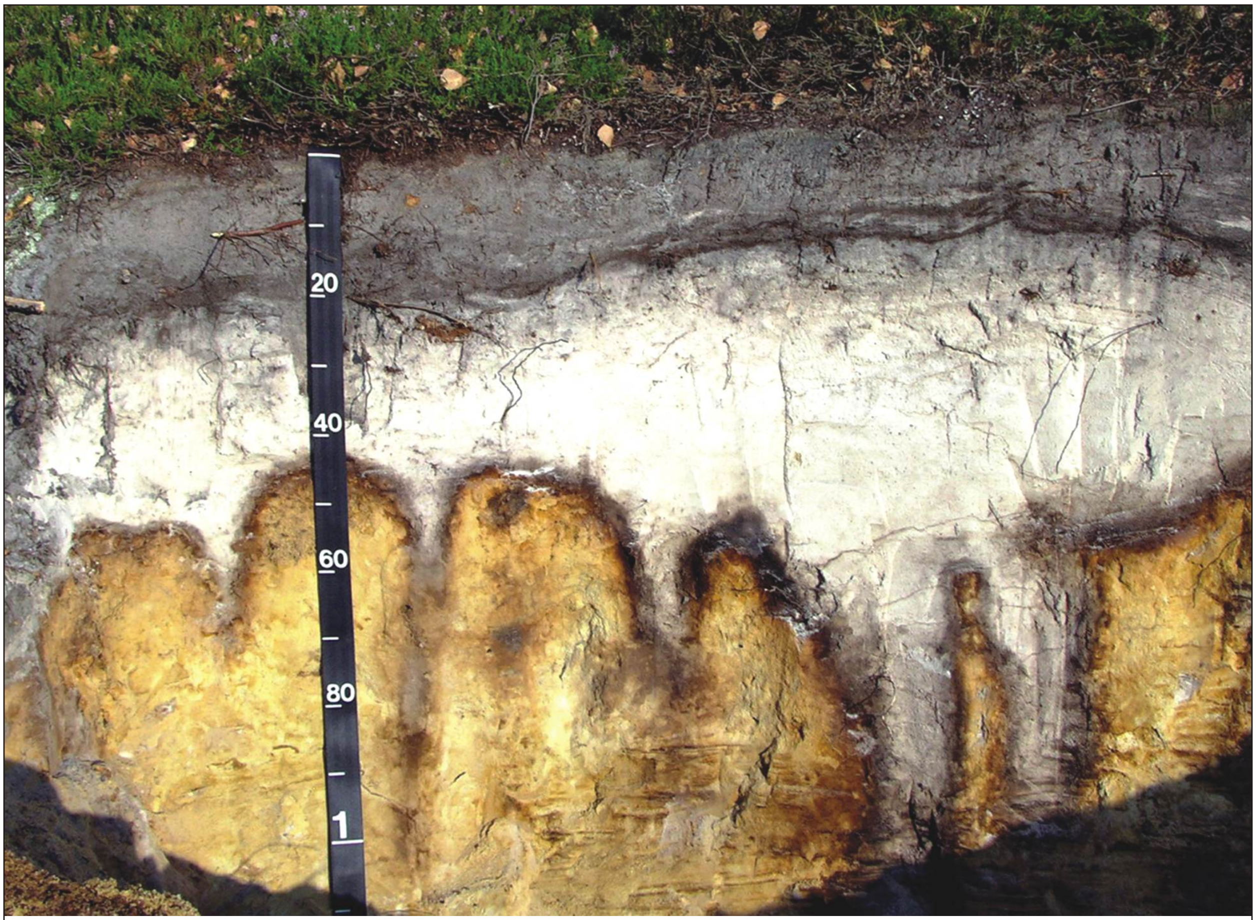


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# Phosphorus Availability in Calcareous Soil Amend with Chemical Phosphorus Fertilizer, Cattle Manure Compost and Sludge Manure

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## ABSTRACT

Addition of organic manure could improve the soil physical and chemical conditions. Besides it might also increase the efficiency of added P fertilizers and provide additional sources of nutrients. Information on the availability of P following chemical fertilizer and compost addition to soil may help in better management of P fertilization. The aim of this work was to study the combined effect of various levels and kinds of organic and chemical P fertilizer on P availability in a calcareous soil, through an incubation experiment. Treatments included four rates of added P (20, 40, 80 and 160 mg $P_2O_5$ $kg^{-1}$ soil) and control, one from an inorganic source ($KH_2PO_4$) and two from organic sources (Cattle manure and Sludge compost). The soil was incubated at 25°C and was maintained at 80% water holding capacity. Change in the amount of available P was measured during 16 weeks. By increasing the time of incubation, P availability in soil significantly decreased for both organic compost and inorganic fertilizer. It is concluded that the most critical time of incubation is the first week. In this time the soil loses almost 50% of the added P. Inorganic P fertilizer yielded more extractable P compared to the two organic sources only in the first week while the rest of incubation period, the amount of P available from the cattle manure compost was significantly higher.

**Key words:** Phosphorus, organic fertilizer, calcareous soil, Olsen-P, phosphorus availability

## INTRODUCTION

Phosphorus (P) is an important nutrient element required for plant growth, however, under calcareous soil conditions, phosphorus nutrient element is less available to the growing plant probably due to their transformation to more complicated forms with $CaCO_3$ and then changed from soluble forms in fixed form and finally rendered less available to growing plants (Bashour *et al.*, 1983). The effect of reduced P availability in alkaline soil is driven by the reaction of P with Ca, forming minerals such as dicalcium phosphate dihydrate. The resulting effect of low P solubility in alkaline and calcareous due to soil is relatively poor fertilizer P efficiency. Plants grown in these conditions can be stunted with shortened internodes and poor root systems due to P deficiency. Deficiency symptoms are sometimes observed as a darkening of the leaf tissue, although it is more common to observe yield loss with no readily seen symptom. Adding fertilizer P at normal rates and with conventional methods may not result in optimal yield and crop quality (Stark and Westermann, 2003; Javid and Rowell, 2003).

Soils of Saudi Arabia are mostly coarse textured and characterized by low available P and high amounts of $CaCO_3$ and low organic matter content (Al-Mustafa, 1993; Leytem and Mikkelson, 2005). Under such conditions the utilization of P by plants is generally very low due to the fixation and adsorption of P by soils. Application of phosphorus fertilizers in agricultural calcareous soils has introduced some problems mainly due to P fixation, low recovery and accumulation in. Addition of organic manure could improve the soil physical, chemical properties of soil and might increase the efficiency of added P fertilizers. Information on the P availability following chemical and organic P fertilizer application to calcareous soils may help with better management of P fertilization. Afif *et al.* (1993) found that available P in calcareous soil was negatively correlated to the amount of $CaCO_3$. Other studies indicated that P fixation increased by the ratio of Fe oxides/$CaCO_3$ (Ryan *et al.*, 1985; Carreira and Lajtha, 1997). Calcareous soils fix applied P due to reaction of P ions with $CaCO_3$. It is evident from the different studies, pertaining to recycling of industrial or agricultural that addition of these wastes to soils may increase the efficiency of applied and native nutrients required by plants (Naeem *et al.*, 2009). Both inorganic and organic species interact extensively with soil components and are subject to various chemical transformations that affect the retention of this element. Maintenance of adequate amounts of soil P through the application of inorganic and/or organic P sources is critical for long-term agricultural productivity. In the soil, applied P is partitioned into a readily-available (labile) and less readily-available (stable) inorganic and organic forms with different desorption, dissolution and mineralization rates that may contribute to plant P nutrition. Studies on phosphorus (P) reactions over time and the role of organic matter in calcareous soils are important for developing P fertilizers and manure management practices. The present research was planned to study the combined effect of various levels and kinds of organic and chemical P fertilizers on P availability in a calcareous soil through an incubation experiment.

## MATERIALS AND METHODS

**Soil sampling and analysis:** The soil used for this experiment was collected from the surface layer of the Experimental and Research Farm at Dirab, 25 km from South Riyadh. The collected samples were air-dried, ground and passed through a 2 mm sieve. Total carbonate was estimated according to Wright (1939). Total soluble salts were determined by measuring the electrical conductivity of the extract of saturated soil paste as explained by Jackson (1967). Soil pH was determined through a suspension sample with a soil air-dried to water (w/w) ratio of 1:2.5 and measured with a pH meter. Soil organic matter was determined by wet oxidation (Black *et al.*, 1965). Available concentrations of nitrogen, phosphorus and potassium were extracted and determined as described by Hesse (1971). Particle size distribution of soil was carried out using the pipette method as described by Dewis and Fertias (1970). Some physical and chemical properties of the experimental soil are presented in Table 1.

Table 1: Some physical and chemical characteristics of calcareous soil

| | | | | Available nutrients (mg kg$^{-1}$) | | | | | | | Particle size distribution (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | EC (dS m$^{-1}$) | $CaCO_3$ (%) | OM (%) | N | P | K | Fe | Zn | Cu | Mn | Sand | Silt | Clay |
| 7.9 | 2.94 | 32.6 | 0.2 | 4.71 | 2.6 | 325 | 1.10 | 2.5 | 0.4 | 6.6 | 88 | 3.6 | 8.4 |

OM: Organic matter, EC: Electrical conductivity

**Characteristics of organic fertilizer and chemical analysis:** The two organic fertilizers used in the study were cattle manure and sludge manure. They were chosen to represent common alternatives to inorganic P fertilizers in agriculture, while varying widely in their physical and chemical properties. The cattle manure compost and sludge manure obtained from Al-Bustan farm, Saudi Arabia. The sludge manure compost has been produced by the activated sludge process followed by mesophilic anaerobic digestion and then processed for the agricultural market by dewatering, centrifugation and compression. The cattle manure was produced from dairy cattle housing. The organic fertilizers samples were thoroughly mixed, lightly ground to pass through a 2 mm sieve. The subsamples were used for the chemical properties. Values of pH and Electrical Conductivity (EC) of cattle manure compost and sludge manure, was determined in 1:2 manure/water slurry as described by Peters *et al.* (2003). Organic carbon was determined by Walkley and Black method according to Hesse (1971). Total N was determined using macro-Kjeldahl method, as described by Peters *et al.* (2003). In order to determine the elemental concentration of organic residues, 0.50 g of each sample was digested using nitric acid, hydrochloric acid and hydrogen peroxide as described by Peters *et al.* (2003). Phosphorus was determined calorimetrically using spectrophotometer according to Jackson (1967). Potassium was determined using flame photometer as described by (Black *et al.*, 1965). Available Zn, Cu, Mn and Fe were extracted using $NH_4HCO_3$-DTPA method (Soltanpour and Schwab, 1997) and measured using ICP-AES spectrometry. Chemical properties of cattle manure compost and sludge composts are presented in Table 2.

**Incubation experiment and available p determination:** Incubation experiment was carried out at the Soil Department, Faculty of Agriculture and Food Sciences, King Saudi University. The experiment includes five application rate of P according to the total P content (e.g., 0, 20, 40, 80 and 160 mg $P_2O_5$ $kg^{-1}$ soil), one from an inorganic source ($KH_2PO_4$) and two from organic sources (Cattle manure and Sludge compost). First, 500 g of air-dried soil was mixed with the above rates of fertilizer in a 1 kg plastic container. Soil control was run without any amendments. Chemical inorganic P fertilizer was applied as water solution. Subsequently, distilled water that amounted to 80% of the water holding capacity of the soil was added and the samples were incubated at 25°C. The moisture content was periodically checked by measuring the weight and was maintained by

Table 2: Some selected properties of cattle manure and sludge compost

| Characteristic | Cattle manure compost | Sludge compost |
|---|---|---|
| Moisture content (%) | 11.4 | 22.1 |
| Electrical conductivity (dS $m^{-1}$) | 0.64 | 0.45 |
| C:N ratio | 1:18 | 1:11 |
| pH | 7.35 | 7.22 |
| Organic matter (%) | 39.5 | 30.7 |
| Total N (%) | 1.22 | 1.68 |
| Total P (%) | 0.41 | 0.76 |
| Total K (%) | 2.13 | 0.63 |
| Total Fe (g $kg^{-1}$) | 2.81 | 7.60 |
| Total Cu (mg $kg^{-1}$) | 51 | 156 |
| Total Mn (mg $kg^{-1}$) | 168 | 68 |
| Total Zn (mg $kg^{-1}$) | 209 | 118 |

adding distilled water when required. At the beginning of the incubation and at 1, 2, 3, 4, 5 and 6 weeks of incubation, Olsen extractable-P was extracted with $NaHCO_3$ at pH 8.5 (Olsen and Dean, 1965) and its content was determined by spectrophotometer.

**Statistical analysis:** The collected data were analyzed by using a statistical analysis system-analysis of variance (SAS, 1985) using least significant difference (LSD 0.05) for mean separation.

## RESULTS AND DISCUSSION

Effect of incubation period on soil available P are shown in Fig. 1. The available P significantly ($p<0.001$) decreased for organic and inorganic P fertilizers which increases the incubation time, however the rates of decreases of P content diminished with incubation periods.

During the first week of incubation, available P decreased sharply from about 57 to 37 mg $kg^{-1}$. This indicated that the critical period of P fertilizer application is the first addition. Figure 2 shows the effect of incubation time and fertilizer sources on soil available P. The results demonstrated that the added P recovery by $NaHCO_3$ extractant differs widely among the organic and chemical P sources and decreased substantially with incubation period. The use of phosphorus chemical fertilizers help increase the amount of available P in the soil in the first stage and then decreases as time of incubation goes on. Chemical P fertilizer yielded more extractable P compared with the organic sources. However, after the first week up to the end of incubation experiment, cattle manure compost recorded the highest available P compared to the other sources. The results agree

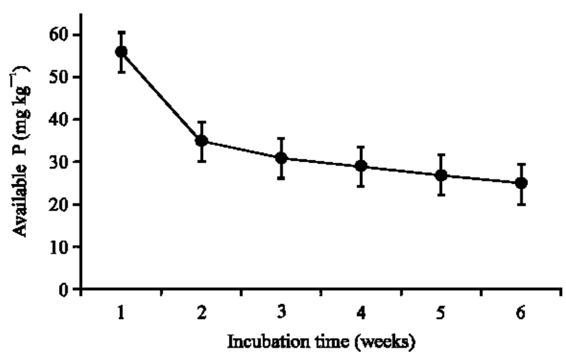


Fig. 1: Effect of incubation period on available P in soil

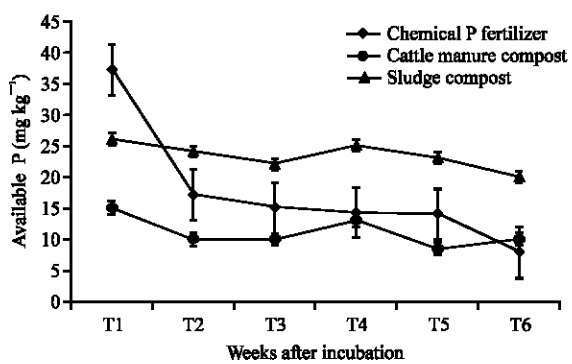


Fig. 2: Effect of incubation time and fertilizer sources on available P in soil

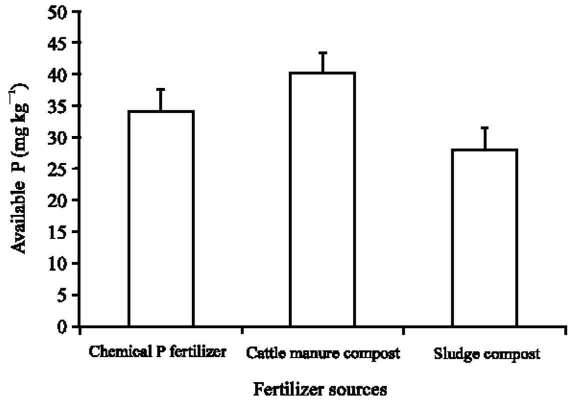


Fig. 3: Available P content as affected by fertilizer P sources

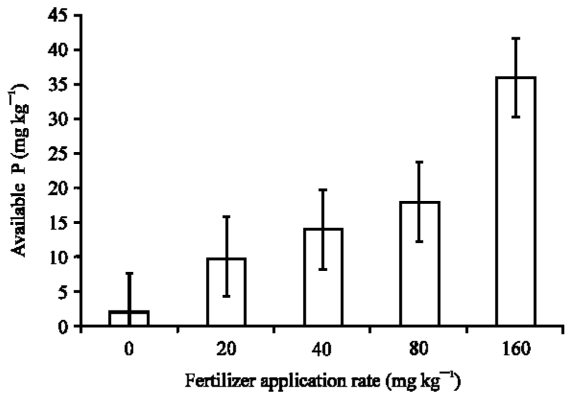


Fig. 4: Effect of organic fertilizer on available P content in soil

with the studies of Siddique and Robinson (2003). The effect of organic matter addition indicated highest amount of Olsen extractable P in cattle manure compost-treated soil followed by sludge manure at different incubation period (Fig. 3). The increase in available P may be attributed to the release of significant quantities of $CO_2$ during organic matter decomposition and complexing of cations such as $Ca^{2+}$ and hence reducing fixation of P in calcareous soil (Tolanur and Badanur, 2003). The results showed that application of organic and chemical P fertilizers led to increases in soil available P. Furthermore, cattle manure compost and sludge manure application along with inorganic P, irrespective, increased the Olsen extractable P thought out the incubation period (Fig. 4, 5). Toor and Bahl (1997) showed that the combined addition of poultry manure and fertilizer P had a synergistic effect and increased Olsen extractable P compared with fertilizer P alone. The application of animal manures may increase the bioavailability of soil P by increasing the concentration of soil dissolved organic carbon (Garg and Bahl, 2008). Table 3 and 4 indicated that the increasing of application rate of both chemical and organic P fertilizers increased available P in the soil. The increase was proportional to the application rate and was much larger for the cattle manure compost treatment compared with the sludge compost (Fig. 3). The higher effect of cattle manure compost on Olsen-P of soil was probably due to the higher organic matter content compared to the sludge compost (Table 2). Adler and Sikora (2003) found that organic fertilizers may increase P solubility by the production of organic acids or humic substances which compete

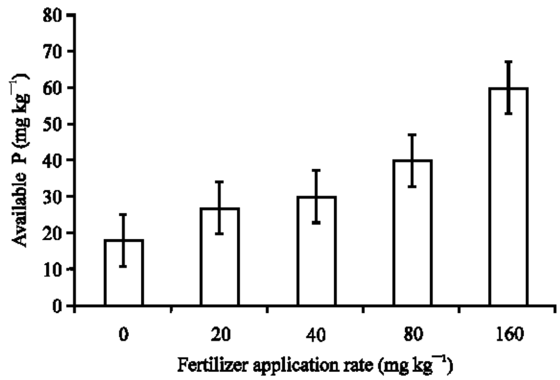


Fig. 5: Effect of organic fertilizer application in the presence of chemical fertilizer on available P content of soil

Table 3: Effect of applied different application rate of $KH_2PO_4$ fertilizer in the presence of organic fertilizer on availability of phosphorus

| | Incubation periods (weeks) | | | | | | |
|---|---|---|---|---|---|---|---|
| Application rate (mg kg$^{-1}$ soil) | 1 | 2 | 3 | 4 | 5 | 6 | Mean |
| 0 | 20.6 | 16.8 | 14.4 | 17.5 | 14.6 | 12.80 | 16.1$^{d}$ |
| 20 | 28.6 | 31.6 | 20.5 | 27.2 | 24.7 | 28.70 | 26.8$^{c}$ |
| 40 | 37.6 | 27.8 | 28.5 | 27.5 | 18.6 | 17.82 | 26.3$^{c}$ |
| 80 | 64.3 | 36.1 | 37.8 | 35.3 | 27.9 | 19.20 | 36.7$^{b}$ |
| 160 | 127.5 | 62.6 | 58.8 | 51.6 | 38.9 | 33.50 | 62.2$^{a}$ |
| Mean | 55.7$^{a}$ | 34.9$^{b}$ | 32.0$^{c}$ | 31.8$^{c}$ | 24.9$^{d}$ | 22.40$^{e}$ | |

$LSD_{(0.01)}$ incubation period: 0.873, P level: 0.797 and interaction: 4.12, Means within treatment variables followed by the same letter are not different at the 0.05 level according to LSD

Table 4: Effect of applied different application rate of organic P fertilizer in the presence of chemical P fertilizer on available P content of calcareous soil

| | Incubation periods (weeks) | | | | | | |
|---|---|---|---|---|---|---|---|
| Application rate (mg kg$^{-1}$ soil) | 1 | 2 | 3 | 4 | 5 | 6 | Mean |
| 0 | 41.8 | 18.8 | 14.4 | 13.1 | 11.3 | 6.8 | 17.7$^{e}$ |
| 20 | 49.3 | 25.4 | 23.6 | 22.0 | 14.7 | 16.1 | 25.2$^{d}$ |
| 40 | 53.2 | 28.3 | 26.1 | 25.7 | 21.3 | 15.2 | 28.3$^{c}$ |
| 80 | 61.6 | 40.3 | 36.3 | 37.2 | 28.1 | 26.6 | 38.4$^{b}$ |
| 160 | 72.8 | 62.2 | 59.7 | 61.1 | 49.4 | 47.2 | 58.7$^{a}$ |
| Mean | 55.7$^{a}$ | 34.9$^{b}$ | 32.1$^{c}$ | 31.8$^{c}$ | 24.9$^{d}$ | 22.4$^{e}$ | |

$LSD_{(0.01)}$ incubation period: 0.873, P level: 0.797 and interaction: 4.12, Means within treatment variables followed by the same letter are not different at the 0.05 level according to LSD

with adsorption P sites and consequently increases the P content in the soil solution. Parham *et al.* (2002) found that the increase is mainly due to increased microbial mass carbon by promoting microbial activity and enhanced phosphatase and dehydrogenase activity responsible for phosphorus solubilization. The available P decreased in incubated soil, between 1 and 6 week (Table 3, 4). The decreases in available-P may be attributed to time-dependent reactions involving the sorption and precipitation of added and native P (Akhtar and Alam, 2001; Erich *et al.*, 2002). It is reported that the initial retention mechanism of added P is adsorption by both ion and ligand exchange (Sample *et al.*, 1979). In calcareous soils, precipitation of insoluble Ca phosphates is believed to be a major factor in the loss of availability of applied P (Sample *et al.*, 1980), although the relative contribution of adsorption and precipitation processes to P fixation in calcareous soils seems to depend on P application rate. Precipitation of Ca phosphates in calcareous soils may significantly contribute to the decrease in P recovery with time (Afif *et al.*, 1993). The synergistic effect of manure application along with P fertilizer on increasing P soil concentration has been reported by Mkhabela and Warman (2005), Garg and Bahl (2008). Delgado *et al.* (2002) reported that organic amendments consisting of a mixture of humic and fulvic acids increased recovery of applied P by $NaHCO_3$ (Olsen-P). This was due to decreases in the precipitation rate of poorly soluble calcium phosphate by organic amendments application.

## CONCLUSION

Application of cattle manure and sludge manure plus chemical phosphorus fertilizer increased Olsen P as compared to separate P application. In general, the results indicated a decrease in the recovery of added P from the chemical source in spite of the initial increase. There was a significant effect due to increasing the rate of both organic and inorganic sources of P fertilizer. The results described here show that increasing the incubation time leads to a sharp decrease in the available phosphorus from both organic and chemical P fertilizers; nevertheless, the losses from chemical fertilizer is more. This suggests that addition of compost may enhance the efficiency of added phosphorus. Therefore, it may be concluded that cattle manure and sludge manure application had an appreciable and different impact on the availability of P in calcareous soils as P from manure gradually turned into available forms over the time.

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