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Copper tolerance of *Aegilops*, *Triticum*, *Secale* and triticale seedlings and copper and iron content in their shoots

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ABSTRACT Twenty-seven different cereal accessions belonging to the *Triticinae* subtribe were screened for copper tolerance in hydroponic cultures. Based on the shoot dry mass reduction and the decreased value of the F_v/F_m fluorescence induction parameter the *Secale* species were the most tolerant ones. Slightly tolerant and relatively sensitive common wheat cultivars were also identified. No significant correlation was found between the copper and iron concentration of the shoots and the degree of tolerance.

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KEY WORDS

copper tolerance
fluorescence induction
wheat
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It has been reported that the long-term application of copper-containing pesticides in vineyards, hop plantations and orchards could result in copper accumulation in soils (Csathó 1994). Perennial plants are able to extend their roots into the deeper soil level, where the copper content is lower, but the roots of cereals cannot grow deep enough to avoid the toxic upper part of the soil, which may cause serious problems during cultivation. Although soil remediation can be used to decrease the toxic copper content, this method is extremely expensive. The breeding of copper-tolerant varieties would to be more economical. The results of previous experiments revealed that there was a significant difference between the copper tolerance of wheat varieties (Tari et al. 2002), but no really resistant one was found. The aim of the present study was to identify really copper-tolerant genotypes among the accessions stored in the Martonvásár genebank. Resistant genotypes or populations could provide gene sources for them breeding of copper-tolerant wheat, or could be used directly in cultivation.

Materials and Methods

Seedlings of twenty-seven different cereal species and wheat varieties were grown for 21 days in a controlled environment in hydroponic cultures supplemented with 0.1 or 100 µM Cu^{2+}.

The plant material used in the present experiment was the following: *Aegilops biuncialis*, *Ae. caudata*, *Ae. cylindrica*, *Ae. kotschyi*, *Ae. speltoides*, *Ae. tauschii*, *Ae. triuncialis*, *Ae. umbellulata*, *Secale cereale* cv. Merkator, *S. montanum*, *Triticum aestivum* ssp. *aestivum* cv. Bánkúti 1201, cv. Cheyenne, cv. Chinese Spring, cv. Kobomugi, cv. Magdaléna, cv. Mv 8, *T. aestivum* ssp. *spelta*, *T. monococcum* (5 accessions), *T. sinskajae*, *T. timonovum*, *T. timopheevii*, *T. zhukovskyi* and triticale cv. Presto.

The fluorescence induction parameter (F_v/F_m) was determined using the youngest fully expanded leaves of dark-adapted plants on the 13th and 18th days. The copper and iron concentrations of the shoots were determined by AAS. The evaluation of the degree of tolerance was based on the calculated *Tolerance Index*, which is the quotient of an adequate parameter acquired under treated and control environments ($TI = parameter_{treated}/parameter_{control}$). All the experiments were replicated three times.

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Results and Discussion

Changes in fluorescence induction parameter (F_v/F_m)

The copper-treated plants showed decreased values of the F_v/F_m parameter by the 11th day, indicating early damage to the photosynthetic apparatus. The extent of this decrease was nearly the same for most of the species (5-10% compared to the control), while only 4 species showed a greater decrease in the fluorescence induction parameter (*Ae. triuncialis*, *T. aestivum* ssp. *aestivum* cv. Mv 8, *T. sinskajae*, triticale cv. Presto). This indicates that these species are more copper-sensitive than the others.

The decrease in the F_v/F_m parameter was more characteristic after the 18th day of treatment. In the case of 18 species the decrease in the F_v/F_m parameter was 20% compared to the untreated control, while in the remaining genotypes this decrease was sometimes higher than 50%. Based on the calculated tolerance index, *Secale montanum* showed the highest level of tolerance (TI=0.983), and the tolerance of the other *Secale* species (TI=0.923) was also outstanding. Among the *Aegilops* species *Ae. cylindrica* (TI=0.943) and *Ae. umbellulata* (TI=0.944) showed the highest level of tolerance. Two *T. monococcum* accessions (TI=0.457; 0.357) and the *T. aestivum* ssp. *aestivum* variety Bánkúti1201 (TI=0.675) were identified as the most sensitive genotypes.

Shoot dry weight

The dry weight of the treated plants significantly decreased by the 21st day compared to the control, and the level of decrease varied between 37-74% of the control. The *Secale cereale* cv. Merkator showed the highest level of tolerance (TI=0.743) based on the Tolerance Index calculated from dry

weight values. Among the *Aegilops* species the most tolerant was *Ae. tauschii*. *Ae. biuncialis*, *Ae. caudata* and *Ae. cylindrica* also had good copper tolerance. Five out of 6 common wheat varieties had similar levels of copper tolerance, while Bánkúti1201 was highly sensitive compared to the other bread wheat varieties. *T. sinskajae* was the most sensitive among all the species tested in this experiment.

Cu content in shoots

The copper content in the treated shoots was generally higher (range: 31.9-171.3 mg kg^{-1} dry weight; mean: 81.2 mg kg^{-1} dry weight) than in the shoots of seedlings grown under control conditions (range: 5.8-26.0 mg kg^{-1} dry weight; mean: 14.0 mg kg^{-1} dry weight). The *Aegilops* species had outstandingly high copper concentrations in their shoots. There was no significant difference between the copper contents of the treated common wheat varieties, which had values varying between 49.2-73.0 mg kg^{-1} dry weight. No significant correlation was found between the shoot copper concentration of the plants and the degree of tolerance.

Fe content in shoots

The iron concentration of the shoots decreased after copper treatment (range: 32-74% of the control), and the level of decrease was significant in most cases. No significant correlation was found between the shoot iron content and the degree of tolerance, or between the changes of iron and copper concentrations.

Based on the present results it can be concluded that among the species studied the most copper-tolerant genotypes were the *Secale* species, but interestingly enough the triticale (rye x wheat hybrid) was as sensitive as the wheat genotypes. The common wheat variety Bánkúti 1201 and *T. sinskajae* were highly sensitive to copper. The present results suggest that there is a high level of genetic polymorphism for copper tolerance, making it possible to produce a useful mapping population for the molecular mapping of the genes controlling copper tolerance in wheat.

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