RESEARCH ARTICLE

Interaction Effect of Vesicular Arbuscular Mycorrhiza with Different Amendments on Increasing Phosphorus Uptake

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ABSTRACT

Phosphorus (P), a essential element for all living organisms is often the most limiting nutrient in soil-plant systems. In order to increase the phosphorus content in plants and its uptake efficiency in alkaline soil, the following study was undertaken. The experiment was carried out in a factorial completely randomized block design with five treatment combinations viz., Control (no P), P alone @ 71.35 kg ha^{-1}, P with Farm Yard Manure (FYM) @ 12.5 t ha^{-1}, Enriched Farm Yard Manure (EFYM) (FYM @ 750 kg ha^{-1} enriched with recommended dose of SSP) and P with Humic acid @ 3 kg ha^{-1}. All the five treatments were tried with and without Vesicular Arbuscular Mycorrhiza (VAM) @ 5 kg ha^{-1} and the experiment was replicated four times. The phosphorus concentration in soil and plant samples were analysed. The available phosphorus status in soil showed a decreasing trend along the growth stages of maize but the application of P with FYM (25.04 kg ha^{-1}) and as EFYM (24.57 kg ha^{-1}) recorded significantly higher available P in all the stages. The plant P concentration also showed the decreasing trend along the crop growth stages and recorded the highest concentration in P with FYM and VAM treatment (0.19 %). The grain P uptake (0.14 g pot^{-1}) and stover uptake (0.10 g pot^{-1}) was also found to be higher in the application of P and FYM with VAM. The combined application of inorganic minerals (SSP @ 71.35 kg ha^{-1}) along with organics (FYM @ 12.5 t ha^{-1}) and bioinoculants (VAM @ 5 kg ha^{-1}) can enhance the soil quality and health for the sustainable crop production.

Keywords: *Phosphorus; VAM; FYM; P uptake*

INTRODUCTION

Phosphorus (P) nutrition of plants has rightly been regarded as the "key to human hunger" because of its pivotal role in the normal growth of plant, but it is often the most limiting nutrient in soil-plant systems. Similarly with increasing demand of agricultural production and as the peak in global production will occur in the next decades, Phosphorus (P) is receiving more attention as a non renewable resource (Cordell *et al.*, 2009; Liu *et al.*, 2017). It has been reported that only 10 to 40% of the applied phosphorus is available to the plants (Aulakh and Pasricha, 1999) and the rest of applied P remains as soil reaction products of lower solubility such as calcium phosphate, iron phosphate and aluminium phosphate, etc. Immediately, 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 kinds of soil microorganism including VAM has the ability to accelerate the P availability. The application of right combination of amendments can improve the uptake of native as well as the applied phosphorus by crop (Roberts & Johnston, 2015).

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). The increment ability in absorbing P by the plant that infected by VAM is predicted to be caused

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by enzyme phosphatase activities (George *et al*., 1992). 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; Daneshgar *et al*., 2018). 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 to 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) 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).

Therefore, exploiting proper management strategies for consumption of P sources and increasing P utilization efficiency are the areas of interest among the scientific community engaged in P acquisition and P utilization (DeLuca *et al*., 2015). One possible strategy to increase P solubilization and mobilisation of P sources is by the application of phosphate mobilisers in our agro-ecosystems. Hence the study was conducted to know the interaction effect of VAM with different organic and inorganic treatments in increasing phosphorus uptake under alkaline condition.

MATERIAL 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 10 kg 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 was assessed by comparing the available P, phosphatase activity and inorganic P fractions. The initial characteristics of the soil and treatment details are shown in Table.1 and Table.2 respectively.

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

Soil and Plant analysis

Available phosphorus status of soil was estimated by Olsen's method (Olsen *et al.,* 1954) and the total phosphorus content of plant was estimated by Triple acid extraction and Vanado molybdo phosphoric acid yellow colour method (Jackson, 2005).

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

Effect of VAM with different amendments on soil available P

The Soil phosphorus content showed a decreasing trend along the crop growth stages (Figure 1 and 2). This may be attributed to the uptake of P by plants or due to the fixation of phosphorus in soil to unavailable forms. The available phosphorus was higher in the treatment receiving inorganic P than the control (Belay *et al.*, 2002). The application of P with FYM and as EFYM recorded significantly higher available P in all the stages. The higher available P in FYM and EFYM applied treatments may be due to the influence of manure in complexation of Ca^{2+} and Mg^{2+} cations and thereby increasing the labile P pool (Gupta *et al.*, 2006).

The data showed that the phosphorus applied with FYM @ 12.5 t ha^{-1} and VAM @ 5 kg ha^{-1} have significantly higher soil available phosphorus content in tasselling, milking and harvest stages of maize. The soil inoculation of VAM increased the available P content by inducing the activity of phosphatase in the rhizosphere zone. Inoculation of VAM showed the higher P availability than other biofertilizers (Guo *et al.*, 2010; Fahramand *et al.*, 2014). The higher phosphorus availability has been observed due to the combined effect of FYM and VAM (Faujdar and Mahendra, 2012). The increased P release under the combined application of organics and inorganics may be due to the release of organic acids during the organic decomposition which in turn improve the P availability by its solubilising action of native P in soil (Urkurkar *et al.*, 2010).

The P applied as 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 tasselling 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) 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 100% P without VAM.

Effect of VAM with different amendments on plant P content and P uptake

The results in Table.3 showed that the plant phosphorus content was highest in the phosphorus and FYM along with VAM applied treatment in all the critical stages. The plant P content follows the decreasing trend along the crop growth. This may be attributed to the increased uptake of phosphorus by the plants. The FYM increases the solubilisation by production of organic acids and the VAM increased mobilisation. The higher P content was noticed in the treatment FYM with VAM than FYM alone (Rekha *et al.*, 2018). Increase in phosphorus content in the presence of FYM and VAM is due to the direct effect of increased root length and increased phosphorus availability (Argal *et al.*, 2017; Yadav *et al.*, 2017).

The results of P uptake shows that the increased P uptake in stover (0.10 g pot^{-1}) and grain (0.14 g pot^{-1}) was observed in P with FYM @ 12.5 t ha^{-1} and VAM @ 5 kg ha^{-1}. 100% RDF with FYM and VAM significantly increased the P uptake by the secretion of growth promoting substances. 40 to 59% of increase in stover and grain P uptake in P with FYM and VAM treated plots than the control is due to the continuous supply of nutrients under integrated nutrient management (Meena *et al.*, 2013). Higher phosphorus uptake was recorded in the application of 100% RDF with VAM and FYM, attributed to the higher dose of nutrient applied along with more mobilization and solubilisation of the phosphorus applied (Rathore *et al.*, 2011; Kumar *et al.*, 2018).

Maximum phosphorus uptake in VAM inoculated plants is associated with the formation of fungal sheath network called ‘Hartig net’ around the roots which helped in the increased mobilization of phosphorus and uptake by roots (Praneeth *et al.*, 2018). The integration of mineral fertilizers, organics with bio inoculants increased the P uptake. The enhanced P uptake and use efficiency in FYM amended, VAM inoculated and P applied plots may be attributed to the increased rate of decomposition and mineralization process, proper root development and higher P availability (Khan *et al.*, 2007).

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

Table 2. 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- EFYM without VAM	T_4V_1- EFYM With VAM
T_5V_0- P + Humic acid without VAM	T_5V_1- P + Humic acid with VAM

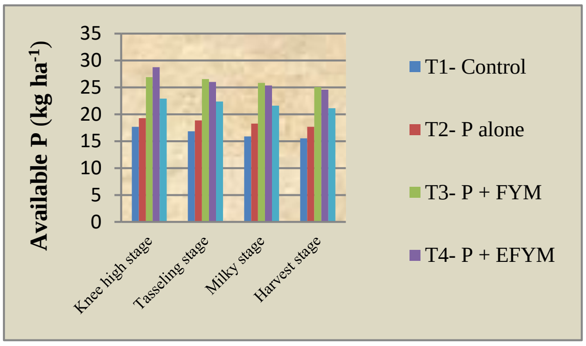

Figure 1. Effect of different amendments on soil available P

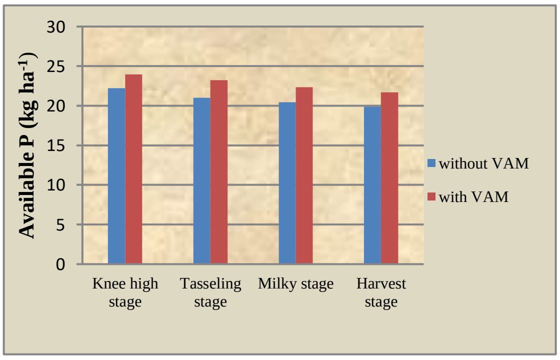

Figure 2. Effect of VAM on soil available P

Table 3. Effect of VAM & different amendments on P content (%) and uptake (g pot^{-1})

Treatments	TOTAL P (%)						P UPTAKE (g pot^{-1})								
	GRAIN			STOVER			GRAIN			STOVER			TOTAL		
	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	0.206	0.274	**0.240**	0.180	0.188	**0.184**	0.07	0.11	**0.09**	0.06	0.08	**0.07**	0.12	0.19	**0.16**
T_2- P alone	0.279	0.321	**0.300**	0.182	0.189	**0.186**	0.07	0.10	**0.08**	0.05	0.06	**0.06**	0.13	0.16	**0.14**
T_3- P + FYM	0.314	0.372	**0.343**	0.190	0.197	**0.194**	0.13	0.15	**0.14**	0.09	0.10	**0.10**	0.22	0.25	**0.24**
T_4- EFYM	0.294	0.366	**0.330**	0.192	0.195	**0.194**	0.09	0.14	**0.11**	0.07	0.09	**0.08**	0.16	0.23	**0.20**
T_5-P + Humic acid	0.214	0.300	**0.257**	0.184	0.189	**0.187**	0.07	0.11	**0.09**	0.09	0.08	**0.09**	0.16	0.19	**0.18**
MEAN	**0.261**	**0.327**	**0.294**	**0.186**	**0.192**	**0.189**	**0.08**	**0.12**	**0.10**	**0.07**	**0.08**	**0.08**	**0.16**	**0.20**	**0.18**
VARIABLES	**SEd**	**CD(5%)**		**SEd**	**CD (5%)**		**SEd**	**CD (5%)**		**SEd**	**CD (5%)**		**SEd**	**CD (5%)**	
Fertiliser (F)	0.003	0.006		0.001	0.003		0.001	0.002		0.001	0.001		0.002	0.004	
VAM(V)	0.002	0.004		0.001	0.002		0.001	0.001		0.001	0.001		0.001	0.002	
F X V	0.004	0.009		0.002	NS		0.002	0.003		0.001	0.002		0.003	0.006	

V_0- Without VAM ; V_1- With VAM

Conclusion

The study revealed that the application of inorganic phosphorus along with Farm yard Manure (FYM) @ 12.5 t ha^{-1} and Vesicular Arbuscular Mycorrhiza (VAM) @ 5 kg ha^{-1} 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 increase in plant phosphorus content and P uptake. Application of organic, inorganic and VAM together was confirmed to be the best phosphorus management practice for alkaline soil.

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