

Effect of Particle Size and Quality of Pruning Wood Residues of Asian Pear (*Pyrus pyrifolia* and *Pyrus communis*) On C-And N-Mineralisation in Soils of Contrasting Textures¹

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Efecto del tamaño de partícula y calidad de la madera de residuos de poda de peras asiáticas sobre la mineralización de C y N en suelos con distinta textura

Key words: Residue particle size, pear pruning residues, C and N mineralisation rates.

ABSTRACT

A laboratory incubation study ($22\text{ °C} \pm 2\text{ °C}$) with pruning residues of Asian pear (*P. pyrifolia*, cv. Hosui) was carried out to determine the effects of residue particle size (< 0.5 mm, 0.5-2 mm and 2-4 mm), residue quality (defined as C-to-N ratio, and total fibre content of each size class) and soil texture on C- and N-mineralisation in two Chilean soils. Particle size had a significant impact on C-mineralisation; however, no differences were observed for N-mineralisation. After 10 days of incubation, particles < 0.5 mm evolved more C-CO₂ than medium (0.5-2 mm) and coarse particles. Thereafter, no significant ($P < 0.05$) differences were observed for the smaller particles, while coarse sizes showed low C-CO₂ evolution during the all incubation period, except at the last sampling where C-CO₂ tended to be similar than < 0.5 and 2-4 mm particles. The higher C-CO₂ evolved from the smallest particles coincided with their low C-to-N ratio and low fibre content. There was no effect of soil texture on C and N-mineralisation. These results were explained on the basis of residue quality rather than soil type.

Palabras claves: Tamaño de particular de los residuos, residuos de poda de perales, tasas de mineralización de C y N

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RESUMEN

Un estudio de incubación en laboratorio ($22\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$) con residuos de poda de pera asiática (*P. pyrifolia*, cv. Hosui) fue conducido para determinar el efecto del tamaño de partículas (<0,5 mm, 0,5-2 mm and 2-4 mm), calidad de la madera (definida por su relación C:N y contenido de fibra total en cada tamaño) y textura del suelo sobre la mineralización de C y N en dos suelos chilenos. El tamaño de partícula tuvo un impacto significativo sobre la mineralización de C; sin embargo, no hubo diferencias para la mineralización de N. Después de 10 días de incubación, las partículas < 0.5 mm liberaron más C- CO₂ que las de tamaño mediano (0,5-2 mm) y grueso. Después, no hubo diferencias significativas ($P < 0,05$) para las partículas pequeñas, mientras que las de tamaño grueso presentaron baja liberación de C-CO₂ durante todo el período de incubación, excepto en el último muestreo donde el C-CO₂ tendió a ser similar que las partículas <0,5 y 2-4 mm. La mayor liberación de C-CO₂ desde las partículas pequeñas coincidió con su baja relación C: N y su bajo contenido de fibra. No hubo efecto de la textura del suelo sobre la mineralización de C y N. Estos resultados fueron explicados sobre la base de la calidad del residuo más que por el tipo de suelo.

INTRODUCTION

In Chile, pear pruning wood residues are often reincorporated into the soil, in order to ameliorate nutrient losses associated with fruit harvesting. Although prunings are usually chopped to promote decomposition, to the best of our knowledge, the impact of residue particle size on decomposition rates has not been studied quantitatively for fruit tree species. In a broader context, controversy still exists regarding the effect of particle size on decomposition. Waksman (1952) and Russell (1961) were perhaps the first to forward the idea that the higher surface/mass ratios of small particles would favour microbial action. However, Sims and Frederick (1970) demonstrated that the decomposition is greater in the coarse than in the fine particles and demonstrated that clay minerals may inhibit N-mineralisation during the first stage of decomposition; this was attributed to a higher protection by clay minerals on microbial biomass and metabolites formed during initial decomposition (Jensen, 1994). On the other hand, decomposition of crop residues may be influenced by residue quality. A number of papers have considered the importance

of residue quality on C- and N-mineralisation (Vanlauwe, 1996; Kachaka et al., 1993; Tian et al., 1992; Oglesby and Fownes, 1992; Palm and Sánchez, 1991). Decomposition is inhibited in low quality residues, because of their high lignin or polyphenols content or high C-to-N ratio. A caveat is appropriate at this point, since Vanlauwe (1996) demonstrated that the effect of residue particle size on the efficiency of chemical extraction in fibre analysis may lead to spurious conclusions.

The objective of this paper is to study the C- and N-mineralisation of pruning residues from Asian pear cultivars Hosui (*Pyrus pyrifolia* and *Pyrus Communis*) as influenced by their particle sizes and quality in two soils of contrasting textures.

MATERIALS AND METHODS

Incubation experiments

Wood residues were collected two months after pruning. All materials were washed with tap water, dried at 70 °C for five days, milled (knife mill) and hand sieved to obtain three particle size classes: < 0.5, 0.5-2 and 2-4 mm. Residues were analyzed for total fibre content by Neutral Detergent Fibre (NDF) (Van Soest and Wine, 1967), Acid Detergent Fibre (ADF) (Van Soest and Wine, 1968) and lignin content using 72% H₂SO₄ (Van Soest, 1963). Organic-C was analysed by dichromate complete oxidation (Matus, 1994) and total-N by Kjeldahl method. Incubations were conducted with two soils: Wapri-loamy soil (clay = 28.5 %, C = 2.9 %, N = 0.3 %) under 5-year-old pear trees and Hualañé-sandy soil (clay = 11.9 %, C = 0.55 %, N = 0.003 %) which had long term cultivation with cereals. The effect of particles size on C- and N-mineralisation were essayed in Wapri soil and the effect of soil texture on C and N-mineralization were only examined on particles of 0.5-2 mm.

Potential C-mineralisation was assayed by mixing 50 g of soil (dry weight basis), sieved through 0.005 m mesh size, with 100 mg of wood materials and moistened to a water potential of -33 kPa. Three replicates of each sample were incubated. The soil and residue samples were placed in a 2 litre airtight glass jar containing a vial with 10 ml of 0.5 M NaOH and incubated at 22 °C (\pm 2 °C) in darkness during 3, 10, 15, 30 and 60 days. At each sampling time, trapped C-CO₂ was precipitated as carbonate with excess 0.75 M BaCl₂ and excess NaOH was titrated with 0.5 M HCl to reach pH 8.3 (Dalal, 1979). At each sampling time, a new vial containing NaOH was placed into the glass jar. Although the decomposition rate is normally described by a first order kinetic, the rate of carbon mineralisation were calculated as the difference of C-CO₂ evolved between two sampling times, divided by the length of the

incubation period. Potential N-mineralisation was essayed following the same procedure as for the C-mineralisation, but 100 g of soil were mixed with 200 mg of wood residues. Incubation was carried out in 0.3 L flasks provided with a perforated lit to allow gas exchange. The moisture content was adjusted weekly with demineralised water. Mineral-N (N-NH₄⁺ and N-NO₃⁻) was extracted after 10, 30 and 90 days of incubation with 2 M KCl solution at soil:solution ratio 1:10. Mineral-N was measured by Kjeldahl method with MgO and Devarda's alloy. As for C-mineralisation, the N-mineralisation rate was calculated as the difference of N-mineralised between two sampling dates, divided by the time elapsed.

Statistical design and analysis

A completely randomized block design was used. Statistical effects of particle size, cultivars and soils type was computed in JMP (SAS Institute, Cary, NC, U.S.A.). Analysis of variance (ANOVA; Statgraphic, 5), and Student's t-test were applied to analyse the differences of means amongst treatments. The probability at which significant differences were compared was set at 5% level.

RESULTS AND DISCUSSION

All residue particle size classes presented statistically similar C content, ranging from 42 % to 44 % (Table 1). Nitrogen varied between 0.66 % and 1.08 % with highest values for the < 0.5 mm particles; therefore, this fraction presented the lowest C-to-N ratio. Total fibre content, determined by NDF and ADF, was always lower for < 0.5 mm particles; however, < 0.5 mm and 0.5-2 mm fractions showed the highest lignin content.

Table 1

Characteristics of various particle size classes from Asian pear pruning wood residues (Hosui cultivar)

Cuadro 1. Característica del residuo de poda de peras asiáticas (cultivar Hosui)

Chemical composition	Particle size classes (mm)		
	< 0.5	0.5-2	2-4
C (%)	43.1 a	44.0 a	42.2 a
N (%)	1.1 a	0.7 b	0.7 b
C-to-N ratio	39.8 b	63.5 a	63.4 a
NDF (%)	59.0 b	77.0 a	76.5 a
ADF (%)	43.7 c	51.4 a	47.2 b
Lignin (%)	14.0 a	12.1 ab	11.3 b

Values followed by different letter within a row, are significantly different at 5 % level.

NDF = Neutral detergent fiber (Van Soest and Wine, 1967).

ADF = Acid detergent fiber (Van Soest and Wine, 1968)

C-CO₂ evolution from all residues and soil doubled the amount produced by the control (Fig. 1). After 3 days of incubation, more C-CO₂ had evolved from the smallest fraction than medium size (0.5-2 mm) and coarse size (2-4 mm) fraction. Medium size particles produced as much C-CO₂ as the coarse fractions during the first 10 days of incubation. Thereafter, C-CO₂ evolution from both < 0.5 and 0.5-2 mm particles was higher than that from the 2-4 mm particles, except at the last sampling time where the C-CO₂ from < 0.5 mm particles was similar than that from 2-4 mm.

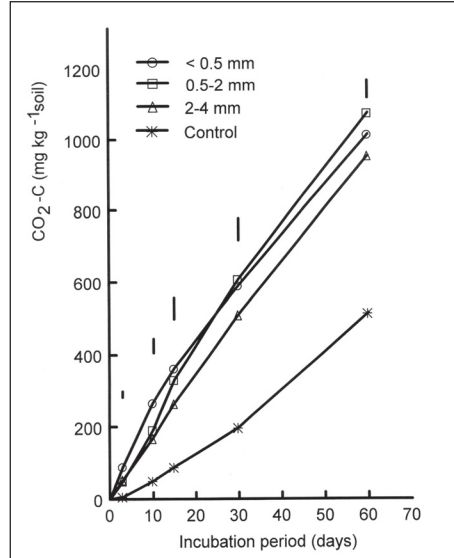


Figure 1. C-CO₂ evolution from Asian pear pruning residues (*Pyrus pyrifolia*, cv. Hosui) of various particle size classes. Error bars indicate LSD (5 %) for comparing treatments with residue additions at the same level of time.

Figura 1 C-CO₂ mineralización de residuos de poda de peras asiáticas (*Pyrus pyrifolia*, cv. Hosui) de varios clases de tamaños de partículas. La barra indica la diferencia mínima significativa (LSD, 5%) para comparar tratamientos con la adición de residuos en el mismo tiempo de muestreo.

No significant differences were observed for N-mineralisation (Fig. 2). After 10 days of incubation, particles between 0.5-2 mm and 2-4 mm tended to mineralise more, while fine particles (< 0.5 mm) tended to show net immobilisation. By day 30, all residues exhibited net immobilisation, but at the last sampling, most particles tended to mineralise more than the control.

The C-CO₂ evolution of particles 0.5-2 mm was higher in Wapri than in Hualañé soil (Fig. 3). Wapri soil had a much higher C content (2.9 %) than Hualañé soil (0.55 %). There were no significant differences for C-mineralization rates between soils (Table 2). Very similar results were observed for N-mineralisation (Fig. 4). During the first 10 days of incubation, Hualañé soils showed a high significant ($P < 0.05$) net N-immobilisation, while Wapri soils showed a net N-mineralisation. Between 10 and 30 days of incubation, both soils showed a net immobilisation but Wapri soils had the highest rate of N-immobilisation. Thereafter, both soils showed a net N-mineralisation and no significant differences were observed.

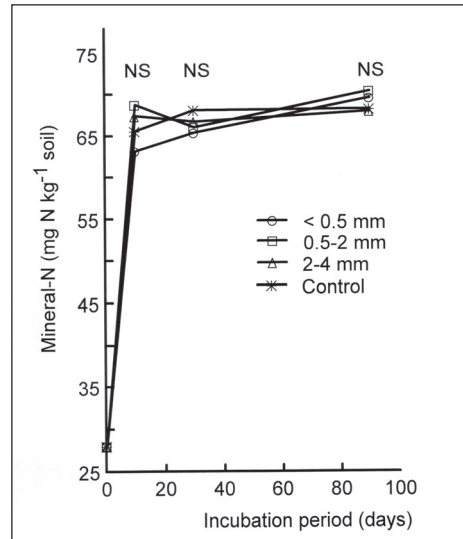


Figure 2. Mineral-N release of pear pruning residues (*Pyrus pyrifolia*) of various particles size classes. NS means 'not significant' (5 %) for comparing treatments with residue additions at the same level of time.

Figura 2. mineralización de residuos de poda de peras asiaticas (*Pyrus pyrifolia*, cv. Hosui) de varios clases de tamaños de partículas. NS significa que no hubo 'diferencias' al nivel (5 %) para comprar tratamientos con la adición de residuos en el mismo tiempo de muestreo.

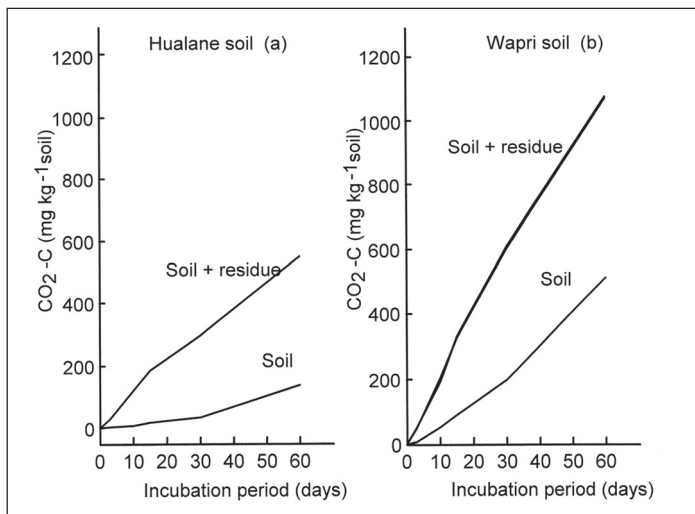


Figure 3. C-CO₂ evolution from pear pruning residues of 0.5-2 mm in (a) Hualañé sandy soil and (b) Wapri loamy soil.

Figura 3. C-CO mineralización de residuos de poda de 0,5-2 mm en: (a) suelo Hualañé, franco arenoso y (b) suelo Wapri, franco.

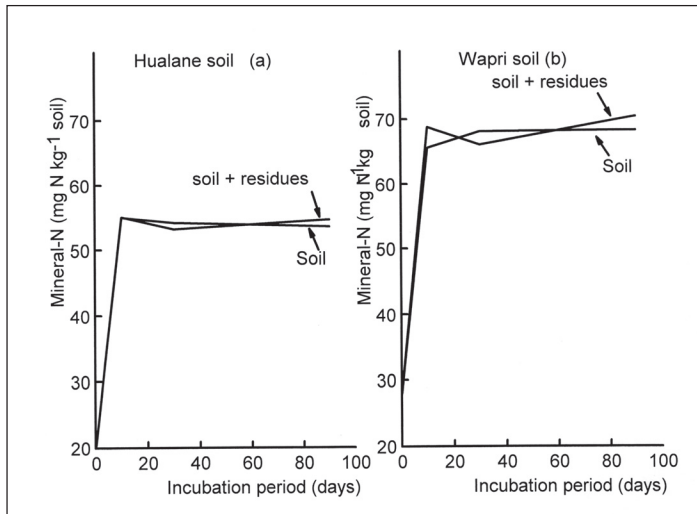


Figure 4. Mineral-N release from pear pruning residues of 0.5-2 mm in (a) Hualañé sandy soil and (b) Wapri loamy soil.

Figura 4. Mienralización de N de residuos de poda de 0,5-2 mm en: (a) suelo Hualañé, franco arenoso y (b) suelo Wapri, franco.

These results show that the some chemical characteristics of the wood residue such as C-to-N ratio and total fibre content (ADF and NDF) were lower in the smallest particles (<0.5 mm). This is consistent with the report from Vanlauwe (1996), who worked with agroforestry leaves (*L. leucocephala*, *S. siamea*, *G. sepium*, *F. macrophylla* and *D. barteri*) and showed that residue particle size had a substantial impact on its quality characteristics; thus, smaller particles resulted in higher cold and hot water-soluble fractions, lower fibre contents and higher polyphenol contents (Table 1). They also demonstrated the occurrence of a methodological artifact since smaller particles led to a more exhaustive extraction of plant components because of their larger contact surface. We intended to verify Vanlauwe's conclusion by further grinding particles of 2-4 mm and 0.5-2 mm to < 1 mm particles in order to compare their chemical characteristics. Unfortunately, fibre analysis were performed for particles 0.5-2 mm only. Although the distribution of < 1 mm particles in 0.5-2 mm were not measured

before grindings, total fibre contents of the ground fractions were very similar to 0.5-2 mm particles (data not shown). This may emphasise the need study in detail the effect of the type (ball or knife mill) and duration of milling on chemical characteristics of wood residues after physical fractionation (Vanlauwe, 1996) and how it affects the intrinsic wood hardness within the plants.

As in most of studies, in this report, the differences between C-CO₂ evolution and mineral N released amongst residue particles size were smaller. We found that the amount of C-CO₂ and mineral-N released after 60 and 90 days of incubation were comparable with the figures found by Vanlauwe (1996) for agroforestry residues decomposing (25 °C) in a sandy soil after 28 days. But contrary to what they found, the smallest particles (< 0.5 mm) in our study, evolved more C-CO₂ than coarse particles (2-4 mm) during the initial stage of decomposition. This also coincided with the lowest C-to-N ratio and poorest fibre content of these fractions. However, our results were consistent with

those of others (Waksman, 1952; Russell, 1961; Van Schreven, 1964) in the sense that fine residues had more C-CO₂ evolution in soil than large materials because finely divided residues have higher specific surface area than coarse particles. Jensen (1994), following earlier ideas from Strickler and Frederick (1959) and Sims and Frederick (1970), showed opposite results and postulated that clay minerals may exert a blocking effect on decomposition. Microbial biomass and its products formed during the initial stage of decomposition, would be better protected from further biodegradation from small particles, because of intimate mixing of residues with the soil. Soil protective effect has not been demonstrated here. Although the net of N-mineralization rates showed significant differences at the beginning of decomposition before 10 days of incubation, any effect of soil texture may have also been observed for C mineralization. After 10 days, Wapril soil (loamy soil) had a significantly higher net-immobilization than Hualañé soil (sandy soil). This coincided with the tendency to find a higher rate of C-mineralisation throughout the all incubation. This was consistent with Vanlauwe's results in which

coarse residues showed a net N-immobilization with the highest C-CO₂ evolution. However in Jensen's (1994) report, coarse materials had a net N-mineralisation with the highest C-CO₂ production. We speculate that the residue quality might have masked the protective effect of soil texture on residue decomposition of small particles, especially at the initial stage of decomposition when the protective effect occurs. The results of our study confirm the importance of standardising residue particle size and residue quality determination to relate their intrinsic chemical characteristics with their rate of C- and N-mineralisation. Research needed to be focused on these topics, especially to establish the interaction between soil texture and C- and N-mineralisation for fruit tree species, particularly when large pieces residues are left on soil.

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