6.2. SUMMARY

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**Mapping of the loci affecting Cu-tolerance and the shoot Cu-, Fe-, Mn- and Zn-concentrations by wheat**

Copper (Cu) is an essential plant micronutrient, which can be phytotoxic if present in soil in high concentrations resulted in yield loss by cultivated plants. Selection of more resistant genotypes could provide gene sources for breeding of Cu-tolerant wheat, and those tolerant varieties which can accumulate high concentration of Cu in their shoots, could be directly used for the extraction of the metals from the polluted soils.

Beside the toxicity of the heavy metals, the micronutrient malnutrition is also a serious problem worldwide. Cereal-based foods have great importance in the compensation of micronutrient deficiency, because 50 % of the foods produced worldwide is made up of cereal grains. Common wheat (*Triticum aestivum* L. ssp. *aestivum*) often contains very low amounts of essential iron and zinc, and to lesser extent of copper and manganese. Therefore, an increase in micronutrient concentrations is an important criterion in the breeding of wheat varieties. When there are higher Cu-, Fe-, Mn- and Zn-concentrations in the shoot tissues, also higher mineral concentrations in the grains can be expected. Therefore, mapping of QTLs determining higher shoot micronutrient concentrations could be used for the marker assisted breeding of wheat varieties with a better nutritional value.

The aims of our work reported here were to determine the chromosomes and loci which are affecting the Cu-tolerance in wheat. Additionally, we wanted to determine the loci having an influence on the heavy metal concentrations of the shoots.

In the first step, twenty-seven different cereal accessions belonging to the *Triticinae* subtribe were screened for Cu-tolerance in hydroponics. Based on the shoot dry mass reduction and the decreased value of the Fv/Fm fluorescence induction parameter the *Secale* (rye) species were the most tolerant ones, and relatively tolerant and sensitive common wheat cultivars were also identified.

In the second step, the Cu-tolerance of the 'Chinese Spring’ (recipient, Cu-tolerant)/'Cappelle Desprez’ (donor, Cu-sensitive) wheat substitution lines was screened in
greenhouse using control and Cu-treated soils. We found that chromosomes 3D, 5A, 5B, 5D, 6B and 7D have an effect on Cu-tolerance. The role of homoeologous group 5 in the Cu-tolerance was reinforced with the testing of wheat rye/substitution lines.

In order to determine the QTLs and loci influencing Cu-tolerance 3 different wheat mapping populations (‘Opata85’ x ‘Synthetic’ (‘ITMI’ mapping population), ‘CS(Ch5A)’ x ‘CS(Tsp5A)’, ‘CS’ x ‘CS(Ch5B)’) and homozygous deletion lines for ‘Chinese Spring’ 5AL and 5DL were screened. The two single chromosome recombinant populations were genotyped using microsatellite (SSR) markers, as well. In addition, QTLs having an influence on the shoot Cu-, Fe-, Mn- and Zn-concentrations under control and Cu-treated environments were also mapped. Major QTL for Cu-tolerance was found on the chromosome 5DL. Slighter effects were mapped on the chromosomes 1AL, 2DS, 4AL, 5AL, 5BL and 7DS, confirming the previously suggested polygenic character of the Cu-tolerance in wheat. Testing the Cu-tolerance of the ‘Chinese Spring’- *Aegilops tauschii* introgression lines an additional locus affecting Cu-tolerance was mapped on the short arm of chromosome 3D.

The concentrations of the investigated metals in the shoots are affected by different QTLs, which suggest the strongly metal specific uptake and/or translocation of these elements. In the control plants there was a significant positive correlation among the shoot metal concentrations, therefore, if a genotype has a higher shoot Cu-concentration, higher Fe-, Mn- and Zn-concentrations could be also expected.

QTLs influencing the shoot Mn- and Zn-concentrations were found on the chromosome 3BL and 3AL, respectively. The shoot Zn-concentrations of the Cu-stressed plants were affected by the locus on the chromosome 7A. The centromeric region on the chromosome 3B plays a role in the regulation of the shoot Fe-concentration in the Cu-stressed plants. Under Cu-stress the QTL affecting shoot Cu-concentrations was found on the chromosome 1BL. On the chromosome 5AL a locus influencing the Cu-accumulation ability of wheat from Cu-polluted soils was determined.

The determination of the shoot Cu-concentration by the RILs of the ‘Opata85’ x ‘Synthetic’ wheat mapping population revealed that lines with better tolerance accumulate lower amount of Cu in their shoots. It suggests that the basic mechanism in Cu-tolerance by wheat could be the restriction of Cu uptake from the soil, or the restricted rate of the translocation from the root to the shoot.

Results obtained from growth and yield data of the Cu-tolerant and Cu-sensitive wheat genotypes in artificial Cu-enriched soil suggest that the tolerant line in contrast to the
sensitive one could have relatively good yield, indicating the usefulness of Cu-tolerant wheat by the reducing the yield loss on Cu-polluted soils.

The use of wheat for the phytoremediation of Cu-polluted soils seems not to become possible, because the Cu-tolerant plants have a lower shoot Cu-accumulation ability, therefore, differences between the total shoot Cu-content (removable Cu from the soil) of the control and Cu-treated plants only small.

The successful utilization of the determined PCR-based markers indicating Cu-tolerance can speed up the selection of Cu-tolerant wheat genotypes and decrease the costs when developing new cultivars with better tolerance.