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Iron deficiency response in relation to iron uptake in two cultivars and a local strain of *Mentha arvensis* L.

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Abstract

The tolerance to iron-deficiency stress and the iron uptake were studied in two Japanese mint (*Mentha arvensis* L.) cultivars MAS1 and MS77 and their local strain MA2. A considerable reduction of pH of the nutrient medium in MAS1 and MS77 treatments associated with different degree of chlorosis was found. A rapid recovery from chlorosis was found only in MS77 and to some degree in MAS1, but not in the MA2. The results indicated that iron uptake and translocation were inversely related to iron stress tolerance.

Introduction

A continuous supply of Fe is needed for plant growth. Although the Fe content in the soil is usually high enough for plant nutrition, plant species and cultivars differ in the efficiency of Fe utilization (Brown 1978, Kannan 1982). The ability to extract the available Fe^{2+} ions from unavailable Fe^{3+} compounds in the soil by reducing pH and releasing root exudates is regarded as a criterion for identifying the "Fe-efficient" plants. The cultivars of several plant species such as sunflower, barley and maize (McDaniel and Brown 1982) have been investigated to distinguish efficient and inefficient genotypes. In contrast to inefficient genotypes, the efficient genotypes acidify the rhizosphere under Fe deficiency and help in reduction of Fe^{2+} to Fe^{3+} for uptake. Therefore, the genetic control of iron deficiency and iron deficiency chlorosis in various crop genotypes (Duke 1982, Fehr 1982) have been emphasized. The present report is aimed to screen the Fe-efficient cultivars of Japanese mint for mint growing areas. Furthermore, the relationship between Fe deficiency and Fe uptake has been examined.

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Material and methods

Two recently evolved cultivars and a local strain of Japanese mint (*Mentha arvensis* L.) were studied. The cultivar MS77 is a common non-flowering agronomically important strain with high menthol content, while MAS1 is a non-flowering strain with lower menthol content than MS77; MA2 is the flowering local strain relative to wild species with very low content of essential oil(s). Efficiency of genotypes was tested according to Brown and Jones (1976).

The experimental plants were grown under 11-h photoperiod (250 μmol m^{-2} s^{-1} PAR) and 25 ± 2 °C in full nutrient medium (*cf.* Steinberg 1953 for details) with micronutrients excepting Fe as in Hoagland and Arnon (1950). Fe-EDTA (ethylenediamine tetraacetic acid) was added to supply 0.05 mg cm^{-3} and the final pH was adjusted to 6.0. Fe-deficiency stress was induced by transferring plants to nutrient medium without Fe (pH 6.4) after 2 weeks of growth.

In another experiment, 2 weeks-old plants of MAS1, MS77 and MA2 were transferred in an aerated distilled water for 24 h and in 0.05 mM $CaSO_4$ for 48 h under 11-h photoperiod (250 μmol m^{-2} s^{-1}) and 22 ± 2 °C. After one day, the extra suckers of each plant were excised. The plants were grown 48 h in 0.05 mM $CaSO_4$ solution for treating them against wounding of roots and to maintain the root permeability properties prior to Fe uptake. The Fe uptake and translocation were measured over 3 h, using ^{59}Fe labelled 0.01 mM $FeSO_4$ or Fe EDDHA (ethylene diamine di-*O*-hydroxy-phenylacetic acid, specific activity 4.61 Bq μmol^{-1}). The pH of the experimental solutions was adjusted to 5.5. At the end of the uptake period the root were placed in chilled 0.05 mM EDDHA of pH 7.0 for 30 min to remove the exchangeable Fe from the free space.

The plant parts were radioassayed in a Liquid Scintillation Spectrometer *LKB Rack Beta 1215.*

Results

The pH was found to decrease in all the cultivars very slowly during the first 4 d, and more rapidly thereafter with exception of MA2. It is revealed that the MS77 decreased pH from 7.2 to 5.5 in 3 d, and MAS1 in 5 d, whereas MA2 did not decrease pH below 6.8 during 15 d of stress (Fig. 1).

Under Fe-deficiency stress, chlorosis began to appear in almost all the cultivars approximately from the 5-d, increased gradually day by day, and persisted in MAS1 and MA2, although to different degree. The cultivar MS77 partially recovered from chlorosis after 12 d, while the recovery was only partial in MA2 and MAS1. The complete greening of the leaves in MS77 were documented clearly after 15 d of stress (Fig. 1).

$FeSO_4$ labelled ^{59}Fe showed higher uptake and translocation in root and shoot than the Fe EDDHA in all the cultivars. The uptake, however, was much higher in MA2 and MAS1 than in MS77. After 3 h, Fe uptake from $FeSO_4$ was more than 1780 ± 21 nmol and 1660 ± 19 nmol in the roots of MA2 and MAS1, respectively (Fig. 2).

Translocation of Fe was 45 ± 0.5 nmol g^{-1} (fresh m.) of shoot of MA2 and 65 ± 3.2 nmol g^{-1} (fresh m.) in efficient MS77. Moreover, the pattern of Fe uptake in these two susceptible cultivars is nearly linear, while in MS77 it is biphasic.

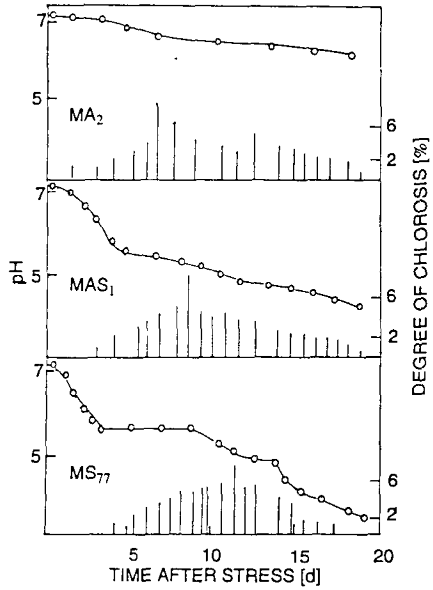

Fig. 1. Changes in the pH of the nutrient solution (*open circles*) and the degree of chlorosis (*vertical lines*) in the Japanese mint cultivars. *LSD* values at 5 % and 1 % levels are 0.46 and 0.62 (pH), 0.12 and 0.19 (chlorosis), respectively.

Discussion

Iron is available in an appreciable amount in soils, generally in an oxidized ferric form. It is largely required for the growth of all plants. However, these differ both in their requirements and in their ability to absorb it from the root medium. Plants which are "Fe-efficient" have a mechanism to convert it to ferrous form (Brown and Jones 1976). During the last two decades, studies have established that this type of mechanism exists in many plant species and this trait is, nevertheless, genetic (Duke 1982, Fehr 1982) Brown (1978) described the sequential chenges induced by Fe-efficient plants. Lowering pH of the medium with the onset of chlorosis is one of the events (Kannan 1981). In the present investigation, it was observed in the MS77 cultivar that the onset of recovery from the chlorosis, and the lowering of the pH are closely associated (Fig. 1). Such a correlation was not obtained in the local strain MA2 and the cultivar MAS1. Thus, it is clearly evident that MS77 is "Fe-efficient". However this trait does not seem to be inherited or at least not fully so, in the two cultivars. This points is very pertinent for the breeders to note and incorporate in their breeding researchers for getting Fe-efficient cultivars and genotypes.

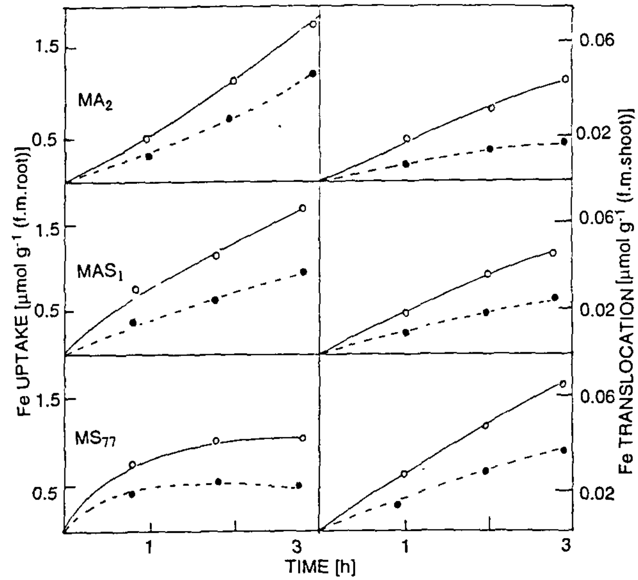

Fig. 2. Time course of Fe uptake and translocation from 0.01 mM $^{59}FeSO_4$ (*open circles*) or ^{59}Fe EDDHA (*closed circles*) by different cultivars of Japanese mint. *LSD* values at 5 % and 1 % levels are 0.18 and 0.21 (Fe uptake), 0.003 and 0.005 (Fe translocation), respectively.

Fe uptake showed a negative correlation with Fe stress tolerance. The most susceptible MA2 cultivar has shown more Fe uptake in root and less Fe translocation in the shoot, than the tolerant MS77. Therefore this point is more clear than Fe-tolerance and susceptibility are not dependent on the rate of uptake (Kannan 1985); in other words, it may be related to the Fe availability to the plant, following the Fe uptake and translocation of it to the leaves.

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