JOURNAL OF PURE AND APPLIED MICROBIOLOGY, Nov. 2013. Vol. 7(Spl. Edn.), p. 801-804

A Study on The Potential of Phosphorus Uptake by Different Maize Varieties Under Low Phosphorus Stress

Liu Qinghua and Zhang Lei*

College of Resource and Environment, Qingdao Agricultural University, Changcheng Road 700, Qingdao, P. R. China.

(Received: 27 September 2013; accepted: 04 November 2013)

A solution culture experiment was conducted to study the tolerance and phosphorus uptake efficiency of different maize genotypes (Jidan 180, Simi 25, Benyu 9) at seedling stage under the condition of phosphorus (P) deficiency. Results showed that the biological indicators of dry matter weight, root length, root density, root radius, total root absorption area, active absorption area of all the genotypes were reduced under the stress of P deficiency. However, compared with other genotypes, Jidan 180 was less affected. At P deficiency, the K_m and C_{min} of Jidan 180 decreased significantly, I_{max} increased significantly. It indicated that Jidan 180 had the higher P affinity and tolerance to P dificiency, whereas Benyu 9 had lower P affinity and weak tolerance to low P condition.

Key words: maize, phosphorus deficiency, biological traits, phosphorus uptake potential.

Phosphorus (P), an important functional material in plants, is the important component forming nucleic acids, ATP and phospholipids, playing crucial regulatory role in crop growth and development. However, low available P in soil is widespread in agricultural field in China, with approximately two thirds of serious soil P deficiency[1]. Due to formation of non-soluble phosphate by combining with cations in soil such as Ca^{2+}, Fe^{3+}, Fe^{2+} and Al^{3+}, more than 95 percent of the P is in existence in soil as non-available form. Thus it is difficult for P to be absorbed by plant. Only 5 to 25 percent of P applied to soil could be utilized by fellowing crops[2]. Phosphate rock resource is not abundant in China and the agricultural P remains largely dependent on imports. However phosphate resource shortage is a global problem[3]. High input to P fertilizer can cause resource depletion, economic benefit decline and environmental pollution aggravation[4]. Therefore, lack of phosphorus has become one of the limiting factors in crop yield[5].

How to improve the effectiveness of phosphate fertilizer has been concerned by many scholars at home and abroad. The mixed application of phosphate fertilizer with VA bacterial manure, phosphate fertilizer with low molecule weight organic acid salts fertilizer, such as oxalic acid and formic acid, all could improve the utilization rate of P. Furthermore, the combined application of organic and chemical phosphate fertilizer could improve the effectiveness of accumulative P in soil[6]. Diammonium phosphate coated by resin material could delay the release of P nutrient and reduce the fixation of soil to P. Previous studies focused on reducing P fixing to raise the utilization ration of phosphate fertilizer. However, P activation and absorption capacity by using crops themselves to improve the utilization ration of phosphate fertilizer

* To whom all correspondence should be addressed.
Tel: +86 532 8803 0461; Fax: +86 532 8803 0461;
E-mail: zhanglei_lw@163.com

was rarely reported. P absorption potential of the different varieties of maize studied in this article from plant root morphology and P uptake kinetics parameters by hydroponic experiment provides the theory basis for the breeding of P efficient maize varieties.

MATERIALS AND METHODS

Solution culture

Three varieties of maize, Jidan 180, Simi 25 and Benyu 9 were used in this experiment. Seeds before germination were suffered to flotation using tap water to remove the flat seeds. Uniform seeds were soaked with 2% NaC1 solution for 10 minutes, washed with water and moved to high temperature sterilization in quartz sand soaked with $CaSO_4$ saturated solution. After sprouting at 25 ! for 3 days, 5 seedlings as uniform were transplanted into a 0.78 L bottle with different phosphorus nutrition solution.

In this experiment, there were two P treatments: without P (P, 0) and adding P (+P, 0.25mmol/L)0Nutrient solution composition was (mol/L) K_2SO_4 (0.75×10^{-3}), $MgSO_4$ (0.65×10^{-3}), KCl (0.1×10^{-3}), $Ca(NO_3)_2$ (2.0×10^{-3}), H_3BO_3 (1×10^{-3}), $MnSO_4$ (1.0×10^{-6}), $CuSO_4$ (1×10^{-7}), $ZnSO_4$ (1×10^{-6}), $(NH_4)_6Mo_7O_{24}$ (5×10^{-9}), Fe-EDTA (1×10^{-4}). Nutrient solution was replaced during the training, the first weeks every four days, the second week every three day, the third week every two day. Artificial conditions of the growth of plant. Day/night temperature was 23°C and 21.5°C, the light was 5000 lx, illumination time was 14 h per day, with ventilation for 5 minutes every 0.5 hour. Each treatment was repeated 5 times, and the indicators were determined after 30 days cultivation.

Analysis of soil samples

Dry matter weight of maize was measured with weighing after drying, and root volume with drainage method, root length with grid crossover method. Total absorption area and active absorption area of root were determined with the adsorption of methylene blue method[7]. Plant phosphorus uptake was analyzed with a H_2O_2 - H_2SO_4 heating digestion[8]. The root system to absorb the kinetic parameters of H_2PO_4 was determined with ion depletion technique[9].

P into the root of net flow expressed by the following formula:

I_n as the Net absorption rate of phosphorus, I_{max} as maximum rate of root absorption of P, K_m as the michaelis constant.

Results and analysis

The biomass of maize influenced by phosphorus levels

Under the condition of P deficiency, the higher plant relative production per unit quantity of phosphorus is, the higher efficiency of phosphorus nutrition will be [10]. Table 1 illustrates that at P deficiency, the relative yield of maize Simi 25, Jidan 180 and Benyu 9 were respectively 83.64%, 84.57% and 81.39%, with the relative production of Jidan 180 being higher than those of Simi 25 and Benyu 9. Under the condition of P deficiency, Jidan 180 could have preferable economic output. Absolute increment analysis also showed that Jidan 180 growth rate was higher than that of Simi 25 and Benyu 9, with no significant difference between the groups.

Table 2 illustrates that the difference of root length, root density in maize Simi25, Jidan 180 and Benyu 9 was obvious, with the total root length Jidan 180, Simi 25, Benyu 9 being 501.1 cm, 474.6 cm, and 416.7 cm, respectively. The root density of maize Jidan 180 was greater than those in the other varieties. Under the condition of phosphorus deficiency stress, the ability to adapt of the root in Jidan 180 was better than those in the other two genotypes.

Phosphorus deficiency stress effect the root-shoot ratio of different genotype maize. Plants under the condition of phosphorus deficiency has strong ability of self adjusting, controlling photosynthesis product transferring more to root system, to ensure the root system growth. At P deficiency, the root-shoot ratio of different genotype maize is higher than that at P enough. The root-shoot ratio of Jidan 180 was greater than Simi 25 and Benyu9.

The total root absorption area and active absorption area of different genotypes maize were shown in table 3. The total absorption area and active absorption area of (+P) treatment were higher than (P0) treatment. The ratio of active absorption surface to total absorption area in P deficiency was higher than in P enough. The results showed that at P deficiency, Jidan 180 was the strongest adaptive ability and the Benyu 9 was weaker.

Effect of P level on the distribution of P in maize plant

The phosphorus uptake of different genotypes maize at P enough was higher than that at P deficiency (Fig. 1). The order of phosphorus amount absorbed by the different genotypes was Simi25 (0.222%) > Benyu 9 (0.220%) > Jidan 180 (0.211%). It indicated that when phosphorus nutrition enough, Jidan 180 had low phosphorus content, whereas had higher dry matter of unit quantity of phosphorus. Jidan 180 was higher in phosphorus efficiency than other genotypes. At P

Table 1. Effect of P level on maize growth of different genotypes maize

Treatment	Simi 25		Jidan180		Benyu9	
	+P	P0	+P	P0	+P	P0
Dry matter weight(g/5plant)	1.65 (100%)	1.38 (83.64%)	1.88 (100%)	1.59 (84.57%)	1.47 (100%)	1.21 (81.39%)
Root/Cap	0.364	0.440	0.390	0.442	0.370	0.424

Footnote: Number in brackets is the relative yield rate.

Table 2. Effect of P level on length, density and radius of root in maize of different genotypes

Treatment	Simi 25		Jidan180		Benyu9	
	+P	P0	+P	P0	+P	P0
Root length (cm/5plant)	533.5	474.6	585.3	501.1	521.7	416.7
Root density (cm/cm3. 5plant)	0.68	0.61	0.79	0.64	0.67	0.53
Root radius (mm/5plant)	0.69	0.54	0.73	0.57	0.67	0.49

Table 3. Effect of P level on the absorbent surface area of root in maize of different genotypes

Treatment	Simi 25		Jidan180		Benyu9	
	+P	P0	+P	P0	+P	P0
Total surface area (m^2/5plant)	3.03	2.65	2.85	2.52	2.57	2.37
Active surface area (m2/5plant)	0.65	0.580	0.600	0.56	0.51	0.43
Active surface area /Total surface area	0.214	0.219	0.211	0.222	0.198	0.181

Table 4. Kinetic parameter of P uptake by different genotypes of maize root

Treatment	Simi 25		Jidan180		Benyu9	
	+P	P0	+P	P0	+P	P0
Km(μmol/L)	8.961	8.031	8.691	7.691	9.224	8.463
Imax [μmol/(cm.min)]$\times 10^{-5}$	6.004	7.123	4.395	6.964	4.799	6.256
Cmin(μmol/L)	0.965	0.754	0.815	0.577	1.029	0.771

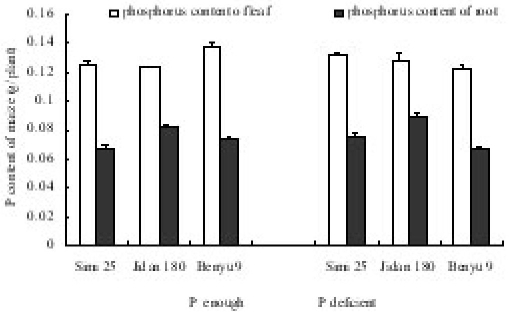

Fig. 1. Effect of P level on the distribution of P in maize

deficiency, the order of phosphorus amount absorbed by the different genotypes was Jidan180 (0.197%) > Simi 25 (0.195%)> Benyu 9 (0.190%), and the same order of dry matter of unit quantity of phosphorus was found. It indicated at p deficiency, Jidan 180 has the higher absorptive P capacity and the P efficiency.

Kinetic parameter of P uptake by different maize genotypes

$1/K_m$ absorption system of affinity, in this experiment showed that the affinity of root of P. Results showed that at P deficiency, K_m and C_{min} of Jidan 180 were 7.691¼Àmol/L and 0.5768 ¼Àmol/L respectively (Table 4). I_{max} was the maximum absorption rate. Generally, the plant genotype with P-efficient has the characteristics of higher I_{max} value. At P deficiency, I_{max} value was different among different genotypes. The I_{max} of Simi 25 was greater than that of Jidan 180 and Benyu 9. The result showed that Jidan 180 root system had the high affinity to phosphorus.

CONCLUSION

The maize growth of three genotypes at P enough was better than that of P deficient treatment, in biological index such as growth quantit, root length, root volume, root density and root surface area and so on. With the comprehensive comparison, Jidan 180 has the higher adaptive capacity than Simi 25 and Benyu 9 under the condition of lack phosphorus.

At P deficient treatment, the K_m and C_{min} of Jidan 180 was lower that of Simi 25 and Benyu 9. The l/K_m of Jidan180 is higher than that of simi 25 and benyu 9.The K_m and C_{min} of the regenotypes of maize increased with the increase of P level. I_{max} of Jidan 180 maize increased significantly. The result shows that Jidan 180 root system has the high affinity to phosphorus.

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