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Estimation of available phosphorus in agricultural soils of Saudi Arabia

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ABSTRACT

Phosphorus availability in calcareous soils is often low despite frequent phosphate applications. Soil samples were collected from eight localities in Saudi Arabia, and analysed for texture, organic matter, pH, total soluble salts and calcium carbonate. Phosphate availability of Saudi Arabian soils was determined after four months following calcium phosphate applications of 100 mg P/kg soil. The addition of calcium phosphate fertilizer to soils led to a marked increase in the concentration of phosphate in most soils. The maximum amount of available phosphate was recorded in Alkharj soil (52 ppm) and the lowest amount of available phosphate was recorded in Hail soil (6.7 ppm) which exhibited the largest content of calcium carbonate and total soluble salts. Generally soil phosphate availability is influenced by soil pH, calcium carbonate content and total soluble salt concentrations in Saudi Arabian soils.

Keywords: Agricultural soil; phosphate availability; Saudi Arabia.

INTRODUCTION

Phosphorus is an essential element in all living systems and often also a limiting nutrient in plant nutrition and plant production. Various studies in different parts of the world about phosphate fertilizers, however, show that the availability of P added to soils as fertilizer amendments is erratic, according to soil conditions and type of fertilizer (Sample *et al.* 1980, Oohara *et al.* 1981, Rehm 1986, Abdulsalam *et al.* 1991).

The availability of phosphorus in soil solution is restricted by its tendency to precipitate in the presence of divalent metals (Ca^{2+}, Mg^{2+}) at neutral to alkaline pH. It is well known that P added as fertilizer to calcareous soils is fixed in the soil as a result of a reaction between P and Ca to form insoluble heterogeneous phosphorus compounds (Sample *et al.* 1979, Robertson & Alexander 1992, Killham 1994, Indiati & Sharpley 1996). Generally, the factors which control the availability of phosphate can be summarised as $CaCO_3$ content, soil pH, soil moisture content, clay content, salinity and microorganisms population (Bashour *et al.* 1985). Robertson and Alexander (1992) found that the pH, Ca and Fe alter the availability of phosphate.

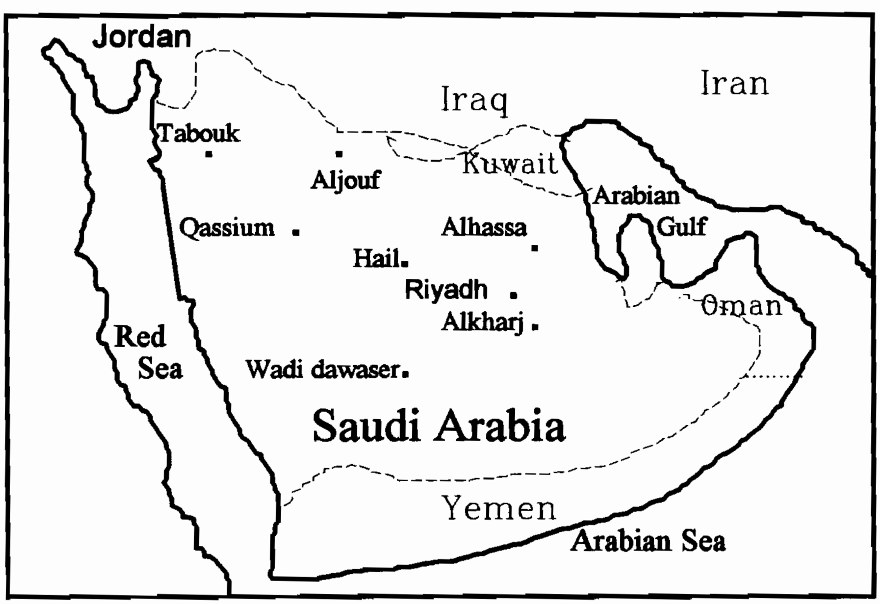
Many regions in Saudi Arabia are characterized by high calcium carbonate content and high pH of the soil (Ayed *et al.* 1983, Bashour *et al.* 1983, Al-Falih 1996). Phosphate solubilization in Saudi Arabian soils has been studied by a few workers, though largely on the central part of Saudi Arabia (Bashour *et al.* 1985, Abdulsalam *et al.* 1991). Data on phosphate availability are scarce or lacking for soils of Saudi Arabia, although such information would be useful in improving management of soils under cultivation. A significant correlation between phosphorus availability and some properties of Saudi calcareous soils was reported recently (Al-Sewailem 1997).

The purpose of this study is to investigate the soil phosphate availability in eight major agricultural regions in Saudi Arabia as affected by soil properties. Eight soils varying in clay content, organic matter content, pH, total soluble salts content and calcium carbonate content were selected from different areas in Saudi Arabia to elucidate the impact of soil properties on phosphorus availability.

MATERIALS AND METHODS

Collection and analysis of soil samples

Soil samples were collected in sterile polyethylene bags from eight different localities at Saudi Arabia (see the map of Saudi Arabia); five samples of soil surfaces (0–15 cm) were collected at each site. Soil at these locations was classified using a hydrometer method according to Day (1965) and soil texture was determined using the soil texture triangle. The method described by Jackson (1962) was used for determination of the total soluble salts (TSS) and calcium carbonate content. Soil pH



Map of Saudi Arabia showing the sites of soil sample collection.

was determined with a glass electrode in a 10:1 water-soil slurry. Soil organic matter percentage was determined colorimetrically using the method described by Walinga *et al.* (1992).

Determination of phosphate availability

Soil samples were amended with calcium phosphate fertilizer (100 mg P/kg soil) in order to determine the magnitude of phosphate solubilization in these soils. The soil samples were incubated in polythene bags, closed with a small hole to allow for gas exchange. The incubations were set up in triplicate. The soils were moistured to a water potential of 9 bar and incubated at 25°C for 4 months.

Phosphate was extracted from the soils using 0.5 N $NaHCO_3$. The soil:extractant ratio used was 1:10 and the slurry was shaken for 15 min's (100 throws min^{-1}). After being shaken, the soil slurries were filtered through Whatman No. 1 filter paper and the concentration of phosphate in the filtrate was determined colorimetrically according to Hesse (1971).

RESULTS AND DISCUSSION

The characteristics of soil samples collected from the different sites in Saudi Arabia are given in Table 1. The particle-size analysis of the soil samples shows that the soil texture class is sand for most samples; exceptions are sandy clay and loamy sand soils in Qassium and Wadi dawaser respectively. The Qassium soil had the highest percentage of clay (37.5%).

All soil samples contained low percentages of organic matter (Table 1). The percentages of organic matter ranged between 0.02 and 0.80%. The effects of organic matter on phosphate availability were probably negligible because all soils contained low percentages, consistent with the findings of previous studies on Saudi Arabian soils (Abdel-Hafez 1981, Ali & Abou-Heila 1984, Al-Falih 1996).

All pH values were slightly alkaline with a range of 7.2 in Alkharj soil to 8.3 in the soil from Hail region. The soil pH reflects the carbonate contents. The pHs were alkaline in both of the Hail and Qassium soils (8.3 and 8.1 respectively) which exhibited the highest concentration of calcium carbonate (20.13 and 15.22%, respectively). On the other hand Alkharj soil that showed the most nearly neutral reaction (pH 7.2) contained the least amount of calcium carbonate (1.87%).

Table 1. Soil characteristics of different regions in Saudi Arabia ($n = 3$)

Soil Locality	Mechanical fraction %			Texture class	OM %	pH	TSS %	$CaCO_3$ %
	Sand	Silt	Clay					
Alhassa	89.0	5.8	5.2	Sand	0.80	7.4	0.23	7.02
Aljouf	98.3	0.9	0.8	Sand	0.13	7.8	0.08	12.30
Alkharj	92.6	1.2	6.2	Sand	0.07	7.2	0.13	1.87
Hail	91.3	3.3	5.4	Sand	0.09	8.3	0.61	20.13
Qassium	56.4	6.1	37.5	Sandy clay	0.68	8.1	0.54	15.22
Riyadh	90.6	4.2	5.2	Sand	0.62	7.5	0.19	9.62
Tabouk	89.0	3.3	7.7	Sand	0.74	7.5	0.16	5.43
Wadi dawaser	82.0	5.5	12.5	Loamy sand	0.02	7.3	0.34	11.92

In general, the soil samples had a low TSS content. Aljouf soil contained the lowest percentage of total soluble salts with 0.08%. The highest percentage of TSS was observed in the soil from Hail, which was 0.61%, followed by the Qassium soil with 0.54%.

Phosphate concentrations in soils from the different regions in Saudi Arabia after amendment with calcium phosphate (100 mg P/kg) are shown in Figs. 1–8. In all control soils with no calcium phosphate added, available phosphate concentrations ranged from 0.7 ppm to 3.0 ppm.

Available phosphate levels in all of the Saudi Arabian soils increased following the addition of calcium phosphate (Figs. 1–8). Alkharj soil was particularly active in this process forming 52 ppm of available phosphate at the end of the incubation period (Fig. 3) followed by Riyadh soil with 40 ppm of phosphate (Fig. 6). On the other hand the Hail (Fig. 4) and Qassium (Fig. 5) soils achieved the lowest levels of available phosphate with 6.7 and 10 ppm of phosphate, respectively, at the end of the incubation period.

Phosphorus availability increased with time following the supplementation of calcium phosphate fertilizer in all soils. The Alkharj, Riyadh and Tabouk soils exceeded 20 ppm of available phosphate after one month of incubation (Figs. 3, 6 and 7), but the Aljouf and Wadi dawaser soils recorded only approximately 10 ppm of available phosphate after one month of incubation (Figs. 2 and 8).

As prior research suggests, the maximum level of available phosphate occurred in Alkharj soil which contained the lowest content of calcium carbonate and total soluble salts. In contrast, the Hail soil which contained the highest percentage

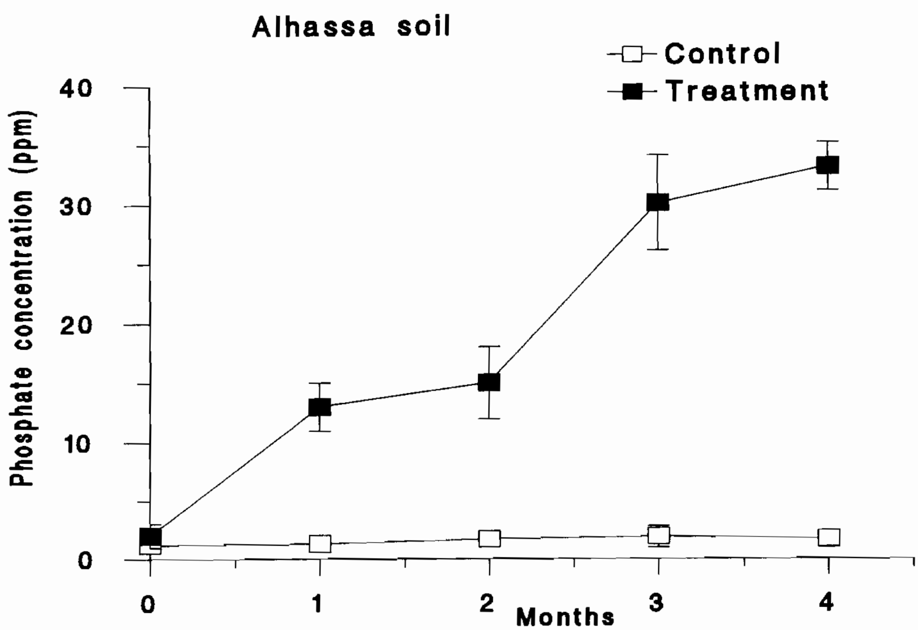


Fig. 1. Calcium phosphate solubilization (100 mg P/kg soil) in Alhassa soil, all values are means of triplicates ±S.D; $P < 0.05$.

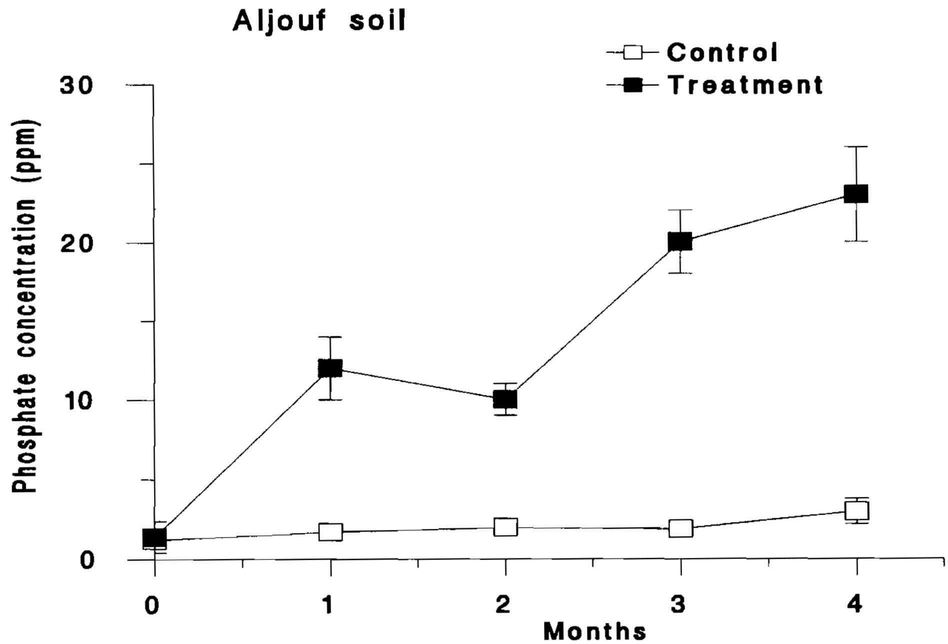


Fig. 2. Calcium phosphate solubilization (100 mg P/kg soil) in Aljouf soil, all values are means of triplicates ±S.D; $P < 0.05$.

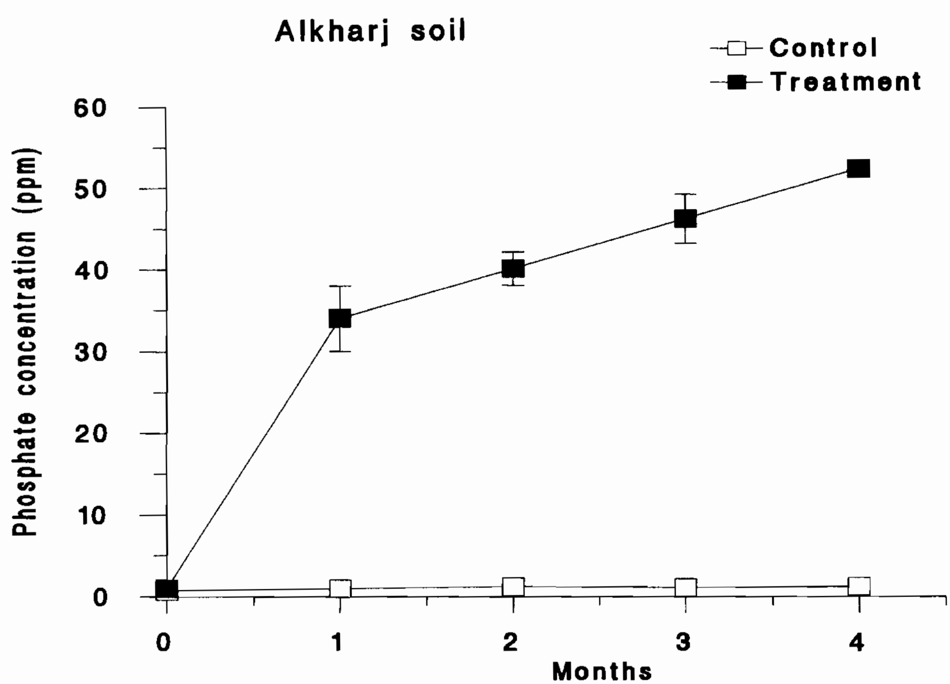


Fig. 3. Calcium phosphate solubilization (100 mg P/kg soil) in Alkharj soil, all values are means of triplicates ±S.D; $P < 0.05$.

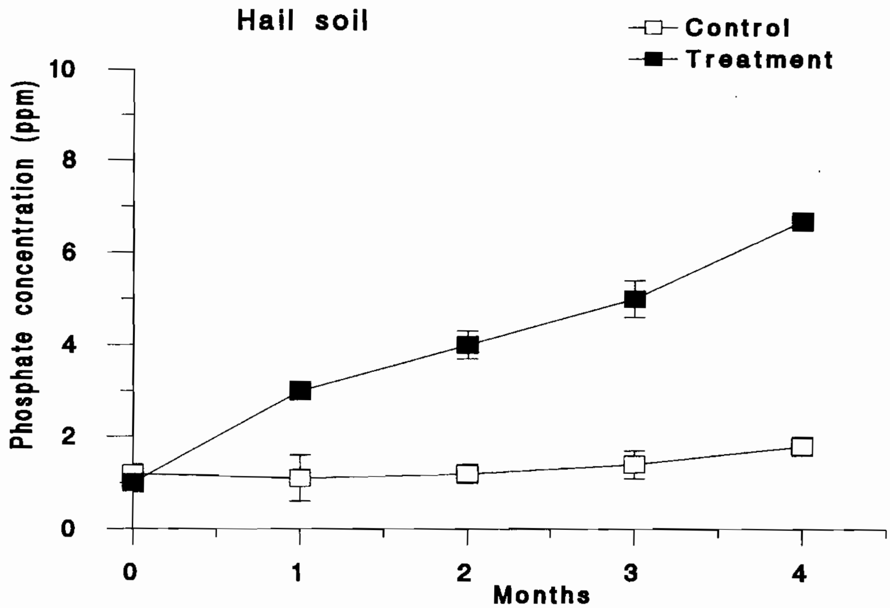


Fig. 4. Calcium phosphate solubilization (100 mg P/kg soil) in Hail soil, all values are means of triplicates ±S.D; $P < 0.05$.

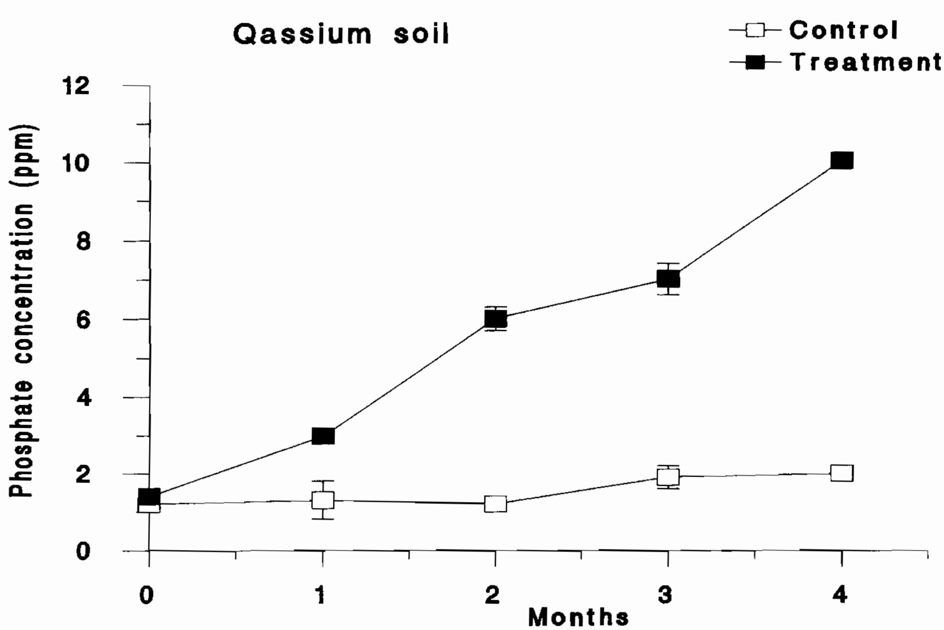


Fig. 5. Calcium phosphate solubilization (100 mg P/kg soil) in Qassium soil, all values are means of triplicates ±S.D; $P < 0.05$.

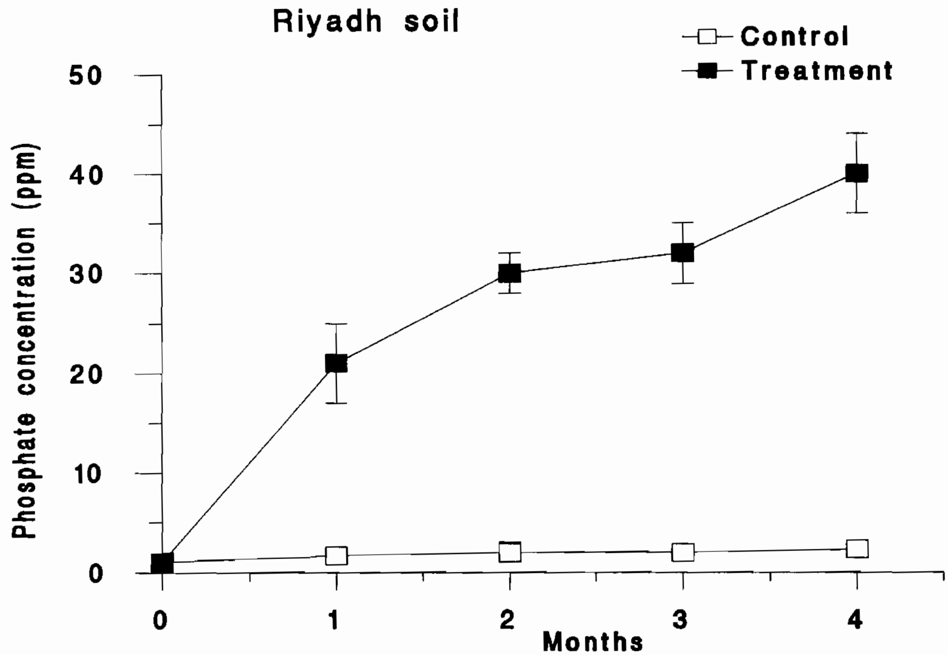


Fig. 6. Calcium phosphate solubilization (100 mg P/kg soil) in Riyadh soil, all values are means of triplicates ±S.D; $P < 0.05$.

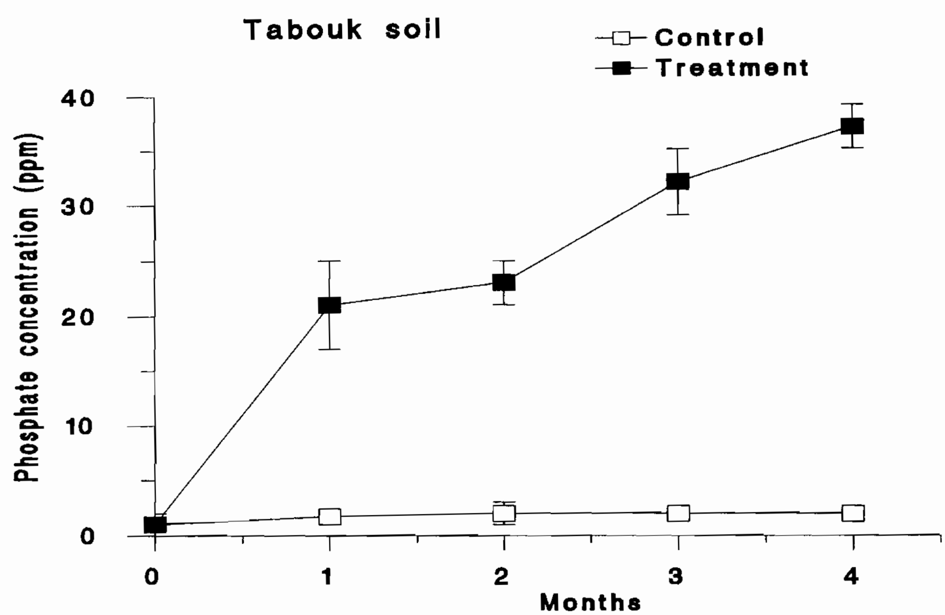


Fig. 7. Calcium phosphate solubilization (100 mg P/kg soil) in Tabouk soil, all values are means of triplicates ±S.D; $P < 0.05$.

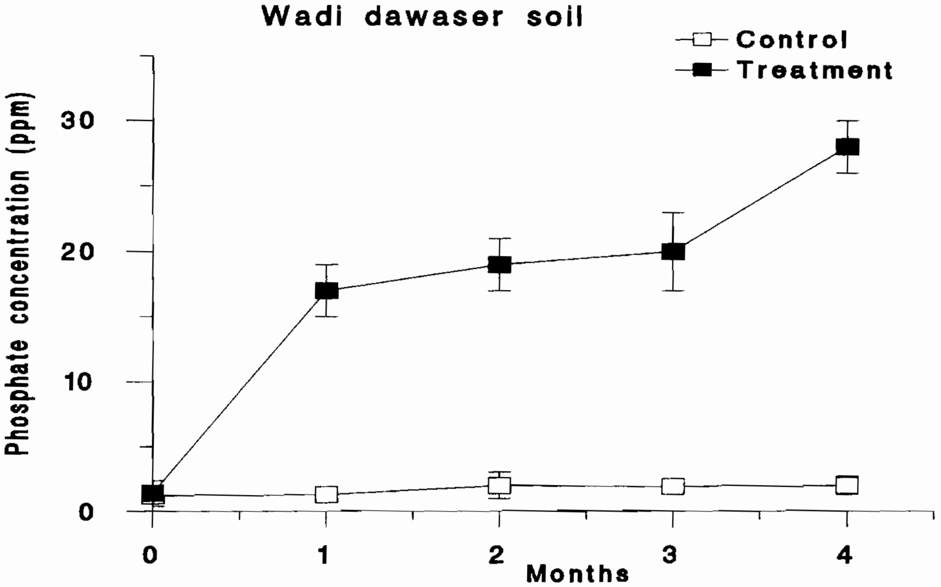


Fig. 8. Calcium phosphate solubilization (100 mg P/kg soil) in Wadi dawaser soil, all values are means of triplicates ±S.D; $P < 0.05$.

of calcium carbonate and total soluble salts exhibited the lowest level of available phosphate. Thus this study suggests that soil phosphate availability is negatively correlated with calcium carbonate and total soluble salt concentrations in Saudi Arabian soils, and is consistent with the findings of previous studies (Bashour *et al.* 1985, Al-Sewailem 1997). A similar relationship between calcium carbonate content and phosphate availability in soils was reported earlier by Sharpley *et al.* (1984) and Westermann (1992). It is important to note that not all the phosphate applied in phosphate fertilizers becomes available to the plant, particularly in calcareous soils such as these in much of Saudi Arabia. The precipitation of relatively insoluble Ca-P is considered to be the major factor limiting phosphate availability in calcareous soils (Sample *et al.* 1980).

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تقدير جاهزية الفسفور في عدد من الترب الزراعية بالمملكة العربية السعودية

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الخلاصة

جاهزية الفسفور في الترب الجيرية منخفضة بالرغم من إضافات الفسفور المتكررة. أجريت تجربة معملية لايجاد العلاقات بين عدد من خواص التربة وجاهزية الفسفور في عينات التربة التي جمعت من ثمان مواقع في المملكة العربية السعودية. إضافة سماد الكالسيوم الفوسفاتي (100 ملجم P/كجم تربة) أدت الى زيادة كبيرة في تركيز الفسفور التربة الذائب خلال أربعة أشهر في جميع العينات.

وجد في هذه الدراسة أن أعلى تركيز للفسفور سجل في تربة الخرج (52 جزء في المليون). بينما ظهر أقل تركيز للفسفور في تربة منطقة حائل بمعدل 607 جزء في المليون وهذا الموقع يحتوي على أعلى معدل لكربونات الكالسيوم والأملاح الكلية الذائبة.

أوضحت نتائج التحليل أن جاهزية الفسفور في الترب الزراعية بالمملكة العربية السعودية السعودية مرتبطة بمعدل حموضة التربة وكربونات الكالسيوم والاملاح الكلية الذائبة.