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Effects of heavy metals on crop quality and soil microbiome health under different fertilization regimes.

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The planet's rapidly growing population and expanding wealth make it necessary to re-think current food production, as demand for agricultural products is expected to increase by 15% in the next decade. Mineral and organic fertilizers are commonly used to improve agricultural productivity. Besides nutrients, fertilizers also contain heavy metals, which pose serious threats to crop production and the functioning of soil ecosystems. Diverse and well-functioning soil microbiomes are essential for supporting plant productivity as they provide nutrients, combat pathogens, promote plant growth, and deliver tolerance to environmental stress. Although studies have focused on the effect of fertilization practices on crop production and soil microbiome dynamics, as well as the effects of fertilization on metal loading and bioavailability in soil, the link between the soil microbiome adaptation to steadily increasing heavy metal contents of the soil due to long-term mineral or organic fertilization and crop quality in terms of their metal contents has not been investigated.

Using a century-old fertilizer experiment, we found that wheat grain contained less cadmium when fertilized organically than minerally, though the soils had similar metal contents. Given the supportive role of soil microbiomes for plant performance, we postulate that organic fertilization positively influences the soil microbiome to better handle heavy metal stress compared to a microbiome having developed in a minerally fertilized soil. To test this hypothesis, we incubated differently fertilized soils under background and elevated metal regimes. Heavy metal bioavailability was lower in organically compared to minerally farmed soils. Potential of heavy metals to affect microbial communities to a lesser extent in organically fertilized soil was confirmed by the fastest regeneration of microbial numbers after metal addition among all the soils tested. Moreover, only in this soil hydrolytic enzyme activities decreased after metal addition. We postulate that metal addition caused a release of nutrients from organically fertilized soils, allowing microorganisms to invest more energy in growth rather than enzyme production. Our results indicate that organic fertilization helps maintain the soil microbiome even in the presence or sudden input of heavy metals, supporting the quality of organically farmed agricultural soils and their output for the future.