R. A. Date et al. (eds.), Plant Soil Interactions at Low pH, 243–247, 1995.

Tolerance and avoidance of Al toxicity by *Mucuna pruriens* var. *utilis* at different levels of P supply

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Key words: acid-subsoils, aluminium, phosphorus, root growth, velvet bean

Abstract

Previous laboratory experiments showed that velvet bean *Mucuna pruriens* is moderately tolerant to the presence of Al (up to 185 μM) in the root environment, but that it only develops a shallow root system in acid soils. Field experiments showed that *Mucuna* can tolerate acid subsoil conditions in a homogeneous root environment, but avoids subsoil if topsoil is present. Subsequent split-root experiments with a recirculating nutrient solution showed that this subsoil avoidance may be based on an Al avoidance mechanism in the root system. This Al avoidance mechanism, however, was not evident when phosphorus (P) supply to the whole plant was adequate. We thus hypothesized that surface application of P may help to overcome Al avoidance in the subsoil.

In a field experiment on an ultisol in Lampung (Indonesia), only a moderate increase in aboveground biomass production was found for a wide range of P application rates, although the soil was low in available P, and the P adsorption isotherm was very steep. An increased P status of the topsoil and an increased P concentration in the aboveground biomass (from 50 to 75 mmol kg^{-1}) had no effect on root development in the subsoil.

Introduction

The most common upland soils in the humid tropics are acid and have a low phosphorus (P) status. These two problems for agricultural production are related, as P in the soil is strongly adsorbed to aluminium (Al) or iron (Fe) at low pH (Blamey and Edwards, 1989). Al toxicity in acid soils hampers root development of many crops, and thus reduces the ability of crop plants to acquire P from the (sub)soil (Edwards, 1991). Phosphorus may be precipitated as Al-PO_4 either on the root surface or in root cell walls (Barlett and Riego, 1972; Mc Cormick and Borden, 1974). Shortage of P depresses legume production and nitrogen (N) fixation and thus strongly affects N supply to food crops in the low-external-input agriculture that is common in the humid tropics. Deep-rooted crops are needed for efficient N uptake under high rainfall conditions (van Noordwijk et al., 1992).

The velvet bean, *Mucuna pruriens* var. *utilis*, is useful as a green manure, reducing the need for N fertilizer and controlling weeds such as *Imperata cylindrica* (alang-alang). *Mucuna* had a shallow root system in ultisols in Nigeria and Sumatera (Indonesia) (Hairiah and van Noordwijk, 1989). *Mucuna* was, however, moderately tolerant to the presence of Al in solution cultures at pH 4.2 (Hairiah et al., 1990). A (nominal) Al concentration of 110 μM even increased root fresh weight, while Al concentrations above 185 μM hampered root growth. In a field experiment on an ultisol in Lampung (Sumatera), a large root system was formed in the subsoil when *Mucuna* was sown directly into the subsoil, after removal of the top soil. P fertilization and higher liming rates placed in local pockets of soil had a positive effect on root length density (Hairiah et al., 1991a). The hypothesis that 'subsoil avoidance' of *Mucuna* roots in the presence of topsoil was based on 'Al avoidance', in combination with moderate Al tolerance in homogeneous media, was tested in a split-root experiment with recirculating nutrient solution (Hairiah et al., 1992). An Al concentration of 185 μM applied to both sides of a root system increased root dry weight and reduced shoot dry weight and shoot:root ratio compared to the control. Application of such Al containing solution to half of the root system led to a significant shift in root growth to the control side. The