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Correlation between specific fine root length and mycorrhizal colonization of maize in different soil types

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Abstract A pot experiment was conducted in a glasshouse to investigate the correlation between specific fine root length (SFRL) and root colonization (RC) of maize inoculated with six arbuscular mycorrhizal fungi (AMF) in three soil types. The results showed that six AMF associated with maize presented different abilities in RC and effects on SFRL. In addition, there was a significant correlation between SFRL and RC of arbuscular mycorrhizal maize in Beijing soil (Cinnamon soil), but no significant correlation in Hubei soil (Brunisolic soil) and Guangdong soil (Red soil). It is concluded that mycorrhizal colonization decreased the SFRL of maize, and the correlation between SFRL and RC of mycorrhizal maize depended on soil type.

Keywords specific fine root length, root colonization, correlation, soil type

1 Introduction

Root systems of crops are the organs which absorb nutrients and water from the soil, and root system effectiveness in taking up water and nutrients depends on the way carbon is invested in the fine roots (Comas et al., 2002). Fine roots (diameter ≤ 2 mm) are the major part of the root system involved in absorbing water and nutrients, and play an important role in the nutrient cycling and energy flow of terrestrial ecosystems (Shi et al., 2007). As an indicator of the root architecture, specific root length (especially specific fine root length, SFRL) is influenced by the diameter and density of the tissue, which reflects the potential for the acquisition of resources from the soil

(Hodge, 2004; Wright and Westoby, 1999).

Symbiosis with arbuscular mycorrhizal fungi (AMF) could increase a root's uptake area (Marschner, 1998) through extended extraradical hyphae across the nutrient depletion zone of roots (Li et al., 1991). Also, AM associations could modify root architecture and morphology, but reports have been inconsistent as to the kind of modifications (Barker et al., 1998; Smilauerova and Smilauer, 2002). It is well acknowledged that plant species with shorter root length (Ryser and Lambers, 1995) and fine roots with greater diameter (Hetrick et al., 1992) benefit more from symbiosis with AMF than those with longer root length and smaller root diameter (Zangaro et al., 2007). Zangaro et al. (2007) found that mycorrhizal root colonization correlated negatively to fine-root diameter in fertile and infertile soils. Nevertheless, up to this date, there are few data about the intraspecific effects of AMF on root morphology, especially on SFRL.

Soil physiochemical properties and soil texture are important factors that influence root morphology (Fitter et al., 1998; Bloom et al., 2003; West et al., 2004). Simultaneously, the above soil factors also markedly regulate the formation of arbuscular mycorrhizas (Clark and Zeto, 1996; Schroeder and Janos, 2005). However, no report has yet been published dealing with the effects of inoculating different AMF species on SFRL of plants and the latter's correlation to the RC in different soils. In the present study, a pot experiment was conducted to investigate (1) the effects of different AMF inoculations on the SFRL of maize, and (2) the correlation between SFRL and RC of mycorrhizal maize in three soil types.

2 Materials and methods

2.1 Soils, AMF and host plants

The three soils (Cinnamon soil, Brunisolic soil and Red soil) and host plants used in the experiment were the same as those reported by Liu (2008). In this study, two other

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AMFs (Table 1), BEG150 and BEG141, were used besides the four fungi tested by Liu (2008).

Table 1 Information about AMF used in the experiment

BEG number	isolated region	species	soil pH of isolated site	isolated agency
BEG141	France	<i>G. intraradices</i>	7.6	–
BEG150	Guangdong	<i>G. claroideum/luteum</i>	3.9	Hong Kong Polytechnic Univ.

Note: BEG represents registered numbers in European Bank of *Glomales*

2.2 Experimental design and determination

The experimental design used and the determination method of root colonization of maize were the same as those described by Liu (2008). After harvest, all fine roots (diameter ≤ 2 mm) were separated from the root systems, cleaned and cut into 1 cm root segments for RC and SFRL determination. After the sub-sample was tested for RC, another 1 g of root segments were sampled for determination of SFRL using the gridline intersect method (Newman, 1966). The root segments were then collected, dried in an oven at 70°C for 48 h, and weighed to calculate the specific fine root length. SFRL was calculated as sample total root length divided by sample dry weight.

3 Results

3.1 RC

BEG141 and BEG150 colonized the fine roots of maize in three soils (Table 2). For BEG141, the root colonization decreased gradually, ranging from 44.0% in Beijing soil, to 30.8% in Hubei soil and 21.2% in Guangdong soil. However, the root colonization of BEG150 was below 9% in all soils, which was somewhat different from the situation of BEG151. Relatively low root colonization of the tested AMF appeared in Guangdong soil.

Table 2 RC of mycorrhizal maize in three soils (%)

isolate	Beijing soil	Hubei soil	Guangdong soil
BEG141	44.0b	30.8ab	21.2a
BEG150	6.8d	7.8c	8.6d
BEG151	34.6c	27.6ab	19.7ab
BEG167	55.6a	25.8b	15.7bc
BEG168	33.0c	24.1b	20.8a
BEG221	31.6c	36.5a	12.5cd

Note: In the same column, values followed by different letters indicate significant differences at 5% level.

3.2 SFRL

Six fungi showed different effects on the SFRL of mycorrhizal maize, which ranged from 45.3 $\text{m} \cdot \text{g}^{-1}$ to 179.3 $\text{m} \cdot \text{g}^{-1}$. Among

the six fungi, the SFRLs of maize colonized by BEG150 and BEG151 were the highest in the three soils (Table 3). Apparently, the SFRLs of maize colonized by six fungi were higher in Guangdong soil than in the other two soils.

Table 3 SFRL of mycorrhizal maize on three soils ($\text{m} \cdot \text{g}^{-1}$ DW)

isolate	Beijing soil	Hubei soil	Guangdong soil
BEG141	45.3d	86.6bc	112.2bc
BEG150	176.2a	126.9a	179.3a
BEG151	93.0b	129.5a	178.8a
BEG167	46.3d	64.6c	103.0c
BEG168	68.3c	107.4ab	125.7bc
BEG221	79.5bc	91.7bc	135.4b

Note: In the same column, values followed by different letters indicate significant differences at 5% level. DW = dry weight.

3.3 Correlation between SFRL and RC

By correlation analysis, it was found that there was a significant correlation between the SFRL of mycorrhizal maize and the corresponding RC of the tested AMF in Beijing soil, but no significant correlation was found in Hubei soil and Guangdong soil (Table 4). Correlation coefficients decreased gradually from Beijing soil to Hubei soil and to Guangdong soil.

Table 4 Correlations between SFRL and root colonization of mycorrhizal maize on three soils ($n = 6$)

SFRL	RC		
	Beijing soil	Hubei soil	Guangdong soil
Beijing soil	0.936**	–	–
Hubei soil	–	0.49	–
Guangdong soil	–	–	0.40

Note: ** indicates significantly correlated at 1% level.

4 Discussion

The present study demonstrated that AMF colonized maize root differently depending on fungal species and soils (Liu, 2008). Apparently, they colonized relatively heavily in Beijing soil compared to their colonization in Hubei soil and Guangdong soil, which may be attributed to changes in soil physiochemical properties such as pH and phosphorus content. Previous reports have suggested that soil pH and phosphorus content are two important factors that influence the degree of colonization of AMF, and the properties of low pH and high phosphorus content could inhibit root colonization by AMF (Clark and Zeto, 1996; Schroeder and Janos, 2005).

In addition, the present results showed that SFRL correlated with root colonization of mycorrhizal maize significantly in Beijing soil, but did not do so in Hubei soil and Guangdong soil. In terms of carbon economy of host

plants, in soils with low pH and high phosphorus content (e.g. Guangdong soil), AMF tended to be at a low colonization rate and in low nutrient contribution soil. Thus, host plants may invest more carbon for root development rather than for AMF. On the contrary, heavy colonization and reduced SFRL will happen in high pH and low phosphorus soil, such as Beijing soil. Balancing the carbon allocation between plant and symbiotic fungi is a biological strategy to maximize the benefits and minimize the damage caused by adversely edaphic conditions. Here, we propose that low colonization due to soil physiochemical properties would reduce the effects of AMF on root morphology. Therefore, SFRL, as an indicator of the root architecture, could be influenced by both the physiochemical properties of soil and symbiotic microorganisms such as AMF. We suggest, therefore, that SFRL may be an indicator for manifesting the symbiotic degree of AMF in soil with low phosphorus and high pH. However, there is still a need for more investigation to understand the correlations of specific fine root length and root colonization rates in soils with the characteristics of low phosphorus and high pH.

Meanwhile, fine roots are the sole crop organs for colonization by AMF in eco-systems. Therefore, the distribution, biomass, diameter and length of fine roots will determine the absorbing capacity and symbiotic potential of crops. Generally, AMF will strengthen the absorption function of root systems by partial substitution of the outspread fungal hyphae. Carbon economy and maximal uptake capacity of root systems are the strategies of mycorrhizal plants. Previous data showed that AMF altered root morphology primarily when phosphorus was limited (Berta et al., 1993), but the ways in which the root morphology changed were not consistent. Mycorrhiza effects on root morphology were commonly attributed to improvement in phosphorus uptake by AMF, but AMF effects on hormone production may also be responsible (Berta et al., 1993). Plants tended to allocate more carbon to fine roots to enlarge the absorbing area, which could be further increased by improving SFRL (Comas et al., 2002). The interactions between AMF, root morphology and soil type as well as physiochemical properties need to be further studied. It is concluded that the correlation between SFRL and RC of mycorrhizal maize depends on soil types.

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