HORST, W.J., MAIER, P., FECHT, M., NAUMANN, A., WISSEMEIER, A.H. (1999): The physiology of manganese toxicity and tolerance in Vigna unguiculata (L.) Walp. J. Plant Nutr. Soil Sci. 162, 263-274.

The physiology of manganese toxicity and tolerance in Vigna unguiculata (L.) Walp

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Abstract

In cowpea (*Vigna unguiculata* (L.) Walp.) tolerance of manganese (Mn) excess depends on genotype, silicon (Si) nutrition, form of nitrogen (N) supply, and leaf age. The physiological mechanisms for improved Mn leaf-tissue tolerance are still poorly understood.

On the basis of the density of brown spots per unit of leaf area and the callose content which are sensitive indicators of Mn toxicity, it was confirmed that cv. TVu 1987 was more Mn-tolerant than cv. TVu 91, young leaves were more Mn-tolerant, Si improved Mn tolerance, and NO_3^--grown plants were more Mn-tolerant than NH_4^+-grown plants. A close positive relationship existed between the bulk-leaf Mn content and the vacuolar Mn concentration from the same leaves. Since no clear and consistent differences existed between leaf tissues differing in Mn tolerance, the results suggest that accumulation of Mn in the vacuoles and its complexation by organic anions do not play a role in Mn leaf-tissue tolerance in cowpea. A near linear relationship was found between leaf Mn contents and concentrations of free (H_2O-soluble) and exchangeable-bound ($BaCl_2$-extractable) Mn in the apoplastic washing fluid (AWF) extracted from whole leaves by an infiltration and centrifugation technique. There were no differences in apoplastic Mn concentrations owing to genotype and form of nitrogen nutrition. However, Si decreased the Mn concentration in the AWF. With increasing bulk-leaf Mn contents, concentrations of organic anions in the AWF also increased. The results suggest that complexation of Mn by organic anions in the leaf apoplast contribute to Mn tolerance due to genotype and more clearly due to NO_3-N nutrition.

Cell wall-bound peroxidase activity increased with leaf age and was higher in the Mn-sensitive cultivar TVu 91 than in cultivar TVu 1987. This was in agreement with a higher H_2O_2 production rate in cultivar TVu 91. Also, a lower ratio of reduced to oxidized ascorbic acid in the AWF revealed that in Mn-sensitive leaf tissue, the apoplastic reduction capacity was lower than in Mn-tolerant leaf tissue when genotypes and leaves of different age were compared. We interpret our results as strong circumstantial evidence that Mn tolerance depends on the control of the free Mn^{2+} concentration and of Mn^{2+}-mediated oxidation/reduction reactions in the leaf apoplast.