

Apoplastic peroxidases and ascorbate are involved in manganese toxicity and tolerance of *Vigna unguiculata*

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Excessive manganese (Mn) supply induced the formation of brown spots on leaves as typical Mn toxicity symptoms in cowpea (*Vigna unguiculata* L. Walp.) grown in hydroponics. Differences in Mn resistance between cv. TVu 91 (Mn-sensitive) and cv. TVu 1987 (Mn-tolerant) expressed in the density of brown spots in older leaves were due to higher Mn tissue tolerance. Apoplastic water-soluble peroxidase (POD) in the apoplastic washing fluid (AWF) was enhanced by increasing Mn leaf content and generally significantly higher in leaves of cv. TVu 91 than in cv. TVu 1987. Electrophoresis of AWF revealed the presence of several water-soluble POD isoenzymes. At toxic Mn supply, the activities of these and additional

POD isoenzymes increased more in the Mn-sensitive cultivar. Levels of ascorbic acid in the apoplast and cytoplasm of the Mn-sensitive cv. TVu 91 decreased with increasing leaf Mn contents, whereas Mn-tolerant cv. TVu 1987 was not affected. Mn treatment led to a stimulation of the enzymes of the ascorbic acid regeneration system (monodehydroascorbic acid reductase and glutathione reductase) in both cultivars, but the activation of glutathione reductase was clearly more enhanced in the Mn-tolerant cultivar TVu 1987. The results provide circumstantial evidence that apoplastic ascorbate and peroxidases are involved in the expression of Mn toxicity and genotypic Mn tolerance.