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Mechanisms of phosphorus efficiency in maize

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Abstract

The National Maize and Sorghum Research Center of the Brazilian Agricultural Research Corporation, has been working for the past two decades to increase plant adaptation to low P levels in acid soils. We have studied several mechanisms in order to clarify the differences between genotypes in relation to phosphorus efficiency using maize standards for phosphorus efficiency developed at Embrapa Maize and Sorghum.

Twelve maize hybrids were evaluated in four P concentrations in nutrient solution. A significant difference among hybrids in P-efficiency was observed, however these differences were closely related to the P contents in the seed rather than the genotypic variability. It is suggested that more efficient plants should be selected under field conditions.

The characterization of the root system of eight genotypes contrasting in P efficiency was studied. P omission in nutrient solution for six days increased the root length in three P efficient genotypes. The increase of root length was 112% for the BRS 3060, and 61% and 55% respectively for the BR 201 and HS 20x723. In the P inefficient genotypes, there was no significant modification in this characteristic.

We used the same genotypes to study the kinetics of P absorption. P omission in nutrient solution increased the maximum influx for P absorption (Imax) in six genotypes after three days of P omission and in five genotypes after six days of P omission. However, there was not correlation between P efficiency and increase in Imax.

Introduction

The National Maize and Sorghum Research Center of the Brazilian Agricultural Research Corporation, Embrapa, has been working for the past two decades to increase plant adaptation to low P levels in acid soils.

Various morphological, physiological and biochemical traits have been indicated to clarify the differences between genotypes in relation to phosphorus efficiency (Marschener, 1998). Analysis of phosphorus absorption characteristics in several crops suggest that P uptake efficiency depends on such traits as root-length density and architecture, root-hair length, mycorrhizae infection, root-induced changes of the rhizosphere through exudates as well as high values of Imax and low values of Km.

We have studied some of these traits using maize genotypes developed at Embrapa Maize and Sorghum for phosphorus efficiency.

Materials and methods

In order to better understand some of the processes involved in the screening for P efficiency in nutrient solution, nine hybrids from the Embrapa Maize and Sorghum breeding program and three commercial hybrids were grown in Steinberg's nutrient solution modified by Foy *et al*. (1967), pH 5.5 in four P concentrations (0.3; 0.9; 2.7 and 5.4 $mg.L^{-1}$) for 20 days after transplanting. The P content in the seeds, shoots and roots and the dry weight of shoot and roots were determined.

To study the effect of P stress in the morphological and physiological root characteristics, two experiments were performed with eight maize genotypes, previously characterized in field conditions (four P inefficient maize hybrids - HS 64x20, HS 20x22, HS 64x724, HS 22x16 and four P efficient maize hybrids - BRS 3060, HS 723x36, BR 201, HS 20x723).

In the first experiment, in green house, after the germination, the seedlings were transferred to 9 L pots with Steinberg nutrient solution, ajusted to pH 5.5. Seven days after transplanting the P was removed in half of the pots. Root length was determined after three, six and nine days of P omission by using SIARCS software (Bassoi *et al.*, 1994).

In the second experiment, in growth chamber, after three and six days of P omission, the kinetics of P absorption was determined. Before starting the kinetics studies, the plants were transferred to a solution containing 15 μM of P and 50 μM of Ca for 90 minutes, for stabilization, and then transferred to the kinetics solution, identical to the stabilizing solution. A 10 ml aliquots were taken at 30 minute intervals for eight hours. The aliquots were frozen immediately after sampling and stored for P analysis. The pots were weighed at the beginning and at the end of the kinetics period to determine the amount of solution lost by evapotranspiration.

Results

It was found a positive and significant correlation between the seed P level and the total dry matter and the shoot dry matter, at the 0.3, 0.9 and 2.7 mg L^{-1} P levels (Table 1). This may be explained by the P provided by the seeds, which accounted (average of 12 hybrids) for 74%, 48% and 24%,respectively, of the P supplied by the P treatments. It was observed a significant variation of the

total P between the hybrids, in the first seven days prior to the treatments.

Table 1. Correlation coefficients between the seed P level and the total dry matter and shoot dry matter, in four P concentrations.

P levels	Correlation Coefficient	
mg L^{-1}	Total Dry Matter	Shoot Dry Mattes
0.3	0.825 **	0.832 **
0.9	0.712 **	0.631 *
2.7	0.691 ***	0.622 *
5.4	0.062 ns	-0.043 ns

ns = non significant
**, * significant diferences at the 1% and 5%, by Tukey's test

The best treatment to evaluate changes in total root length under P stress was that of six days of P omission. This treatment increased significantly the root length of three of the P efficient genotypes (Figure 1). It was observed, under P stress, a significant increases in root length of the P efficient hybrids, triplecross BRS 3060 (112%), doublecross BR 201 (61%) and singlecross HS 20x723 (55%), contrasting with the P inefficient genotypes, where no significant increase was observed.

These results indicate that increase in root length under P stress may be one of the possible mechanisms of P efficiency in maize.

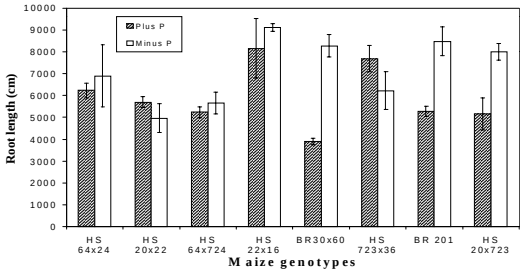

Figure 1. Root length in four P inefficient maize hybrids (HS 64x20, HS 20x22, HS 64x724, HS 22x16) and in four P efficient maize hybrids (BRS 3060, HS 723x36, BR 201, HS 20x723), after six days of P omission in nutrient solution

The omission of P in nutrient solution significantly increased the maximum rate of P absorption (Imax) of six genotypes after three days of omission (Figure 2) and in five genotypes after six days of omission. However, there was no correlation between P efficiency and increase in Imax, in both, efficient and inefficient genotypes had an increase in Imax with P omission. The Km was not affected by P omission in nutrient solution, in both periods studied.

Discussion

A significant difference among hybrids for P efficiency utilization was observed. However, these differences were basically due to the P concentration in the seeds rather than the genotypic variability of the materials. In the literature, previous studies showed that the seed vigour, the seed size and the seed P content affected more the relative growth rate of the plants, in soils with low P levels, up to three or four weeks growth than the morphological or physiological differences in the P absorption capacity. It was observed that the remaining seeds, when removed from the seedlings, did not overcome the seed effect. Thus suggesting that more efficient plant should be selected in field conditions, where a mature plant can better characterize the nutrient efficiency.

The P absorption by the roots is a result of the interaction between morphological and physiological roots characteristics, of the adjacent root rhizosphere and of soils traits that determine the flux of nutrients to the soil – root interface. When the access of the roots to the nutrients is a limiting factor, the morphological characteristics can be critical and the efficiency of the physiological mechanism of absorption could be secondary. However, when the ion access to the root surface is not a limiting factor, the physiological traits could be decisive.

The results show that the adaptation of maize genotypes to low levels of soil P is closely related to a better developed root system. Internal cycling of P may be also involved.

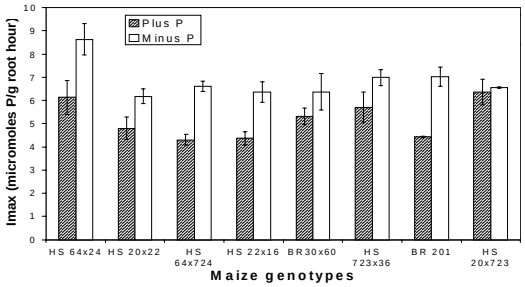

Figure 2. Maximum rate of P absorption (Imax) in four P inefficient maize hybrids (HS 64x20, HS 20x22, HS 64x724, HS 22x16) and in four P efficient maize hybrids (BRS 3060, HS 723x36, BR 201, HS 20x723), after three days of P omission in nutrient solution

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