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The effect of NO_3 or NH4 nutrition on the utilization of Syrian rock phosphate by Chicpea and Maize plants

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❒ Abstract ❒

A sand-pot experiment was carried out to investigate P-utilization efficiency from rock phosphate by chickpea and maize plants. Pots were watered frequently with either +/- P-nutrient solutions containing NO_3 or NH4-N according to treatment. Plants were harvested after /49/ days, dry weights of shoots and roots were recorded, Phosphorus and nitrogen were determined in the shoots tissues and the percent utilization efficiency of phosphorus was calculated.

Chickpea plants were able to extract sufficient quantities of P from RP and consequently, the growth of plants was not affected when compared to +P plants. For Maize plants, although they were able to solubilize some phosphate, it was not enough to maintain constant growth and plants developed symptoms of phosphorus deficiency.

The form in which nitrogen was supplied had no effect neither on growth nor on P uptake by chickpea plants under any form of P nutrition. In the case of maize, NO_3-N fed plants grew better under all forms of P nutrition than those supplied with NH4-N.

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أثر التغذية النتراتية والأمونياكية على تحسين الاستفادة من الصخور الفوسفاتية السورية من قبل نباتات الحمص والذرة

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□ ملخص □

أجريت تجربة أصص (باستخدام الرمل) لدراسة كفاءة استخدام الفوسفور من الصخور الفوسفاتية من قبل نباتات الحمص والذرة. رويت الأصص باستمرار بمحلول غذائي نتراتي أو أمونياكي بوجود الفوسفور أو عدمه وذلك حسب المعاملات. حصدت النباتات بعد [49] يوماً من الزراعة وسجلت الأوزان الجافة لكل من المجموعين الخضري والجذري. كما قدر كل من الفوسفور والآزوت في الأنسجة الورقية وحسب معدلات الاستفادة من الصخور الفوسفاتية.

لقد كانت نباتات الحمص قادرة على استخلاص كمية كافية من الفوسفور فنمت بشكل جيد. أما نباتات الذرة، وعلى الرغم من أنها أذابت بعض الفوسفور، لكنه لم يمكن كافياً لنموها بشكل طبيعي وظهرت على مجموعها الخضري علائم لنقص الفوسفور.

لم يكن للشكل الآزوتي المقدم تأثير على النمو أو امتصاص الفوسفور من قبل نباتات الحمص، بينما بالنسبة لنباتات الذرة فقد تميزت نباتات المعاملات النتراتية بنمو أفضل بالمقارنة مع نباتات المعاملات الأمونياكية.

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Introduction

Rock phosphate of Gloconic type is exposed to surface in four different locations in the coastal mountains of Syria. The estimated quantity of rock phosphate (18%P_2O_5) available from one location (Ain Lyloon) is about /10.5/ million ton. Most of the exploited RP in Syria is used for exportation or/and production of Triple Super phosphate (TSP).

Although direct application of RP is mainly recommended for acid soils [1,2], there is a growing interest in Syria, where soils are dominantly calcareous, to investigate the possible use of RP directly as a fertilizer. The reported beneficial effects of applied RP are so far not of great importance neither for plant growth nor for yield production[3].

Solubilization and consequent mobilization of P from RP in soil by different crops involve factors such as chemical, microbial and plant induced changes in the rhizosphere[3,4] which, however, differ greatly according to plant species.

The form in which nitrogen is supplied to plants has a characteristic effect on rhizosphere pH and consequently on mineral composition of plants[5,6]. When NO_3-N is supplied to plants, uptake of anion exceeds cation and the pH of the rhizosphere increases[5,6,7]. With NH4-N nutrition cation uptake exceeds anion uptake and there is a net release of H^+ into the growth medium and the pH of the rhizosphere decreases[5,6,7].

This normal pattern of behaviour can be disturbed when plants suffer from shortage of phosphorus nutrition. It has been reported that NH4-N fed plants under P-stress condition, responded by releasing the H^+ or/and organic acids which could possibly be a mechanism by which phosphate is solubilized in the rhizosphere.

In this paper, results are reported for chickpea and maize plants grown in sand culture with different sources of P and nitrogen nutrition. The aim of this study is to relate the effect of nitrogen fertilization on the efficient use of phosphorus from RP by two crops representing legumes and cereals. Data are presented according to plant species.

Materials and methods

* Growth media:

Sea sand (particle size < 1mm) was collected from Lattakia beaches. The sand was washed thoroughly with water to remove salt residues and contaminating dust. The sand was then air-dried and stored in bags until use.

A batch of sand /35.2/kg was mixed with /3.2/kg of rock phosphate (friable type, collected from Ain Lyloon in the coastal area of Syria). The mixture was delevered into /16/ pots, so each pot contained /2.4/kg of the mixture (containing 200g of RP). Another batch of sand /38.4/ g was mixed with /8.42/g of KH_2PO_4 (as solution) to give concentration of /50/mg P/kg of snad. For other treatments, pots were filled with /2.4/kg of cleaned sand.

Planting:

Seeds of chickpea (CV. Gab 1, ILC: 482) and maize (Sweet Corn. cv. Golden Cross Nantam) were soaked in distilled water over-night. Five seeds were placed at /1/cm depth according to treatment and watered immediately with distilled water. After /7/ days from sowing, seedlings were thinned to /2/ in each pot.

This experiment was a randomized factorial design and therefore consisted of six treatments for each plant species (chickpea and maize):

NO_3		-P		Chickpea				
	X	+P	X		X	4 Replicated		= 48 pots
NH_4		+RP		Maize				

Treatments were:

NO_3+P	NO_3+RP	NO_3-P
NH_4+P	NH_4+RP	NH4-P

Pots were numbered from 1-48, so each treatment had 4 consequent numbers, randomized in an open area under natural conditions starting on the 23rd of April 1994 and for 49 days during which temperature did not drop below 10°C.

Pots were watered frequently from below with 3×200 ml a week of freshly prepared nutrient solution (1/2 strength) according to treatment. The "NO_3 solution" consisted of: $Ca(NO_3)_2$, 1.5 mM; K_2SO_4, 0.5 mM; $MgSO_4$, 0.5 mM; and for the "NH_4 solution": $(NH_4)_2SO_4$, 1.5 mM; was replacing $Ca(NO_3)_2$ in the above mentioned nutrient solution. In both solutions, micronutrients were supplied according to Long Ashton formula[8]. The pH of each of the two nutrient solutions was adjusted to /6.0/ before being used for irrigation.

Harvest Procedures:

After 49 days of growth, the four replicate plants of each treatment were harvested. Roots were carefully separated from the sand washed thoroughly with a jet of water. Plant parts (shoots and roots) were then oven-dried at 70°C for at least /24/ hours. and dry weights were recorded and ground prior to chemical analysis.

Chemical Analysis:

Subsamples of ground shoot materials (0.25-0.50)g were dry-ashed and digested in /10/ml of /6/M HCl, followed by final preparation in 4% HCl[9]. In the digest, P was measured spectrophotometrically by the Vanadate-Molybdate methods[9].

Statistical Analysis:

The data obtained from this experiment and for all recorded variables were subjected to statistical analysis as two sets of data according to plant species (Chickpea and Maize). Anova and LSD calculations were obtained using SAS prgram.

Results

The results in this section are reported according to plant species.

*** For Chickpea plants:**

The general effect on recorded variables was mainly due to the type of phosphorus application (Table 1). The form in which nitrogen was supplied had no effect on plant growth or nutrient uptake, and so was the interaction between types of nutritions.

Table 1: General analysis of variance for chickpea plants:

Variables/Factors	phosphorus	nitrogen	phosph*Nitrog
Shoots dry wt.	***	-	-
Roots dry wt.	**	-	-
Total dry wt.	***	-	-
P concentration	***	-	*
P content	***	-	-

For NO_3-N fed plants, there were no significant differences in shoots or roots of plants supplied with either forms of P nutrition (+P and RP). Plants supplied with +P or +RP grew better than those in which P was omitted from their growth media. Application of available P increased the growth of shoots and roots by 47 and 26% respectively, compared to P-stressed plants (Figure 1). Plants received P application (+P and RP) took up similar quantities of P but, howerver, they had higher concentrations and contents of P in the shoots compared to P-stressed plants (Figure 2).

In the case of NH4-N fed plants, the form of P application (+P and RP) had similar effect to that reported for NO_3-N fed plants (Figure 2).

*** For maize plants:**

The general effect on plant growth and nutrient uptake was mianly due to the form of phosphorus application. The form nitrogen (NO_3 and NH4-N) had generally an effect on plant growth. The interaction between P and N applications showed occasionally a cite of interst (Table 2).

Table 2: General analysis of variance for maize plants:

Variables/Factors	phosphorus	Nitrogen	Phosph*Nitrog
Shoots dry wt.	***	***	-
Roots dry wt.	**	*	-
Total dry wt.	***	***	-
P concentration	***	**	**
P content	***	-	-

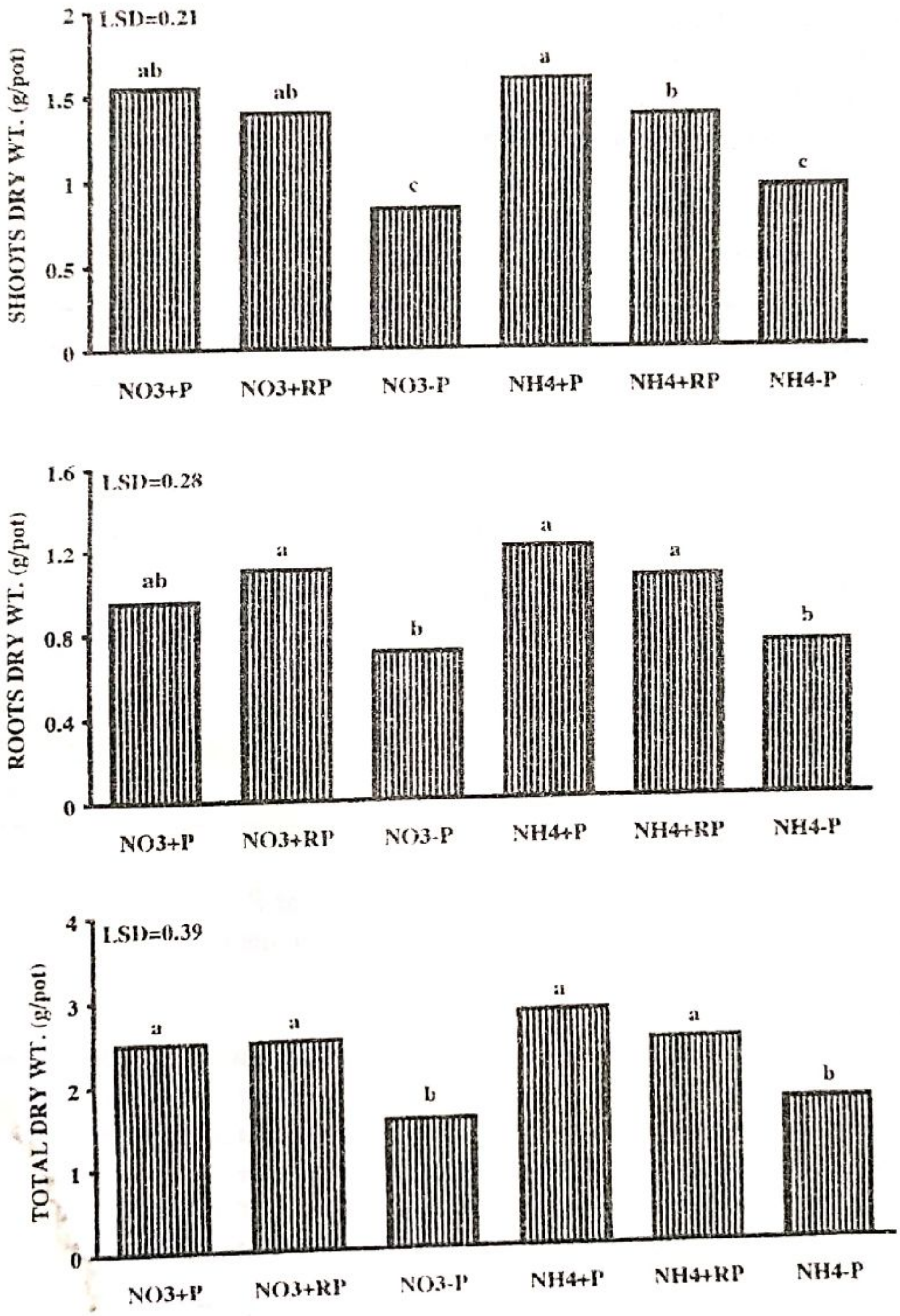
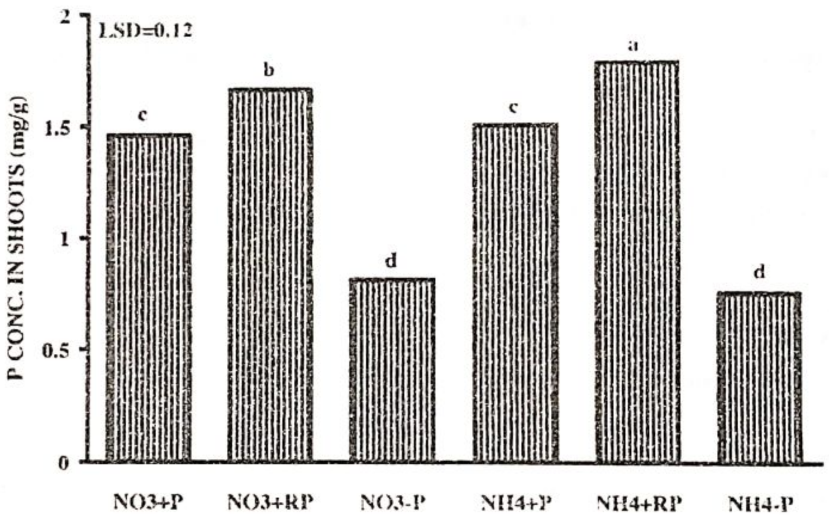


Figure 1: Chickpea dry matter production and distribution between shoots and roots. Bars with the same letters are not significantly different according to LSD (0.05) value.



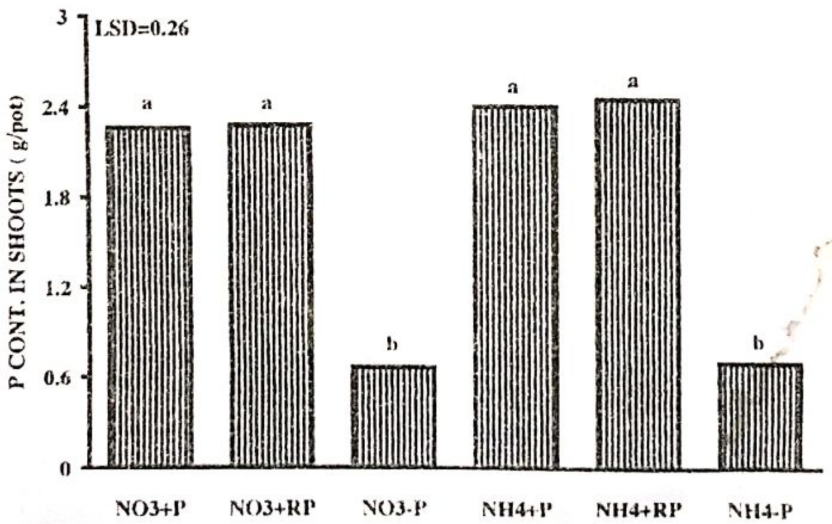


Figure 2: phosphorus concentration and content of chickpea shoots.
Bars with the same letters are not significantly different according to LSD (0.05) value.

In the NO_3-N fed plants, the application of available P (+P treatment) significantly increased shoots dry matter production compared to other treatment. Howerver, RP plants were greater in size compared to P-stressed plants (Figure 3). When comparing +P and RP, root growth was not significantly affected. P-stressed plants had smaller root system compared to +P plants but, were not significantly different from those supplied with RP.

Concentrations and contents of P in the shoots of +P plants were significantly higher than those of RP or P-stressed plants (Figure 4). Although there were higher concentrations and contents of P in the shoots of RP plants compared to P-stressed, plants these differences were not significant.

In the NH4-N fed plants, the form of P application led to significant differences among treatments. The growth of the root system was not affected by the form of P application. RP plants had significantly larger root system compared to P-stressed plants (Figure 3).

Phosphorus concentrations and content in the +P plant were significantly superior to those in either RP or P-stressed plants which were however more or less not different (Figure 4). However, regardless of the P nutritional status, Maize plants seemed to grow better with NO_3-N nutrition. Concentration of P was higher in the shoots of NH4-N fed plants compared to NO_3-N fed plants.

Discussion

Row rock phosphate is the least soluble form of the phosphatic fertilizers depending on chemical reactivty. When Finely ground, RP is beneficial on some acid soils and mineral soils with considerable organic matter. Because of its low solubility, however, it is generally used as a source for manufacturing other soluble forms of fertilizers[10]. The use of those fertilizers is convenient as they supply the required dose of P to crops if the soil is moist[11]. The increase in the cost of manufacturing soluble P fertilizers and the desirability of considering long-term application in cropping system lead to considering rock phosphate as a cheap source of P fertilizer.

The question remains whether different crops could utilize phosphorus from RP efficiently to maintain growth and continue their life cycle with high productivity.

Chickpea plants were able to extract quantities of P from RP and consequently grew even better than those supplied with available P fertilizers. In contrast, maize plants were not able to maintain sufficient supply of P from RP, so plants developed symptoms of P defficiency right from the start of the experiment. The quantity of solubilized P was very little when compared to that obtained by chickpea plants. This conclusion can be made clearer by calculations of relative utilization efficiency using the following equation:

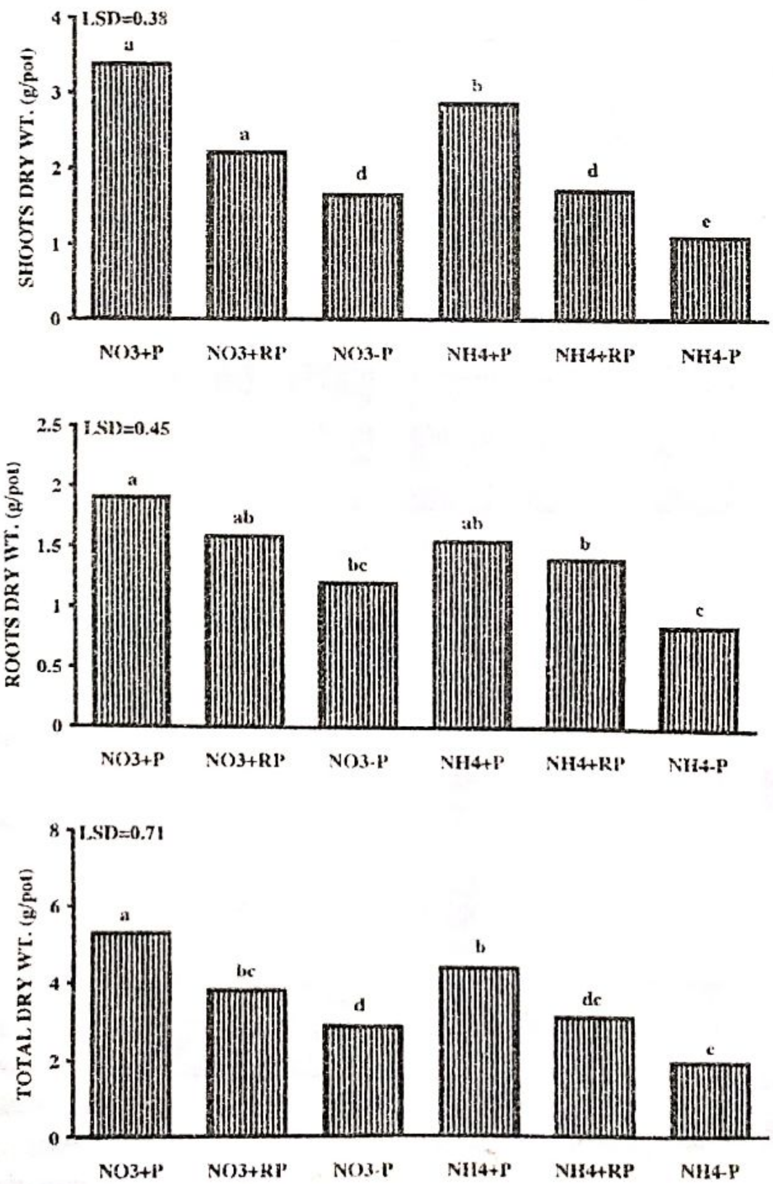


Figure 3: Maize dry matter production and distribution between shoots and roots. Bars with the same letters not significantly different acording to LSD (0.05) value.

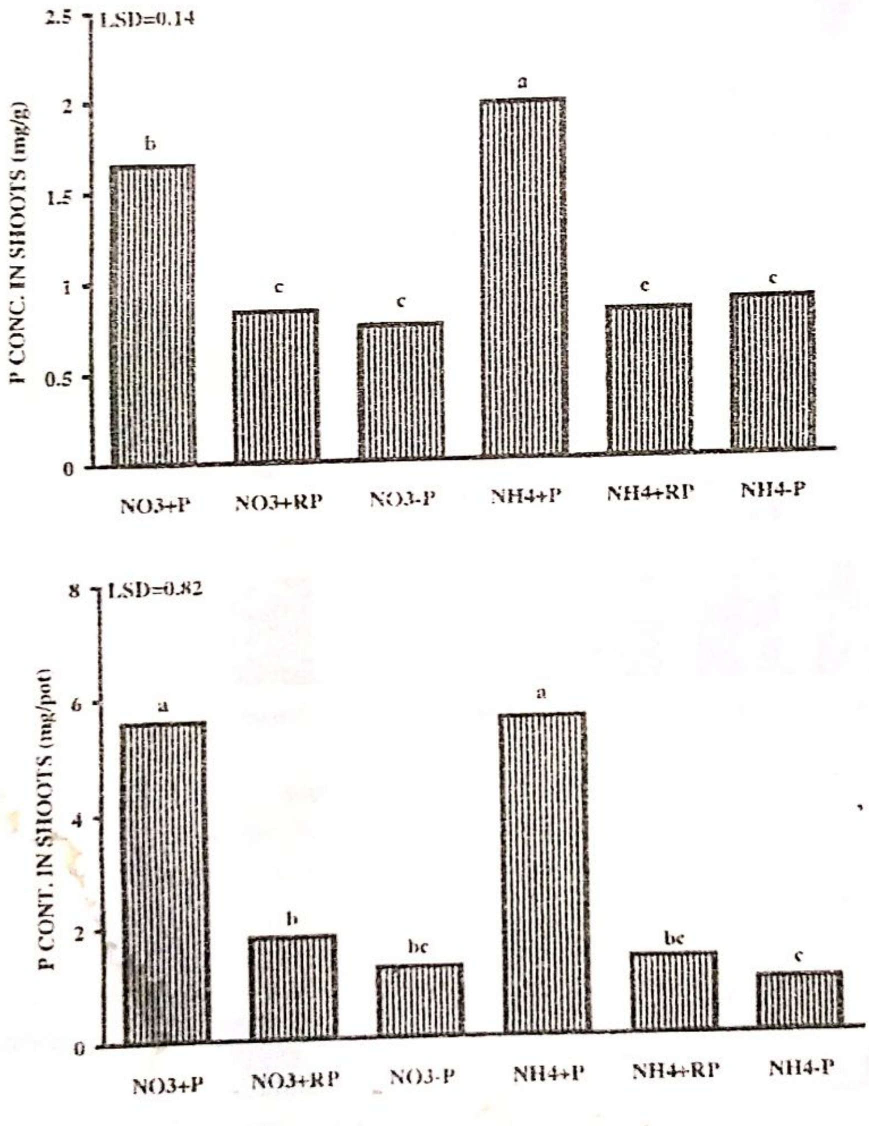


Figure 4: phosphorus concentration and content of maize shoots.
Bars with the same letters are not significantly different according to LSD (0.05) value.

$$RUE = \frac{\text{P Content of (RP) Plants - P Content of (-P) plants}}{\text{P Content of (+P) Plants - P Content of (-P) plants}} \times 100$$

The results of these calculations are shown in table 3.

Table 3: Relative utilization efficiency of RP by chickpea and maize plants with NO_3 or NH_4 nutrition.

	Utilization Efficiency (%)	
	NO_3	NH_4
Chickpea	101	104
Maize	32	24

The form in which nitrogen was supplied had no effect on growth and P uptake by chickpea plants under any form of P nutrition. In the case of maize plants, NO_3-N fed plants grew better under all forms of P nutrition than those supplied with NH_4-N. These differences were mainly due to the depression in growth of the shoot part of the plants.

Regardless of the form in which nitrogen was supplied (NO_3 or NH_4-N), striking differences in the rhizosphere pH exist among species growing on the same soil. Chickpea plants were shown to have a very low rhizospheric pH compared, for example, with that of wheat or maize [12]. These genotoypical differences reflect differences in cation/anion uptake ratios [13,14] and/or in the dominant sites of nitrate reduction (roots or shoots). As the cation-exchange capacity of plants is higher in dicot-(chickpea) than monocot-(maize), the ratio of cation to anion uptake is usually higher and consequently lowers the rhizosphere pH [15]. Therefore, the utilization of rock phosphate differed between the two species (Figures 2,4). It was shown in previous research that chickpea plants release great quantities of organic acids regardless of their nutritional status [16]. These acids contribute to acidification of the rhizosphere [17,18] and consequently mobilization of P from rock phosphate. The chemical reaction can be simplified in the following equation:

$$Ca_{10}(PO_4)_6(OH)_2 + 14H^+ \rightarrow 10Ca^{2+} + 6H_2PO_4 + 2H_2O$$

The chelation and, may be, the precipitation of calcium resulting from this equation by organic acids as such oxalic, citric and malic lead the reaction towards further solubilization of rock phosphate [18,19] and increasing quantities of phosphorus utilization by chickpea plants. This is in addition to the role of organic acids in increasing phosphorus mobilization by ligand exchange or/chelation [20].

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