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Investigation of *Imperata* sp. as a Primary Feedstock for Compost Production in Ucayali region, Peru

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Abstract

Five compost piles with different initial C : N ratios have been investigated in this study. As a primary feedstock *Imperata* sp. was used. The primary feedstock was mixed with poultry litter and vegetable refuse in order to obtain different C : N ratio. The results show that during 64 days of well managed composting under tropical conditions the initial C : N ratio between 30:1 and 50:1 decreased to ratio 11:1 to 15:1, respectively. Results of bioassay tests expressed as the germination index (GI) indicate particular compost phytotoxicity. The value of GI was 51.4%, 48.6%, 47.8%, 46.7% and 40.0% for samples from the compost with initial C : N ratios of 30:1, 37:1, 40:1, 44:1 and 50:1, respectively.

Keywords: Composting, *Imperata* sp., allelopathy, Peruvian Amazon, compost phytotoxicity

1 Introduction

The earth contains 4.5 billion ha of forests, of which 43% are in the tropics. Tropical forest area is decreasing at the rate of 13.5 million ha/year, mainly due to the clearing for agricultural purposes (Kobayashi, 2004). Peru contains about 12% of tropical rain forests located in the Amazon Basin (Goulding *et al.*, 2003). One of the most important and less developed regions in Peruvian Amazon is the Ucayali region which includes 1.3 million ha of tropical forests and the deforestation is proceeding at 30,787 ha/year (Kobayashi, 2004).

Farmer-settlers in the Ucayali region have traditionally practiced slash-and-burn agriculture to produce annual crops. This farming system results among others to high infestation of large areas by *Imperata* sp. (known as Cogongrass or locally as Cashaucsha) together with high soil degradation. Cogongrass (*Imperata* spp.) is one of the most troublesome aggressive perennial weed grasses in degraded soils of the humid tropics.

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Cogongrass (Imperata cylindrica) is the most varied and cosmopolitan species in the genus, which also includes *I. conferta*, *I. contracta*, *I. brevifolia*, *I. brasiliensis*, *I. tenius*, *I. cheesemanii*, *I. condensata*, and *I. minutiflora* (MacDonald, 2004). Based on results of a study that was conducted among farmer-settlers near Pucallpa, the capital city of Ucayali region, more than 50% of respondents named *I. brasiliensis* as the worst weed followed by *Rottboellia cochinchinensis* (Fujisaka *et al.*, 2000).

The soils in non-flooded areas in Ucayali region are degraded, acid, and high in aluminium ultisols with poor organic matter (OM) and physical properties (Fujisaka and White, 1998). Arresting the decline of soil OM is the most potent weapon in fighting against soil degradation and threatened sustainability of agriculture in the region. Improving soil OM is, therefore, crucial in the sustenance of soil quality and future agricultural productivity (Katyal *et al.*, 2001). Composting is the biological decomposition of organic matter under controlled aerobic conditions leading to the improvement of soil OM content and fertility trough application of stable and mature compost (Epstein, 1997; Rynk, 1992).

Since *Imperata* sp. has a large prevalence in the region and at the same time there is lack of suitable raw material for compost production on non-flooded areas mainly due to low livestock production (Fujisaka and White, 1998), the main objective of this study was to investigate the possibility of using *Imperata* as a prime matter for compost production in the Ucayali region.

2 Materials and Methods

2.1 Raw materials and procedure

As a predominant composting material the dry leaves and stalks of *Imperata* sp. were used. Aerial parts of *Imperata* sp. were collected from the agricultural areas in Antonio Raymondi village 25 km west from Pucallpa city. As an amendments mixed with the primary feedstock to balance the $\mathrm{C:N}$ ratio and moisture content, two year old deep poultry litter and vegetable refuse were used. The deep poultry litter was purchased from the local poultry farm located on the main road 19 km west from Pucallpa city. The vegetable refuse was collected from the local vegetable market Bellavista in Pucallpa.

Nitrogen and carbon content, moisture content and bulk density were determined for each raw material before composting. Nitrogen content was evaluated by Kjeldahl method, OM content by weight loss on ignition at 540°C for 16 h. Total carbon content (TCC) was estimated by the following equation proposed by Guerra-Rodríguez *et al.* (2000).

$$TCC = (TOMC - 9,33)/1.745 \qquad (1)$$

where $TOMC$ is the total organic matter content. Moisture was determined by the oven method (105°C for 24 h). The initial chemical and physicochemical properties of composted raw materials are presented in Table 1. The experimental composting was done at the National University of Ucayali in Pucallpa. The experiments were carried out in five wooden bins (width 1m x length 1m x height 1.5m) as batch aerobic runs. Each bin was loaded by a mixture of shredded organic feedstock (*Imperata* sp., poultry litter and vegetable refuse) with different initial $\mathrm{C:N}$ ratio reaching 1m3 of volume. The experimental bins were labeled C-30, C-37, C-40, C-44 and C-50 with initial $\mathrm{C:N}$ ratios 30:1, 37:1, 40:1, 44:1 and 50:1, respectively. The compost bin C-30 with an optimal $\mathrm{C:N}$ ratio of 30:1 was used as a control. A percentage content of *Imperata* sp. was 57%, 67%, 72%, 76% and 81 %; the content of deep poultry litter was 25%, 20%, 18%, 15% and 11%; the content of vegetable refuse was 18%, 13%, 10%, 9% and 8% for compost C-30, C-37, C-40, C-44 and C-50, respectively. During the composting process a feed material in each bin was turned weekly and after 14 days once every two weeks to ensure the aeration. Also water was added each week to the composts to maintain the desired moisture content between 50% and 60%.

Table 1: Chemical and physical characteristics of compost feed materials

Characteristics	*Deep poultry litter*	*Imperata sp.*	*Vegetable refuse*
Moisture content (% w.b.)	18.58	3.29	80
Total nitrogen (% d. b.)	0.62	0.49	1.70
Total carbon (% d. b.)	7.81	50.6	46.3
Bulk density (kg.m^{-3})	690	66	800
$\mathrm{C:N}$ ratio	12.6	103	27.2

w.b. - wet basis
d.b. - dry basis

2.2 Monitoring the composting process

During the experimental runs the composting process in each bin was monitored. Monitoring was mainly focused on temperature, moisture content and pH. Other conditions like change in color of the compost components and rate of shrinkage was monitored as well. The temperature was measured daily at 11:00 a.m. by mercurial thermometers in three different parts of each compost pile. The data were averaged to give a representative temperature value. Samples of 20g were taken every three days during the composting to assess the pH. The moisture of compost samples was determined by the oven method. The pH was determined from an aqueous extract of 5 g aliquot of sample with distilled water at a solid : water ratio of 1:25 (w/v) (Guerra-Rodríguez *et al.*, 2000).

2.3 Evaluation of mature composts

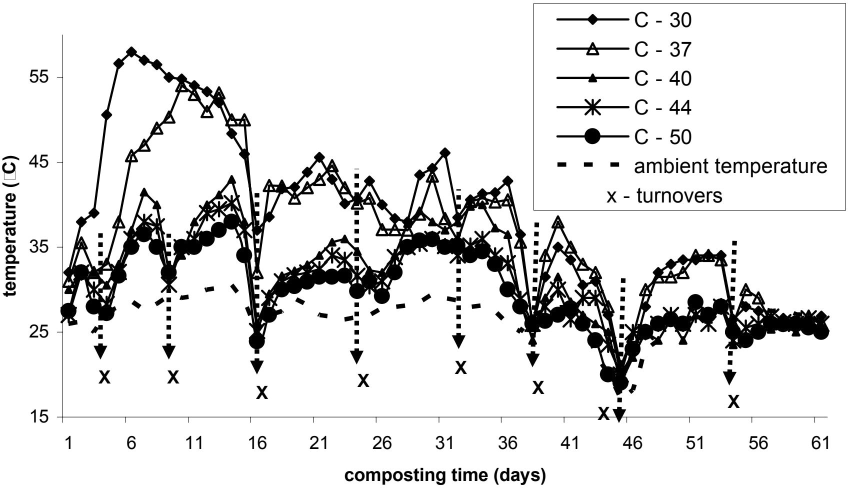
After nine weeks of composting ten 30 g subsamples of compost were taken at the random from each compost bins. Compost subsamples were then homogenized, air-dried (air-drying was done after compost moisture estimation) and labeled C-30, C-37, C-40, C-44, C-50 according to the compost bins. All samples were kept in dark plastic bottles at 4°C, then chemical analyses and bioassay tests were carried out. The pH was determined in the aqueous extract of 5 g aliquot of sample with distilled water at a solid:water ratio of 1:25 (w/v). Moisture was determined by the oven method (105°C for 24h) and organic matter (OM) content by weight loss on ignition at 540°C for 16 h. Total carbon content (TCC) was estimated by the expression proposed by GUERRA-RODRÍGUEZ *et al.* (2000). Total nitrogen content was determined by Kjeldahl method. Available phosphorus was extracted with 0.5 M CO_3HNa and measured by UV-VIS spectrophotometry (VILLAR *et al.*, 1993). Available nutrients (Ca, Na, K and Mg) in dry matter were estimated by Flame Atomic Emission Spectroscopy (FAES) (SOLANO *et al.*, 2001). Heavy metal (Cu, Zn, Cd, Pb, Cr, Ni, Hg, As, Mo) content of the compost samples was measured using atomic absorption as expressed by HASSOUNEH *et al.* (1999). The bioassay tests for phytotoxicity evaluation were based on germination index method on cress seed of *Lepidium sativum* (ZUCCONI *et al.*, 1981). In this biological method the influence of compost sample leach on cress seed germination was examined. The germination index was obtained by multiplying the percentage of germination by the percentage of root growth as related to the control. Each result in the study is the mean of three replicates.

3 Results and Discussion

3.1 The composting process

Temperature has been widely recognized as one of the most important parameters in the composting process (TIQUIA *et al.*, 2002). The temperature profiles for all compost piles together with ambient temperature are presented in Figure 1. During the composting period, the ambient temperature fluctuated between 26°C and 28°C. The temperature of all treatments increased rapidly from the first day of composting, however the optimal temperature patterns are represented by compost C-30 and C-37. Reference to Figure 1 shows that in case of compost C-30 and C-37, the temperature was in the range of 26-50°C within the first three days, which is well close to the optimum range of 15-40°C for mesophilic bacteria which colonize the compost during this period (MBULIGWE *et al.*, 2002). From day 3 to day 25 the temperature range was 40-60°C, which is close to the range for thermophilic bacteria and fungi to colonize and degrade the organic compounds. From day 30 to day 64, the temperature was in the range of 28-38°C, which is predominantly within the range which is favorable for actinomycetes and fungi to colonize the compost. It is also evident that during the last week the temperatures inside the heaps were close to the ambient temperatures due to low microbial activity and compost maturity. The temperature curves of compost C-40, C-44 and C-50 corresponded to C-30 and C-37 but with lower temperature values mainly in mesophilic and thermophilic periods. It is also evident that lowest temperature patterns from 24°C to 38°C during the whole composting process are referring to compost C-50. These conditions were caused by the inappropriate initial $C:N$ ratio, leading to an insufficient content of nitrogen in the pile. Figure 1 also shows that only in case of compost C-30 the temperature exceeded 55°C for several days which is important for pathogen reduction (EPSTEIN, 1997). The turnovers during the composting are well perceptible from Figure 1. The moisture content during the whole process varied between 40% and 60% in all compost piles.

Figure 1: The ambient and composting temperature patterns



The variations of pH during all experiments were in ranges described by many authors as optimal (Epstein, 1997; Haug, 1993; Rynk, 1992). At the beginning the pH was slightly acid (5.5 - 5.7) and during the termophilic period raised to alkaline values up to 8.3. Then during compost curing the pH decreased to neutral values from 6.8 to 7.6.

During the first two weeks of composting a 52%, 54%, 53%, 52% and 51% of volume reduction was achieved in compost C-30, C-37, C-40, C-44 and C-50, respectively. After the first two weeks the shrinkage with time slowed down and at the end of composting process stopped at values of 65%, 64%, 71%, 73% and 73% for compost C-30, C-37, C-40, C-44 and C-50, respectively. High shrinkage can be explained by the high rate of primary feedstock dry grass *Imperata* (bulky material), mainly in composts C-40, C-44, and C-50. Changes in the color of the compost materials during the composting process indicate the degree of stability. The initial color of tested composts in this study was almost brown-whitish with some green parts. After 21 days, the compost C-30 had a dark-brown color, the compost C-37, C-40 and C-44, C-50 had brown and auburn color, respectively. At the end of the composting process (after 64 days) the composts had the following colors: compost C-30 and C-37 black, compost C-40 dark-brown and compost C-44 and C-50 brown. In case of compost color it is evident that color changes between each compost heap depend on the amount of *Imperata* in the compost mixture. The compost with the highest share of *Imperata* C-50 had the lightest color.

3.2 Evaluation of finished compost

The physical and chemical characteristics of all compost samples are presented in Table 2. Final moisture content (MC) of all tested samples was within the recommended range from 40% to 60% (Epstein, 1997). The lowest bulk density was observed in

compost C-50, which corresponded to the highest content of *Imperata*. The C : N ratio usually decreased during the composting process and its end to initial values was one of compost stability indicators. Referring to Table 2, the final C : N ratio of all analyzed composts was between 11 and 15 hence well below 20 which is the upper limit for stable compost (JIMENEZ and GARCIA, 1989; EPSTEIN, 1997). Further a significant C : N ratio decreasing rate is evident in all composts, even compost C-40, C-44 and C-50 have been prepared as composts with a high initial C : N ratio. The OM contents ranged between 20.0% and 29.3% (d.b.) in all tested composts, which is near the minimum of 25% in d.b. required for compost by EC specifications (GUERRA-RODRÍGUEZ *et al.*, 2000). The low OM content could be explained by very low TCC of deep poultry litter (7.8% d.b.), which is evident from the OM content of compost C-30 with the highest content of this compost feed material. The final pH of all tested composts was between the recommended ranges 6 – 8.
Total macro-nutrient contents in all compost samples are presented in Table 3. The macro-nutrient values in all composts are well above the minimal values required by EC regulations and are within the range reported by other authors (VILLAR *et al.*, 1993).

Table 2: Chemical and physical properties of final composts.

Compost sample	*Moisture Content (% w. b.)*	*Bulk density (kg m^{-3})*	*pH*	*Organic Matter (% d.b.)*	*Total C (% d.b.)*	*Total N (% d.b.)*	C : N *ratio*
C-30	50.50	780	7.8	20.00	10.68	0.98	11:1
C-37	41.22	705	8.0	25.00	13.23	1.12	13:1
C-40	40.75	660	7.3	25.10	13.28	0.98	14:1
C-44	46.64	612	8.0	29.26	15.40	1.13	14:1
C-50	40.66	552	7.7	28.62	15.08	1.01	15:1

Table 3: Macro nutrient contents of final composts.

Compost sample	K	Ca	Mg	P	Na
			mg kg^{-1}		
C-30	10.187	73.843	5.869	15.179	1.963
C-37	9.176	85.036	5.292	15.963	1.636
C-40	8.137	72.606	7.496	13.214	1.365
C-44	8.593	81.393	5.441	15.394	1.437
C-50	7.155	69.730	4.422	13.726	1.243

Table 4 shows the heavy metal contents in all tested composts. Referring to this table it is evident that concentrations of all heavy metals in all tested composts are well below the required limits (COMPOST COUNCIL OF CANADA, 1999; HEGBERG *et al.*, 1991) except the concentrations of zinc. The concentration of Zn may not complete some very rigorous regulations, for instance EEC Organic Rule 2092/91 where a value of 200 mg kg^{-1} of Zn is considered as maximum (BIDLINGMAIER and BARTH, 1993). From Table 4 it is also evident that there is no relationship between the content of *Imperata* in compost piles and the content of various heavy metals. Results of bioassay tests expressed as the germination index (GI) were 51.4%, 48.6%, 47.8%, 46.7% and 40.0% for sample C-30, C-37, C-40, C-44 and C-50, respectively. According to ZUCCONI *et al.* (1981), GI values greater than 50% indicate a phytotoxic-free compost which is only the case of sample C-30. The majority of literature sources reported germination over 80% as essential for mature and phytotoxic-free compost (GUERRA-RODRÍGUEZ *et al.*, 2000; BREWER and SULLIVAN, 2001). However, the GI results can indicate a compost immaturity in all tested samples, the final $C:N$ ratios indicate that all tested composts may be considered as mature. Further Table 4 confirmed that the compost phytotoxicity predicted by the bioassay tests is not a result of redundant heavy metal content.

Table 4: Heavy metal contents of final composts.

Compost sample	Cu	Zn	Cd	Pb	Cr	Ni	Hg	As	Mo
					mg.kg^{-1}				
C-30	29.31	303.1	0.191	4.458	32.57	5.831	0.0316	7.681	2.401
C-37	39.33	336.1	0.304	6.860	32.23	6.595	0.0338	7.935	2.568
C-40	30.01	283.2	0.208	4.036	30.84	4.792	0.0300	6.829	1.935
C-44	30.63	321.3	0.224	2.667	32.30	6.994	0.0377	6.161	2.284
C-50	26.40	275.1	0.195	2.963	29.83	5.632	0.0300	6.598	1.761

The relatively low GI values may be explained by phytotoxic effect of the major compost feedstock *Imperata*. It was reported that *Imperata* sp. contains phenolic compounds which significantly inhibit germination and growth of other plants and cause an allelopathic effect (INDERJIT and DAKSHINI, 1991; HONG *et al.*, 2003). The bioassay tests show a decline of GI from sample C-30 to C-50 which corresponds to an increasing content of *Imperata* sp. in these composts. The direct effect of *Imperata* on the final compost phytotoxicity has not been verified in this study; however some particular relationships have been described. Hence further tests to verify a relationship between the allelopathic effects of *Imperata* sp. and final compost phytotoxicity are strongly encouraged.

4 Conclusions

(1) In all tests a considerable $C:N$ ratio reduction was achieved during 64 days of well managed composting under tropical climatic conditions.

(2) Composts prepared with *Imperata* sp. as a prime feedstock were found as convenient in terms of physical and chemical properties.

(3) No over limits of heavy metal concentrations have been observed in the tested composts.

(4) A particular compost phytotoxicty, which may be caused by the allelopathic effect of the main component *Imperata* sp. has been observed in this study.

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