FERTILISING VALUE OF PHOSPHORUS FROM URBAN AND AGRICULTURAL ORGANIC WASTE

M. Linères, C. Morel

INRA, UMR TCEM, Reaserch Center of Bordeaux-Aquitaine, 71 av. Edouard Bourlaux, BP81, 33883 Villenave d' Ornon, France. lineres@bordeaux.inra.fr

ABSTRACT

Organic wastes contain quantities of phosphorus (P) potentially available for the plants, which justify their use in agriculture. However, in practice, organic waste spreading does not take sufficiently into account the corresponding phosphorus supply. The aim of this contribution is to present a synthesis of several studies of the relative phosphorus availability (RPA), i.e. the plant availability of waste P expressed as that of water soluble mineral P fertiliser, of sewage sludges, municipal composts, solid and liquid manures, following the same method. This method consists to cultivate ryegrass (*Lolium perenne* L.) in greenhouse experiments during three to four months. Before mixing with soil organic wastes or the soluble mineral phosphate, P ions of the soil are labelled with radioactive ^{32}P. The determination of the total P and isotopic composition of P taken up by crop allows to differentiate P derived from the soil and P derived from the applied P source.

Among several indicators of P availability, the contribution of the applied P (= Pdff) is the most reliable. Approximately 60 (soil × wastes) systems were tested. The RPA values were generally higher than 80%, except for wastes that were stabilised by digestion and composting.

Keywords: *phosphorus, fertilising value, organic waste,* ^{32}P.

INTRODUCTION

Wide variation exists in the literature about the effectiveness of different P sources such as mineral fertilisers, urban sewage sludge, municipal composts, manures etc. A part of this variability is explained by the use of different methodologies and the use of different criteria to assess the effect of applied P on plant response: the dry matter yield, the amount of P taken up by plant or their change between fertilised and non fertilised soil. To appropriately assess the effect of applied P on plant response it is necessary to determine its effective contribution to plant nutrition because there is a possible interaction of applied P on plant P uptake which could be positive, nil or negative depending on the type of applied P (Morel and Fardeau, 1990). This paper presents a synthesis of the works developed last few years. The relevance of different indicators of bioavailability is discussed. The plant-availability of applied P was determined by its effective contribution (Pa) and by the interaction of applied P on plant P uptake, especially from plant-available soil P. Finally, the most reliable criteria was selected to compare the Pa value of the different organic products to that of a water-soluble mineral fertiliser by calculating the fertilising P value, also called relative P availability (RPA).

MATERIALS AND METHODS

Soils : Surface layers (0-25 cm) of two loamy soils were collected. Soil 1 has been heavily fertilised (P-Olsen = 52 mg kg^{-1}) and is slightly acid (pH = 6.2). Soil 2 is P deficient (P-Olsen = 6.1 mg kg^{-1}), with pH = 8.2. Soil samples were air-dried and sieved at 4 mm.

Organic wastes : Seventeen sludges were sampled from wastewater treatment plants in various locations in France. They are representative of the main kinds of treatments applied to water and sludge : biological only filtered (3), biological treated with $FeSO_4$ (1) or lime (2) or both (2), biological thereafter composted with green wastes (3), biological digested and treated with $FeSO_4$ (2) or $FeSO_4$ and lime (1) or by a thermal process (1), physicochemical with Fe salts and lime(2). Two composts containing household refuse were tested, a municipal solid waste and a biowaste containing also green wastes. Livestock residues included eight solid manures of cattle (2), poultry (1) and pig litter (5, straw or wood shavings). Moreover two solid phases (from screw press or decanter centrifuge separation) as well as corresponding sludges were sampled in treatment plants of pig slurry. Every waste was air dried and crushed to 1 mm before mixing with five replicates of soil at a rate equivalent to 50 mg P kg^{-1} soil

Pot experiments : Five pot experiments were carried out from May to July in 1998, 1999, 2001 and 2003 to analyse the origin of P taken up by plant. Complete description of pot experiment are in Morel and Fardeau (1990), Guivarch (2001) and Kvarnström et al. (2004). We present only briefly their principles and the protocol. To differentiate the role of each source in plant nutrition, the plant-available soil P was labelled with carrier-free $^{32}PO_4$ ions before adding the different P sources. A non-fertilised soil was also labelled similarly to assess the isotopic composition (IC) of P taken up from plant-available soil P alone ($IC_0=r_0/P_0$). Assuming that IC of P taken up from plant-available soil P is constant for all treatments ($r/Ps= r_0/P_0$), the determination of the ^{32}P (r) and total P (Pt = Ps + Pa) taken up from fertilised soil allow us to calculate the P taken up by plant from soil (Ps) and the P taken up from applied P (Pa) : $Ps = P_0(r/r_0)$ and $Pa = Pt - P_0(r/r_0)$. All pot experiments were conducted in a completely randomised design. Basal fertilisation prior to sowing and after each harvest was added. Aerial parts of ryegrass harvested every 3-4 weeks were weighted and analysed after calcination and subsequent solubilisation of the ashes in 10% HNO_3. ^{32}P content was measured by liquid scintillation counting and total P content by a green malachite colorimetric method.

RESULTS AND DISCUSSION

All the results (Guivarch, 2001, Morel et al., 2003) are not presented *in extenso*. Only some examples (table 1) will illustrate the search for a reliable indicator of P bioavailability. A biological sewage sludge without secondary treatment mixed with the highly fertilised soil 1, a municipal solid waste (MSW) and a cattle manure in the deficient soil 2 have been selected.

***Table 1**. Dry matter production (DMW), total P (Pt=Ps+Pa), P taken up by crop from soil (Ps) and applied P (Pa), and bioavailability indicators, effective P recovery from applied P (REC) and relative contribution of applied P to plant nutrition (Pdff).*

	DMW	Pt	Ps	Pa	REC	Pdff
	g kg^{-1}	--------- mg kg^{-1} ---------			%	%
Soil 1 with high content in Olsen-P						
Control	6.3	41.2	41.2			
KH_2PO_4	6.3	39.4	32.4	7.0	14.0	17.8
Sewage sludge	6.9	49.4	41.6	7.8	15.6	15.8
Soil 2 with low content in Olsen-P						
Control	6.2	5.51	5.51			
KH_2PO_4	12.5	27.1	11.7	15.5	30.9	57.0
MSW	7.7	8.8	4. 5	4.3	8.6	49.3
Cattle manure	12.3	18.3	11.0	7.3	14.6	39.7

Indirect effect of P application on the soil P removed by plants. The addition of soluble fertiliser (KH_2PO_4) in the soil 1 slightly but significantly reduced the Pt value, whereas the dry matter production was identical to that of the control (table 2). In this case, the reduction of the development of roots and/or the reduction of the effectiveness of mycorrhizal fungi could be an explanation to this phenomenon scarcely observed. In the same time the Ps value was also reduced. In the soil 2, both cattle manure and mineral KH_2PO_4 highly increased both Pt and Ps. However it is noted that the MSW had a depressive effect on the crop development : some factors other than P, but dependent on the waste composition and modifications of the cycles of the carbon and nitrogen induced in the soil after mixture can influence the global development of the culture (N and P microbial organisation, reduction of root growth). These selected examples highlight that the application of mineral or organic P exerts on the uptake of Ps a positive or negative effect, accurately measured by an isotopic labelling of Ps. A simple subtraction between Pt values in control and fertilised treatments can lead to erroneous values of Ps.

***Table 2**. Calculation of RPA from various indicators of bioavailability : Increase in production (Δ DMW) or total P taken up (Δ Pt), real recovery of P by crop (REC) and P derived from fertiliser in crop (Pdff). The RPA value for the soluble reference is equal to 100.*

Indicators	ÄDMW	ÄPt	REC	Pdff
Soil 1 with high content in Olsen-P				
KH_2PO_4	100	100	100	100
Sewage sludge	n.c.	-455	111	89
Soil 2 with low content in Olsen-P				
KH_2PO_4	100	100	100	100
MSW	24	15	28	86
Cattle manure	97	59	47	70

Direct effect of the P supply. Two indicators of availability built from Pa are the actual coefficient of recovery (REC = Pa/added P ×100) which takes into account only the part of added P taken up by the crop and, on the other hand, the participation of P derived from the fertiliser in the plant nutrition (Pdff = Pa/Pt ×100). In the soil 1, Pa values of sludge and KH_2PO_4 do not vary significantly. The difference between the two P sources is mostly due to the depressive effect on Ps in the KH_2PO_4 treatment, also visible on REC value. But the Pdff value is slightly higher for KH_2PO_4. In the soil 2, a small Pa is derived from MSW, only 8.6% of the P applied, but almost 50% of total P taken up by the crop.

Choice of the indicator to express RPA. In fact, indicators using DMW and Pt are not well adapted to assess RPA (table 2) for the reasons discussed above. Thus the RPA values can be aberrant (see sludge treatment) or be skewed because factors other than the bioavailability of P can influence strongly Ps values.

To a lesser extent, that is true also for REC because the Pa amount closely depends on the capacity of the crop to develop in a given context. The mode of calculation of Pdff is more appropriated to take into account both the influence of the context on the crop and the actual effectiveness of P supply by waste.

Pdff was thus retained like the most relevant indicator to calculate relative phosphorus availability values (RPA) compared to the soluble fertiliser of reference (table 3).

Sixty two different situations (soil × waste) are accounted. All the wastes appeared to be effective sources of P. The average values were generally higher than 80%, excepted some wastes very stabilised by composting or digestion. From the RPA values a better management of the P fertilisation is therefore possible.

***Table 3**. Relative phosphorus availability of urban and agricultural wastes*

Product	Treatment		RPA % (*)
Soluble mineral phosphate			100
Sewage sludge(**)	biological, and treated with :	iron salts or iron salts and lime only lime	92 (18, ±16)
	physico-chemical with iron salts or iron salts and lime		88 (6, ±5)
	digestion and treated with iron salts or iron salts and lime	thermic treatment	71 (16,± 20)
	composting		73 (5, ± 18)
Municipal compost	composting		84 (1)
Biowaste	composting		54 (1)
Bovine manure			76 (4, ±8)
Pig litter			99 (5, ± 8)
Pig slurry	solid separation phase sludge		86 (2, ±2) 97 (2, ±5)
Poultry faeces			87 (2, ±15)

(*) in column RPA% : average (the number of soil ×P source systems, ± standard deviation)
(**) data obtained by Guivarch (2001), Zhang (1991), Frossard et al. (1992, 1996).

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