

# MICONUTRIENT STATUS IN TWO LONG-TERM TRIALS WITH FERTILISATION TREATMENTS AND DIFFERENT CROPPING SYSTEMS

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## Abstract

Although organic fertilisers always contain micronutrients, we have to pay attention to the question of whether continuous fertilisation will lead to lower contents in plants or lower availability in the long run. We investigated topsoil samples from long-term trials with farmyard manure and mineral fertilisation and with different organic and conventional farming systems. Input of micronutrients via organic fertilisers was obviously more significant in the case of poor sandy soil than in that of loamy soil with high total contents and higher mineralising potential.

## Introduction

For macronutrients it is well known that proper management is needed to avoid deficiencies. Usually, we are far less aware that the same is true for micronutrients. Their function is not only to support plant growth and disease resistance (Kirkby and Römheld, 2004), but also to prevent a reduction of soil fertility, especially on sandy soils with naturally low contents of total and available micronutrients. Although organic fertilisation always entails an input of micronutrients, in the long run even low annual deficits could result in a noticeable decrease of micronutrients in the soil.

As long-term trials show, organically fertilised soils or soils of organic cropping systems have higher organic carbon contents and a higher microbial activity than those treated by mineral fertilisation or soils of conventional cropping, respectively (Mäder *et al.*, 2002; Raupp, 2001). Such findings may have implications for micronutrients, as soil organic matter enlarges the sorption capacity of a soil. Consequently, micronutrient availability may be lowered if their adsorption to organic matter is too strong (e.g. for Cu).

This paper deals with the question of whether organic and mineral fertilisation for many years can influence the total contents of manganese (Mn), copper (Cu) and zinc (Zn) in the soil as well as their plant-available fractions. We investigated soil samples collected in a long-term fertilisation trial in Germany comparing different farmyard manure and mineral fertilisation treatments and in another long-term trial in Switzerland comparing different organic and conventional farming systems.

## Methodology

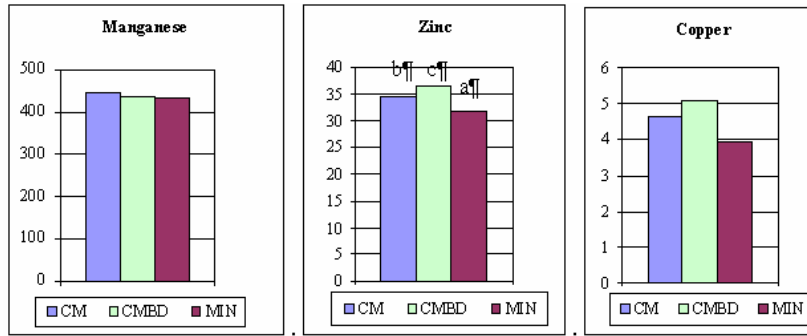
Starting in 1980, the long-term fertilisation trial in Darmstadt, Germany, has examined the effects of mineral fertiliser (MIN, i.e. calcium ammonium nitrate, super phosphate, potassium magnesia) and composted cattle manure (CM). As a third fertilisation type CM with all biodynamic preparations is applied (CMBD). Both manure treatments are identical as regards manure origin, composting period (approx. 5-6 months) and conditions, and differ only as regards use of the preparations. All three types of fertilisers are given at three different levels, corresponding to 50, 100 and 150 kg ha<sup>-1</sup> total N. In this way, fertiliser types and levels are combined to give nine treatments, implemented in four replicates. Except for fertilisation, all other elements of cultivation are the same in all treatments and follow normal organic farming practices. The site is characterised by a very sandy soil and a dry, warm climate (590 mm precipitation per year, 9.5°C annual mean air temperature).

In Therwil, Switzerland, the DOC trial started in 1978 on a loamy soil under site conditions of 792 mm precipitation and 9.5°C air temperature. The DOC trial examines three farming systems, i.e. biodynamic (D) and organic (O) with organic fertilisation, and a conventional system with combined manure and mineral fertilisation (C). These systems are compared with a conventional treatment using mineral fertilisers solely (M) and a control treatment without any fertiliser but with application of all biodynamic preparations (N). Each farming system purchased its farmyard manure from a different farm according to its cultivation guidelines.

Soil analysis for total Mn, Zn and Cu (aqua regia extraction) contents and plant available Mn, Zn, Cu (CaCl<sub>2</sub>/DTPA extraction) contents in topsoil samples from Darmstadt and Therwil were carried out in 2004 at the Institute for Plant Nutrition at the University of Hohenheim, Germany. Where appropriate, analysis of variance was calculated with the aid of the SAS program (SAS Institute Inc., USA) using the MIXED procedure for Darmstadt and GLM for the DOC trial.

## Results and brief discussion

### 1. Long-term fertilisation trial, Darmstadt



**Figure 1: Total contents of micronutrients (mg kg<sup>-1</sup> dry matter) in topsoil in the year 2004, depending upon fertilisation; results with different letters are statistically different (p<0.05)**

Total soil contents of Mn and Cu were about the same with all types of fertiliser (Fig. 1). Total Zn content was highest with manure fertilisation and application of biodynamic preparations. The lowest total Zn content was observed with mineral fertiliser, while manure without the preparations yielded an intermediate result between those of the two other treatments. Organic fertilisation gives a higher input, especially of Zn and Cu, than do inorganic fertilisers, as both these elements contained in feedstuffs are excreted by animals to a large extent.

An enhanced content of organic matter in the CMBD treatment was observed earlier (Raupp, 2001). Mainly Cu, but also Zn and to a lower extent Mn can form stable complexes with soil organic matter, so that the content of organic matter in the soil can influence the total contents of micronutrients.

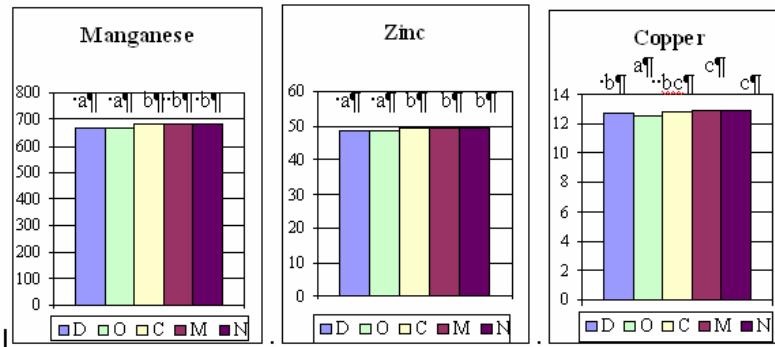
**Table 1: Amounts of plant-available micronutrients in topsoil (mg kg<sup>-1</sup> dry matter) and soil pH values, by fertilisation; results with different letters are statistically different (p<0.05)**

	Mn	Zn	Cu	pH
CM	101	5.4 a	1.7	6.7 a
CMBD	94	5.4 a	1.7	6.7 a
MIN	97	4.0 b	1.4	6.5 b

The available Mn did not differ among the treatments (Table 1). A lower pH of 6.5 with the mineral treatment as against 6.7 after organic fertilisation may have caused Mn mobilisation. This may have offset the potentially positive effect of Mn supplied by organic fertilisers. Cu also showed no significant

differences in availability. The amount of available Zn was distinctly lower in the mineral treatment than in the organic treatments. Regarding mineral fertiliser, a higher availability can be expected because of its slightly pH-lowering, physiological effect, which can mobilise Cu and Zn. Altogether, the micronutrients availability status is very good, considering the poor sandy soil conditions (VDLUF A, 2002).

## 2. DOC trial, Therwil



**Figure 2: Total contents of micronutrients in topsoil (mg kg<sup>-1</sup> dry matter) in the year 2004 in different cropping systems; results with different letters are statistically different (p<0.05)**

Total contents of micronutrients in the topsoil of the DOC trial were rather high for Mn, but those for Cu and Zn corresponded to the background values for loamy soils. Total content of Mn was significantly lower in the exclusively organically fertilised soils than in those that received the C, M and N treatments. Although statistically significant, the difference is less than 2% and can be interpreted as negligible for plant nutrition. Total contents of Zn and Cu differed, the patterns being similar to that for Mn, but much less pronounced. Organic fertilisation was not able to produce similar total contents of micronutrients as in the other systems with mineral fertilisers, although farmyard manure and slurry is regarded as the main input of micronutrients in the trial.

On the Therwil site, the loess soil with higher amounts of micronutrients shows slightly lower contents in the organically treated plots, whereas the Darmstadt site, with its sandy soil, sometimes has higher contents of micronutrients with the organic treatments. Input of micronutrients via organic fertilisers seems to be more important for the poor sandy soil than for the loamy soil.

**Table 2: Amounts of plant-available micronutrients in topsoil (mg kg<sup>-1</sup> dry matter) and soil pH value in different cropping systems in the year 2004; results with different letters are statistically different (p<0.05)**

	Mn	Zn	Cu	pH
D	97	4.0	4.0	6.8 a
O	96	4.0	4.3	6.6 ab
C	96	3.9	4.1	6.5 bc
M	96	3.4	4.2	6.2 dc
N	96	3.0	3.5	6.0 d

The availability of Mn did not differ significantly among the treatments, nor did that of Zn or Cu (Table 2), although there are striking differences in pH, which is known to have an influence on the availability of micronutrients. For Zn there is a tendency for higher availability in organic treatments despite the higher pH in these plots. Organic fertiliser, especially biodynamically composted farmyard manure, has shown positive effects on microbial activity and supports humus formation in soil (Mäder et al., 2002). These components can form complexes with micronutrients that are not plant available; Cu and Zn are known to form stable

complexes with organic matter in soil. On the other hand, a high microbial activity can enhance the plant-serving pools. The extent of the processes responsible can exceed the effects of pH and fixation by organic matter. According to the literature (VDLUFa, 2002), the loess soil has a high micronutrient status with all treatments,

Plant uptake of micronutrients is much more dependent on rhizosphere conditions than on bulk soil conditions. Differences in rhizosphere conditions could appear even without any differences in bulk soil, and they would influence the uptake of micronutrients by plants. In fact, first results of plant analysis show lower micronutrient contents in organically fertilised plants than in minerally fertilised plants (results not presented here). Further research on the rhizosphere is needed to explain these results. According to the lower micronutrient concentrations in plants under organic fertilisation, it would be of interest for organic farming systems to enhance the micronutrient status of the plants to achieve a higher tolerance against abiotic and biotic stress. Some strategies based on rhizosphere management that might be implemented to enhance plant acquisition of micronutrients are improved rotation with crop plants that have a high capability for micronutrient mobilisation in the rhizosphere, e.g. oats as preliminary crop, application of micronutrient-mobilising microorganisms such as *Trichoderma* spp., or selection of micronutrient-efficient cultivars and seeds with higher micronutrient contents.

### Conclusions

Input of micronutrients via organic fertilisers was more important in the case of poor soils such as are seen at the Darmstadt site than for soils with high total contents and therefore higher mineralising and weathering potential, as in Therwil. In both trials available Zn appeared to be the most limiting of the examined micronutrients. To enhance micronutrient acquisition of the plant, the rhizosphere is an important factor that should be considered, and several management strategies can be developed.

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