COMBINE APPLICATION OF ROCKPHOSHPATE AND NH_4-ZEOLITE TO MAIZE CROP FOR ENHANCING P UPTAKE AND DRY MATTER YIELD UNDER CALCAREOUS SOIL

Ahmed Shah Kakar[1], Mohammad Tahir[1], Nasarullah[1], Saqibullah[1], and Ahmed Jan[1]
[1]Balochistan Agriculture College Quetta, Pakistan
Corresponding author: kaintkk@gmail.com

ABSTRACT: *The availability of phosphorus to crops in calcareous soil is limited. Together with that the cost of phosphaic fertilizer is escalating and becoming out of farmer purchasing power. For alternate, the use of rock phosphate is an appropriate option when applied with some activating agent like farmyard manure or zeolite mineral. Since, a pot experiment was conducted at the Net house of Directorate of Agriculture Research Soil and Water Testing ARI, Sariab Quetta during 2016 aiming to enhance P uptake and dry matter yield of maize under the influence of NH_4-Zeolite and rockphoshpate. The study was based on randomized complete design (RCD) in two factorial arrangements with three replications. The factors were: factor (A)-rock phosphate rates (0, 2.5, 5.0 and 7.5 g) and factor (B)-zeolite rates (0, 125, 250, 375 g). The crop was harvested after 6 weeks. The results revealed that the separate application of each rock phosphate and zeolite affected maize dry matter, P concentration and uptake significantly but their interactive effect was non-significant. The higher maize tissue P concentration (0.323%), P uptake (0.207 g pot^{-1}) and dry matter (63.53%) were recorded at higher RP rate of 7.5 g pot^{-1} but all zeolite rates showed lower values of these parameters. So, it can be evidenced that zeolite did not work well in release of P from rock phosphate under calcareous soil and have no effect on growth and nutrient uptake of the tested maize* crop.

Keywords: Zeolite, rock phosphate, P uptake, maize, growth, dry matter

INTRODUCTION

The availability of phosphorus in calcareous soil is a limiting factor in crop production and above all the high cost phosphatic fertilizer now become unaffordable by small farmers. There are some approaches that can be utilized for searching alternate source of low cost phosphatic fertilizer which is being put forward globally to apply low grade rock phosphate directly in to the soil to meet P requirement of crops where locally available [1:2:3]. There are vast deposits of low grade rock phosphate in developing countries including Pakistan which can be exploited as a source of P for substituting high cost phosphatic fertilizer. In fact, it is inexpensive than soluble P fertilizers made from high grade phosphate rock but the direct application of rock phosphate to soil need some amendments in term of organic sources addition and/or some P stimulating mineral like zeolite [4: 5]. There are two prominent uses of rock phosphate. It can be used for preparation of water soluble phosphatic fertilizer and for direct application to agricultural soils as a source of P. Many researchers have investigated the effect of rock phosphate on different crops by direct application to soil and in some cases they have obtained very excellent results even than chemical fertilizer [6]. Zeolites are hydrated alumino silicate minerals of alkaline and alkaline-earth metals having a general formula of M_xD_y [Al $_{(x+}2_{y)}$ + 2_ySi$_{n-(x+}2_{y)}$ O_{2n}] m H_2O. Both synthetic and naturally occurring are known. This alumino silicate mineral known as zeolites, when saturated with mono-valent nutrient cations such as NH_4^+ and K^+, have been reported to increase the solubility of rock phosphate [7]. It consists of a regular tetrahedral structure (SiO_4) having silicon in the center and 4 oxygens placed at four corners of a tetrahedron. Each oxygen is again shared by the adjacent octahedron where all the charges are balanced giving rise to neutral structures [8]. In zeolite structure the quadrivalent silicon is replaced by trivalent aluminum giving rise to deficiency of one positive charge. This negative charge can be balanced by monovalent cation such as ammonium [9] and is termed as NH_4-zeolite. The direct application of ground, natural rock phosphate as a source of P for crops is a practice that has been utilized with varying degrees of success over years. Numerous field and greenhouse experiments have been conducted to assess the capabilities of these materials to supply P to crops and to define the most favourable conditions for their application. The studies show an increase in P release from rock phosphate when combined with zeolite. [10] in his studies of rock phosphate and zeolite showed that P uptake in sunflower enhanced greatly when applied in combination with NH_4-zeolite. Similar results were observed by [11] using lettuce, tomato and rice crops. Different ratios of rock phosphate and zeolite have been applied in different crops. [1] used 170 and 340 mg of rock phosphate in factorial combination with zeolite and rock phosphate rates of 0, 1.5, 3, and 4.5, 6 and 7.5:1. Increasing rock phosphate and zeolite ratio in soil generally increased plant P concentration and uptake. The largest dry matter yield of sorghum was found at 340 mg P kg^{-1} increasing rock phosphate and zeolite ratio linearly. [12] found that 20% zeolite 80% soil ratio was the best in increasing plant height, green herbage and dry root weight of alfalfa. [13] also found that these rates of zeolite improved tomato yield and were best medium for growing tomatoes. [14] used 0, 20 and 40 g zeolite and 2 kg soil by growing soybean and found that 20 g zeolite was the best application by giving highest grain yield. Utilization of zeolite in agriculture is possible due to their special cation exchange, which enhances the availability of P from rock phosphate. The objectives of this study was to find the extent of P availability from rock phosphate mixed with zeolite and to assess the influence of various treatments on dry matter yield and P uptake in maize.

MATERIALS AND METHODS

This pot study was carried out at Directorate of Agriculture Research Soil and Water Testing ARI, Sariab Quetta during 2015 which was based on completely randomized design

(CRD) in two factorial arrangements with three replications. The treatments were comprised of two factors including factor (A)-rates of rock phosphate (0, 2.5, 5.0 and 7.5 g) and factor (B)-rates of zeolite (0, 125, 250, 375 g). The seeds of golden maize variety was sown using 6 seeds per pot. Recommended N and K at 150 and 60 kg ha^{-1} in the form of urea and sulphate of potash (SOP) were applied as a basal dose. Tube well water was used for irrigation purpose according to the requirement of the crop. After six weeks, maize crop was harvested and dried in the shed to determine its dry matter yield. For the determination of plant P concentration, the plants were oven dried at 65 to 68 ^{o}C till constant weight was obtained and then grinded to pulverize. The P uptake was calculated as a product of P concentration and dry matter divided by hundred. Plant P in maize shoot was determined by first digesting in an acid mixture, followed by P analysis on spectrophotometer by vanadomolybdo-phosphoric acid yellow colour method [15].

Soil analysis

All the samples were analyzed for some physico-chemical properties by standard methods. Particle size distribution was determined by Bouyoucos hydrometer method [16]. Soil electrical conductivity (EC) and pH were determined in 1:2 soil water extract using EC meter and pH meter respectively. Organic matter was determined by Walkley-Black method [17], which involved oxidation of organic carbon by potassium dichromate ($K_2Cr_2O_7$) and subsequent determination of the unutilized dichromate by oxidation-reduction titration with ferrous ammonium sulfate. Available P and K in soil were extracted by AB-DTPA extraction method [18] and quantified by using spectro photometer.

Statistical analysis

The collected data was subjected to analysis of variance using computer program Statistix 8.1. While, LSD test was performed for comparison of means at 5% probability level when F value was found significant.

RESULTS

This study was carried out during 2015 aiming to investigate the synergistic effect of NH_4^+-zeolite and rock phosphate on growth of maize. The soil used in study was sandy clay loam in texture with 47.8% sand, 27.6% silt and 24.6% clay, non-saline and alkaline in reaction. Organic matter contents (0.67%), total nitrogen (0.051%) and AB-DTPA extractable P were low but AB-available K was in medium range (Table 1). The studied parameters were included P accumulation in plant tissues, P uptake and dry matter yield of maize which were significantly affected by the combine application of zeolite and rock phosphate. The overall plant tissue P concentration was ranged from 0.15 to 0.38% with mean value of 0.26%, P uptake was ranged from 0.04 to 0.38 g pot^{-1} with mean value of 0.14 g pot^{-1} while dry matter yield was ranged from 30.10 to 75.70 g pot^{-1} with mean value of 50.64 g pot^{-1}.

Phosphorus accumulation in plant tissues (%)

Determination of nutrients in plant tissue is one of the important indicators of nutrients availability. Under this study, the phosphorus accumulation in maize tissue was evaluated across different rock phosphate and zeolite rates. The analysis of variance showed highly significant ($p<0.01$) differences for rock phosphate and zeolite rates but the interactive effect of rock phosphate x zeolite revealed non-significant changes in maize plant tissue P concentration (Table 2). The LSD Test ($p<0.05$) for mean comparison exhibited greater P accumulation (0.323%) at higher rate of rock phosphate (7.5 g pot^{-1}) followed by 0.30% at rock phosphate rate of 5.0 g pot^{-1} while minimum P accumulation was recorded in pot where no rock phosphate was used (Table 3). In case of zeolite rates, greater P accumulation was observed in pot where no zeolite was applied and P accumulation manifested decreasing trend from lower to higher zeolite rates while higher zeolite rate (375 g pot^{-1}) expressed comparatively lower P accumulation (0.251%). It means that zeolite application did not help in rock phosphate solubility and P availability under alkaline calcareous soils. However, in acid soil it works well in solubility of rock phosphate as reported by [19] who observed increased in N, P and K uptake in maize by use of zeolite which might be due to nutrient retention potential of zeolite when applied along with synthetic fertilizer. The interactive effect of rock phosphate x zeolite showed non-significant differences for maize tissue P accumulation. The results showed that the interaction of 7.5 g pot^{-1} rock phosphate x 0.0 g zeolite recorded maximum P accumulation (0.336%) followed by 0.323% P accumulation at the interaction of 7.5 g pot^{-1} rock phosphate x 125 g pot^{-1} zeolite. The entire rock phosphate rates showed decreasing trend in the interaction of different zeolite rates. While minimum P accumulation (0.173%) was observed in the interaction of 0.0 g rock phosphate x 375 g pot^{-1} zeolite (Table 3). These interactions explain that there was no synergistic effect of rock phosphate and zeolite on P accumulation in maize under calcareous condition. However, available scientific literature reflected significant effect of rock phosphate on maize when combined with NH_4^+- zeolite in acid soil, but no literature is available about use of zeolite with rock phosphate in calcareous soil. However, [20] have reported that combine use of zeolite plus rock phosphate increased P concentration of maize tissue in acid soil.

Phosphorus uptake (g pot^{-1})

Phosphorus is low in soils of Pakistan and the available soluble phosphatic fertilizer cost high to poor farmers. The direct application of rock phosphate is a good alternate to expensive and high soluble P fertilizer. The uptake of phosphorus by maize plant grown in pots was affected by different rock phosphate and zeolite rates. The analysis of variance showed highly significant ($p<0.01$) differences for rock phosphate and zeolite rates, but the interactive effect of rock phosphate x zeolite revealed non-significant changes in P uptake by maize plants (Table 2). The LSD Test ($p<0.05$) for mean comparison exhibited greater P uptake (0.207 g pot^{-1}) at higher rate of rock phosphate (7.5 g pot^{-1}) followed by 0.175 g pot^{-1} at rock phosphate rate of 5.0 g pot^{-1} while minimum P uptake (0.069 g pot^{-1}) was recorded in pot where no rock phosphate was used (Table 3). In case of zeolite rates, greater P uptake (0.152 g pot^{-1}) was observed in pot where no zeolite was applied and P uptake manifested decreasing trend from lower to higher zeolite rates while higher zeolite rate (375 g pot^{-1}) expressed comparatively lower P uptake (0.128 g pot^{-1}). It means that zeolite application did not help in P uptake by releasing P from rock phosphate under alkaline calcareous soils. Through exchange reaction zeolite adsorb Ca^{+2} from rock phosphate make P available/ soluble but in calcareous soil there is already huge quantity of calcium and it would be hard for zeolite to adsorb calcium from rock phosphate. According to [21] that P uptake by corn can only be increased when zeolite is applied in very large quantity which is economically not possible. However, in acid soil it works well in solubility of rock phosphate as reported by [19] that in presence of zeolite P uptake was increased when rock phosphate was applied to maize crop in acid soils. In acid soils, [19] observed increased in N, P and K uptake in maize by use of zeolite which might be due to nutrient retention potential of zeolite when applied along with synthetic fertilizer. [22] also reported that combine use of zeolite and fertilizer will enhance soil fertility and productivity for a long time. The study of [10] categorically indicated that combine application of rock phosphate and ammonium zeolite increased P uptake by sunflower in acid soil. The interactive effect of rock phosphate x zeolite showed non-significant differences for P uptake by maize. The results showed that the interaction of 7.5 g pot^{-1} rock phosphate x 0.0 g zeolite recorded maximum P uptake (0.22 g pot^{-1}) followed by 0.210 g pot^{-1} at the interaction of 7.5 g pot^{-1} rock phosphate x 125 g pot^{-1} zeolite. The entire rock phosphate rates showed decreasing trend in the interaction of different zeolite rates. While minimum P uptake (0.060 g pot^{-1}) was observed in the interaction of 0.0 g rock phosphate x 375 g pot^{-1} zeolite (Table 3). These interactions explain that there was no synergistic effect of rock phosphate and zeolite on P uptake in maize under calcareous condition. However, under acid soils significant interactive effect of rock phosphate x zeolite on rock phosphate dissolution was recorded by [23] using maize as a test crop. The available scientific literature predicts that nutrients equilibrium between soil and plant is disturbed when cations are removed the soil by plants leading to rock phosphate dissolution.

Dry matter yield (g pot^{-1})

Maize growth is controlled by many factors and phosphorus is one of the essential major nutrients that play major role in the development and growth of maize plant. In this study, dry matter yield of maize was affected by different rock phosphate and zeolite rates. The analysis of variance showed highly significant ($p<0.01$) differences for rock phosphate and zeolite rates, but the interactive effect of rock phosphate x zeolite showed non-significant changes in dry matter yield of maize (Table 2). The LSD Test ($p<0.05$) for mean comparison exhibited greater dry matter yield (63.53 g pot^{-1}) at higher rate of rock phosphate (7.5 g pot^{-1}) followed by 57.80 g pot^{-1} at rock phosphate rate of 5.0 g pot^{-1} while minimum dry matter yield (36.63 g pot^{-1}) was recorded in pot where no rock phosphate was applied (Table 3). In case of zeolite rates, greater dry matter yield (52.54 g pot^{-1}) was noted in pot where no zeolite was applied and dry matter exhibited decreasing trend from lower to higher zeolite rates while higher zeolite rate (375 g pot^{-1}) expressed comparatively lower dry matter (48.15 g pot^{-1}). It means that zeolite application did not help in releasing P from rock phosphate under alkaline calcareous soils. However, in acid soil, zeolite plus rock phosphate increased dry matter yield of maize [20]. The interactive effect of rock phosphate x zeolite showed non-significant differences for dry matter yield. The results indicated that the interaction of 7.5 g pot^{-1} rock phosphate x 0.0 g zeolite recorded maximum dry matter (65.56 g pot^{-1}) followed by 63.83 g pot^{-1} at the interaction of 7.5 g pot^{-1} rock phosphate x 125 g pot^{-1} zeolite. The entire rock phosphate rates showed decreasing trend in the interaction of different zeolite rates. While minimum dry matter (35.06 g pot^{-1}) was observed in the interaction of 0.0 g rock phosphate x 375 g pot^{-1} zeolite (Table 3). These interactions explain that there was no synergistic effect of rock phosphate and zeolite on dry matter yield of maize under calcareous condition.

CORRELATION

Linear regression analysis as shown in Fig 1a and b was performed on the studied parameters which indicate that there was positive and highly significant correlation between dry matter yield and P concentration (Fig. 1a) with coefficient of determination (R^2) of 0.934 and dry matter yield and P uptake with R^2 value of 0.9838. It demonstrates that dry matter yield is associated with P accumulation and uptake because a unit increase in plant P concentration will consequently increase dry matter yield by 201.38 g pot^{-1} and a unit increase in P uptake will ultimately increase dry matter yield by 195.19 g pot^{-1}. These results are in line with correlation study of [1] who noted that dry matter yield of sorghum was significantly correlated with increasing rate of rock phosphate and they also indicated positive and significant correlation between dry matter yield and zeolite and zeolite + rock phosphate rates. However, their study was conducted in acid soil.

CONCLUSION

From this study it was infered that the sole application of rock phosphate with higher rates increased maize tissue P concentration, P uptake and dry matter but zeolite application separately and in combination with rock phosphate did not affect the parameters. So, it can be evidenced that zeolite did not work well in release of P from rock phosphate under calcareous soil and have no effect on growth and nutrient uptake of the tested maize crop.

Table 1. Pre soil analysis of the experimental site for physic-chemical properties

Soil characteristics	Units	Results
Sand	(%)	47.8
Silt	(%)	27.6
Clay	(%)	24.6
Textural Class		Sandy clay loam
pH		8.11
EC	(dSm^{-1})	1.22
O.M.	(%)	0.67
Total Nitrogen	(%)	0.051
AB-DTPA extractable P	mg kg^{-1}	2.7
AB-DTPA extractable K	mg kg^{-1}	88.6

Table 2. Analysis of variance indicating mean square values of P concentration, P uptake and dry matter yield of maize

Source of variance	P conc. (%)	P uptake (g pot^{-1})	Dry matter yield (g pot^{-1})
Replication	0.01254	0.01893	903.05
Zeolite	0.00147^{**}	0.00118^{**}	39.89^{**}
Rock phosphate	0.04633^{**}	0.04655^{**}	1803.19^{**}
Zeolite x rock phosphate	0.00004^{NS}	0.00002^{NS}	0.65^{NS}
Error	0.00012	0.00024	2.69
CV	**4.17**	**11.08**	**3.24**

Table 3. Effect of rock phosphate, Zeolite and rock phosphate x zeolite on leaf tissue P concentration, P uptake and dry matter yield of maize

Treatments		P concentration (%)	P uptake (g pot^{-1})	Dry matter yield (g pot^{-1})
Rock phosphate (g pot^{-1})				
0.0		0.185 d	0.069 d	36.63 d
2.5		0.241 c	0.109 c	44.56 c
5.0		0.300 b	0.175 b	57.80 b
7.5		0.323 a	0.207 a	63.53 a
S.E.±		**0.004**	**0.006**	**0.669**
LSD (p<0.05)		**0.012**	**0.017**	**1.822**
Zeolite (g pot^{-1})				
0		0.276 a	0.152 a	52.54 a
125		0.267 ab	0.143 ab	51.06 a
250		0.255 bc	0.136 ab	50.76 a
375		0.251 c	0.128 b	48.15 b
S.E.±		**0.004**	**0.006**	**0.669**
LSD (p<0.05)		**0.012**	**0.017**	**1.822**
Rock phosphate x zeolite				
0	0	0.193 e	0.076 def	38.00 gh
0	125	0.193 e	0.073 def	37.00 gh
0	250	0.180 e	0.066 ef	36.46 h
0	375	0.173 e	0.060 f	35.06 h
2.5	0	0.256 d	0.120 cd	46.93 e
2.5	125	0.246 d	0.113 de	44.86 ef
2.5	250	0.233 d	0.106 def	44.70 ef
2.5	375	0.227 d	0.096 def	41.73 fg
5.0	0	0.316 abc	0.190 ab	59.66 bcd
5.0	125	0.303 bc	0.176 ab	58.56 cd
5.0	250	0.290 c	0.179 b	58.06 cd
5.0	375	0.290 c	0.163 bc	54.93 d
7.5	0	0.336 a	0.220 a	65.56 a
7.5	125	0.323 ab	0.210 ab	63.83 ab

7.5	250	0.316 abc	0.203 ab	63.83 ab
7.5	375	0.316 abc	0.193 ab	60.90 abc
S.E.±		**0.008**	**0.012**	**1.33**
LSD (p<0.05)		**0.033**	**0.047**	**4.99**

Mean bearing the same letters are statistically alike

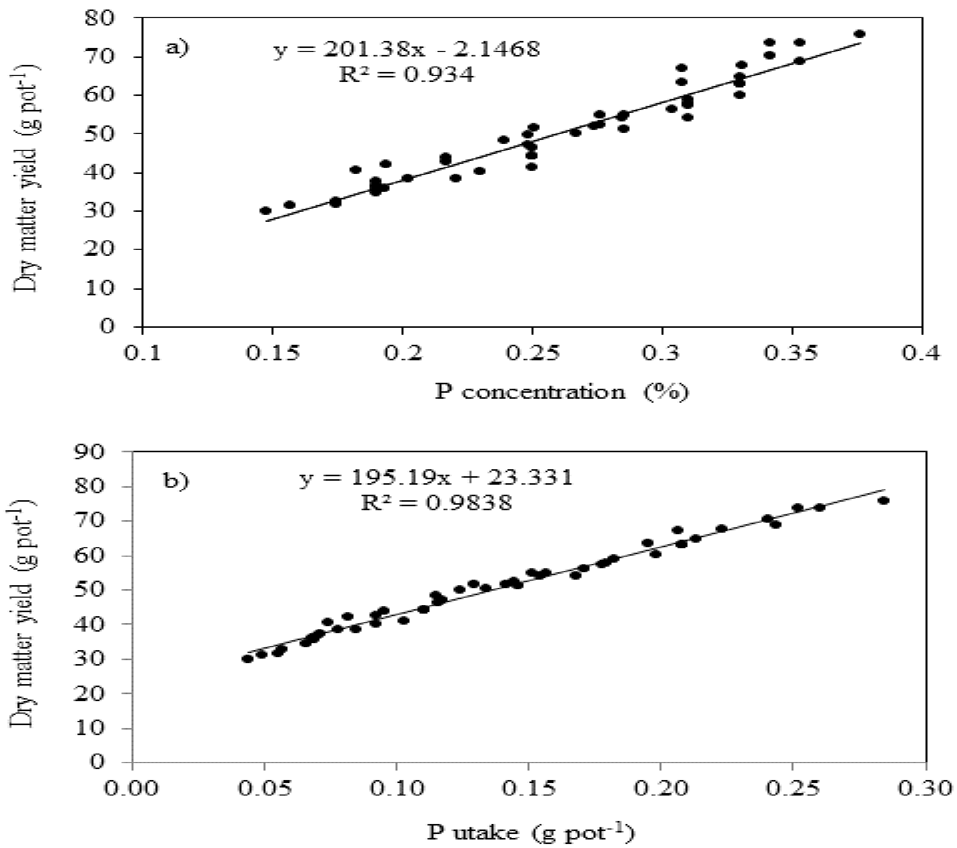

Fig. 1. Linear correlation between dry matter yield and P concentration (a), dry matter yield and P uptake (b)

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