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EFFECT OF COMPOST APPLICATION ON SOIL CHEMICAL AND BIOLOGICAL PROPERTIES UNDER POTATO CROP IN THE MANTARO VALLEY-PERU

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Abstract: The fertilization of potato (*Solanum tuberosum* L.) crop in the Andean region of Peru is strongly dependant on local sources of organic matter. A field experiment was set up to evaluate the effect of the application of four composts on some chemical properties and microbial population of an alluvial soil cultivated with potato in the farm community of Sincos (Junin-Peru). Two crop residues: wheat (*Triticum aestivum* L.) straw and common vetch (*Vicia sativa* L.) residue were composted with and without the addition of wood ash at 0.41% w/w using mixed farmyard manure. A control without organic matter application was included. Composts were applied at seeding time on plant furrows at a dose of 16.7 t ha^{-1}. The contents of total organic C, labile C, extractable P, total N, NH_4^+-N, NO_3^--N, populations of total bacteria, actinomycetes and fungi and microbial activity were evaluated in the soil at harvest time using a complete randomized blocks design. All compost applied significantly increased the contents of organic C, extractable P and total N in the soil compared to control. Labile organic C was significantly increased by all treatments. For the content of N-NO_3^-; only the compost of mixed residues + ash was similar to control. All composts increased also soil basal respiration and microbial biomass carbon. Composted wheat straw + ash significantly increased soil bacterial population and produced the highest basal respiration rate, followed by compost of the mixture of residues with and without ash. Soil microbial biomass carbon was the highest after application of composted vetch residue + ash.
Key Words: Compost, Crop residues, Soil microbial population, Soil microbial biomass.

1. INTRODUCTION

Crop production in the Andean region is the support of food supply in Peru. Traditionally, agriculture in the Andes has been based on the use of local sources of organic matter and to lesser extend, on the application of chemical fertilizers. Applying organic fertilizers such as composted animal manure (compost) may help to preserve SOC in agroecosystems (Whalen et al., 2008).

Organic amendments are a good source of moderately available phosphorus for crops and also enhance root growth and thus increase the uptake efficiency of this element, reducing the risks of eutrophication of water sources for excessive application of fertilizer-P (Erich et al., 2002). La aplicación de materia orgánica junto con altos niveles de fertilización mineral y labranza han generado un notable incremento de la biomasa microbiana en el suelo del cultivo de papa (Anzalone and Lazo, 2010).

Further research is needed about adequate fertilization practices and about the effect of the use of locally available sources for potato fertilization under High Andean conditions and providing a good information base for improving the use of organic matter sources in sustainable agriculture, maintaining de la soil fertility and reducing the dependence on inorganic fertilizers. The objective of this study was evaluating the effect of application of different compost mixtures on chemical properties, C and N fractions and on microbial populations (bacteria, actinomycetes, fungi and free living diazotrophs) of an alluvial soil cultivated with potato (*Solanum tuberosum* L) cv Perricholi in the Mantaro Valley (Central Andes of Peru), soil microbial activity (respiration and microbial biomass carbon).

2. MATERIALS AND METHODS

2.1. Location and experimental conditions

Field experiment was conducted on a farm plot in the District of Sincos (11° 52’ 54” S, 75° 23’ 56” W, 3303 masl). The soil was located in a low alluvial terrace of the Mantaro River as was classified as *Typic Ustifluvents* (USDA, 2003). Soil analysis of the furrow slice (0.30 m) showed: sand, 50%; silt, 38%; clay, 12%; pH (H_2O), 7.4; organic C, 1.4%; Total N, 1600 mg kg^{-1}; available ($NaHCO_3$-extractable) P, 11.7 mg kg^{-1}; available (CH_3COONH_4-extractable) K, 193 mg kg^{-1}; cation exchange capacity (CH_3COONH_4), 9.9 cMol kg^{-1}. Average temperature during the field experiment was 12.0 °C. The averages for maximum and minimum temperatures were 19.9 °C and 4.5 °C respectively. Total accumulated precipitation was 490.8 mm.

2.2. Experimental compost preparation

Two crop residues: wheat straw and common vetch residue were composted separately with a mixture of cow and guinea pig manures (1:1 on wet weight basis). Piles were set up with a proportion of 2:1 (on wet weight basis) from manure mixture to green waste with and without the addition of wood ash at 0.41% (on total weight basis). Mixed manures and chopped green wastes were placed in alternate layers (0.15 m each) up to 0.80 m height air piles. Wood ash was broadcasted over each layer of manure. The piles were turned over and watered every 15 days. The four compost preparations were harvested three months after installation.

Potato cv. Perricholi was hand-planted on November 25th 2006, using a 0.66 m row spacing and a 0.40 m within-row spacing. Experimental plots were distributed in a completely randomized blocks design with four replicates. Each plot consisted of 5.0 m of four rows (13.3 m^2).

All prepared composts were applied at a rate of 16.7 t ha^{-1}. Application was made uniformly at the center of each row (1 kg m^{-1}) over the seed tubers at planting time. One treatment without application of compost was left as control. No inorganic fertilizers were applied to the crop and tested composts were the exclusive sources of nutrients.

At harvest time (135 days after planting), soil composite samples were taken from each experimental plot, just below the place where the tubers were harvested. Samples were conserved in sterile plastic bags at 4 °C until microbiological analysis.

2.3. Soil Nutrients Contents

For chemical analysis, soil portions were air-dried, ground and sieved through a 2 mm mesh. The content of total organic carbon was measured by sulphuric acid-potassium dichromate digestion (method of Walkey and Black), and spectrocolorimetry (Nelson and Sommers, 1996). Active (labile) organic carbon was measured by potassium permanganate digestion (Weil et al., 2003). Available phosphorus was measured by extraction with $NaHCO_3$ and spectrocolorimetry (Kuo, 1996). Total nitrogen content was analyzed by Kjeldahl method (Bremner, 1996). Soil NH_4-N and NO_3-N were extracted with 1M KCl and measured by Kjeldahl method and spectrophotometry, respectively (Yang et al., 1998).

2.4. Soil Microbial Populations

Soil portions were air-dried, ground and sieved through a 4 mm mesh. Total populations of mesophilic bacteria, actinomycetes and fungi were determined by the dilution plate method. Nutrient media used were egg albumin agar, starch-casein agar and potato-dextrose agar (Dhingra and Sinclair, 1995), for bacteria, actinomycetes and fungi, respectively. Plates were surface-strike and incubated at 28º C and were evaluated after six, three and two days for bacteria, actinomycetes and fungi, respectively. Population of free living N-fixing bacteria was determined by most probable number (MPN) method using liquid nutrient media in assay tubes (Frioni, 1999). Tubes were evaluated after 10 days of incubation at 25º C.

The basal respiration (µg CO_2 g^{-1} day^{-1}) was measured by the alkali absorption and titration method (Wagner and Wolf, 1999). Samples of 100 g of sieved soil were moistened (22% on weight basis) and incubated in hermetic glass jars. A small beaker containing NaOH 1N was placed in each jar. After 10 days, the remaining NaOH was titrated with standardized HCl 0.2 N.

Microbial biomass carbon (µg C g^{-1}) was measured by chloroform fumigation and incubation method (Delgado and España, 2000, Jenkinson and Powlson, 1976). 25 g of air-dried soil were fumigated with ethanol-free chloroform for 48 hours under a hermetic chamber. After gas exhausting, the fumigated soils were re-inoculated by adding 0.5% of fresh soil, moistened to field capacity and incubated for 10 days at 25º C in glass jars. CO_2 released was captured in NaOH and quantitatively related to initial microbial biomass considering 41% of mineralized carbon (Paul and Clark, 1996, Wagner and Wolf, 1999).

2.5. Statistical Analysis

Data from soil nutrients content, basal respiration and microbial biomass carbon were analyzed directly and those obtained from microbial populations were transformed to $\log_{10}$ of the results previous to analysis. All data were subjected to analysis of variance (ANOVA) using the General Linear Model of SAS (SAS Institute Inc., Cary, NC, version 9.1) and the effects of green waste and addition of ash were tested. The means were compared by using the honestly significant difference (HSD) test of Tukey ($p<0.05$).

3. RESULTS AND DISCUSSION

The content of nutrients in the tested compost is shown in table 1. Although no statistical comparison was performed between the sources and limited effects of green waste or ash application were expected due to low rate of green waste to manure in the preparation, some trends were nevertheless observed. The use of vetch residue resulted in higher content of C and N in the compost compared with the wheat straw. The application of ash increased pH and K content in compost prepared with both residues, but did not affect other nutrients.

3.1. Soil Nutrients

Application of compost significantly increased the content of total organic carbon in the soil but did not affect significantly the content of labile carbon (Table 2). Compost application increased soil organic carbon compared with the control regardless the green waste used and the application of wood ash.

Table 1. Nutrient content of experimental organic matter sources applied

	Wheat straw compost (WSC)		Vetch residue compost (VRC)	
	- Ash	+ Ash	- Ash	+ Ash
H_2O (g kg^{-1} wet weight)	614	609	560	616
pH (H_2O)	7.95	8.49	7.71	7.85
O.C. (g kg^{-1} dry weight)	227	230	217	284
N (g kg^{-1} dry weight)	23.1	22.6	20.9	28.5
P_2O_5 (g kg^{-1} dry weight)	14.0	12.4	12.6	16.2
K_2O (g kg^{-1} dry weight)	19.3	33.2	28.6	37.3
CaO (g kg^{-1} dry weight)	72.1	66.9	68.0	74.7
MgO (g kg^{-1} dry weight)	13.6	12.2	12.6	14.0

All organic sources were similar for labile organic carbon, but only the compost of vetch residue with ash was significantly higher than control. The proportion of labile carbon to total organic carbon ranged within 2.88% and 3.25%, which was lower than that for the unfertilized soil (3.81%). This decrease is related to the addition of heavy organic compound through the compost.

All composts applied significantly increased soil total N (Table 3). The application of compost increased significantly soil NO_3^--N content, but the compost of vetch residue did not differ from the control. Compost of wheat straw resulted in numerically higher levels of soil total and NO_3^--N in spite of the higher N content in the compost of vetch residue. The content of NH_4^+-N was not affected by treatments applied (table 3). Soil NO_3^--N increases were comparatively higher than those for total N indicating high availability of N in the composts. Levels of NH_4^+-N were for lower than those for NO_3^--N. Compost application also increased significantly the content of soil available ($NaHCO_3$-extractable) P. All composts were higher than the control (table 3). No differences were found between the green wastes applied.

Addition of wood ash in the compost preparation resulted in numerically higher levels of all nutrients evaluated with exception of NH_4^+-N. Although these levels were not significantly higher; the results indicate a beneficial effect on applying wood ash in the organic matter preparation.

3.2. Soil Microbial Populations and Activity

The analysis of variance showed significant differences between the treatments applied on total populations of bacteria, actinomycetes, fungi and free living N-fixing bacteria. All compost applied exhibited higher populations of studied microbial groups compared with the control, but only the compost of wheat straw with ash was significantly higher than control for total bacteria. The compost of wheat straw was higher than control for total actinomycetes and fungi. The compost of vetch residue with ash was also higher than control for total fungi (Table 4). All composts applied were higher than control for free living N-fixing bacteria and both composts of vetch residue (with and without ash) were higher than compost of wheat straw.

The observed increase in microbial populations can be related to the supply of carbon, nitrogen and other nutrients to the soil through the compost application (Romero-Lima et al., 2000), and also to the improved soil physical conditions, which can benefit microorganisms (Larkin et al., 2006). The addition of ash to compost increased the population of bacteria in the soil, which can be related to increased pH in the composts, and subsequently in the soil environment were they were applied. Predominance of a particular microbial group in the soil can be associated to specific nutrients supplied by organic source applied (Torres and Lizardo, 2006); although in the case of N-fixing bacteria, populations and distribution is conditioned to additional factors as soil humidity, C/N ratio, pH and root exudates (Lara et al., 2007).

All compost tested significantly increased both basal respiration and microbial biomass carbon in the soil compared with the control (Table 5). Similar increases in soil respiration has been reported after the application of crop residues (Álvarez-Solís and Anzueto-Martínez, 2004) and composted cow manure (Ros et al., 2006b). There were no differences within the compost applied for basal respiration.

For microbial biomass carbon, compost prepared with addition of ash resulted in significantly higher levels than those prepared without ash, regardless the green waste used. The relative proportion of microbial biomass carbon to total organic carbon was also increased by compost application, indicating a promotion on soil microbial activity. Increases in soil microbial biomass have been found in short-time field experiments with application of compost and poultry manure (Romero-Lima et al., 2000) and in long-term field experiments with application of composted cow manure (Ros et al., 2006a), although in short-time experiments, the microbial biomass can further decrease.

Table 2. Effect of wheat straw compost and vetch residue compost (with and without ash) on contents of total and active organic carbon in a soil cultivated with potato cv Perricholi

Treatment	Total organic carbon	Labile organic carbon	
	($g\ kg^{-1}$)	($mg\ kg^{-1}$)	(%)
WSC	20.95 a	626.47 ab	2.99
WSC + ash	21.05 a	606.09 ab	2.88
VRC	18.95 a	615.90 ab	3.25
VCR + ash	22.95 a	667.61 a	2.91
Control	14.13 b	538.42 b	3.81
C.V. (%)	8.43	8.54	---

Values are means of four replicates; treatment means within a column followed by the same letter are not significantly different by HSD Tukey ($P<0.05$)

Table 3. Effect of wheat straw compost and vetch residue compost (with and without ash) on Available-P and N fractions in a soil cultivated with potato cv Perricholi

Treatment	Available P (mg kg^{-1})	Nitrogen (mg kg^{-1})		
		Total	NH_4	NO_3
WSC	46.65 a	2525 a	4.90 a	88.11 a
WSC + ash	46.12 a	2350 a	5.87 a	101.75 a
VRC	42.20 a	2275 a	5.83 a	71.62 ab
VCR + ash	48.05 a	2650 a	5.51 a	86.79 a
Control	9.10 b	1550 b	5.52 a	36.72 b
C.V. (%)	10.19	9.81	18.38	21.71

Values are means of four replicates; treatment means within a column followed by the same letter are not significantly different by HSD Tukey (P<0.05)

Table 4. Effect of wheat straw compost and vetch residue compost (with and without ash) on total microbial populations in a soil cultivated with potato cv Perricholi

Treatment	Total mesophilic populations (ufc g^{-1})			Free living N_2-fixing bacteria (NMP g^{-1} x 10^5)
	Bacteria x 10^6	Actinomycetes x 10^6	Fungi x 10^4	
WSC	11.97 ab	18.43 a	18.48 a	7.31 b
WSC + ash	23.17 a	8.06 ab	6.81 ab	8.08 ab
VRC	7.41 ab	4.32 ab	10.96 ab	8.94 a
VCR + ash	12.82 ab	10.02 ab	12.90 a	9.24 a
Control	4.42 b	3.10 b	2.53 b	5.87 c
C.V. (%)	6.11	5.89	8.48	4.90

Values are means of four replicates; treatment means within a column followed by the same letter are not significantly different by HSD Tukey (P<0.05)

Table 5. Effect of wheat straw compost and vetch residue compost (with and without ash) on total basal respiration and microbial biomass carbon in a soil cultivated with potato cv Perricholi

Treatment	Basal respiration	Microbial biomass carbon	
	(mg CO_2 kg^{-1} day^{-1})	(mg C kg^{-1})	(%)
WSC	124.07 a	352.50 b	1.68
WSC + ash	116.85 a	457.94 a	2.17
VRC	110.14 a	350.22 b	1.84
VCR + ash	110.42 a	486.41 a	2.12
Control	62.58 b	226.10 c	1.60
C.V. (%)	14.23	19.74	---

Values are means of four replicates; treatment means within a column followed by the same letter are not significantly different by HSD Tukey (P<0.05)

4. CONCLUSION

Compost application was effective to increase the contents of organic carbon, available phosphorus and total nitrogen in the experimental soil compared with the untreated control. Compost application increased the availability of N in the soil. Incorporation of wood ash in compost and organic matter preparation showed to be a recommendable practice for sustainable agriculture in Central Andes of Peru.

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