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Nitrogen controls spatial and temporal variability of substrate-induced respiration within seven years of bare fallow

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Bare fallow management goes along with lacking supply of new C sources; yet, little is known on the spatio-temporal controls of microbial adaptation processes. Here we hypothesized that microbial activity parameters decline upon bare fallow but that their spatial patterns are increasingly controlled by nutrient status as fallow management proceeds. To test these hypotheses, we investigated spatial and temporal patterns of substrate-induced respiration (SIR) and basal respiration curves in an arable field after 1, 3, and 7 years of bare fallow but with large within-field heterogeneity of physicochemical soil parameters. The analyses comprised the contents of SOC, mineral nitrogen (Nmin), particulate organic matter (POM), texture of the fine earth, and the proportion of rock fragments as well as basal respiration and several SIR fitting parameters (microbial biomass, microbial growth rates, peak respiration rates, cumulative CO_2 release) each with and without additions of mineral N and P. We also repeated substrate (i.e. glucose) additions following the first SIR measurement.

The results revealed that most respiration parameters like basal respiration, microbial biomass, and growth rates showed no or inconsistent responses to spatial and temporal patterns of basic soil properties like SOC, Nmin or texture. However, bare fallow changed the shape of the SIR curves; it developed two distinct microbial growth peaks at advanced stages of fallow, i.e. a delayed CO_2 release. Likewise, the maximum respiration rate during the first growth phase declined during 7 years of fallow by 47% but its spatial distribution was always correlated with Nmin contents ($r = 0.43 – 0.79$). The nutrient additions suggested that these changes in SIR curves were caused by N deficiency; the first peak increased after N additions while the second growth phase diminished. Intriguingly, a repeated glucose addition had a similar effect on the SIR curves as the glucose+N addition. Thus, N deficiency apparently subsided during SIR.

The results suggested that soil microbes acquire nitrogen from refractory SOM pools (i.e. microbial nitrogen mining). Hence, there was no significant decrease in cumulative CO_2 evolution with proceeding time of fallow. As soil microorganisms maintained their functionality there was no overall loss in potential microbial activity, irrespective of the spatial patterns of other soil properties.