RESEARCH ARTICLE

Soil-nutrient availability affected by different biomass-ash applications

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Abstract

This study, through an incubation experiment, evaluates the effect that different biomass ashes exert on the extractability of nutrients and some chemical parameters and dehydrogenase activity of a slightly acid soil. Three types of as were selected: two new ashes generated by the dry combustion of olive cake or by gasification of greenhouse vegetable wastes, and a third produced by wood combustion. The ash significantly increased the pH, electrical conductivity, and dehydrogenase activity of the soil. Dry olive-cake ash was the most effective in raising the levels of soil AB-DTPA extractable P, K, and Cu. By contrast, wood ash caused the greatest increases in soil AB-DTPA-extractable Zn. The three as he showed little effectiveness for increasing soil ABDTPA extractable Fe and Mn. Ash from dry olive cake could be used as a low-cost potassium fertilizer.

Keywords: Wood ash, dry olive cake ash, greenhouse vegetable wastes ash, soil incubation, dehydrogenase activity, AB-DTPA extractable nutrients

1. Introduction

Biomass is the most important global renewable energy resource, used in developed as well as developing countries. Biomass ashes are the final products accumulating from the thermal combustion and gasification of biomass for heat and electricity production.

Many studies have shown that wood ash applied to agricultural, forestry, and grass lands is practical for enriching soils and boosting yields (Demeyer *et al*., 2001; Knapp and Insam, 2011). Andalusia is the leader in Spain in generating power using biomass, having 18 power plants with a total capacity of 205 MW. Over 75% of the biomass comes from the wastes generated by the olive-oil industry (olive cake, among others), followed by the wood debris and plant wastes produced by the greenhouses. Today, scant information is available concerning the characteristics and potential agricultural use of new types of biomass ash.

ABDTPA extraction is a universal soil test used for assessing available macro- and micronutrients as well as some heavy metals in soils (Soltanpour and

Schwab 1977). It has been used to diagnose soil-nutrient deficiencies, to assess soils polluted with heavy metals, and to predict the crop-yield responses to nutrient addition (Molina *et al.*, 2012; Hosseinpur and Motaghian, 2015)

In this study, the effects of different types of biomass ash on the soil nutrients availability were compared. Therefore, three types were assayed; the two new types of ash indicated above and a third produced by wood combustion. In addition, the changes of some soil chemical parameters and dehydrogenase activity were also determined.

2. Materials and Methods

A slightly acid, sandy loam (Chromic cambisol) soil (S) with C/N of 7 was used in this study. Three biomass ash were used: wood ash (W) produced by at 350°C, dry olive-cake ash (O) by burning at 450°C, and greenhouse vegetable waste ash (G) by gasification at 270 °C. The total nutrient concentrations in the W, O, and G ash were, respectively: P: 1, 4.2, and 2.7 g kg^{-1}; K: 6.4, 58 and 31 g kg^{-1}; Fe: 16, 6.3, and 9.7 g kg^{-1}; Mn: 386, 172, and 379 mg kg^{-1}; Cu: 247, 181, and 88 mg kg^{-1} and Zn: 2054, 274, and 169 mg kg^{-1}. Other properties of the soil and ash are given in Table 1.

Table 1. pH, electrical conductivity (EC), total organic carbon (TOC), dehydrogenase activity (DHA) and AB-DTPA nutrients in the soil, biomass ash and in the treatments after 32 weeks of incubation

	pH	EC dS m^{-1}	TOC g kg^{-1}	DHA µg INTF g^{-1}h^{-1}	AB-DTPA P mg kg^{-1}	AB-DTPA K mg kg^{-1}	AB-DTPA Fe mg kg^{-1}	AB-DTPA Mn mg kg^{-1}	AB-DTPA Cu mg kg^{-1}	AB-DTPA Zn mg kg^{-1}
S	6.4±0.05	0.12±0.01	7.6±0.4	0.90±0.02	0.02±0.0	43±1	44±1	31±1	1.1±0.2	0.83±0.05
W	12.8±0.3	6±0.4	9.4±0.5	nd	3.8±0.2	90±9	46±3	386±20	31±1	299±22
O	10.7±0.4	132±5	9.4±0.5	nd	106±3	19000±660	0.92±0.12	172±5	73±2	69±1
G	9.9±0.3	42.1±2	93±2	nd	22±2	9000±195	76±5	379±14	18±1	66±3
					After 32 weeks of incubation*					
C	5.79±0.11a	0.40±0.03a	6.9±0.5c	0.60±0.1a	0.01±0.0a	48±1a	63±3e	11.3±1a	1.0±0.04a	0.73±0.06a
+W5	7.4±0.1b	0.49±0.06a	5.70±0.5ac	1.36±0.1b	0.07±0.01ab	44±1a	54±4d	12±2	1.35±0.39ab	2.47±0.31c
+W25	8.05±0.22cd	0.76±0.1a	5.0±0.5ab	1.25±0.1b	0.19±0.01bc	48±1a	46±2c	12.5±0.5a	2.13±0.27c	9.64±0.39e
+O5	8.34±0.05d	1.84±0.06b	5.1±0.4ab	1.54±0.1b	1.08±0.1e	1265±82c	42±1bc	13±1.1ab	1.75±0.08bc	1.75±0.11b
+O25	10.4±0.1e	12.8±0.7d	4.4±0.6a	1.63±0.3b	1.97±0.07f	7100±406c	35±5ab	14.7±0.7b	3.89±0.24d	4.15±0.05d
+G5	7.4±0.1	1.10±0.02a	6.0±0.7bc	1.42±0.1b	0.24±0.03c	69±1ab	39±1bc	11.6±0.4a	1.10±0.03a	1.12±0.16a
+G25	7.69±0.06bc	3.72±0.16c	5.6±0.5ac	1.5±0.3b	0.77±0.05d	487±14b	28±1a	12.2±0.9a	1.70±0051bc	2.22±0.02c

S: Soil; W: wood ash; O: dry olive-cake ash; G: greenhouse vegetable waste ash; C: unamended soil; +W5: soil amended with 5 Mg ha^{-1} of wood ash; +W25: soil amended with 25 Mg ha^{-1} of wood ash; +O5: soil amended with 5 Mg ha^{-1} of dry olive-cake ash; +W25: soil amended with 25 Mg ha^{-1} of dry olive-cake ash; +G5: soil amended with 5 Mg ha^{-1} of greenhouse vegetable waste; +W25: soil amended with 25 Mg ha^{-1} of greenhouse vegetable waste ash.

*After 32 weeks of incubation, means ± SD in the same column followed by same letters are not significantly different from each other ($p<0.05$).

The incubation experiment was performed in a dark growth chamber (25±1°C) for 32 weeks. Three pots were prepared, containing 100 g of the soil (< 2mm) either unamended (Control, C) or amended with 5 Mg ha^{-1} (1/150 ash/soil, v/v) or 25 Mg ha^{-1} (1/30 ash/soil, v/v) of each biomass ash (< 2 mm). During the incubation period, the soil moisture in each pot was maintained at 80% water-holding capacity. After the incubation period, soil samples of pots were divided into two parts: one part was air dried for chemical analysis while the other part was stored in a plastic vial at -20 °C until dehydrogenase activity was determined.

Soil texture, pH, electrical conductivity, total organic carbon (TOC), nitrogen, and total concentrations of nutrients in ashes after the digestion with concentrated aqua regia were determined following validated official methods (MAPA, 1986). Available P, K, Fe, Mn, Cu, and Zn were extracted from soil or ashes with 1M NH$_4$HCO$_3$-0.005M diethylenetriaminepenta acetic acid (AB-DTPA), pH 7.6 on a 1:2 w/v (Soltanpour and Schwab, 1977). In the extracts, P was measured using the ammonium vanadomolyb date method; K by flame-photometry; and Fe, Mn, Cu, and Zn with atomic-absorption spectrophotometer (GBC 932 plus). Finally, dehydrogenase activity DHA was determined according to García *et al.,* 1997).

3. Results and Discussion

Application of the biomass ash significantly raised the pH and electrical conductivity of the soil (Table 1). The liming effect of the ashes can be attributed to the high alkalinity and to Ca, Mg, and K carbonates in the ashes as well as to its fine structure (Sirikare *et al*., 2015 and authors therein). The increases in soil electrical conductivity depended on the amount of ash applied and on the soluble-salt content in each ash, this being highest in the dry olive-cake ash. The total

organic carbon content (TOC) of the soil diminished after the application of different biomass ashes. Dehydrogenase, an intracellular enzyme involved in oxidative phosphorylation, the activity of which is used to assess overall microbial activity in soils, increased significantly after the addition of ashes (Table 1). This fact would be related to the rising pH, which would stimulate soil microbial biomass and activity, and therefore the biological soil fertility in acid soils (Bougnon *et al.,* 2011).

Dry olive-cake ash was the most effective in raising the levels of soil AB-DTPA extractable P, K, and Cu (Table 1). By contrast, wood ash (W) caused the greatest increases in soil AB-DTPA-extractable Zn. The effectiveness of ashes assayed in increasing soil available P, K, Cu, and Zn depended on the dose applied and the total nutrient concentration, and was closely correlated (p <0.001) with the AB-DTPA levels of these nutrients extracted from the ash. The capacity of the ashes assayed for increasing the soil availability of these nutrients was very low for P (<3%), moderate for Cu and Zn (15-40%), and higher for K, especially when dry olive ash was applied (>50%). The phosphorus content in the ash would be occluded mostly with aluminium silicate or weakly soluble as aluminium phosphate, whereby only a small fraction increases the available soil P after ash addition (Omil *et al.,* 2011). Although a fraction of K, Cu, and Zn in the ash can form insoluble complexes, other major fractions appear in the form of oxides, hydroxides, carbonates, and bicarbonates with different degrees of dissolution (Demeyer *et al*., 2001 and authors therein), appreciably increasing the available soil K, Cu, and Zn (Huotori *et al.,* 2006). The high concentrations of Zn and Cu recorded in the wood ash (2064 and 247 mg kg^{-1}, respectively), came possibly from burning wood panels that still had paints and metal elements (Krook *et al*., 2006).

The types of ash assayed proved less effective in raising the levels of soil AB-DTPA extractable Fe and Mn (Table 1). This was presumably due, first, to the soil's very high contents in Fe and Mn extracted with AB-DTPA (Soltanpour, 1985), which may mask the effect of ash applied. In addition, despite that the ashes had high levels of total Fe and Mn, both micronutrients must form part of the crystal structure of these materials, reducing their availability after application to the soil ($< 1\%$ for Fe, $< 5\%$ for Mn). Finally, the rise in soil pH due to the ash applied tended to reduce Fe and Mn solubility, increasing the insoluble forms of these micronutrients in the soil (Barman *et al*., 2014).

Acknowledgements

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