ASPECTS OF THE Fe AND Mn NUTRITION OF RICE PLANTS

II. IRON AND MANGANESE UPTAKE BY RICE PLANTS, GROWN ON AEROBIC WATER CULTURES

by P. D. J. VAN DER VORM and A. VAN DIEST

Department of Soil Science and Plant Nutrition, Agricultural University, Wageningen, Netherlands

KEY WORDS
Chlorophyll content  Fe nutrition  Mn excess  Mn nutrition  N form  Oryza sativa  P nutrition  Rice  Si nutrition  Water culture

SUMMARY
In three water-culture experiments, the effects of variations in pH, N form, and Si- and P level on the uptake and translocation of Fe and Mn, and on the chlorophyll contents of lowland rice were examined.

It was found that Mn uptake increased with increasing pH, that it was not affected by variations in N form (NO₃ or NH₄), and that Si had a suppressive effect on Mn uptake. With increasing pH, the translocation of Fe to the shoots was reduced. This pH effect might be indirect, in that Fe translocation is hampered by excessive Mn uptake induced by high pH. Variations in N form and in Si level did not influence Fe uptake and -translocation.

A combination of high P- and high Mn levels in solution proved to reduce the translocation of Fe to the rice shoots. Precipitation of Mn phosphate on the roots is likely to occur at high concentrations of both Mn and P in the root medium.

A negative correlation was found between chlorophyll content and Mn content of the leaves. The chlorophyll content was not related to the iron content of the leaves. It is likely that chlorosis of rice leaves in an early growth stage can be caused by several combinations of the following factors: 1. high Mn supply, 2. NO₃ nutrition inducing an increase in solution pH favouring a further increase in Mn uptake, 3. absence of Si which exerts a suppressive effect on Mn uptake, and 4. high P supply. These factors can induce chlorosis, with and without exerting a concomitant influence on the uptake and translocation of Fe.

INTRODUCTION
For optimum production, the new high-yielding rice varieties require high levels of available nutrients in the soil. Such high levels may result from a naturally high level of soil fertility, or may be induced by high rates of fertilizer application. In practical rice culture, farmers usually restrict their fertilizer appli-
cations to the addition of macro-nutrients. The resulting yield increases, however, lead to higher demands being placed on the soil to supply the necessary quantities of secondary and minor nutrients.

Chimania et al.\textsuperscript{2} reported responses of rice to applications of manganese, copper and molybdenum under conditions of high levels of available nitrogen, phosphate, and potassium. In many locations, lowland rice is found to start suffering from Zn deficiency, when increased applications of macro-nutrients enable higher yields to be obtained.

In the present study, some aspects of the relationship between macro- and micro-nutrients in the nutrition of rice were investigated. Use was made of water cultures in which especially the influence of pH, N-form, Si, and P on the Fe- and Mn content of rice received attention.

During the growth of lowland rice, periods may occur in which the leaves display a light-green color, resembling the well-known symptoms of iron chlorosis in cereals. The symptoms do not persist, and may disappear after a few weeks. Also in water cultures this phenomenon is known, especially when rice is grown on nitrate-containing solutions having pH values higher than 6. Similar findings are obtained with other cereals, whereas dicotyledonous plants, when grown on identical solutions, do not show such symptoms.

Kashirad and Marschner\textsuperscript{7} observed a difference in the response of monocots and dicots to conditions of increasing Fe shortage. Dicots, which often absorb equivalent quantities of nutritive cations and anions\textsuperscript{3,4}, manage to reduce their uptake of anions, when Fe shortage is impending. The resulting decrease in pH of the root medium may promote the availability of iron. Monocots, which from a nitrate-containing medium absorb many more nutritive anions than cations, are probably unable to rearrange their uptake pattern to the extent that the pH of the root medium is lowered. Such a lowering can probably only be expected when, instead of NO\textsubscript{3}, NH\textsubscript{4} is the source of nitrogen. The NH\textsubscript{4}-fed cereals usually show a dark-green color of the leaves.

In the authors' laboratory it was found, in an experiment not described here, that a negative correlation existed between the Mn content of tops of young rice plants and the dry-matter production. The Mn content in the above-ground dry matter of those rice plants was in the order of magnitude of 1000–2000 ppm. The Fe contents varied between 100–260 ppm.

Gangwar\textsuperscript{5}, however, reported a positive correlation between Mn content of rice leaves and growth. This relationship became evident at the end of the growth period. It pointed out the necessity to include a time factor in investigations regarding the effect of Mn on the growth and nutrient contents of rice.

Vlamis and Williams\textsuperscript{10,11} reported an influence of Si on the uptake of Fe and