Evaluation of phosphorus bioavailability according to the soil organic matter content

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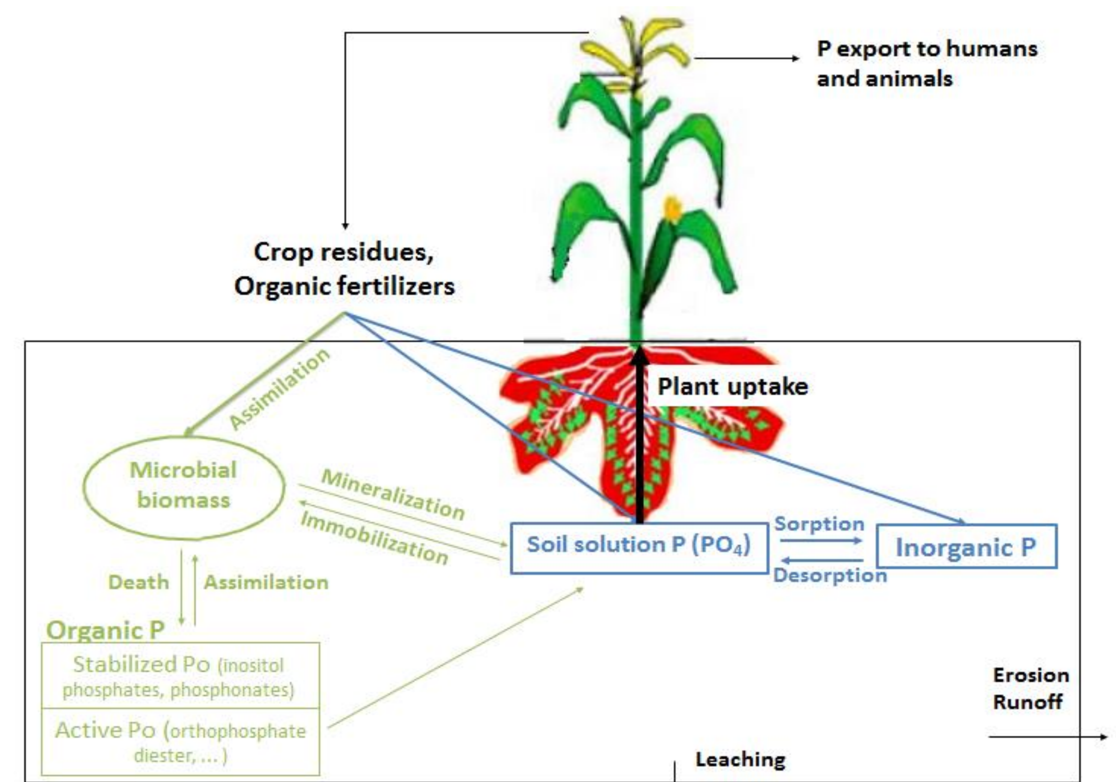
Context and objectives



Phosphorus (P) is an essential nutrient for plants. The organic matter contains significant amounts of P which can be mineralized and supply soil solution during plant development.

Hypothesis: increasing P organic pools in soils is a way to improve its gradual release for plants and alleviate risks of immobilization under mineral forms.

Objective: evaluate the P bioavailability and its uptake by plants according to differences of soil organic matter (SOM) content.

Material & Methods

Incubation (without plant)
100 g of dry soil (pre-incubated at 80% of FC during 21 days at 28°C)
Maintain at 80% of FC
3 sampling for analyses: 15, 30 & 45 days (at each harvest)

Bioavailability test (Stanford & Dement procedure)
1. Development of ryegrass in sand without addition of P
2 g of ryegrass seeds in 500 g of sand
Addition of nutrient P-free solution (Hoagland)
Maintain at 80% of FC
2. Development of ryegrass on soil
200 g of dry soil (pre-incubated at 80% of FC during 21 days at 28°C)
3 harvests: every 15 days (15, 30 & 45 days)

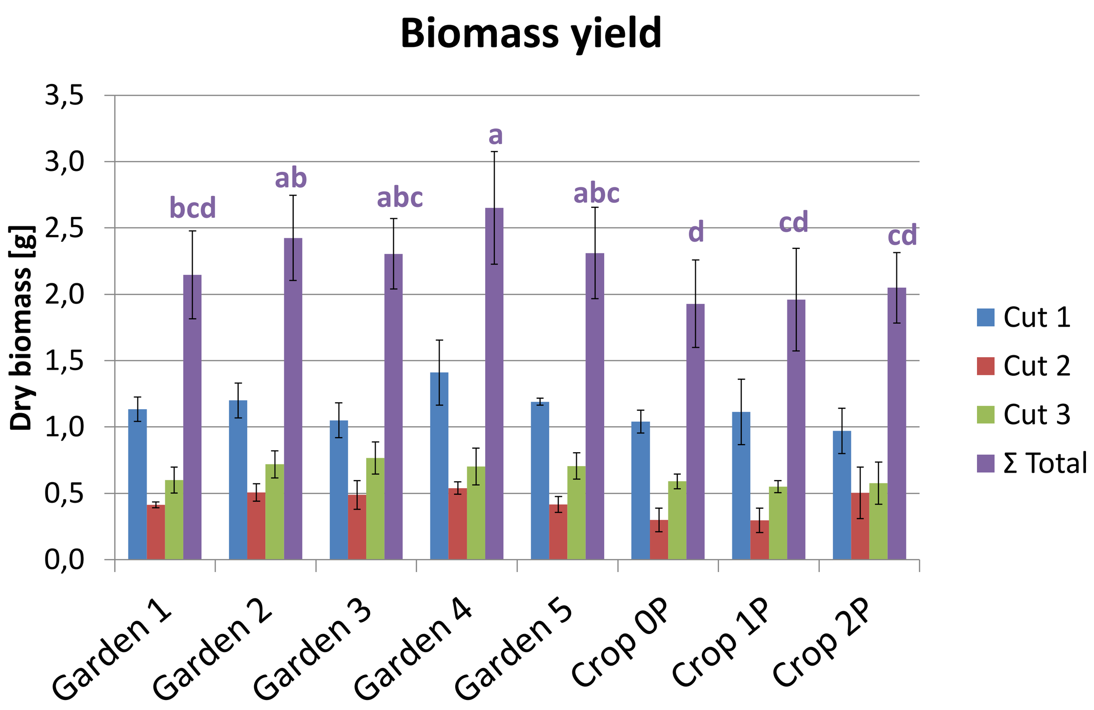
Table 1. Initial soil parameters

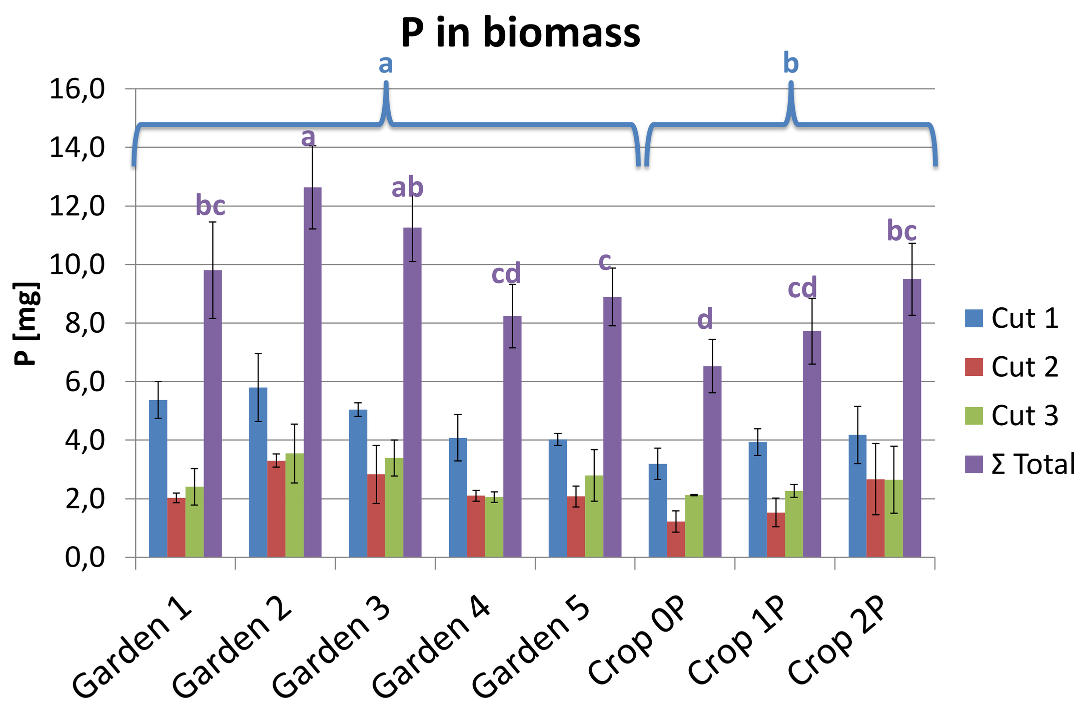
Soil	Land Use	TOC [mg/100g]	pH KCl	Ptot [mg/100g]	Porga [mg/100g]	Pav [mg/100g]
Garden 1	Veg. Garden	3.25	6.24	138.8	28.7	8.0
Garden 2	Veg. Garden	4.6	6.09	156.0	30.3	10.9
Garden 3	Veg. Garden	2.95	6.35	163.4	36.9	25.0
Garden 4	Veg. Garden	3.05	7.08	128.6	23.2	28.0
Garden 5	Veg. Garden	4.3	7.1	261.8	54.7	54.4
Crop 0P	Crop	1.05	5.61	86.8	18.2	4.8
Crop 1P	Crop	1.03	5.42	103.4	16.3	6.4
Crop 2P	Crop	1.11	5.63	110.2	14.9	9.9

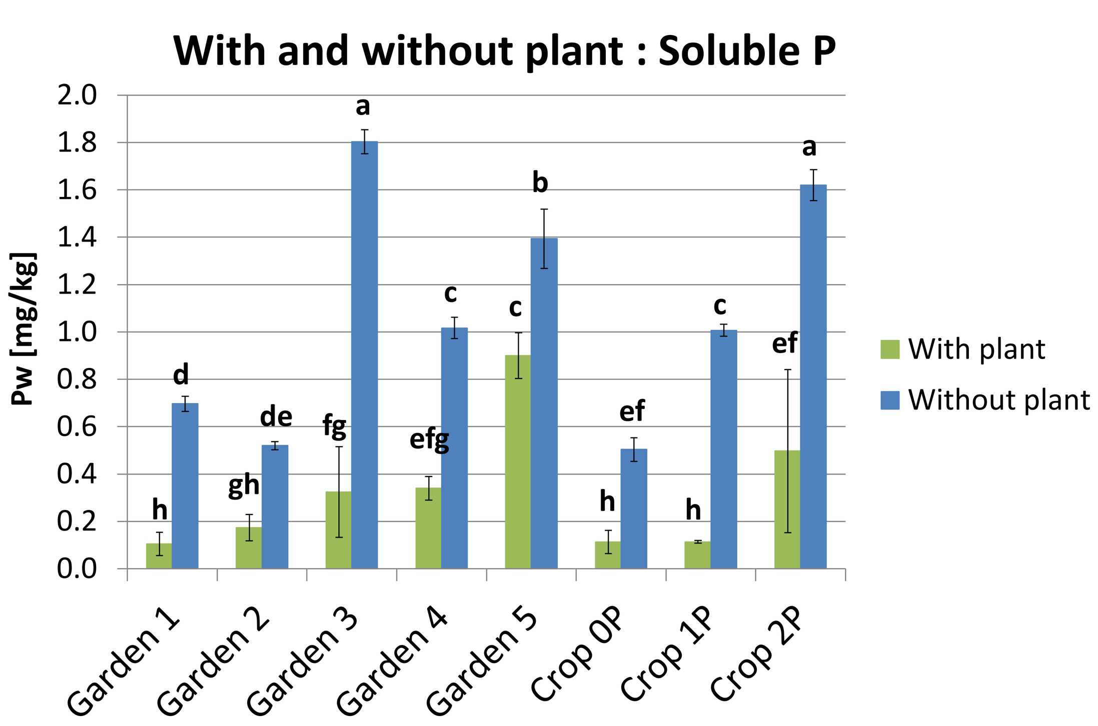
Soil analyses
Total organic carbon (TOC): Walkley & Black method
pH: KCl 1N (w:v 2:5)
Total P (Ptot): $HClO_4$ 70% conc. extraction (w:v 1:10)
Mineral P & Organic P (Porga): H_2SO_4 6N extraction (w:v 1:40)
Available P (Pav): Lakanen-Erviö method
(CH_3-COO-NH_4 + EDTA, pH 4.65, w:v 1:5)
Soluble P (Pw): water extraction (w:v 2:10)
Acid phosphatases: Tabatabai & Bremmer method (*p*-NPP hydrolysis)
Hot Water-extractable carbon (HWC): (w:v 1:10)
Nitrate (NO3): KCl 0.1N extraction (w:v 1:5)

Plant analyses (each harvest)
Yield (dry biomass – MS)
Total P (Ptot)

Results







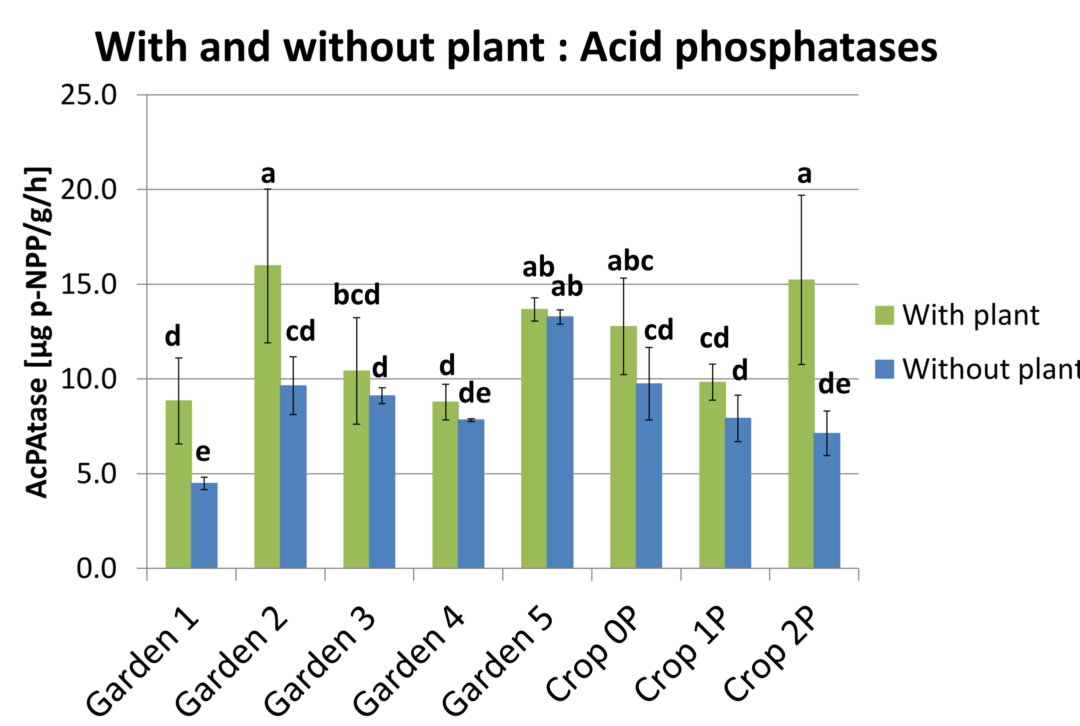


Table 2. Pearson's correlation coefficients for soils without plant (incubation)

		Initial parameters					Incubation		
		TOC	pH_KCl	Ptot	Porga	Pav	Pw	acPAtase	HWC
Initial parameters	pH_KCl	**0.732**							
	Ptot	**0.768**	**0.728**						
	Porga	**0.780**	**0.726**	**0.971**					
	Pav	*0.576*	**0.847**	**0.892**	**0.853**				
Incubation	Pw	-0.080	0.209	0.342	0.280	0.471			
	acPAtase	0.317	0.331	*0.602*	*0.595*	**0.641**	0.156		
	HWC	**0.957**	**0.681**	**0.832**	**0.842**	**0.644**	0.041	0.466	
	NO3	**0.674**	**0.656**	0.427	0.379	0.460	-0.153	0.261	*0.608*

P < 0.001 ***
*P < 0.010 ***
P < 0.050 *

Table 3. Pearson's correlation coefficients for soils with plant (bioavailability test)

		Initial parameters					Bioavailability test			
		TOC	pH_KCl	Ptot	Porga	Pav	Pw	acPAtase	NO3	MS_tot
Bioavailability test	Pw	0.328	*0.547*	**0.717**	*0.620*	**0.786**				
	acPAtase	0.132	-0.166	0.152	0.087	-0.003	0.427			
	NO3	*0.573*	**0.653**	*0.603*	*0.603*	**0.639**	0.461	0.028		
	MS_tot	*0.590*	**0.660**	0.353	0.338	0.430	0.258	-0.009	0.386	
	Ptot_MS	*0.573*	0.139	0.305	0.303	0.048	0.141	0.415	0.102	*0.529*

Discussions

Studied soils present marked differences in soil organic and acido-basic status. Gardens present higher SOM and P (organic and available fractions) than crop soils. It should be noticed that the proportion of organic P to total is higher in gardens (20-25% under garden and 15-20% under cropland).

Biomass
The biomass yield was the most important for the 1st harvest and the least for the 2nd one.
Significant differences were observed between soils. Two groups can be identified : the first group includes gardens 2 to 5 and the second one consists of crops soils; garden 1 is at intermediate level between the two groups.
Thus, globally, difference were detected between land uses with gardens presenting higher biomass of ryegrass. No significant variability was observed between crop soils.

P content of plants
As for biomass, the highest P content (in mg) was measured for the 1st harvest.
Vegetable garden and crop soils are significantly different. Among gardens, garden 2 presents the highest P content while gardens 4 and 5 present the lowest → No direct relation with biomass was observed. However, the lower P amounts in plants for garden 5 despite the large reserves in soil can be linked with higher pH.
Within crop soils, a clear effect of fertilization was observed.

Soil soluble P
Marked differences were found between soils with and without plants → uptake by plant of a fraction of Pw (same observations for NO3 – not shown).
Garden soils were not different than crop soils. In the latter, differences were observed according to the fertilization gradient.
Within gardens, the Pw for soils with plants was correlated to available P. Without plants, the soils with the lowest content presented the lowest pH and Pav content (gardens 1 and 2), while the soils with the highest content have more important Pav reserves .

Phosphatases activity
Overall, the activity of acid phosphatase was higher in soils with plants than without, although statistically proven in only 3 cases (gardens 1, 2 and crop 2P) → additional effect from plants → production of acid phosphatases by plants. Gardens 1 and 2 present the lowest pH within gardens; crop 2P is the richest in P of crop soils.
In soils without plants, the response of the enzymatic activity in garden soils appeared to be linked to Pav while in soils under cultivation it seemed inversely proportional to Pav.

Correlations analyses
All initial parameters (TOC, pH KCl, Ptot, Porga, Pav) were correlated and the analysis of individual effect of organic matter requires specific statistical methods.
Concerning incubation results, HWC and NO3 are global indicators of biological activity. They responded to the soil organic status. The phosphatase activity which is a more specific indicator of biological activity was positively correlated to soil P status.
Regarding bioavailability test, an effect of soil pH was observed on NO3 and the yield of ryegrass. Pw was correlated with P reserves and a significant correlation (p<0,05) was observed between Pw and phosphatase activity.

Conclusions

The two land uses present different behaviors in terms of P availability but globally, more P is available for plants in garden than in crop soils.
Biological activity, indicated by HWC and NO3, is strongly positively correlated with the parameters of soil organic status while enzymatic activity originated from soil microorganisms (acid phosphatases in incubation) is highly linked to P reserves → improved biological activity in soil with higher OM content.