

# AVAILABLE P ENHANCEMENT IN ANDISOLS UNDER PASTURE AND ROCK PHOSPHATE AMENDED WITH POULTRY MANURE<sup>†</sup>

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**Abstract:** Poultry manure (PM) is a great nutrients source for plant growth. PM enhances soil properties and increases the crop yield. As an important strategy to decrease the amount of inorganic phosphorus (P) fertilizers, the combined use of rock phosphate (RP) with PM has been found to be more advantageous for sustainable agriculture than their single use. The objective was to assess the effect of PM on P availability in Andisols and RP dissolution. In the first incubation an Andisol was mixed with 100, 200 and 300 mg P kg<sup>-1</sup> rate using PM and Olsen P was determined at 1, 3, 5, 7, 10 days. In the second experiment, four Andisols were incubated with 200 and 300 mg P kg<sup>-1</sup> soil during 20 days and acid phosphatase activity (APase) was measured. In last experiment, PM and rock phosphate (RP) were mixed at two different rates: 50:50 and 70:30 during 30 days and total inorganic P was determined. We found that Andisols amended with PM increased P availability and APase and the mixture of PM:RP at 70:30 showed the highest inorganic P. We therefore conclude that PM addition may improve P availability in soil as well as combining with RP.

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## 1. Introduction

Dairy and meat production in Southern Chile are based on the use of permanent pastures established on Andisols as the main source of food for cattle [1]. These soils have acidic properties and immobilize highly reactive phosphate anions through sorption and/or precipitation with cations such as Al and Fe [2–4]. As a result of this immobilization, available phosphorus (P) to plant uptake in soil solution is very low. In Southern Chile the 91% of the 1.3 million ha of pasture are naturalized, where a total of 48% is under grazing and does not receive any type of fertilizers to compensate for the nutritional losses [5]. Thus, improving pasture production by fertilization management on Andisols is a major concern that must be approached in a sustainable manner [5,6]. Lately, the combined use of low P available rock phosphate (RP) fertilizers with organic manures have resulted in increased P availability and crop yields [7–10]. Among organic manures, poultry manure (PM) is a great source of plant macro and micro nutrients and may have an important effect on the soils' physicochemical properties [7,11–13], and some biological properties, such as the activity of acid phosphatases (APase) enzyme [12,14,15]. Is an important issue to consider that PM applied to soil will improve soil properties and increase

of crop production, while it will a way to reuse waste material from broiler production. The latest represents an important strategy under the context of circular economy by adding value to this waste and thus decreasing the amount of inorganic P fertilizers application. The aim of this study was to assess the effect of PM on P availability in Andisols under pastures as well as in the dissolution of RP.

## 2. Materials and Methods

### 2.1. Characterization of Poultry manure:

2.1.1 Chemical characterization: Composted poultry manure (PM) was purchased from Pucalan (<http://www.serviciospucalan.cl/>). PM was homogenized, freeze-dried, ground to pass 2 mm, and stored at -20°C until use. Chemical analysis were performed in accordance to the methodology described by Sadzawka et al. [16]. Total P was determined in extracts by alkaline digestion with sodium hypobromite (NaBrO) in accordance to Dick and Tabatabai [17] methodology and determined through spectrophotometer at 880 nm following the method of Murphy and Riley [18]. Selected poultry manure properties are showed in table 1.

**Table 1.** Selected poultry manure properties.

	Moisture %	pH (H <sub>2</sub> O)	Total OC	Total N (g kg <sup>-1</sup> )	Total P
Poultry manure	56.1	8.77	267.8	37.1	25.0

### 2.2. Soil sampling

One soil was collected from Santa Elena farm, located at 50 km of Temuco city, in Freire (La Araucanía region, Chile). Soil belonged to Barros Arana series (BAR), classified as *Typic Hapludand* (Table 2). Soil was sieved (2mm), air dried, and stored at room temperature. In addition, four soils were collected from pastures farms belonging to Cunco (CUN), Villarrica (VILL1 and VILL2) and Los Lagos (LLA) series (Table 2).

**Table 2.** Selected soil physicochemical properties.

Soil	Soil order	Soil Family	Density (g cm <sup>-3</sup> )	pH (H <sub>2</sub> O)	Olsen P (mg kg <sup>-1</sup> )	Total OC (g kg <sup>-1</sup> )	Total N (g kg <sup>-1</sup> )
BAR	Andisol	<i>Typic Hapludand</i>	0.85	5.7	10.0	87.0	2.1
CUN	Andisol	<i>Acrudoxic Hapludand</i>	1.05	6.0	11.0	32.9	8.2
VILL1	Andisol	<i>Acrudoxic Fulvudands</i>	0.65	5.2	6.1	130.3	7.7
VILL2	Andisol	<i>Acrudoxic Fulvudands</i>	0.65	5.2	6.9	130.3	6.6
LLA	Andisol	<i>Typic Durundands</i>	0.84	6.1	2.8	82.7	5.3

### 2.3. Incubation assays:

2.3.1 We carried out three incubation experiments. First, we incubated an Andisol belonging to Barros Arana series (BAR) with poultry manure to assess its effect on available P. Briefly, 1 kg of bulk soil was moistened to field capacity in polyethylene bags. Soil was then thoroughly mixed with PM using three replicates to provide 100 (PM100), 200 (PM200) and 300 (PM300) mg P kg<sup>-1</sup> soil (2.5, 5.0 and 7.5 g PM kg<sup>-1</sup> dry soil). Additionally, unfertilized soil was used as Control. Soil was incubated under controlled conditions at 25°C. Subsamples were taken at 1, 3, 5, 7, 10 days after incorporation and soil available P was measured according to Olsen and Sommers [19] by extracting 2.5 g soil with 0.5 M sodium bicarbonate (pH 8.5) during 30 min and measured by spectrophotometry at 880 nm according to the Murphy and Riley [18] method.

2.3.2 The second incubation experiment was performed in order to test the poultry manure effect on Andisol acid phosphatase activity. The four Andisols corresponding to Cunco (CUN), Villarrica (VILL1 and VILL2) and Los Lagos (LLA) (Table 2) were sieved

(2mm), air dried, and stored at room temperature. Each soil was incubated using 1 kg of soil, in three replicates, and mixed at two PM rates of 200 (PM200) and 300 (PM300) mg P kg<sup>-1</sup> soil during 30 days at 25°C. Acid phosphatase activity (APase) was determined following *p*-nitrophenol release (*p*-NP) according to the methodology of Tabatabai and Bremer [20] modified by Rubio et al. [21].

2.3.3 In the third incubation we quantified inorganic P availability of rock phosphate mixed with poultry manure. Rock phosphate selected properties are listed in table 3. PM and RP were combined, in three replicates, at 50:50 and 70:30 ratios. Samples were moistened in polyethylene bags and incubated at 25°C during 30 days. Total inorganic P content was then measured after 0.5 M sodium bicarbonate (pH 8.5) extraction during 16 hours and determined using the Murphy and Riley [18] method.

**Table 3.** Selected properties of rock phosphate

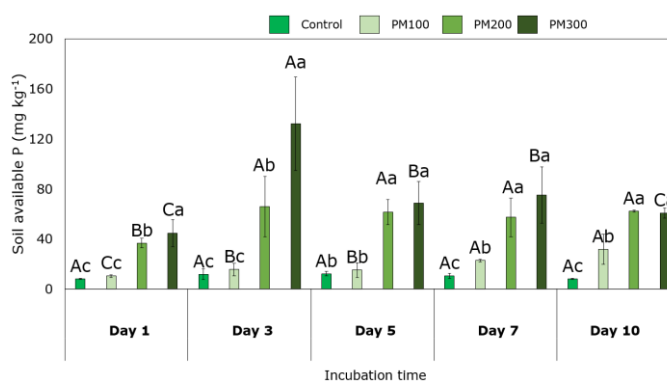
	pH H <sub>2</sub> O	Total P g kg <sup>-1</sup>	CaO	MgO %	CaCO <sub>3</sub>	Reactivity
Rock phosphate	8.72	82.8	30	1.2	10	90

2.4 Statistical analyses: Data was normality and homogeneity checked using Shapiro-Wilk and Levene test. Significant differences (p≤0.05) between treatments and sampling days were performed by two-ways ANOVA followed by *post hoc* Tuckey test using R statistical platform (R foundation for statistical computing version 3.6.3).

### 3. Results

#### 3.1. Available P in an Andisol amended with poultry manure

PM treatments increased highly the soil available P in BAR soil from the first day of incubation (Figure 1). In the BAR soil, the available P varied between 10.4–31.8 mg kg<sup>-1</sup> for PM100, 36.6–65.9 mg kg<sup>-1</sup> for PM200, and 44.5–131.9 mg kg<sup>-1</sup> for PM300. Soil available P was significantly (p≤0.05) improved by increasing PM rate at 200PM and 300PM. The highest values were showed in the BAR soil amended with PM300 at the 3<sup>rd</sup> sampling day. Then, available P decreased for the 200PM and 300PM treatments, but maintained higher values than control. For the BAR soil amended with 100PM treatment, available P didn't show any differences as compared to the control until the 5<sup>th</sup> day, while in the 7<sup>th</sup> and 10<sup>th</sup> day available P increased significantly.

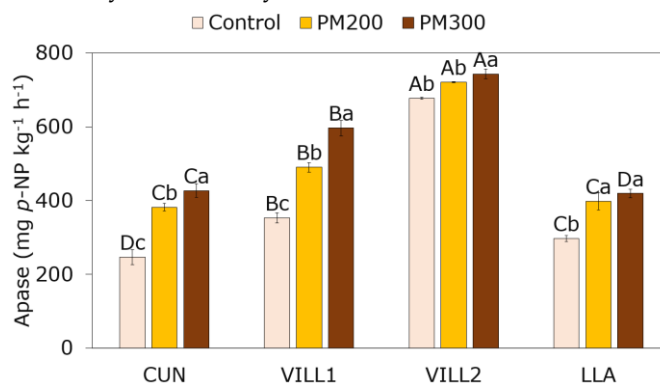


**Figure 1.** Soil available P from an unfertilized (control) Andisol (Barros Arana series: BAR) or following different poultry manure rates: 100PM (100 mg P kg<sup>-1</sup> soil), 200PM (200 mg P kg<sup>-1</sup> soil) and 300PM (300 mg P kg<sup>-1</sup> soil) at different sampling days (1, 3, 5, 7 and 10). Lowercase letters indicate significant differences (p<0.05) between the treatments in the same sampling day and capital letters indicate significant differences (p<0.05) of sampling day in the same treatment (two-way ANOVA followed by Tukey test).

#### 3.2. Acid phosphatase activity in Andisols amended with poultry manure

The incubation of soil with different rates of PM results in an important increase of acid phosphatase (APase) activity after 10 days (Figure 2). APase activity in the four Andisols ranged from 246 to 743 mg *p*-NP kg<sup>-1</sup> h<sup>-1</sup>. The 300PM treatment obtained the

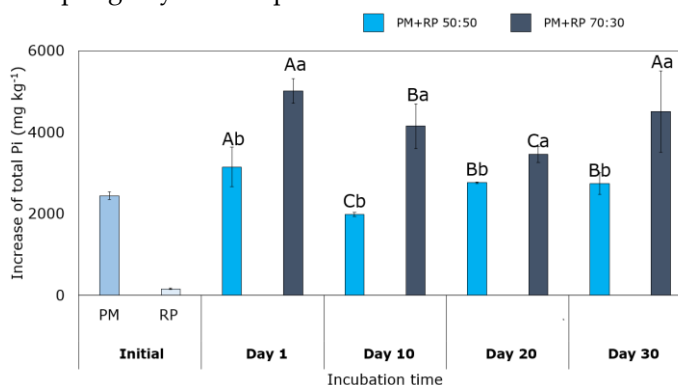
highest APase activity in CUN, VILL1 and VILL2 soils, while in the LLA soil the 200PM and 300PM treatments showed similar values. Among unfertilized soils, VILL2 showed the highest APase activity, followed by VILL1, LLA and CUN.



**Figure 2.** Acid phosphatase activity (APase) in unamended (Control) Andisols (Cunco: CUN; Villarica: VILL1 and VILL2; and Los Lagos: LLA series) or with poultry manure applied at different rates: 200PM (200 mg P kg<sup>-1</sup> soil) and 300PM (300 mg P kg<sup>-1</sup> soil) after 10 days of incubation. Lowercase letters indicate significant differences ( $p < 0.05$ ) between the treatments in the same sampling day and capital letters indicate significant differences ( $p < 0.05$ ) of sampling day in the same treatment (two-way ANOVA followed by Tukey test).

### 3.3. Total inorganic P in the mixture of poultry manure and rock phosphate

The increase of total inorganic P (Pi) was calculated as the difference between the initial values of total inorganic P in the PM and RP and values obtained by the mixtures at each sampled day (Figure 3). Initial total Pi of PM was 2440 mg kg<sup>-1</sup>, while RP showed the lowest value of 156 mg kg<sup>-1</sup>. PM and RP mixed at 50:50 ratio showed the highest total Pi increase at the 1<sup>st</sup> day followed similarly by the 20<sup>th</sup> and 30<sup>th</sup> day and finally by the 10<sup>th</sup> day. On the other hand, in the 70:30 ratio the greatest values of total Pi occurred similarly after the 1<sup>st</sup> and 30<sup>th</sup> day followed by the 10<sup>th</sup> and finally the 20<sup>th</sup> day. Total Pi released from PM:RP mixture was increased at the 30<sup>th</sup> day. PM and RP mixed at 70:30 ratio was higher in total Pi at all sampling days as compared to 50:50 ratio.



**Figure 3.** Increase of total inorganic P (Pi) of the combination of poultry manure and rock phosphate at 50:50 and 70:30 rates in different sampling days (1, 10, 20 and 30). Lowercase letters indicate significant differences ( $p < 0.05$ ) between the treatments in the same sampling day and capital letters indicate significant differences ( $p < 0.05$ ) of sampling day in the same treatment (two-way ANOVA followed by Tukey test).

## 4. Discussion

We assessed the poultry manure effect on P availability in Andisols as well as from the dissolution of rock phosphate through investigating three incubation experiments. Our results showed that the greatest values of available P were obtained by amending Andisol with the highest PM rates (200 to 300 mg P kg<sup>-1</sup>). In practical terms treatments used in this study represented 4.2, 8.5 and 12.7 Mg of PM ha<sup>-1</sup>, which is a very high P input. These results are in accordance with the study performed by Waldrip et al. [12],

who amended a Typic Haplorthod soil with 42.6 Mg of PM ha<sup>-1</sup>. In addition, Blair et al. [14] indicated that in a Typic Fragiudult a PM amendment corresponding to more than 56 kg P ha<sup>-1</sup> was sufficient to increase the soluble P pool. Moreover, they found that acid phosphatase (APase) activity was increased immediately, which was attributed to the organic matter input from PM. We found that the APase activity was also improved in the four assessed soils following PM treatments. APase activity in soils is associated to macromolecular organic P solubilization leading to its utilization by plants which mainly occurs under P deficient conditions, while lately was also reported in P-sufficient soils receiving organic manures [15]. Thus, the improvement effect of PM on soil P availability could additionally exert an enhancement of the APase activity in Andisols. Accordingly, Poblete-Grant et al. [13] studied the long-term effect of PM applied in Andisols concluding that increases on soil P availability could be associated to a remobilization from P contained in less available pools, direct P input from the amendment or by decreases of sorption P sites.

In order to decrease the amount of PM used, we suggested the combined application with rock phosphate (RP) in 50:50 and 70:30 mixture. We found that from the 1<sup>st</sup> day, the total inorganic P (Pi) was highly increased in the mixture of 70:30, which might be attributed to the organic acids released during PM decomposition and microorganisms existing in this amendment [9]. Additionally, Abbasi et al. [7] reported an 80% increase of P release from RP when applied in combination with PM (50:50) as compared to its application alone, which might be explained by higher microbial activity due to amendment with organic manures. On the contrary, Mahimairaja et al. [10] reported low levels of RP dissolution mainly attributed to small amounts of protons released during nitrification processes or/and high concentrations of calcium. However, our findings showed that rock phosphate mixed with poultry manure increased considerably the amount of total inorganic P, which might enhance its fertilizer efficiency to provide P to plants. Poblete-Grant et al. [8] reported that soil microbial biomass P was greatly increased by combination of RP with PM as compared to its single application. We therefore suggest that poultry manure could be suitable P fertilizer to increase either available P and acid phosphatase activity in Andisols, as well as inorganic P from the low P amendments such as rock phosphate.

## 5. Conclusion

Combined use of PM and RP at 70:30 mixing rate resulted in the greatest increase of available P released from RP during PM decomposition. The Andisols amended with the highest PM dose (300 mg P kg<sup>-1</sup>) showed the highest P availability and acid phosphatase activity. We therefore concluded that poultry manure addition might increase availability P in Andisols through the improved acid phosphatase activity. Long-term results will be necessary to analyze the combined effect of PM and RP in pasture growth.

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