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Effects of P and C inputs on microbial activities in P limiting bulk and rhizosphere soil

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Phosphorus (P) is the second important nutrient for plants and limiting element in many ecosystems. P is a non-renewable resource, and based on its current rate of use, it has been estimated that the worlds known reserves of P rocks may be depleted within the current century. Soils with high-sorption P capacity require higher P additions, but, do not provide plants with sufficient available P. Therefore, it is necessary to reduce P application rates, but facilitate soil microbiological activity to maintain good P availability for plants.

We aimed to study soil adenosine triphosphate (ATP), microbial biomass (MBC) and phosphatase activity as microbial response to contrasting P input in a low P Cambisol in a 5 days incubation experiment. The treatments were i) bulk soil (no C), ii) rhizosphere soil (10 μg C g^{-1} soil day^{-1} – root exudates imitation) and iii) glucose addition to soil (50 μg C g^{-1} soil – for microbial activation). Three rates of P as KH_2PO_4 were applied at each C treatments: i) no P (P0) – for P severe limitation; ii) 10% P from initial extractable soil P (P10) – low P input; and iii) 50% P from initial extractable soil P (P50) – high P input.

We tested the following hypotheses: 1) the better response of MBC and ATP to P is expected to be in the rhizosphere soil, as continuous C input resulted in gradual microbial activation; 2) phosphatase activity will decrease with increasing P rates in all soils.

Microbial biomass grew linear (R^2=0.99) and simultaneously with incremental P addition in bulk soil. In rhizosphere and C-amended soils, on contrary, the MBC response to P level was represented by quadratic model ($y=-0.06x^2+2.84x+37.03$; R^2=0.93). This model shows the highest MBC value at P23, which indicates optimal and the most effective application rate for this soil type.

The correlation between soil ATP content and P rates ascended in the order bulk soil (R^2=0.34) $>$ C-amended soil (R^2=0.51) $>$ rhizosphere soil (R^2=0.97). That proves our hypothesis that continuous C input (similar to root exudations) stimulates gradual microorganism activation.

The soil ATP content per gram of microbial biomass C increased linearly ($y=5.09x + 21.4$; R^2= 0.99) with increasing P rates in rhizosphere, whereas in bulk and C-amendment soils the effect of P was less pronounced.

Phosphatase activity declined (57 and 64%) exponentially with increasing P rates for rhizosphere (R^2=0.84) and C-amended (R^2=0.98) soils, that complies with our hypothesis. In bulk soil, on contrary, phosphatase activity increased (35%) at P10 and remained constant at P50. P0 was resulted in 5-folds higher phosphatase activity in rhizosphere and C-amended soils compared to bulk soil. This proves the significance of root exudates in facilitation of microbial phosphatase production.

Our results show that P (re)cycling can be accelerated in P-deficient soils by C addition and so, excessive P fertilization can be avoided to maintain ecosystem sustainability.