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Comparing Effects of Treated Rock Phosphate and TSP on Soil P Availability and P Concentration in Apple (*Malus pumila*) Trees

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ABSTRACT
Phosphorus is one of the major elements in plant nutrition and crop productivity, participating in many biochemical processes and translocation of energy. In addition, P is a constituent of cell nucleic acids. Application of phosphate fertilizers is a common practice to correct P-deficiency in plants. For a long time, rock phosphate (RP) has been a major source to P fertilizer production. For evaluation of the efficiency of combined rock phosphate with different constituents, a garden experiment, as a completely randomized block design, was carried out in Torough Station of Agricultural Center of Khorasan with eleven treatments and three replications. Each replication included two apple trees (there should be 11 treatments or 22 apple trees in each replicate row). Treatments were: T_1: control (without phosphorous use), T_2: Using P as triple super phosphate, T_3: 40% concentrated R P. + 40% S(powdered) + 16% cow manure (CM) + 4% zinc sulphate, T_4: T_3 + 20 grams *Thiobacillus* sp. inoculant (10^7 cfu g^{-1}), T_5: T_3 + 40 grams *Thiobacillus* sp. inoculant, T_6: T_3 + Tea residues instead of CM, T_7: T_4 + Tea residues instead of CM, T_8: T_5 + Tea residues instead of CM, T_9: T_3 + plant residue compost instead of CM, T_{10}: T_4 + plant residue compost instead of CM, T_{11}: T_5 + plant residue compost instead of CM. In all treatments, 1 kg of each fertilizer was used for each apple tree at a 40 cm depth. Results indicated that there were significant differences among treatments including concentrated RP + S, *Thiobacillus* sp. bacteria and CM, with control treatment and treatments with no *Thiobacillus* from the aspect of available-P and leaves-P concentrations. Based on the results ($P<0.05$) using of RP + S, *Thiobacillus* sp. bacteria + CM at a rate of 1 kg.tree^{-1} for each apple tree had the same effect as triple super phosphate.

Keywords: *Thiobacillus,* Rock phosphate, Apple, Phosphorus

INTRODUCTION

Phosphorus is one of the major elements in plant nutrition and crop productivity. This element involves in many biochemical processes and translocation of energy. In addition, P is a constituent of cell nucleic acids. Application of phosphate fertilizers is a common practice to correct P-deficiency in plants. For a long time, Rock phosphate (RP) has been a major source in P fertilizer production.

Since for the oxidation of S by *Thiobacillus* sp. in the fertilizer, as a biological process, enough time is required, so field crops may not be suitable for this study, therefore a horticultural crop, apple (*Malus pumila*) tree, was selected for this study. Apple tree is one of the most important horticultural crops in Iran. The planting area of apple orchards in Iran is about 158000 hectares (Malakouti, 2000). There are some factors decreasing the amount of apple yield in Iran, including calcareous soils, incorrect irrigation methods and unsuitable quality of irrigation water. Practices such as correction of water, fertilizers management and plant nutrition disorders may increase apple yield and improve the quality of productions (Malakouti, 2000, 2002). The results of researches on the application of RP in acid soils have showed that RP can meet plant demand to P and/or increase the soluble P of phosphate fertilizers. However in calcareous soils of most areas of Iran, RP have low efficiency and addition of some treatments may improve its efficiency. Nourgholipour *et al.* (2000), and Koochak Zadeh (2001), reported that S, *Thiobacillus* sp. and R.P. as well as triple super phosphate can increase the uptake of P and yield of corn when the soil TNV haven't been upper 5 percent. Lotfollahi *et al*. (2000) showed that RP + organic matter, S and *Thiobacillus* sp. significantly increased corn yield and P uptake. Bakhtiari *et al.* (2001) reported that RP + S and *Thiobacillus* including Zn as well as triple super phosphate can increase the yield and P uptake of apple trees. Khavazi *et al.* (2001) showed that RP + S and *Thiobacillus* sp. significantly increased the dry yield of corn, in comparison with control, but there were no significant differences between this treatment and triple super phosphate. Since there are high amounts of RP sources and plenty of S in Iran, we purposed this research to investigate the effects of different constituents on the efficiency of RP, and, hence, apple yield.

MATERIALS AND METHODS

In 2002, a garden experiment, as a completely randomized block design, was carried out in Torough Station of Agricultural Center of Khorasan with eleven treatments and three replications. Each replication included two apple trees. Treatments were: T_1: control (without any phosphorous), T_2: using P as triple super phosphate, T_3: 40% concentrated R P. + 40% S + 16% cow manure (CM) + 4% zinc sulfate, T_4 : T_3 + 20 grams *Thiobacillus* inoculant (10^7 cfu g^{-1}), T_5: T_3 + 40 grams *Thiobacillus* inoculant, T_6: T_3 + Tea residues instead of CM, T_7: T_4 + Tea residues instead of CM, T_8: T_5 + Tea residues instead of CM, T_9: T_3 + composted plant residues instead of CM, T_{10}: T_4 + composted plant residues instead of CM, T_{11}: T_5 + composted plant residues instead of CM. In all treatments mentioned, 1kg of each fertilizer was used for each apple tree at a 40-cm depth, in deep placement method. Irrigation, performed once in every 10 days. Soil chemical characteristics for the depths of 0 to 30 and 30 to 60 cm are presented in Table 1. Also some of the chemical characteristics of the applied RP are presented in Table 3.

Plant element requirements (except P) for determination of fertilizers application was carried out based on the results of leaf analysis. Nine months after applying the treatments, pH and concentration of available P in pits, concentration of leaves P, Zn in pits and Zn in leaves were measured. Data analysis and diagram plotting were performed using SAS (9.1) and excel statistical software, respectively.

Effect of different treatments on pit pH

Effects of different treatments on pit pH nine months after treatments application are presented in Figure 1. Among different treatments, control and super phosphate treatments resulted in the highest pit pH values. However, there were no significant effects (*P<0.05*) among the treatments. Application of treatments including S and organic matter decreased pit pH. This is attributed to the production of organic acids, CO2 and sulfuric acid due to the microbial decomposition of organic matter and S oxidation by native microorganisms, respectively. Decomposition of organic matter and CO2 production, in treatments including *Thiobacillus* sp. inoculant (T4, T5, T7, T8, T10, T11) may be higher, compared with other treatments. It seems that the high reduction of pH in these treatments is due to the application of *Thiobacillus* sp. inoculant as S oxidizing bacteria. Producing sulfuric acid. Higher reduction of pH due to simultaneous use of *Thiobacillus* sp. and S has also been reported by other researchers (Mc Cready and Krouse, 1982).

RESULTS AND DISCUSSION

According to Table 1 the available P concentration is less than the critical level for apple trees. The leaves analysis of apple trees before applying the treatments is presented in Table 2. Accordingly, the concentration of P is lower than the optimum level. In comparison with the external sources of RP the concentration of Cd in applied RP was low.

Table 1. Soil chemical characteristic for the depths of 0 to 30 and 30 to 60 cm

mg/kg						%			pH	EC	Depth
Mn	Cu	Zn	Fe	K	P	Total N	O.C	T. N. V.		dS/m	(cm)
12.5	0.9	1.6	13.9	270	5.4	0.62	0.98	12.8	8.1	1.2	0-30
15.6	0.8	1.0	8.2	210	4.3	0.49	0.85	9.2	8.1	1	30-60

Table 2. Mean nutrient contents of apple leaves before applying treatments (n= 3)

mg/kg					%		
B	Cu	Zn	Mn	Fe	K	P	N
18	20	23	77	157	1	0.11	1.4

Table 3. Characteristics of the applied rock phosphate

mg/kg			%		EC	pH
Total Cd	Zn	Fe	P_2O_5 Total	P_2O_5 Soluble	(dS/m)	(1:1)
2	0.04	2.8	37.5	0.15	0.2	8.9

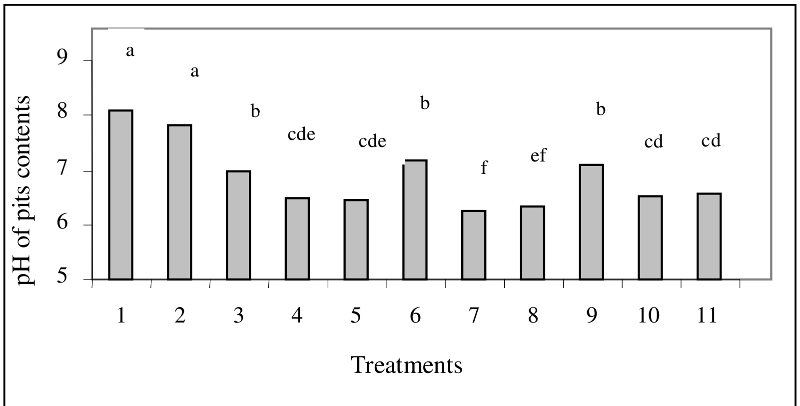

Figure 1. Effects of different treatments on pit pH

Effect of different treatments on available P

Available P concentration in pits, nine months after application, is presented in Figure 2. There were significant differences among control and other treatments. There were no significant differences ($P<0.05$) between T_2 and T4, T5, T7, T8, T10, and T11 treatments. In these treatments the produced sulfuric acid reacts with dissoluble calcium phosphate, producing the available form of P. This has been reported by many researchers (Stevenson and Col, 1999; Malakouti *et al.*, 2001; Khavazi *et al*., 2001). In treatments T_3, T_6 and T_9 due to the lack of *Thiobacillus* sp., lower rates of pH reduction and P release occurred. This may show the importance of *Thiobacillus* sp. as a necessary part of the fertilizer. Figure 4 shows the reverse relation between pH and the concentration of available P in pits. The effects of different treatments on P concentration of apple tree leaves are presented in Figure 3. Control had the lowest concentration of P (0.12%), significantly different ($P<0.05$) from other treatments. Treatments T_3, T_6, T_9 were significantly different ($P<0.05$) from control. In these treatments P concentration increased at a lower rate, compared with T_2 (triple super phosphate). Treatments T_4, T_5, T_7, T_8, T_{10}, and T_{11} were not significantly different from T_2. These results are in agreement with those, reported by Deluca *et al.* (1989), Malakouti *et al.* (2001) and Khavazi *et al.* (2001).

Effect of different treatments on Zn concentration

The effect of different treatments on the Zn concentration of apple leaves, are presented in Figure 4. Treatments T8 and T9 resulted in the lowest and highest Zn concentration of apple leaves, respectively. According to Figure 5 there is a negative relationship between soil available P and leaves Zn concentration. This result is in agreement with those reported by Dawood *et al.* (1985), Malakouti and Nafisi (1994) confirming the antagonism relationship between P and Zn. This negative effect may be attributed to the transportation of P and Zn from the roots to the upper parts of plant. After P and Zn uptake by plant, they react in the roots and produce organic compounds with low solubility, inhibiting the transport of Zn to the upper part of plant (Tandon, 1992). Also high amounts of P in soil may interfere with some metabolic tasks of Zn in plant, making the transporters of Zn in plant inactive (Dawood *et al.*, 1985).

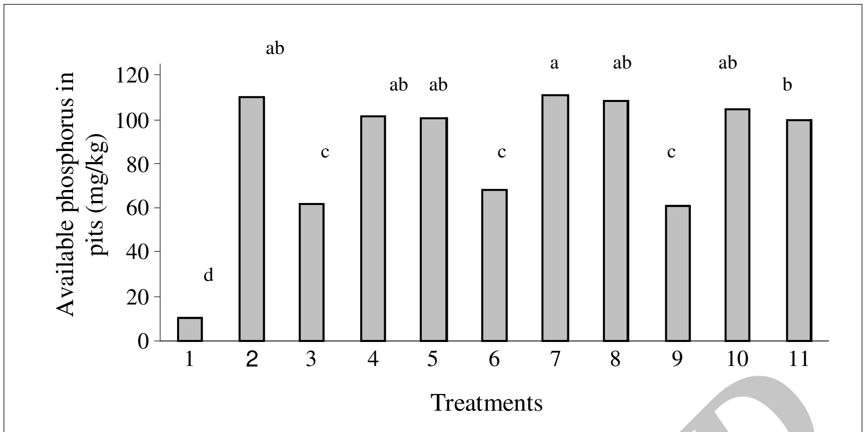

Figure 2. Effect of different treatments on available phosphorus in pits

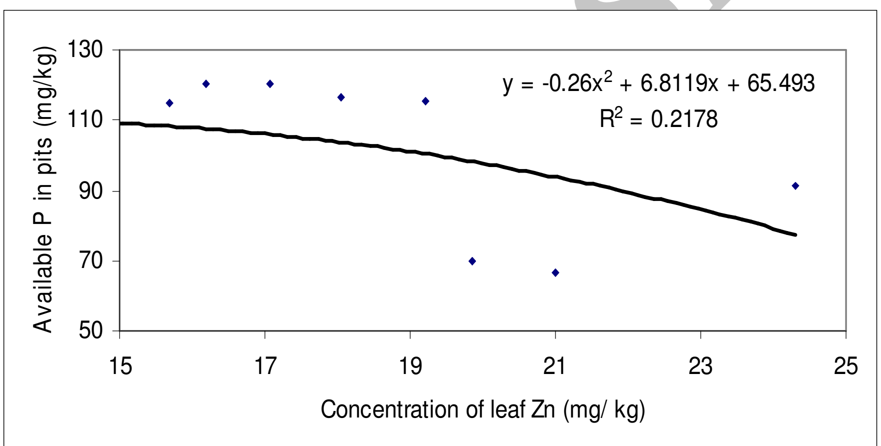

Figure 3. Relationship between P and Zn concentration in apple leaves

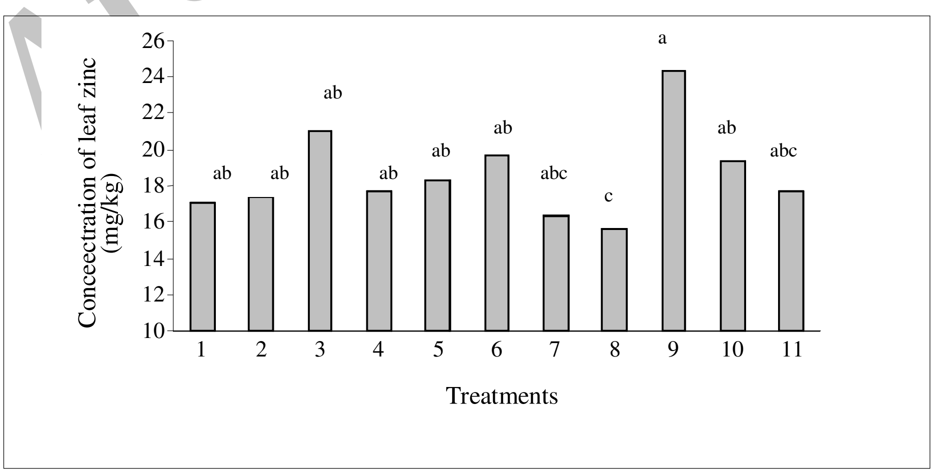

Figure 4. Effects of different treatments on leaves Zn concentration

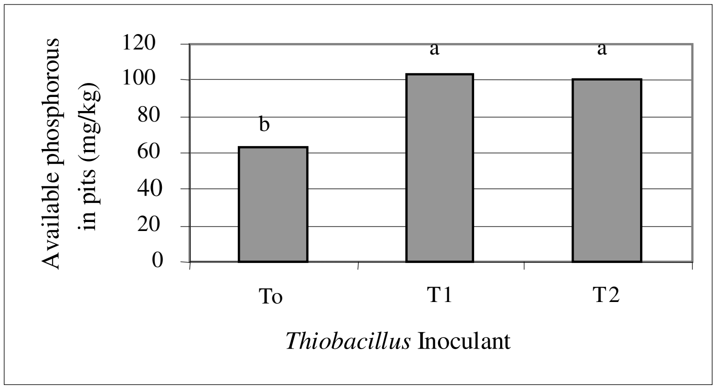

Figure 5.Effect of different levels of *Thiobacillus* sp. inoculant, on the concentration of pit available P

Effect of different levels of Thiobacillus sp. inoculant on pit pH

Effect of different levels of *Thiobacillus* sp. inoculant on pH of pits is presented in Figure 6. In this Fig. Ti_0, Ti_1 and Ti_2 are related to 0, 20 and 40 grams *Thiobacillus* inoculant /kg (related to the materials and methods section). According to this graph application of 20 and 40 gr *Thiobacillus* sp. inoculant significantly ($P<0.05$) reduced the pH of pits (pH changing from 7.13 in Ti_0 to 6.46 in Ti_1 and Ti_2 treatments). There was no significant difference ($P<0.05$) between Ti_1 and Ti_2. In these two treatments with increase in the population of *Thiobacillus* sp. bacteria S, the rate of S oxidation remained constant. It seems that, according to the ecological requirements of these bacteria and the interaction among the different microorganisms in soil, the population of *Thiobacillus* bacteria has stayed in a constant level and hence, their population did not increase with increased number of *Thiobacillus* sp. inoculant. Effect of different number of *Thiobacillus* sp. inoculant on the concentration of available P in pits is presented in Fig. 5. In this graph, similar to Figure 6 Ti_0, Ti_1 and Ti_2 are related to 0, 20 and 40 grams *Thiobacillus* sp. inoculant /kg, respectively. Application of 20 and 40 gr *Thiobacillus* sp. reduced the pH of pits, and in turn increased the concentration of soil available P, due to increasing P solubility with reducing pH. There were significant differences among Ti_0, Ti_1 and Ti_2, but not between Ti_1 and Ti_2.

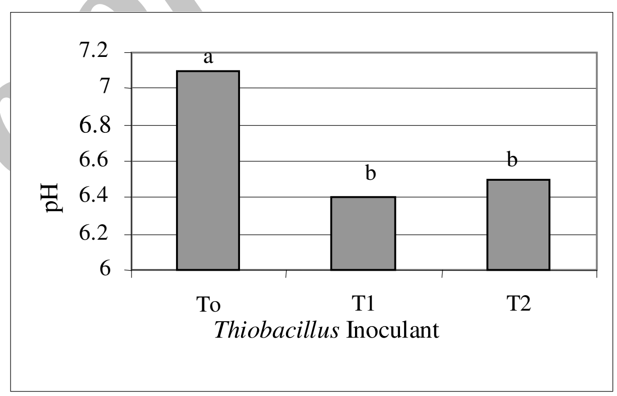

Figure 6. Effects of different levels of *Thiobacillus* sp. inoculant, on pit pH

Effect of organic matter types on pH and P availability

Effects of organic matter types on reducing pits pH are presented in Figure 7. There was significant differences ($P<0.05$) between treatments tea residues, compost and CM, but not between compost and CM treatments. These treatments significantly reduced the pH of pits (pH changing from 6.71 in tea residues treatment to 6.51 in compost and CM treatments). It seems that this is due to the low pH of tea residues (values, between 3- 4) in comparison to compost and CM.

Effect of organic matter types on the concentration of available P in pits, are presented in Figure 8. There were no significant differences ($P<0.05$) between compost and CM treatments, but application of tea residues instead of CM and compost, resulted in significant increase in the concentration of available P in pits.

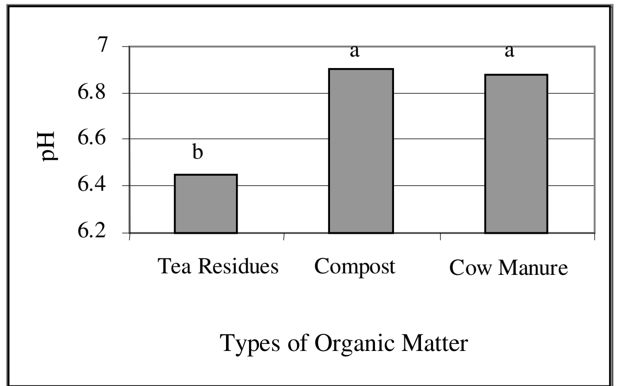

Figure 7. Effect of organic mater type on pit pH

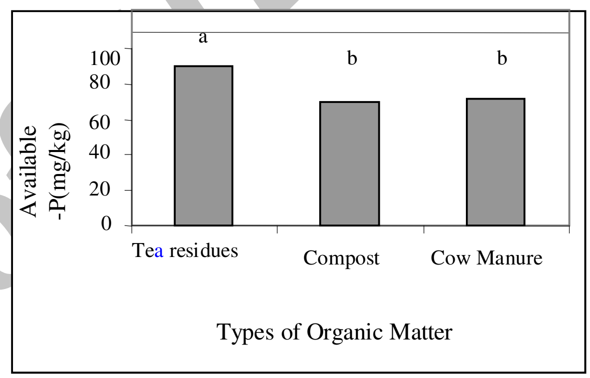

Figure 8. Effect of different types of organic matter, on the concentration of pitsavailable P

CONCLUSION

Application of compost instead of CM didn't have any significant effect on available P concentration, but application of tea residues significantly increased the concentration of available P in pits. *Thiobacillus* sp. inoculant was significantly effective. But there was no significant difference between its different levels. It seems that use of 500 gr *Thiobacillus* sp. inoculant per 25 kg is economical and effective. Based on the results it seems that, 40% concentrated R P. + 40% S + 16% cow manure (CM) + 4% zinc sulfate + 20 grams *Thiobacillus* inoculant (10^7 cfu g^{-1}), can be used at a rate of 1 kg/tree in apple orchards, instead of triple super phosphate fertilizer. The efficiency of this fertilizer should be investigated in different areas and also for different crops.

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