

Compost-N recovery: ^{15}N natural abundance quantitative approach

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Abstract

The remarkable influence of organic inputs, such as manure and compost, on $\delta^{15}\text{N}$ values of growing plants suggests the possible use of ^{15}N natural abundance as a tracer of N. Thus, using ^{15}N natural abundance might be possible to estimate compost-N recovery as an alternative method to the use of ^{15}N -enriched materials. The objective of this study was to verify the feasibility of using $\delta^{15}\text{N}$ value to estimate compost-N recovery by plants. Head lettuce, carrots and broccoli were cultivated (randomized blocks) in sequence under increasing levels (0 to 2.5 kg/m², dry matter) of compost application. Pearson correlations were significant and positive between plants $\delta^{15}\text{N}$ and yield (except lettuce, no yield response). A new equation for estimating compost-N recovery by plants was proposed using differences in $\delta^{15}\text{N}$ -plant with and without compost application. The compost-N recoveries were 2-8 % for lettuce, 4-9 % for carrots, and 9-18 % for broccoli. Unrealistic estimates were disregarded and assigned primarily to non-representative sampling because of intra-plant $\delta^{15}\text{N}$ variations. This study showed the theoretical and experimental basis of using $\delta^{15}\text{N}$ values to estimate compost-N recovery by test plants.

Key Words

nitrogen, $\delta^{15}\text{N}$, compost, organic fertilizers, vegetables, plant nutrition

Introduction

Composts of organic wastes are important sources of nutrients, mainly nitrogen (N), for organic vegetable farming around the World. Similar to animal excreta, composts are naturally 'enriched' having ^{15}N natural abundance values ($\delta^{15}\text{N}$) generally more positive than soils (Chalk 2014). The remarkable influence of organic inputs on $\delta^{15}\text{N}$ values of growing plants suggests the possible use of ^{15}N natural abundance of composts as a tracer of N (Chalk 2013). $\delta^{15}\text{N}$ values of plants and soil have been suggested as an indicator for compost-N surplus based on the similarity of the $\delta^{15}\text{N}$ values of available nitrate and plant shoots (Yun and Ro 2009). In addition, the $\delta^{15}\text{N}$ values of lettuce were a tool to identify the N fertilizer regime (organic or synthetic N fertilizer) and the relative contribution of different organic inputs to the N nutrition (Inácio 2015). Despite of the ^{15}N isotopic fractionation processes in soil, quantitative estimates of N recovery using ^{15}N natural abundance might be possible alternatively to the use of ^{15}N -enriched materials, the latter is a time- and labor-consuming technique. This study aimed to verify the feasibility of using $\delta^{15}\text{N}$ value to estimate compost-N recovery by plants.

Methods

Experiment

Head lettuce, carrots and broccoli were cultivated in sequence under increasing levels of compost application (0, 0.5, 1.0, 1.5, 2.0, and 2.5 kg/m², dry weight) equivalent to 0, 7, 14, 21, 28, and 35 g N/m² (base dressing). The experimental design was randomized blocks with 24 rectangular plots of 2 m² (4 blocks × 6 levels). Vegetables were cultivated in a greenhouse with drip irrigation located in Teresópolis, Rio de Janeiro, Brazil (900 m altitude, humid subtropical climate - Cwa). Compost was made from horse-bedding manure and lettuce residues showing $\delta^{15}\text{N} = 15.5 \text{ ‰}$; C:N = 12.8, total N = 14 g/kg, bulk density = 370 kg/m³, and moisture = 50 % (w/w). Soil (0-20 cm) showed $\delta^{15}\text{N} = 12.3 \text{ ‰}$, total N = 0.9 g/kg, total C = 7.3 g/kg¹, pH = 6.5, CEC = 9.3 cmol_c/dm³, Base Saturation = 8.0 cmol_c/dm³, and sandy clay loam texture. Lettuce (leaves), carrots (shoot and root) and broccoli (leaves) samples were collected 61, 66 and 92 days after planting, respectively.

Elemental and Isotopic Analyses

Plant samples, compost and soil samples were dried at 60 °C for 72 h with forced-draft air circulation and then homogenized and ball-milled to a fine powder. Samples were weighed into tin capsules to give 40 µg N ($\pm 5 \text{ ‰}$) for isotope ratio analysis ($\delta^{15}\text{N}$), using a mass spectrometer (Delta Plus, Thermo Finnigan) coupled to

an elemental analyzer (ECS 4010, Costech Instruments). Working in-house standards (finely ground wheat seed, $\delta^{15}\text{N} = +4.5 \text{ ‰}$, and soil, $\delta^{15}\text{N} = +11.6 \text{ ‰}$) were calibrated (single point) against international reference materials IAEA-600 caffeine ($\delta^{15}\text{N} = +1.0 \text{ ‰}$). When plant material was being analyzed, the mass spectrometer was calibrated for $\delta^{15}\text{N}$ using the finely ground wheat standard, and when soil was being analyzed the in-house soil sample was used. Precision for δ -value was $\pm 0.2 \text{ ‰}$.

Data Analysis

$\delta^{15}\text{N}$ data are presented as means \pm standard deviation. Prior one-way analyses of variance, data were tested for normal distribution and equality of variances and tests of means were applied ($\alpha = 0.05$) using Minitab 17 software. Pearson correlation and regression analysis were performed using Origin 6.0 software.

Results

Yield response

Yield response to increasing levels of compost fits to quadratic function for both carrots ($R^2 = 0.99$, $P < 0.0001$) and broccoli ($R^2 = 0.76$, $P = 0.053$). There was no yield response for lettuce. The coefficient of variation within each level of compost was 13 and 18 % for carrots (shoot and root), and 27 % for broccoli. Plant N concentration was found in a normal range for all vegetables, implying no N deficiency. The $\delta^{15}\text{N}$ values increased with the increasing levels of compost for carrots (+11.7 to +13.4 ‰, shoot; +11.9 to +13.1 ‰, root); and (+11.9 to +13.1 ‰), and lettuce (+12.4 to +14.3 ‰), following a linear response plateau curve.

$\delta^{15}\text{N}$ values

Plant $\delta^{15}\text{N}$ values from plots without compost (lettuce, $+12.1 \pm 0.2 \text{ ‰}$; carrot-shoot, $+11.7 \pm 0.4 \text{ ‰}$; carrot-root, $+11.8 \pm 0.2 \text{ ‰}$; broccoli, $+11.9 \pm 0.2 \text{ ‰}$) were not statistically different from soil ($+12.3 \pm 0.4 \text{ ‰}$). In that case, $\delta^{15}\text{N}$ -plant reflected the $\delta^{15}\text{N}$ of bulk soil, and soil-plant isotopic fractionation effect could be neglected. Therefore, we assume that $\delta^{15}\text{N}$ -plant higher than $\delta^{15}\text{N}$ -soil reflect the plant uptake of compost-N in some proportion. Additionally, Pearson correlations were significant and positive between plant $\delta^{15}\text{N}$ and yield for carrot-roots ($r = 0.88$, $P = 0.02$) (Figure 1) and), but the correlation was not significant ($p = 0.05$) for carrot-shoots ($r = 0.76$, $P = 0.08$), broccoli ($r = 0.62$, $P = 0.19$) and for lettuce ($r = -0.43$, $P = 0.40$). As $\delta^{15}\text{N}$ -plant value is the mean of N uptake from the two different sources (compost and soil), more close to $\delta^{15}\text{N}$ -compost the higher was the proportion compost-N to soil-N uptaken by plants. Thus, the difference between $\delta^{15}\text{N}$ values of soil and compost was used as a scale of proportional contribution of two N sources to plants.

Compost-N recovery

Considering above results and assumptions, the compost-N recovery by plants (%NRec) was calculated using the following new equation:

$$\%N\text{Rec} = [(\delta_{\text{plant}+} - \delta_{\text{plant}-}) \div (\delta_{\text{compost}} - \delta_{\text{soil}})] \times [N_{\text{harvested}} \div N_{\text{applied}}]$$

where;

$\delta_{\text{plant}+}$ is the $\delta^{15}\text{N}$ -plant values with compost;

$\delta_{\text{plant}-}$ is the $\delta^{15}\text{N}$ -plant values without compost;

δ_{compost} is the $\delta^{15}\text{N}$ of compost;

δ_{soil} is the $\delta^{15}\text{N}$ of soil,

$N_{\text{harvested}}$ is the total N harvested in test plant dry mass, and

N_{applied} is the total compost-N applied to soil.

The compost-N recoveries were 2-8 % for lettuce, 4-9 % for carrots, and 9-18 % for broccoli (Table 1) Unrealistic estimates (e.g. $> 100 \text{ ‰}$ or negative estimates) were disregarded and assigned primarily to non-representative sampling because of intra-plant $\delta^{15}\text{N}$ variations. Comparatively, estimates of N recovery using ^{15}N -labeled compost have been reported in the range from 3.8 to 26.8 % (vegetables and grains) (Chalk 2013). Results confirm compost as a “weak” source of N for vegetables although the yield response might also be related to other factors (e.g. water retention).

Table 1. Compost-N recovery (%Rec) under increasing levels of compost application.

Plant ^a	Level of compost (kg/m ²) ^b					mean
	0.5	1	1.5	2	2.5	
Lettuce	-2%	8	2	4	3	3.4 ^d
Carrot ^c	4	9	8	4	4	5.8
Broccoli	108	80	9	12	18	13.0 ^e

^a Cultivated in sequence, single base compost application. ^b Dry base. ^c Roots and leaves. ^d Negative value was discarded. ^e Unrealistic values were discarded.

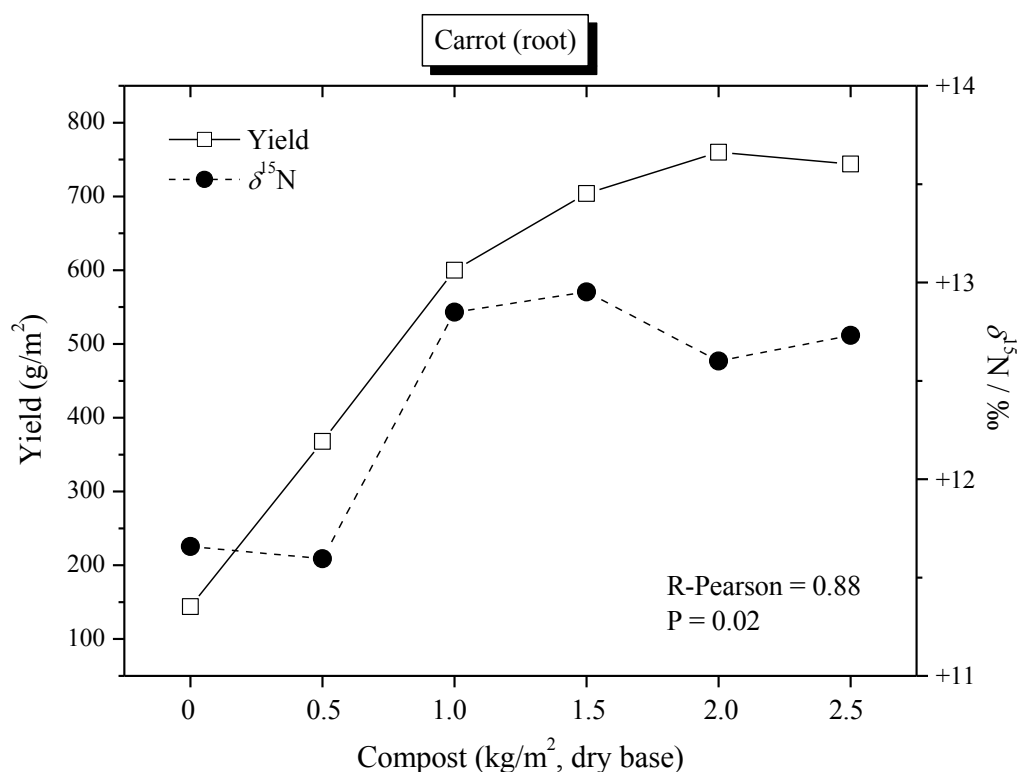


Figure 1. Correlation between yield response and $\delta^{15}\text{N}$ values of carrot under increasing levels of compost application (base dressing). Compost $\delta^{15}\text{N} = 15.5 \pm 0.2 \text{ ‰}$ and soil $\delta^{15}\text{N} = 12.4 \pm 0.4 \text{ ‰}$.

Conclusion

The $\delta^{15}\text{N}$ values of vegetables were influenced by compost application to soil, reflecting the compost-N recovery by plants. Plant $\delta^{15}\text{N}$ values follow a linear response plateau curve when there was yield response to the increasing doses of compost. Yield correlated positively with $\delta^{15}\text{N}$ -plant values ($p = 0.05$) except for lettuce (no yield response). A new equation for estimate compost-N recovery by plants is proposed using differences in $\delta^{15}\text{N}$ -plant with/without compost application. Compost-N recovery estimated by ^{15}N natural abundance fell within the range of estimates using labeled ^{15}N -compost reported in the literature.

Nevertheless, unrealistic estimates were also found. Factors such as the narrow difference between $\delta^{15}\text{N}$ of soil and compost, intra-plant isotopic fractionation / variation, and lack of data of soil and compost inorganic N δ -values variation were sources of 'low' precision and variation of $\delta^{15}\text{N}$ -plant values, resulting in uncertainty of estimates. This study shows the theoretical and experimental basis of using $\delta^{15}\text{N}$ values to estimate compost-N recovery by plants. Nevertheless, the methodology needs to be validated by comparing ^{15}N natural abundance with ^{15}N enrichment techniques (^{15}N -labeled compost). Therefore, further research is needed to confirm this promising methodology for studying N recovery from compost and manures.

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