeye Hélène Diallo[1], Dominique Masse[2]

(1) Laboratoire National de Recherches sur les Productions Végétales, ISRA Bel-Air BP 3120 Dakar Sénégal
(2) LEMSAT/UMR Eco&Sol, IRD-INRA-CIRAD-Supagro, Université Montpellier, 2 place Viala, Bat.12, 34064 Montpellier Cedex 1, France
(3) Ndiénor Agro-consulting, LEMSAT/ LMI IESOL Centre ISRA/IRD BP 1386 Dakar, Sénégal
farma.cisse@isra.sn

Abstract

The objective of this study was to gain a better understanding on nutrients release from a range of Organic Residuals Products (ORP). A total of fourteen different ORP were characterized using chemical analysis and fractionation by Van Soest method. A 181-day incubation was performed using two major types of Senegalese soil (Dek and Dior) to assess their decomposition. Results showed that CO_2–C evolution rates and net N mineralization rates were generally higher in Dior soil than in Dek soil. Addition of ORP led to different inorganic N dynamics but most of the ORP released inorganic N at concentrations that would be high enough to warrant a reduction in inorganic N fertilizer application rates. For PM, FF SS and AS, the amount of N released was high indicating that application rates could be reduced to minimize leaching losses. Multifactor analysis were performed to establish relationship between the composition of ORP and their decomposition.

Introduction

Urban and Periurban Agriculture adapts to new economic and spatial conditions as there is strong competition for access to inputs (water, fertilizer) and land. In addition, tremendous and continuing urbanization process, and population growth implies an increasing pressure on urban agriculture for production. Such constraints require intensification of farming system, which is mainly done through high fertilizer inputs in developing countries (1, 2).

The use of organic matter, although very frequent, is not widespread. In Antananarivo, organic matter is provided by manure, which is sometimes on-farm compost or compost from solid city waste (3). In Dakar, it has been estimated that 25% of the nutrients for horticultural crops come from plant compost and another 25% from animal manure (4). Recent studies (data not published) in Dakar, showed that farmers have reduced their use of chemical fertilizer, because of their high cost, with a consequent increase of organic matter supplement. However, the use of organic amendment in UPA is limited by their availability in terms of distance between the exploitation and the supply source, and also in terms of cost. Thus, due to the increase of market gardening and to prevent lack of manures, it is necessary to identify other organic materials originating from urban and industrial activities. Moreover, organic amendments vary greatly in their composition and degree of stabilization and thus in their capacity to release nutrients. To successfully manage nutrient cycling from organic amendments it is necessary to acquire more knowledge on their decomposition.

The aim of this study is therefore to investigate biodegradability of different ORP or other potentially available fertilizer, in the main site of UPA in Dakar: the *Niayes* zone, especially at Pikine and Rufisque, through their C and N mineralization as well as their biochemical composition. Both chemical characteristics and Van Soest analysis were completed, and C and N decomposition (mineralization rate) were quantified. This information is required to develop guidelines for amendment incorporation into commercial horticultural productions systems.

Material and Methods

Origin and nature of the ORP

Various ORP derived from urban waste, crop residues, or animal manure were sampled (table 1).

Table 1 Type, nature and short description of studied ORP

Origin	Denomination	Additional information	*Code*
Urban waste	Activated sludge	Sampled in purification station of municipal wastewater at Pikine	*AS*
	Stabilised sludge		*SS*
	Composted household waste	Sample in the municipality of Hann Bel Air	*CHW*
	Riddled discharge	Derived from the screening of naturally composted municipal solid waste in Mbeubeuss landfill, the only authorized dumping trash in Dakar	*RD*
Crop residues	Peanut dust	Crushed peanut shell obtained after decorticating peanuts	*PD*
Industrial process	Bioferty	Bagasse and manure based product, phosphate-enriched	*Bf*
Animal waste	Horse manure	The most used ORP in UPA. Two sample was realised in fields at Rufisque	*HM, HM1*
	Poultry manure	From poultry waste in cage layer, two sample was realised in fields at Rufisque	*PM, PM1*
	Fish flour	Derived from the processing of waste and of unsold fish at Rufisque	*FF*
	Sheep manure	Sheep manure with few wood chips, sampled in fields at Rufisque	*SM*
		Sheep manure with many wood chips, sample in fields at Rufisque	*SMW*
	Cattle manure	Sample at Rufisque	*CM*
	Slaughterhouse waste	Rumen content from cattle and sheep stomach, sample in fresh heap in fields at Rufisque	*SWY*
		Rumen content from cattle and sheep stomach, sample in old heap in fields at Rufisque	*SWO*
Co-products	Slaughterhouse waste + Poultry manure	Mix of SWY (2/3) and PM (1/3)	*SWY+PM*
	Peanut dust + Poultry manure	Mix of PD (2/3) and PM (1/3)	*PD+PM*

Analysis

Total N and C content of ORP were analysed and biochemical characteristics were determined by Van Soest method (5). Two main cultivated soils were sampled (0-10 cm): the first one is a ferruginous tropical soil, locally called Dior (C= 1.06%; N= 0.12%), and the second one is pseudo-gley mineral soils, locally called Dek (C= 1.17%; N= 0.068 %). ORP were incorporated to soil at a standard rate of 2 mgC.g-1 soil and incubated in dark, at 28°C during 181 days. Potential carbon mineralization was measured as respired CO_2-C in closed chamber, and potential N mineralization, was followed after extraction using KCl solution and analysed using Bremmers method (6).

Results

Chemical and Biochemical composition of ORP

High nitrogen content was found in poultry manure (6.02% for PM and 4.10% for PM1), sludge with respectively 3.95% and 3.07% for AS and SS, and FF with 3.86%. Horse manure also contained high levels of nitrogen with 2.27% for FC1. Other ORP have nitrogen contents below 2%, the lowest value was found in peanut dust (0.47%). The highest levels of total phosphorus were found in these same ORP ranging from 1.13% to 3.05% except for Bioferty which is an industrial product enriched with phosphorus exhibiting 2.67% of Ptot. The C/N ratios showed a wide range with values less than 15 for most of urban wastes (AS, SS, CHW) and animal manure, and high ratio (≥20) for SMW and SWY.

Van Soest analysis showed that relative size of fractions varied considerably between ORP: ash represents the larger fraction for most of them, at least 30%, with highest value obtain for RD (92%). A second important fraction is soluble compounds which values reach 32% and concern mainly urban waste. Hemicelluloses, lignin and cellulose fraction, are more important in animal manure, and industrial process but showed large variation.

Carbon and N mineralization of ORP

Two steps on C mineralization occurred. The first step is characterized by rapid mineralisation, particularly for PM and FF that mineralized at least 30% of added C, in just 7 days. In the second step we note a decrease of kinetics that levels off over time.

At the end of incubation, in Dek soil, we can distinguish three classes of ORP. The first class is characterized with high value of CO_2 rates ≥ 40%, corresponding to unstable ORP (FM and PM). The second exhibit intermediary values (15% ≤CO_2 ≤ 30%) and so ORP with medium stability. The last class contains stable ORP exhibiting values that don't reach 10% (RD, PD, Bf, CHW). Carbon mineralization of OPR was enhanced when incubated in Dior (up to 1.5 times). This, results in a redistribution of ORP into two classes, those with CO_2 rates ≥ 40% and those with CO_2 rates between 20% and 40%.

In both soils, the course of N mineralization differed, but positive net N-mineralization was recorded for most ORP, particularly, for PM and FF which exhibit the highest values (respectively 297 and 212 mgN.kg in Dek soil) at the end of incubation. A slight immobilization occurred for animal waste, and sometimes for the entire incubation as in the case of CM. Moreover, mixing PM with SWY resulted in a great increase of N-mineralization (at least 10 fold). Results showed that the mineralization pattern could differ according to the type of soil. We did not observe an enhancement of N mineralization when comparing results between Dek and Dior, as for C mineralization, but rather the opposite where we recorded 181 mgN.kg soil in Dior Nmin for PM.

Relationship between waste characteristics and behaviour

When doing coinertia analysis using first, chemical and biochemical data, and second, C mineralization (fig. 1), ORP with large lignin cellulose and carbon content were separated on the right side and include essentially animal manure, characterized by medium to low mineralization kinetics. At the opposite side, we have ORP with high N content and large soluble fraction including the urban waste and FF and PM. The latter exhibits the highest N and C mineralization, and so, could be considered as good fertilizer.

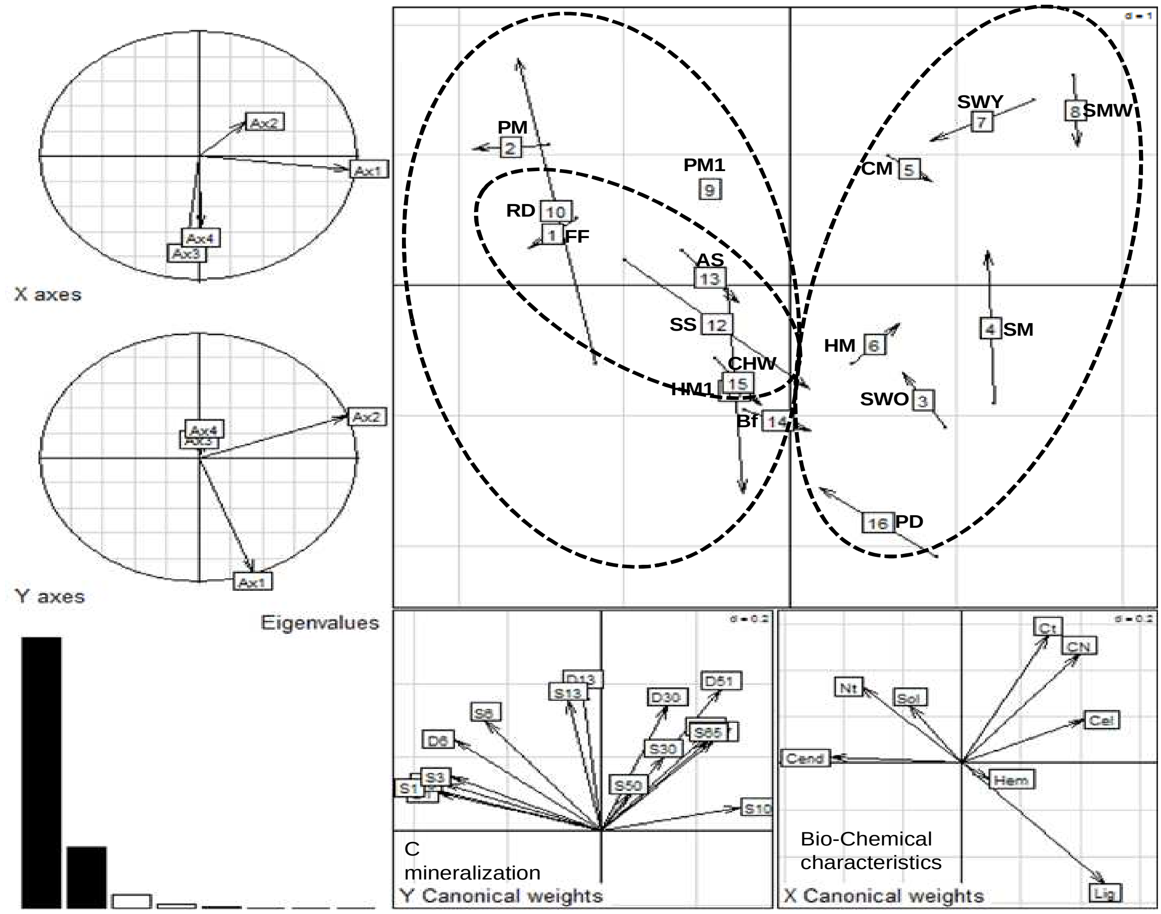

Figure 1: Carbon mineralization vs biochemical and chemical characteristic of ORP. S and D refer respectively to Dior and Dek and the number following to the date of incubation. Framed numbers refers to ORP which identifications are listed in table 1. Cend: Ash, Hem: hemicelluloses, lig: lignine, Cel: cellulose, Sol: soluble compounds, Nt: % of total N content, Ct: % of total C content, CN: C/N ratio.

Curiously, RD clustered with FF and PM, du certainly to its high ash content. These results, together with different pattern obtain between two samples of the ORP (HM, PM), confirm previous studies showing that biochemical fractions are related to potential N availability, like C/N ratio (7,8, 9).

Conclusion and perspectives

This work dealt with the mineralization kinetics of various other ORP. Higher proportion of C and N mineralisation was found in the animal- originated ORP particularly those rich in N. They can be classified as quickly efficient N fertilizer with a reserve of immobilized N further available for plant. That from urban waste and crop residues was of a lesser extent and can be used both for amendment and N fertilisation. Mixing ORP rich in N can be helpful in improving the quality of ORP. These results should be completed by green house experiments with a crop, to follow N uptake by plant. Future investigations should also explore “intra ORP” variability for process normalization.

References

1. De Bon H., Parrot L., Moustier P. (2010). Sustainable urban agriculture in developing countries. A review. Agron. Sustain. Dev. 30 : 21–32.
2. Predotova M., Gebauer J., Diogo R.V.C., Schlecht E, Buerkert A. (2010). Emissions of ammonia, nitrous oxide and carbon dioxide from urban gardens in Niamey, Niger. Field Crops Research 115: 1–8.
3. N’Dienor M. (2006). Fertilité et gestion de la fertilisation dans les systèmes maraîchers périurbains des pays en développement : intérêts et limites de la valorisation agricole des

déchets urbains dans ces systèmes, cas de l'agglomération d'Antananarivo (Madagascar). Paris : Institut National Agronomique Paris-Grignon, 242p. Thèse (Dr. Sciences Agronomiques).
4. Fall, A. S., Cissé, T., Badiane, A. N., Diao, M. B. (2000). Caractéristiques de la zone des Niayes, CRDI, Canada.
5. Van Soest P.J. (1963). Use of detergent in the analysis of fibrous feeds. I. Preparation of fiber residues of low nitrogen content. Journal of the Association of Agricultural Chemists 46: 825-835.
6. Bremmer J.M. (1965). Inorganic forms of nitrogen. In C.A. Black et al. (eds) Methods of soil analysis. Part 2 Agron. Monogr. 9, ASA, SSSA, Madison, WI pp1179-1237.
7. Jensen, L.S., Salo, T., Palmason, F., Breland, T.A., Henriksen, T.M., Stenberg, B., Pedersen, A., Lundstrom, C., Esala, M., 2005. Influence of biochemical quality on C and N mineralisation from a broad variety of plant materials in soil. Plant Soil 273, 307–326.
8. Flavel, T.C., Murphy, D.V., 2006. Carbon and nitrogen mineralization rates after application of organic amendments to soil. J. Environ. Qual. 35, 183–193.
9. Morvan, T., Nicolardot, B., Péan, L., 2005. Biochemical composition and kinetics of C and N mineralization of animal wastes: a typological approach. Biol. Fert. Soils 42, 513–522.