Title
Effect of low pH on Uptake of Inorganic Nitrogen by Different Plant Seedlings

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Introduction

Inorganic nitrogen uptake by plant roots was affected by many factors, such as plant species and varieties, medium pH, other nutrients' form and amount. Though medium becomes acidified for NH_4^+ uptake and alkalified for NO_3^- uptake (Mengel K, 2001; Liao H and Yan XL, 2003), soil pH changes little after application of nitrogen fertilizers for the strong buffering effect. pH in differrent soil types varied greatly, even reached 4 units in China soil (Chinese Soil Survey Office, 1998). Chemical nitrogen fertilizers used in China are predominantly urea, ammonium sulfate, and ammonium bicarbonate. After these NH_4^+-N fertilizers and amide N fertilizers enter soils, nitogen presents first in NH_4^+ form for the hydrolysis of fertilizers, and then transforms slowly to NO_3^- for nitrification under the good aeration conditon. High concentration of NH_4^+-N exists in acid soil for its low nitrification rate after nitrogen fertilizers are applied, while inorganic N exist mainly as NO_3^--N in neutral and alkali soil for fast nitrification (Mao ZY, 1997).

Though research of the relation between pH and N uptake is of great significance, reported experiments usually carried out only with single plant variety and neglected the difference between differrent plant species and varieties (Chen P, et al, 2003; Fan MS, et al, 2005; Kronzucker HJ et al, 1996; Ullrich WR, 1992). The aim of the present experiments was to study uptake rate of NH_4^+-N and NO_3^--N by seedlings of different varieties of rice, wheat and maize at low medium pH (4.0).

Materials and Methods

Rice (Yandao 8, Huaidao 8, Yangdao 4 and Yangdao 6), maize (Suyu19, Zhendan 958, Yedan13, Nongda108), wheat (Yannong19, Yangmai 11, Yangmai12) were selected as experimental materials. Plants were grown under the controlled environmental conditions in nutrient solution with 4.0 $mmol \cdot L^{-1}$ NH_4^+-N or NO_3^--N at pH 4.0 or 6.0. 2, 3 and 4-week-old seedlings were used to measure the uptake rate of NH_4^+-N and NO_3^--N. After 24h starvation, roots of 5maize seedlings, 10 wheat seedlings, 10 rice seedlings were separately immersed in 250mL, 100mL and 100mL absorption solution, containing $1mmol \cdot L^{-1}$ NO_3^--N or NH_4^+-N in $0.2mmol \cdot L^{-1} CaSO_4$, pH4.0 or 6.0. After 5h absorption, roots were weighted, and NO_3^--N and NH_4^+-N in absorption solutions were measured with ultraviolet spectrophotometer method and modified semi-micro Kjeldahl method. According the change of N content before and after absorption, fresh weight of roots and weight decrease of absorption solution, the uptake rate of NH_4^+-N and NO_3^--N were calculated.

Results

Effects of low pH on NO_3^--N uptake rate

Change of nitrate uptake rate with seedling ages were different among plant species. Maize and wheat showed an increasing tendency, while rice was contrary (Fig 1). Indica rice varieties (Yangdao 6 and Yangdao 4) had the superiority of nitrate uptake rate, compared with Japonica rice (Yandao 8 and Huaidao 8). At both pH levels, Yangdao 6 always showed higher nitrate uptake rate than Yangdao 4, which indicated that difference of nitrate uptake characteristic also existed among rice subspecies. Rice uptook nitrate more rapidly at pH4.0 than at pH6.0. It's commonly accepted that low pH faciliates nitrate uptake for cotransport of NO_3^- and H^+, but there were some exceptions. Except for 2-week-old Nongda108 and Yedan 13, maize seedlings uptook nitrate faster at pH 6.0 than at pH 4.0. Yangmai 12 presented different uptake characteristics from Yangmai 11 and Yannong 19, and also exibited faster uptake rate at pH 6.0 than at pH4.0.

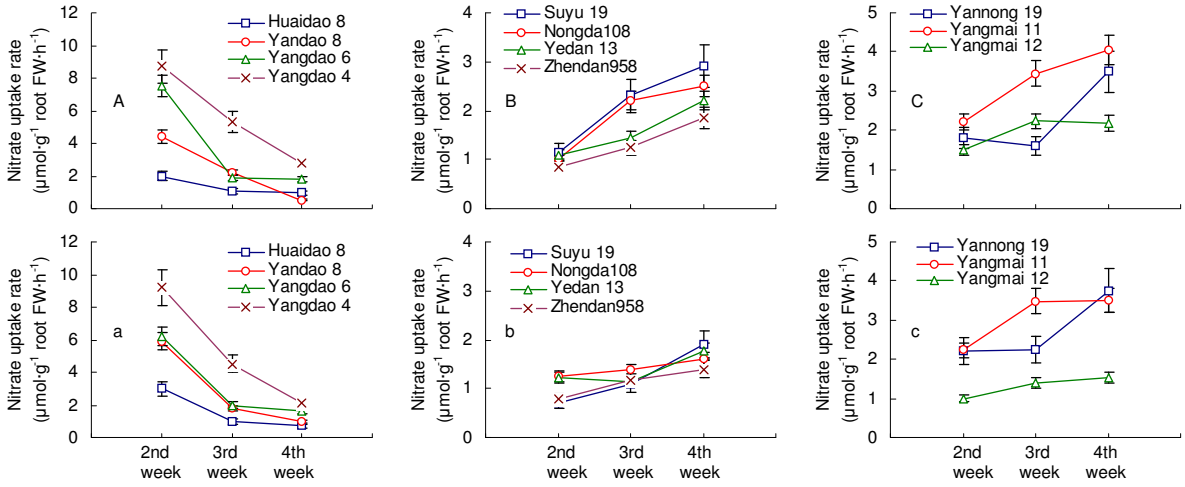

Fig 1. Nitrate uptake rates by roots of rice (A, a), maize (B, b) and wheat (C, c) at normal pH level (pH6.0, capital letters) and low pH level (pH4.0, small letters) .

Effects of low pH on NH_4^+-N uptake rate

Ammonium uptake rate of rice, maize and wheat increased with seedling ages. Difference of NH_4^+ uptake characteristics existed among plant varieties (Fig 2). 4-week-old indica rice (Yangdao 6 and Yangdao 4) uptook NH_4^+ significantly faster than Japonica rice (Yandao8 and Huaidao8). Yangmai 12 uptooke NH_4^+ obviously slower than other two wheat varieties. Moreover, the uptake differences at low pH level enlarged with the seedling ages. Majority varieties uptook NH_4^+ faster at pH6.0 than at pH4.0, but there were some exceptions (Fig 2). Yangmai12 and Nongda 108 uptook NH_4^+ irregularly rapid at low pH level, probably due to their strong tolerance to NH_4^+ toxicity and low pH stress. These experimental varieties had dark green leaves and strong stems, though roots short and thick, and showed no obvious NH_4^+ toxic symptoms at pH 4.0. Uptake rate of NH_4^+ by Suyu 19 and Zhendan 958 showed no significant difference at both pH levels.

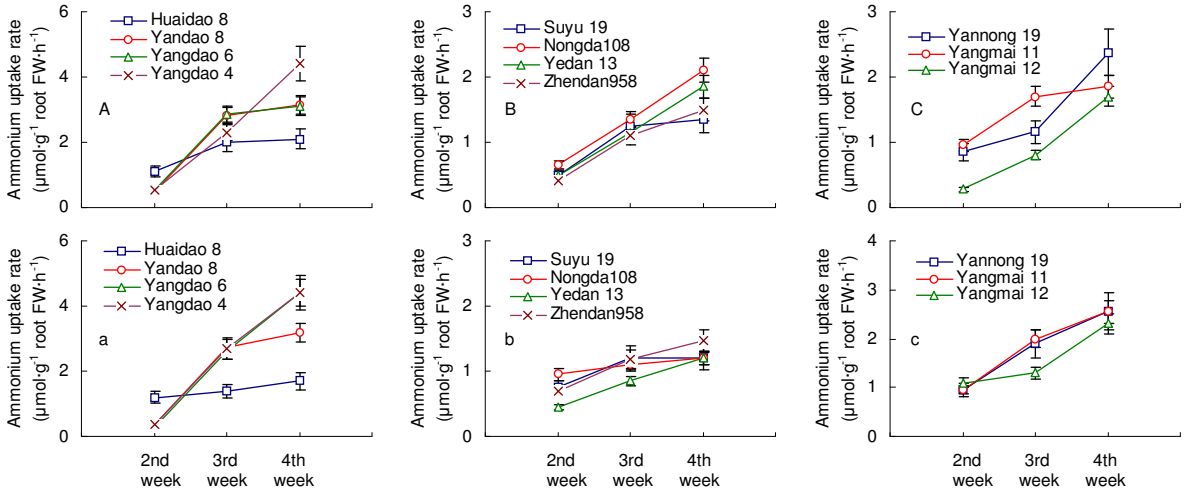

Fig 2. Ammonium uptake rates by roots of rice (A, a), maize (B, b) and wheat (C, c) at normal pH level (pH6.0, capital letters) and low pH level (pH4.0, small letters) .

Discussion

Nirate is commonly considered to cotransport with H^+ through membrane, and nitrate uptake by plants theorically causes increased pH in growth medium (Glass ADM, et al, 1992; McClure PR, et al, 1990). That is to say, low pH facilitats nitrate uptake. In this study, some exceptions ocurred, for example, Suyu 19, Zhendan958 and Yangmai12 (Fig 1). These exceptions probably caused from severe inhibition of H^+-ATPase activity in plasma membrane by too high content of medium H^+ (Costa MS and Meis L, 1996; Zhang FQ, et al, 2000), disequilibration of the stability and selective permeability of plasma membrane, and excessive outflux rate of nitrate (Matzke H and Mengek K, 1993).

Ammonium uptake by plants theorically causes decreased pH in growth medium (Kronzucker HJ et al, 1996; Ullrich WR, 1992), therefore low pH restains ammonium uptake. Low pH in medium inhibits cation uptake, for high content of H^+ reduced the activity of H^+-ATPase in plasma membrane (Yan F, et al, 1992). In this study, there were some exceptions, such as Huaidao 8, Nongda108 and Yangmai 12 (Fig 2). The exceptional varieties showed strong torlerance to ammnium toxity and low pH stress, for they exibited no obvious toxic symptoms at pH 4.0.

The effect of low pH on uptake rate of NH_4^+-N and NO_3^--N varied with plant species, varieties, and the difference increased with the growth age of seedlings. Roots of wheat and maize seedlings had increasing uptake rates of both nitrate and ammonium with the growth ages. The uptake rate of nitrate by rice roots decreased with the growth ages, while that of ammonium increased.The decreasing uptake rate of nitrate by rice seedlings probably caused by the reduction of plant growth rate (Feng K, et al, 2003).

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