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# Interaction effect of vesicular arbuscular mycorrhiza on increasing phosphorus availability in alkaline soil

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**Abstract**
This study aims at elucidating the combined effects of Vesicular Arbuscular Mycorrhiza with different organic and inorganic treatments in increasing the phosphorus content of alkaline soil. A pot experiment was conducted to study the interactive effect of VAM on soil pH, soil available P, phosphatase activity and inorganic P fractions. The experiment was carried out in a factorial completely randomized block design (FCRD) with four replications and five different treatment combinations. Control (no P), P alone, P + FYM, P + EFYM, P + Humic Acid. The five treatments were tried with and without VAM. The results showed that the treatment in which phosphorus was applied along with FYM and VAM showed greater soil available P (26.12 kg $ha^{-1}$) and alkaline phosphatase activity (69.80µg p-nitro phenol released $g^{-1}$ soil $hr^{-1}$) at the harvest stage of the crop. The significant difference in soil pH was also observed under the application of FYM along with VAM. The phosphorus fixed as inorganic fractions such as Saloid P, Reductant soluble P, Ca P, Fe P and Al P was also significantly reduced by VAM application along with FYM.

**Keywords:** VAM, FYM, phosphorus, maize

## Introduction

Phosphorus (P) is a critical resource for agricultural productivity and plays a vital role in the soil-plant system (Condron and Newman, 2011) [1]. It is involved in several key plant functions, such as energy metabolism, photosynthesis, respiration, nitrogen fixation, enzyme regulation, nutrient movement within the plant and transfer of genetic characteristics (DNA) from one generation to the next (Hameeda *et al*., 2008) [2]. Plants absorb P either as $HPO_4$ or $H_2PO_4$ ions. However, in most soils, the concentration of soluble orthophosphates is low, normally 1 mg $kg^{-1}$ or lower (Rodríguez and Fraga, 1999) [3] and must be replenished from other pools of soil P to meet plant requirements (Richardson *et al*., 2009) [4]. As the availability of soil P is extremely complex, a holistic understanding of P dynamics and transformation among various P pools in soil system needs to be systematically evaluated for optimizing P management.

Phosphorus (P) is receiving more attention as a nonrenewable resource (Cordell *et al*., 2009) [5]. Immedietly, after the phosphatic fertilizer is applied, the phosphorus will get fixed as calcium phosphate in case of alkaline soil which will be released only when it interacts with organic matter. Also, use of P fertilizer combined with bio fertilizer mediate the availability of P for plant uptake. Many kind of soil microorganism including VAM has the ability to accelerate the P availability for the plantations (Elsheikh *et al*., 2000) [6].

Vesicular Arbuscular Mycorrhiza (VAM) is a complex structure in plant roots formed by mutual interactions of soil fungus and roots tissues. The main role of VAM is to increase the available soil P and hence P uptake by macrosymbiont (Toljander, 2006) [7]. The increment ability in absorbing P by the plant that infected by VAM is predicted to be caused by enzyme phosphatase activities (George *et al*., 1992) [8]. VAM forms mutualistic symbiosis with the host plant and a positive effect in the absorption of nutrients, plant health and soil fertility, so it gives a positive effect on plant growth (Ramasamy *et al*., 2011) [9]. The hyphae of VAM extend the rhizosphere into a larger soil volume and access more plant-available P, also VAM produce certain organic acids and phosphatase enzymes than increase the plant-available P concentration. Mechanisms of mycorrhizal enhanced P uptake in P stress soils have been suggested previously depending either on the production of $CO_2$, which controls the solubility of Ca-phosphate minerals (Knight *et al*., 1989) [10] or on increased production of oxalate in the mycorrhizosphere, which is able to scavenge Ca $^{2+}$ ions from the soil solution (Jurinak *et al*.,1986) [11]. The aim of the study is to know the interaction of VAM with different organic and inorganic treatments in increasing phosphorus availability under alkaline condition.

## Materials and methods

### Soil collection and pot experiment

Soil sample collected from field no.31 of Eastern block in Tamil Nadu Agricultural University was used for conducting pot culture experiment on maize (CO 8). The experiment was conducted in a factorial completely randomized block design consisting of five different treatments with and without VAM. Soil was filled in 10kg pots and STCR Based recommendation of NPK fertilizers were applied in each pot followed by the application of various treatments in respective pots. The effectiveness of VAM inoculation on P availability assessed by comparing the available P, phosphatase activity and inorganic P fractions. The initial characteristics of the soil is shown in Table.1

**Table 1:** Initial characteristics of soil

| | |
|---|---|
| pH | 8.19 |
| EC (dS $m^{-1}$) | 0.24 |
| Organic Carbon (g $kg^{-1}$) | 5.5 |
| CEC (c mol ($p^{+}$) $kg^{-1}$) | 34.7 |
| Available N (kg $ha^{-1}$) | 266 |
| Available P (kg $ha^{-1}$) | 20.4 |
| Available K (kg $ha^{-1}$) | 630 |
| Inorganic P fractions (mg $kg^{-1}$) | |
| 1. Saloid P | 18.20 |
| 2. Reductant solube P | 10.61 |
| 3. Calcium P | 84.20 |
| 4. Iron P | 27.89 |
| 5. Aluminum P | 19.22 |

Treatment details

| | |
|---|---|
| $T_1V_0$- Control without VAM | $T_1V_1$- Control with VAM |
| $T_2V_0$- P alone without VAM | $T_2V_1$- P alone with VAM |
| $T_3V_0$- P + FYM without VAM | $T_3V_1$- P + FYM with VAM |
| $T_4V_0$- P+ EFYM without VAM | $T_4V_1$- P +EFYM With VAM |
| $T_5V_0$- P + Humic acid without VAM | $T_5V_1$- P + Humic acid with VAM |

All those treatments (except control) received uniform application of P @ the rate of 71.35 kg $ha^{-1}$ as SSP, VAM was applied @ rate of 5 kg $ha^{-1}$, FYM @ rate of 12.5 tones $ha^{-1}$, EFYM @ rate of 750 kg $ha^{-1}$ and Humic acid @ rate of 3 kg $ha^{-1}$.

### Soil analysis

Available phosphorus status of soil was estimated by Olsen's method (Olsen *et al.*, 1954). The rhizosphere phosphatase activity (alkaline) was analysed as proposed by Eivazi and Tabatabai (1977) and inorganic phosphates in soil were determined following the methodology of Mehta *et al*. (1954. All those parameters were analysed in knee high stage, tasseling stage, milky stage and harvest stage of the crop.

### Statistical Analysis

The data recorded were analyzed statistically using analysis of variance techniques appropriate for Factorial completely randomized design (FCRD). SPSS was used for the statistical analysis of data. Means were compared by least significant difference test (CD < 5%).

## Results and discussion

### Soil pH

The change in soil pH during different crop growth stages of the crop were shown in the Table.2. The soil pH at four critical stages of the crop shows the significant difference under the impact of different treatments and VAM. The phosphorus applied with Humic acid and VAM (7.70) showed the greater reduction in pH towards neutral which is on par with P alone with VAM, Humic acid without VAM, FYM with VAM. The significant impact of different treatment combinations with VAM was observed on soil pH. Frahat *et al*. (2018) [12] reported the increased P% in *P. aculeate* seedlings due to the reduction of pH in alkaline soil under the application of humic acid along with VAM.

### Available phosphorus (kg $ha^{-1}$)

The data in the Table.3 showed that the Phosphorus applied with FYM and VAM have significantly higher soil available phosphorus content in tasseling, milking and harvest stages of maize. The P applied with EFYM and VAM (29.92 kg $ha^{-1}$) showed the highest available phosphorus content in knee high stage followed by P with FYM and VAM (27.68 kg $ha^{-1}$). The available phosphorus in the tasseling stage, milky stage and harvest stage of the Phosphorus with FYM and VAM treatment was found to be 27.53 kg $ha^{-1}$, 26.98 kg $ha^{-1}$, 26.12 kg $ha^{-1}$ respectively. This significant increase was due to the positive interaction effect of FYM and VAM. The results obtained shows close conformity with the reports of Suri *et al*.(2011) [13] who reported the increasing P levels from no P application to 50% and 75% of recommended $P_2O_5$ dose along with VAM culture inoculations than the 100% P without VAM.

### Alkaline phosphatase activity (µg $g^{-1}$ $hr^{-1}$)

The alkaline phosphatase activity was recorded in knee high stage, tasseling stage, milky stage and harvest stage of maize as depicted in the figure 1. The alkaline phosphatase activity was found to be significantly higher in phosphorus with FYM and VAM treatment at all the four critical stages and was found to be 61.89, 21.51, 51.99, 69.80 (µg p-nitro phenol released $g^{-1}$ soil $hr^{-1}$). The significant increase in phosphatase enzyme activity also shows the positive interaction of FYM and VAM. Faujdar and Sharma (2012) [14] reported that the alkaline phosphatase activity increased 12.28% due to the application of FYM and VAM over other treatments.

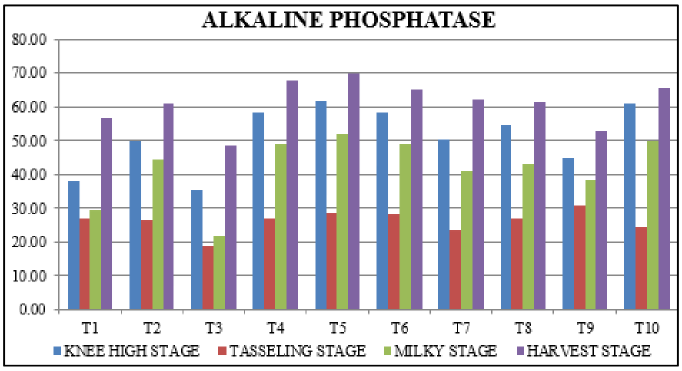


**Fig 1:** Effect of VAM on alkaline phosphatase activity

**Table 2.** Effect of VAM application on Soil pH.

| Treatments | Knee high stage | | | Tasseling stage | | | Milky stage | | | Harvest stage | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $V_0$ | $V_1$ | Mean | $V_0$ | $V_1$ | Mean | $V_0$ | $V_1$ | Mean | $V_0$ | $V_1$ | Mean |
| $T_1$- Control | 8.21 | 8.13 | 8.17 | 8.20 | 8.17 | 8.19 | 8.22 | 8.11 | 8.17 | 8.19 | 8.07 | 8.13 |
| $T_2$- P alone | 8.12 | 8.10 | 8.11 | 8.09 | 8.02 | 8.06 | 8.22 | 7.98 | 8.10 | 8.12 | 7.80 | 7.96 |
| $T_3$- P + FYM | 8.09 | 8.00 | 8.05 | 7.99 | 7.97 | 7.98 | 7.94 | 7.88 | 7.91 | 7.92 | 7.84 | 7.88 |
| $T_4$- P + EFYM | 8.25 | 8.20 | 8.23 | 8.20 | 8.18 | 8.19 | 8.22 | 8.16 | 8.19 | 8.18 | 8.24 | 8.21 |
| $T_5$- P + Humic acid | 7.99 | 7.90 | 7.95 | 7.82 | 7.78 | 7.80 | 7.82 | 7.67 | 7.75 | 7.83 | 7.70 | 7.77 |
| MEAN | 8.13 | 8.07 | 8.10 | 8.06 | 8.02 | 8.04 | 8.08 | 7.96 | 8.02 | 8.05 | 7.93 | 7.99 |
| VARIABLES | SED | CD (5%) | | SED | CD (5%) | | SED | CD (5%) | | SED | CD (5%) | |
| FERTILISER (F) | 0.07 | 0.16 | | 0.09 | 0.20 | | 0.08 | 0.16 | | 0.08 | 0.17 | |
| VAM(V) | 0.05 | 0.10 | | 0.06 | 0.12 | | 0.05 | 0.10 | | 0.05 | 0.11 | |
| F X V | 0.11 | NS | | 0.13 | NS | | 0.11 | NS | | 0.12 | NS | |

$V_1$ – With VAM; $V_0$ – Without VAM

**Table 3:** Effect of VAM application on soil available phosphorus content (kg $ha^{-1}$).

| Treatments | Knee high stage | | | Tasseling stage | | | Milky stage | | | Harvest stage | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $V_0$ | $V_1$ | Mean | $V_0$ | $V_1$ | Mean | $V_0$ | $V_1$ | Mean | $V_0$ | $V_1$ | Mean |
| $T_1$- Control | 16.60 | 18.72 | 17.66 | 15.42 | 18.21 | 16.82 | 14.60 | 17.16 | 15.88 | 14.12 | 16.89 | 15.51 |
| $T_2$- P alone | 18.76 | 19.84 | 19.30 | 18.01 | 19.72 | 18.87 | 17.64 | 18.86 | 18.25 | 17.11 | 18.28 | 17.70 |
| $T_3$- P + FYM | 25.96 | 27.86 | 26.91 | 25.40 | 27.68 | 26.54 | 24.72 | 26.98 | 25.85 | 23.96 | 26.12 | 25.04 |
| $T_4$- P + EFYM | 27.56 | 29.92 | 28.74 | 24.49 | 27.53 | 26.01 | 24.13 | 26.62 | 25.38 | 23.84 | 25.29 | 24.57 |
| $T_5$- P + Humic acid | 22.29 | 23.49 | 22.89 | 21.74 | 22.99 | 22.37 | 21.12 | 22.14 | 21.63 | 20.32 | 21.92 | 21.12 |
| MEAN | 22.23 | 23.97 | 23.10 | 21.01 | 23.23 | 22.12 | 20.44 | 22.35 | 21.40 | 19.87 | 21.70 | 20.79 |
| VARIABLES | SED | CD (5%) | | SED | CD (5%) | | SED | CD (5%) | | SED | CD (5%) | |
| FERTILISER (F) | 0.24 | 0.50 | | 0.28 | 0.57 | | 0.22 | 0.46 | | 0.19 | 0.40 | |
| VAM(V) | 0.15 | 0.32 | | 0.17 | 0.36 | | 0.14 | 0.29 | | 0.12 | 0.25 | |
| F X V | 0.35 | 0.71 | | 0.40 | 0.81 | | 0.32 | 0.65 | | 0.28 | 0.57 | |

$V_1$–With VAM; $V_0$–Without VAM

**Table 4:** Effect of VAM application on Soil inorganic P fractions (mg $kg^{-1}$).

| Treatments | Saloid P | | | Reductant soluble P | | | Calcium P | | | Iron P | | | Aluminum P | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $V_0$ | $V_1$ | Mean | $V_0$ | $V_1$ | Mean | $V_0$ | $V_1$ | Mean | $V_0$ | $V_1$ | Mean | $V_0$ | $V_1$ | Mean |
| $T_1$- Control | 18.24 | 20.21 | 19.23 | 11.00 | 10.72 | 10.86 | 90.12 | 86.23 | 88.18 | 29.64 | 27.24 | 28.44 | 19.72 | 19.45 | 19.59 |
| $T_2$- P alone | 23.41 | 22.12 | 22.77 | 12.92 | 12.72 | 12.82 | 92.87 | 91.72 | 92.30 | 30.14 | 30.11 | 30.13 | 21.11 | 20.97 | 21.04 |
| $T_3$- P + FYM | 23.24 | 20.91 | 22.08 | 14.92 | 12.67 | 13.80 | 97.32 | 91.42 | 94.37 | 32.56 | 30.42 | 31.49 | 22.32 | 20.52 | 21.42 |
| $T_4$- P + EFYM | 26.14 | 23.14 | 24.64 | 14.89 | 14.74 | 14.82 | 101.41 | 94.21 | 97.81 | 35.21 | 32.82 | 34.02 | 23.94 | 21.07 | 22.51 |
| $T_5$- P + Humic acid | 27.82 | 25.91 | 26.87 | 13.94 | 13.12 | 13.53 | 95.28 | 94.79 | 95.04 | 33.32 | 32.11 | 32.72 | 22.34 | 21.31 | 21.83 |
| MEAN | 23.77 | 22.46 | 23.11 | 13.53 | 12.79 | 13.16 | 95.40 | 91.67 | 93.54 | 32.17 | 30.54 | 31.36 | 21.89 | 20.66 | 21.28 |
| VARIABLES | SED | CD (5%) | | SED | CD (5%) | | SED | CD (5%) | | SED | CD (5%) | | SED | CD (5%) | |
| FERTILISER (F) | 0.24 | 0.50 | | 0.13 | 0.27 | | 0.99 | 2.02 | | 0.35 | 0.71 | | 0.22 | 0.46 | |
| VAM(V) | 0.15 | 0.32 | | 0.08 | 0.17 | | 0.62 | 1.28 | | 0.22 | 0.45 | | 0.14 | 0.29 | |
| F X V | 0.35 | 0.71 | | 0.19 | 0.39 | | 1.40 | 2.86 | | 0.49 | 1.01 | | 0.32 | 0.66 | |

$V_1$ – With VAM; $V_0$ – Without VAM

### Inorganic P fractions (mg $kg^{-1}$)

The dynamics of inorganic P fractions were studied initially and also at harvest stage. The initial values of inorganic P fractions such as saloid P, Reductant soluble P, Ca- P, Fe - P and Al - P were depicted in Table.1. Phosphorus applied with FYM and VAM has recorded greatest significant difference in P fractions and lowest values than all other treatments. At harvest stage, the inorganic P fractions such saloid P, Reductant soluble P, Ca- P, Fe - P and Al - P of the treatment was found to be 20.91 mg $kg^{-1}$, 12.67 mg $kg^{-1}$, 91.42 mg $kg^{-1}$, 30.42 mg $kg^{-1}$ and 20.52 mg $kg^{-1}$ respectively. This shows the positive interaction of VAM with FYM. The result on inorganic P fractions obtained were corroborating with those reported by Geetha and Radder (2015) [15], that the treatment containing 80 kg $P_2O_5$ /ha+ FYM + PSB +VAM shown the significant difference in inorganic P fractions than all other treatment combinations.

### Conclusion

The study revealed that the application of inorganic phosphorus along with farm yard manure and Vesicular Arbuscular Mycorrhiza (VAM) increased the phosphorus availability by solubilising and mobilising the different phosphorus bound fractions, mainly the Calcium bound fraction, which is usually the dominant P bound fraction in alkaline soil. The same treatment also showed the decrease in pH towards neutral thereby facilitating the increased P availability. Application of organic, inorganic and VAM together was confirmed to be the best phosphorus management practice for alkaline soil.

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