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Soil microbial communities as suitable bioindicators of trace metal pollution in agricultural volcanic soils

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Summary: The biological, chemical and physical properties of soil confer unique characteristics that enhance or influence its overall biodiversity. The adaptive character of soil microbial communities (SMCs) to metal pollution allows discriminating soil health, since changes in microbial populations and activities may function as excellent indicators of soil pollutants. Volcanic soils are unique naturally fertile resources, extensively used for agricultural purposes and with particular physicochemical properties that may result in accumulation of toxic substances, such as trace metals (TM). In our previous works, we identified priority TM affecting agricultural Andosols under different agricultural land uses. Within this particular context, the objectives of this study were to (i) assess the effect of soil TM pollution in different agricultural systems (conventional, traditional and organic) on the following soil properties: microbial biomass carbon, basal soil respiration, metabolic quotient, enzymatic activities (β-glucosidase, acid phosphatase and dehydrogenase) and RNA to DNA ratio; and (ii) evaluate the impact of TM in the soil ecosystem using the integrated biomarker response (IBR) based on a set of biochemical responses of SMCs. This multi-biomarker approach will support the development of the “Trace Metal Footprint” for different agricultural land uses in volcanic soils.
Methods: The study was conducted in S. Miguel Island (Azores, Portugal). Microbial biomass carbon was measured by chloroform-fumigation-incubation-assay (Vance et al., 1987). Basal respiration was determined by the Jenkinson & Powlson (1976) technique. Metabolic quotient was calculated as the ratio of basal respiration to microbial biomass C (Sparkling & West, 1988). The enzymatic activities of β-glucosidase and acid phosphatase were determined by the Dick et al. (1996) method and dehydrogenase activity by the Rossel et al. (1997) method. The RNA and DNA were co-extracted from the same soil sample and quantified spectrophotometrically using a Nanodrop ND-1000. Analysis of variance (ANOVA) was carried out in order to evaluate the significant differences in SMCs activity between all soil matrices. To associate the SMCs responses to the tracers of distinct agricultural farming systems, data were further explored under Principal Component Analysis (PCA). Biomarkers responses were combined into a stress index (IBR), described by Beliaeff & Burgeot (2002).
Results/Discussion: All SMCs parameters displayed significant differences between agricultural soils and reference soils, except for metabolic quotient and RNA to DNA ratio ($p<0.05$), revealing that SMCs are suitable bioindicators of agricultural soil quality in volcanic soils. No significant differences were found for the soil basal respiration and acid phosphatase among the farming systems, suggesting that soils amendments (a cross farming practice) are a stressing factor disrupting local SMCs activities. The PCA analysis revealed that lithium is the priority metal affecting the SMCs responses in conventional farming systems. The IBR values indicated that soils ecosystem health between farming systems are ranked as: organic (4.96) > traditional (12.94) > conventional (17.28) (the higher the value, the worse the soil health status).
Conclusion: Results support the soil microbial toolbox as suitable bioindicators of metal pollution in agricultural volcanic soils, highlighting the importance of integrated biomarker-based strategies for the development of the “Trace Metal Footprint” in Andosols.