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Physical and ecological controllers of the microbial responses to drying and rewetting in soil

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Soil moisture is one of the most powerful factors that regulate microbial activity in soil. The variation of moisture leads to drying-rewetting (DRW) events which are known to induce enormous dynamics in soil biogeochemistry; however, the microbial underpinnings are mostly unknown. Rewetting a dry soil can result in two response patterns of bacterial growth. In the Type 1 response, bacteria start growing immediately after rewetting with rates that increase in a linear fashion to converge with those prior to the DRW within hours. This growth response coincides with respiration rates that peak immediately after rewetting to then exponentially decrease. In the Type 2 response, bacterial growth remains very low after rewetting during a lag period of up to 20 hours. Bacteria then increase their growth rates exponentially to much higher rates than those before the DRW event. This growth response coincides with respiration rates that increase to high rates immediately after rewetting that then remain elevated and sometimes even increase further in sync with the growth increase.

Previous studies have shown that (i) extended drying (ii) starving before DRW and (iii) inhibitors combined with drought could change the bacterial response from Type 1 to Type 2. This suggested that the response of bacteria upon rewetting could be related to the harshness of the disturbance as experienced by the microbes. In the present study, we set out to study if reduced harshness could change a Type 2 response into a Type 1 response. We hypothesized that (1) a reduced physical harshness of drying and (2) induced tolerance to drying in microbial communities could change a Type 2 response into a Type 1 growth response upon rewetting. To address this, two experiments were performed. First, soils were partially dried to different water contents and bacterial response upon rewetting was measured. Second, soils were exposed to repeated DRW cycles (< 9 cycles) and the bacterial response was followed after rewetting.

A less harsh drying (partial drying) of a soil could change the growth responses to rewetting. The lag period decreased with less complete drying to eventually became 0, transitioning from a Type 2 to a Type 1. Even after a Type 1 response was induced, further reduction of harshness could also lead to a faster recovery of growth rates. Our results support the hypothesis: the physical harshness of drying can determine the microbial survival and thus the type of bacterial growth response. Subjecting soil to DRW cycles could also induce a change from a Type 2 to Type 1 growth response. This suggested that there was a community shift towards higher drought-tolerance. Thus, identical physical disturbance was less harsh for a community that has been subjected to more drying rewetting cycles.

To predict how the microbial community's control of the soil C budget of ecosystems is affected warming-induced drought, our results demonstrate that both the physical characteristics of the disturbance and the community's tolerance to drought need to be considered.