Acta Agronomica Óváriensis Vol. 50. No. 1.

Manganese deficiency in plants growing on different soils with high lime-content

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Summary

Manganese deficiency is described by assessment of visible symptoms and plant analytical results on five different Austrian soils with high lime content. In one case the deficiency is induced by Cu contamination as a result from longterm application of fungicide sprays. Affected plants were conifers (*Thuja sp., Pinus nigra, Picea abies*), horticultural crops (*Prunus persica, Prunus cerasus, Fragaria ananassa, Rubus idaeus*) and wheat (*Triticum aestivum*).
Keywords: Chlorosis, leaf analysis, calcareous soil, Cu contamination.

Introduction

Manganese is present generally in the oxidation states +II, +III, and +IV. Mn contents in most soils are in a range between 300 and 1000 mg·kg^{-1}; the mobile fraction, containing the free ion and low molecular complexes of Mn^{2+}, shows variable concentrations, depending on redox potential and pH. Under aerobic and neutral conditions Mn^{2+} may be oxidised to a great portion by different microorganisms to immobile MnO_2. Under reducing and strongly acidic conditions Mn^{2+} is dominating in soil solutions and may be toxic for sensitive plants (*Adriano* 2001).

Plants take up only Mn^{2+} which is, besides weak complexes, dominating in tissue, but its concentrations are variable, depending on soil conditions and plant species. The concentration range in plants is observed frequently between 30 and > 1000 mg·kg^{-1} in dry matter. Excessive amounts of the element are stored in specific compartments: MnO_2 is precipitated in the Apoplast and in intercellular space while Mn^{2+} is accumulating as soluble complex in the vacuole (*Marschner* 1995).

The essential functions of Mn in biological systems are primarily concerned with electron transfer in redox enzymes (Hill reaction in photosynthesis; Superoxide dismutase as part of the antioxidative system). Other functions of Mn are its role in activation of several enzymes (*Marschner* 1995).

Visible symptoms of Mn deficiency are chlorosis and growth reduction in connection with critical tissue concentrations of < 15–30 $mg \cdot kg^{-1}$ in dry matter. Mn deficiency can be observed mainly in calcareous soils, and enhancing factors are high contents of organic matter and Ca^{2+} as well as drought (*Bergmann* 1993).

In Austria, Mn deficiency can be observed in forest-, ornamental-, and fruit trees, as well as in cultivated raspberries, strawberries and cereals. Some typical examples, appearing on soils with high lime content are presented in this report.

Materials and methods

Trace elements in plant material were determined by AAS-flame and -graphite furnace techniques after wet digestion with a mixture of perchloric and nitric acids (5 + 1 volume parts). Soil pH was measured in 0.01 mol. $CaCl_2$, carbonate content was determined by the Scheibler method; total carbon was measured with a Carlo Erba elemental analyzer, and the organic carbon was calculated by subtraction of carbonate.

Results and discussion

Thuja (var.), hedge in a garden in Traismauer (Niederösterreich):

On a soil with 40% $CaCO_3$ most trees of *Thuja* are chlorotic with Mn contents of 12 $mg \cdot kg^{-1}$, while single trees with green shoots show no deficiency with 33 $mg \cdot kg^{-1}$ of Mn in shoots (*Figure 1.*). Contents of Fe and Zn seem to be in a normal range.

Pinus nigra, on a shallow Rendzina, covering limestone, location Wien-Rodaun:

In spring, especially after a period of dryness in winter, chlorosis appears in 1-year old needles. The Mn content of pine needles was found below the critical level of 20 $mg \cdot kg^{-1}$. In healthy trees, growing on a north-exposed slope, the Mn content was 70 – 123 $mg \cdot kg^{-1}$ (*Figure 2.*).

Picea abies, growing in Gutenstein (Niederösterreich) on a shallow Rendzina, covering dolomite:

Gutenstein is situated in the valley of Piesting, northern of the Schneeberg (2075 m). On dry slopes, where a shallow soil layer is covering the rock, Norway spruce frequently shows reduced growth and some trees are chlorotic; on sites with a deeper soil layer the trees look healthy. Mn contents in needles of deficient and healthy trees are significantly different (*Figure 3.*): In chlorotic needles Mn contents are distinctly below the critical deficiency level, given by *Hüttl* (1987). Moreover, the values in deficient needles decrease with increasing age. This effect may be an indicator of leaching loss of Mn and insufficient resupply by root uptake and xylem transport (*Zöttl* and *Hüttl* 1986).

The variation of Mn contents in Norway spruce is considerable, depending on soil conditions. *Zvacek* (1988) reported values in needle dry matter as low as 3.0 mg·kg^{-1} on calcareous soils with pH > 7.0 and about 1000–2000 mg·kg^{-1} on acid Cambisols with pH < 4.0.

Figure 1. Trace element contents in shoot dry matter of chlorotic and healthy (green) *Thuja*. Critical level of Mn in conifers: 20 mg·kg^{-1}

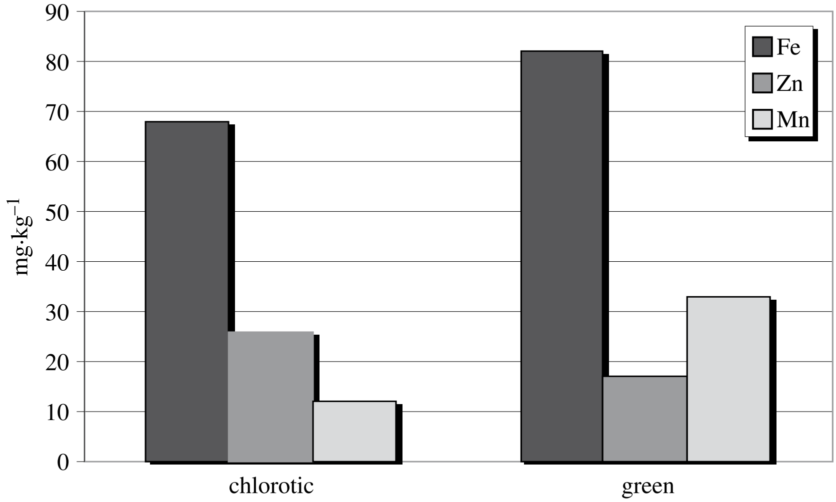


Figure 2. Trace element contents in 1- and 2-years old needles of chlorotic and healthy *Pinus nigra*

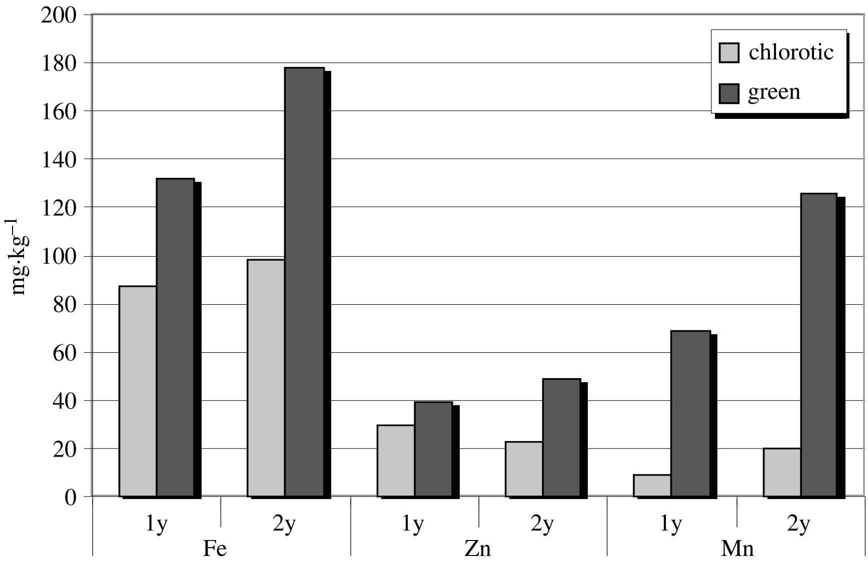
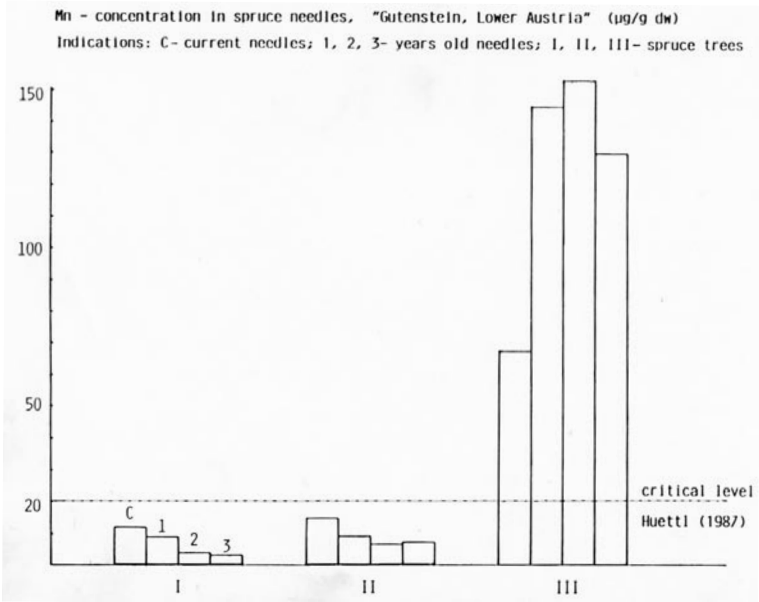


Figure 3. Mn content in needles of different age in *Picea abies;*
two deficient trees are compared to a healthy tree
Location: Gutenstein, Niederösterreich (*Zvacek,* 1988)



Mn deficiency in fruit trees, induced by Cu contamination on a former vineyard soil, Arnsdorf, Niederösterreich:
As a consequence of longterm application of copper fungicides the soil is Cu contaminated. Following to viniculture several species of fruit trees were planted. In Cu sensitive trees, such as peach or morello cherry, chlorosis appeared, while plum was not affected. The data in *Table 1.* indicate Mn deficiency in fruit trees and also in strawberry, while Cu contents are slightly elevated but still in the normal range. Also the iron content is very low in chlorotic leaves.

Table 1. Element content in chlorotic and green leaves of fruit trees and strawberry and soil data; location Arnsdorf, Niederösterreich

Plant species	**Fe**	**Mn**	**Cu**	**Mn, sufficient level** (*Bergmann,* 1993)
	mg·kg^{-1}			
Prunus persica (chlorotic)	41	3	9.3	35
Prunus persica (green)	56	3	6.1	
Prunus cerasus (chlorotic)	42	14	7.6	35
Prunus cerasus (green)	89	28	5.8	
Fragaria ananassa (chlorotic)	53	9	7.9	40
Fragaria ananassa (green)	72	15	7.2	
Soil element content and pH $CaCO_3$ in soil	10.100	365	180	7.4 23%

The suppression of Fe- and Mn-uptake by excessive Cu concentrations in the substrate is reported by *Bergmann* (1993). It seems that excessive Cu is detoxified by immobilisation in the rhizosphere and this reaction affects also other trace elements. Soil data are also presented in *Table 1.*, showing a Cu level typical for vineyard soils (*Scholl* and *Enkelmann* 1984). The high pH can be considered as an additional factor, that may enhance the deficiency situation.

Micronutrients in raspberry and wheat growing on a Calcic Chernozem in Ebreichsdorf, Niederösterreich:

As may be seen from the analytical data presented in *Table 2.* the trace element supply of plants is insufficient for Mn and Zn, while Fe seems to be in a normal range. Visible symptoms are chlorosis for Raspberry and ”Grey speck disease” for wheat. Element contents in leaves are far below the sufficient level (*Bergmann* 1993) and also below 20 mg·kg^{-1}, considered as the critical level of appearance of visible deficiency symptoms.

Table 2. Element content in chlorotic and green leaves and soil data; location Ebreichsdorf, Niederösterreich

Plant species	Fe	Mn	Zn	Sufficient (*Bergmann,* 1993) Mn	Zn
	mg·kg^{-1}				
Rubus idaeus (chlorotic)	75	13	12	35	20
Rubus idaeus (green)	86	15	18		
Triticum aestivum (ear leaf)	180	10	12	30	20
Triticum aestivum (straw)	140	9	11		
Triticum aestivum (grain)	33	15	38		
Soil characteristics	pH = 7.3		$CaCO_3$ = 70%	humus content = 6.3%	

Conclusions

Manganese deficiency is observed widespread on calcareous soils, especially under dry weather conditions in spring. Also Cu excess may induce Mn deficiency. The visible symptoms are typically associated to the phenomenon of ”Lime-induced Chlorosis”. Leaf analysis is considered as a general requisite for the assessment of the deficiency situation.

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