Physical, chemical and biological management of composting - effects on nutrient availability and bulk reduction.

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Introduction

The local transformation of organic waste into value added organic fertilizers by composting is an important strategy to enhance the sustainability of our food and farming systems. Especially in the context of developing countries where organic wastes and by-products (agricultural, industrial and residential) rarely are recycled and primarily discarded into landfills if at all collected (Acurio et *al.* 1997).

At the same time agriculture may be facing a range of future challenges in regard crop nutrient supply. Major issues such as future limitations of phosphorus supply, expected to reach global depletion within the next 50-100 years (Cordell et *al.* 2009) and future limitations of fossil fuel on which chemical fertilizer production rely, which is expected to increase fertilizer prices. In many developing countries the availability and high cost of mineral fertilizer is already limiting the use by poor farmers. Here various forms of organic matter are the dominant nutrient sources, however often material heterogeneity and bulkiness makes them sub-optimal to use. Low tech composting of organic waste may hold a potential to produce more homogeneous and less bulky source of nutrients.

Nevertheless compost suffers some major shortcomings compared to chemical fertilizers; generally having low concentration and bioavailability of nutrients especially the organic bound fraction and being prone to nutrient losses during the processing and storage (e.g. volatile N species and leaching of soluble nutrients). In order for compost to qualify as a potent organic fertilizer it has to be a concentrated product with a high content of available nutrients.

Most strategies for optimizing compost quality and processing has been focusing on the management of physical and chemical properties such as the C/N ratio (optimally around 20-25), moisture level (50-60% moisture) and aeration (turning piles or via forced/ passive ventilation) to yield optimal conditions for the existing microbial populations.

High C/N ratio may slow down the composting process due to relative limited N available for microbes. Contrary a Low C/N ratio may induce higher N losses (especially during the thermophilic phase) because of a relative excess of available N. A rule of thumb is 25 as C/N the threshold. However, when using a particular N substrate for the compost, one strategy to reduce N losses without compromising the C/N ratio could be to add N substrate after the thermophilic phase.

Another important parameter is maintaining aerobic conditions in the compost. In technological composting systems this can be done by passive or forced air ventilation pipes through the compost vessel. A low tech approach is to turn and mix the compost piles at regular basis though the tradeoff is the labor intensity of compost mixing if the appropriate machines are not available. In the context of developing countries where financial resources are limited, compost aeration will typically be manually. More frequent turning may also lead to more N-volatilization during the thermophile phase and greater water loss, while too infrequent turning may inhibit the composting by lack of air (Getahun et al. 2012).

The inoculation of compost with selected functional microbes for an improved process and end product from a plant nutrient perspective is to our knowledge a somewhat “under explored” area of research. The vast majority of compost inoculation studies are focusing on the pathogen, odor or other sanitation effects. Nevertheless microbial inoculums are accepted and frequently used in both solid and liquid biotransformation processes in many small scale organic farming systems particularly in the developing world.

The objective of the current study is to investigate composting management strategies to increase nutrient availability and reduce nutrient losses and reduce bulk. Two composting experiments were conducted i) which aimed to investigate the influence of turning frequency and time of N addition on the compost on drymatter loss and nutrient availability (mainly N) and ii) which aimed to investigate to what extent inoculation with selected microorganisms can optimize the compost process and increase the bioavailability of nutrients in the mature compost. This was approached by assessing the population dynamics of inoculated microbes during composting and linking it to material degradation and the nutrient fluxes (of particularly N and P) from the compost material between mineral forms and microbial incorporation.

Material and Methods

Experiment I

Compost was made from residues of sugar cane (*Saccharum officinarum* L.) (i.e. bagasse as bulking agent and filtercake as C source) and poultry manure as N source. Mixing ratio was based on reaching a C/N ratio of 20 or 30 and a moisture level between 50-60%. 1m3 piles of compost (approx. 360 kg FW) were set up in a randomized (4x3) block design in a roofed concrete floor greenhouse at CATIE, Costa Rica during spring 2011.

The 4 treatments were:
I. (E_3): Early N input (t=0) of high N (C/=20) and mixing every 3 day
II. (E_9): Early N input (t=0) of high N (C/=20) and mixing every 9 day
III. (L_3): Late N input (t=27) of high N (from C/N=30 to 20) and mixing every 3 day
IV: (L_9): Late N input (t=27) of high N (from C/N=30 to 20) and mixing every 9 day
The early vs. late N input was given by a load of 40 kg of poultry manure added initially (t=0) or after the thermophile phase at 27 days (t=27).

Composite samples were taken at day 9, 18, 27, 36, 45 and 54 and analysed for total N, C, mineral N and fiber fractions (by Van Soest). Further, gravimetric moisture (oven drying 24h at 105 C), pile core temperature and dry matter loss (compost weight) was monitored during the process.

Experiment II

Organic household waste was composted mixed with structural material (eg. straw/wood chips/paper/cardboard) and a high organic N and P material (eg. bone meal or animal litter) to enhance initial C/N ratio, N and P level. Portions of approximately 50 L (8 kg fresh weight) were composted in foam boxes for heat insulation. The compost was inoculated with commercial microbial strains *Bacillus spp* and *Trichoderma spp*. The inoculums were added at compost initiation and after the thermophile phase. Concentrations were in accordance with recommendations from the product distributers (10^5 – 10^6 CFU/g of material).

The 6 treatments were:
I. (H_B): High N & P and Bacillus inoculum
II. (L_B): Low N & P and Bacillus inoculum
III. (H_T): High N & P and Trichoderma inoculum
IV: (L_T): Low N & P and Trichoderma inoculum
V. (H_0): High N & P and no inoculum
VI: (L_0): Low N & P and no inoculum

Core temperatures were measured every 3 day and the composting was continued for 4 weeks with material mixing every 7 days. Non-destructive samples were taken at 4 times during the composting and the mass balance monitored. At each sampling time microbial diversity and population sizes will be determined at DNA level using qPCR. Samples will also be analyzed for total C, N and P, mineral N, extractable N and P. Soil microbial biomass N and P will be determined by fumigation and extraction. Structural changes in the compost material will be determined by digestion (Van Soest).

Results

Experiment I

All treatment exhibeted peak temperatures between 65-70 degrees within the first 2 weeks, though the two treatments with 9 day mixing intervals showed their peak temperature after the first mixing (figure 1). For 39 days the core temperatures of all treatments stayed above 50 degrees whereafter they leveled off nearing the ambient temperature.

Mineral given as the sum of NH4+ and NO3- in mg N/kg compost was higher for treatment Late_3 and Late_9 compared to Early_3 and Early_9, showing that the late addition of N rich material gave much a higher plant available N in mature compost (figure 2). High turning frequency also decreases plant available N, if N rich material was added before the thermofilic phase (treatment Early_3 vs Early_9, figure 2)

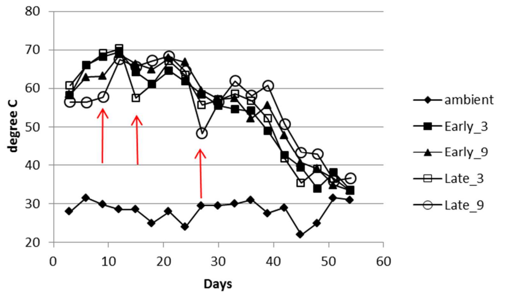

Figure 1: Temperature development (in degree C) during compostin. Aarrows indicate points of pile turning every 9 days, during the thermophilic phase. Ambient temperature is the mean daytime temperature.

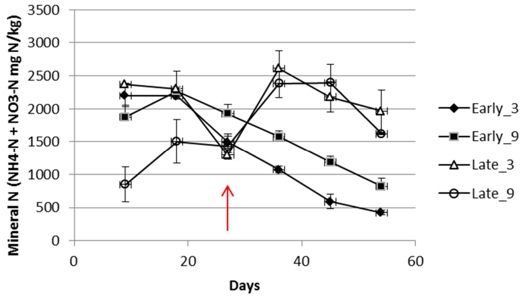

Figure 2: Mineral N in compost given as the sum of NH4+ and NO3- in mg N/kg compost. Arrows indicate time of addition of N rich material to treatment, Late_3 and Late_9. Bars indicate SEM (n=3)

The late addition of N rich material did not affect overall composting efficiency and total dry matter loss (Figure 3). Though a difference ($P<0.05$) was found between turning frequency of 3 and 9 days, where less frequent turning yielded less DM loss. Higher variations in drymatter determination was found initially, probably due to compost material still being very heterogeneous and little degraded.

The final total N loss was higher for Early_3 treatment compared to the two late addition treatments (figure 4), indicating the combination of frequent turning and high N is more prone to N losses rather than adding the N rich material after the thermophilic phase. However during the composting process high fluctuations were found in the determination of total N loss.

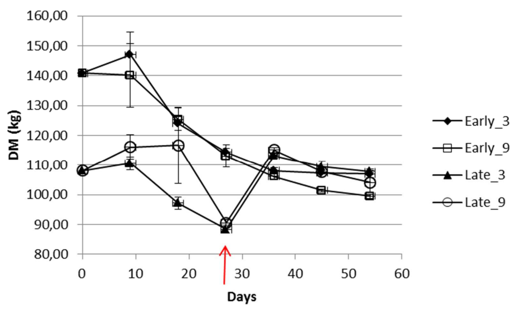

Figure 3: Total drymatter during composting in kg/pile. Arrows indicate time of addition of N rich material to treatment, Late_3 and Late_9. Bars indicate SEM (n=3)

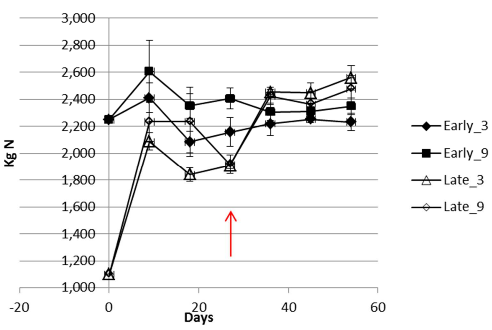

Figure 4: Total in kg/pile. Arrows indicate time of addition of N rich material to treatment, Late_3 and Late_9. Bars indicate SEM (n=3)

Experiment II

Yet to be disclosed

Conclusion and perspectives

For experiment I it can be concluded that:

1) Late addition of N rich material gives higher plant available N in mature compost.
2) High turning frequency decreases plant available N, if N rich material is added before the thermofilic phase
3) Late addition of N rich material does not affect overall composting efficiency and mass loss
4) Total N losses were highest when frequent turning is combined with early addition of high N material.

For experiment II we wish to test if microbial inoculations to organic household compost can:
1) increase the bioavailability of N and P by more efficient compost turnover and
2) reduce potential losses as more nutrient elements will be incorporated in the microbial mass, rather than occur in mineral forms.

The hypothesis' are:
1) That N and P bound in microbial biomass is of more uniform nature and will mineralize easier than when bound in non-living organic material.
2) The microbial inoculation has the potential of accelerating the degradation of complex bound carbon and thus reducing bulk faster.
3) Monitoring the dynamics of the inoculated microbial populations, their survival and colonisation is important even if no statistical effects are found because it is the first step in understanding under which conditions inoculums may be effective.

In order to fully conclude on the potential of microbial inoculations a range of different compost substrates should be evaluated. Further the enhanced composts must to be tested as an organic fertilizer for crop growth where the secondary turnover of microbial biomass and nutrient release can be evaluated.

References

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