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VESICULAR ARBUSCULAR MYCORRHIZAE (VAM): A SUSTAINABLE APPROACH FOR SOIL PHOSPHORUS AND RAIN-HARVESTED WATER ECONOMY MANAGEMENT IN ACID SOILS OF WESTERN HIMALAYAN SOIL

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The present scenario reveals that the world population is increasing day by day whereas, food grain production is not increasing proportionately due to various factors such as decline in soil health and climate change phenomenon as manifested by unpredictable patterns of rainfall and temperature. The major reason for poor soil health seems to be the unbalanced nutrient application to crops. One of the most important strategies, particularly in the wake of the intense energy crisis is the improvement in fertilizer phosphorus use efficiency, which is the lowest amongst all plant nutrients. Fertilizer phosphorus has contributed tremendously towards increasing food production, yet even with best agronomic practices, the recovery of fertilizer phosphorus hardly exceeds 10-20 per cent because of the reason that most of the applied phosphorus get precipitated/ fixed and thus becoming unavailable for plant use.

A number of approaches such as liming, sub-soil placement, application of P in splits and dipping of seedlings into soluble P slurry, etc. aimed at increasing phosphorus use efficiency have been developed in India and abroad, but unfortunately, none of the above strategies has been found to be equally has been found to be equally effective under different situations. (Cordell *et al*. 2009). Among the first three macro-nutrients, phosphorus is one of the prime nutrients necessary for the growth of all forms of life on planet earth covering plants, animals and micro-organisms as a structural component of cell constituents *(cell membranes, chloroplasts & mitochondria)* and that of metabolically active compounds. Some important compounds of which P is a component are viz. sugar phosphates (ADP, ATP, etc.), nucleic acids, nucleoproteins, nucleotides, NADP, pyridoxal phosphate and thiamine pyrophosphate.

Above compounds actually play an important role in growth *(cell division and elongation)*, photosynthesis, respiration, energy storage/ transfer and several other plant processes. As such, phosphorus promotes early root formation and overall crop growth and thereby hastening maturity. Phosphorus improves the quality of fruits, vegetables and that of food grain crops, it being a component of RNA and nucleoproteins (Vance *et al*. 2003). The acid soils occupy about 39.5 million square kilometres of area in the world, which happens to be about 25.9 per cent of the total geographical area. Out of the total cultivatable area (141 m ha) in India, approximately 49 m ha of land suffers from soil acidity. Out of49 m ha area, 25.9 m ha area has pH less than 5.6, whereas 23.1 m ha has pH ranging between 5.6 to 6.5 (Sharma and Sarkar 2005).

Barring the situation around neutral pH (6.5-7.0 ±0.5), phosphorus availability to plants is a major constraint in both acid and alkaline soils; its average efficiency being 10-20 per cent. In case of acid soils, much of the applied phosphorus may react with Fe and Al ions *(existing in insoluble and exchangeable forms)* thereby, getting precipitated/ fixed as Fe and Al hydroxyl phosphates and thus becoming unavailable for plant use. In alkaline soils, much of it may react with Ca^{2+} ion *(existing in above forms)* thereby getting precipitated as Ca hydroxyl phosphate and turning, out of bounds, for plant use (Brady 2002). In both the above situations, the concentration of P in soil solution is in the micro-molar range; besides, P diffuses slowly in most soils. Hence, depletion of P in the root zone commonly limits further uptake of P by existing roots and potentially, by the plants as a whole.

A number of approaches such as liming, sub-soil placement, application of P in splits and dipping of seedlings into soluble P slurry, etc. all aimed at increasing phosphorus use efficiency have been developed both in India and abroad, but unfortunately, none of the above strategies is equally effective under different situations. Therefore, there is an urgent need to attempt some alternative approach to tackle the problem of low phosphorus use efficiency, especially in acid soils. The majority of Himalayan farmers are small and marginal. They are unable to apply chemical fertilizers in recommended amounts because of their low purchasing power, small and scattered land holdings, remoteness, rainfed/ subsistence nature of farming and lack of awareness about new technologies. Phosphorus is the costliest fertilizer due to which the farmers apply only a nominal amount to their crops due to obvious reasons.

In the Indian Himalaya, the most of the soils come under acid soils which represent about 33 per cent of cultivable land in the various Himalayan States. About 75 per cent of the total rainfall occurs during just four months of the year (June to September). Unfortunately, most of the rainwater gets wasted by as excess run-off in streams, rivers, etc. carrying along with it the fertile soil and nutrients. Run-off water could be harvested and stored in the farm ponds followed by its judicious utilization, particularly in vegetable crops, which are more remunerative (Singh and Mal, 2014). However, in acid soil, especially of high rainfall regions such as Palam Valley, phosphorus availability is much limited because of the reason that applied phosphorus gradually reacts with Fe and Al compounds present in the soil and consequently, it gets transformed into relatively insoluble compounds *(variscite and strengite*), which are hardly available to plants. Phosphorus and harvested rainwater are costly commodities and therefore, must be used efficiently with the aim of maximum economic returns to the farmers.

The soil is a good habitat for many beneficial microbes, including mycorrhizal fungi. Mycorrhiza biofertilizer (VAM), is an inexpensive and eco-friendly input which is capable of enhancing both P availability and water-use–efficiency of crops. Mycorrhizae belong to kingdom fungi, division Glomeromycota, class Glomeromycetes, order Glomerales and family Glomeraceae. Above fungi are associated with plants either upon root surfaces (*ectomycorrhizae*) or inside root tissues (*endo mycorrhizae*). The VAM fungi are a common member of *endo mycorrhizae*. Vesicular arbuscular mycorrhizal (VAM) symbiosis refers to a mutualistic, symbiotic relationship formed between fungi and living roots of higher plants. Mycorrhizae are associated with plants either upon root surfaces (*ectomycorrhizae*) or inside root tissues (*endo mycorrhizae*).

The VAM fungi are a common member of *endo mycorrhizae*. The VAM symbiosis is characterized by fungal structures inside roots, namely hyphae, arbuscules*(highly branched structures)* and vesicles *(drop-shaped storage organs, not always present).* The VAM fungi receive carbon compounds/ nutritional requirements from host plant roots. In turn, they supply nutrients to the plants (N, P, K, Ca, Cu, Zn, etc), which are absorbed by them from the soils (Lalitha*et al*. 2017).Over 95 per cent of plants, form mycorrhizae. However, members of *Brassicaceae*and *Chenopodiaceae* families do not form the above association. The VAM fungi do so by expanding the surface area of the plant root system by 10 to 1000 fold into the soil through ramifying hyphae, thereby increasing their exploratory area for harnessing especially phosphorus and water (Meena*et al*. 2019).

Above fungi solubilize inorganic forms of P through the release of low molecular weight organic acids *(oxalic, malic acids, etc.)*. Above compounds solubilize insoluble phosphates by lowering soil pH, causing chelation of Fe and Al cations and competing with phosphate ions for adsorption sites on soil exchange complex, thereby releasing P into soil solution for plant use. Further, through secretion of a number of enzymes *(chitinase, peroxidase, cellulase, protease, phosphatase, etc.),* VAM fungi attack complex organic compounds converting them into simple ones, which can be absorbed and used by fungi/ host plants to meet their energy needs for growth and reproduction (Chen *et al.* 2007). Some workers have reported that combined use of mycorrhizal biofertilizer (VAM) with 75 per cent of soil test based recommended Pdose improved yields and quality of wheat, soybean, maize and okra to the same extent as 100 per cent P_2O_5 application, indicating a saving of 25 per cent fertilizer phosphorus (Suri *et al.* 2011).

Use of mycorrhizal biofertilizer (VAM) may be a good proposition to enhance P use efficiencies of crops. The VAM fungi do so by extending the plant root system into the soil through ramifying hyphae, thereby increasing its exploratory area for harnessing especially phosphorus and water. Above fungi not only partially meet our nutrient requirements of crops but, also confer other associated benefits on plants such as increased resistance to diseases, drought, soil salinity and also enhance nitrogen fixation in legumes. Many workers have reported increased uptake of nutrients (N, P, K, Ca, Mg, Fe, Zn, Cu and Mn) in plants inoculated with VAM biofertilizer under various soil and climatic conditions (Kumar 2010).

The VAM symbiosis often results in altered rates of water movement into, through and out of host plants, with consequent effects on tissue hydration and leaf physiology. Mycorrhizal fungi (VAM), which is an inexpensive and eco-friendly input, is capable of enhancing water-use–efficiency of crops. The VAM fungi do so by extending the plant root system into the soil through ramifying hyphae, thereby increasing its exploratory area for harnessing especially phosphorus and water. Mycorrhizal hyphae penetrate soil pores which are inaccessible to root hairs and thus absorb water which is not available to non-mycorrhizal plants. The higher water use efficiency in mycorrhizal plants might be due to the enhanced ability of roots to absorb soil moisture, thereby maintaining stomata in an open condition.

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Enhanced water conductivity is attributed to increased surface area for water uptake provided by fungal hyphae in the soil. VAM fungi improved the capability of root systems to draw water in dry soil, resulting in less water stress to foliage and hence, higher transpiration.

The state of Western Himalaya has favourable soil and climatic conditions for the cultivation of various vegetable crops, which are far more profitable than the traditional cereal-based cropping systems. As such, it is worthwhile that the farmers should divert a part of their land from conventional rice (or maize)-wheat sequence to a profitable and sustainable vegetable-based cropping sequence; One of the crops in the sequence should preferably be a legume crop. The legume crops enhance soil fertility and being rich in protein, help provide nutritional security to the farmers. Garden pea (*Pisumsativum* L.) is an important vegetable crop being very palatable, nutritious and amenable to preservation and consumption in the off-season. Presently, it is fetching a high premium in local and super vegetable markets. The area under pea is increasing rapidly in the state, especially under high and mid-hill zones, leaving behind the most important and major vegetable crop i.e. potato (Suri *et al.* 2011). Above trend is perhaps because of easy availability of high yielding disease resistant varieties of pea.

Conclusion

Though the use efficiency of phosphorus is very low, it has a tremendous role in increasing food grain production. Phosphorus is one of the prime nutrients necessary for the growth of all forms of life on planet earth covering plants, animals and micro-organisms as a structural component of cell constituents *(cell membranes, chloroplasts & mitochondria)* and that of metabolically active compounds. In acid soils, high quantity of Fe and Al compounds restrict the phosphorus use efficiency. Mycorrhiza biofertilizer (VAM), is an inexpensive and eco-friendly input which is capable of enhancing both P availability and water-use–efficiency of crops. The VAM symbiosis is characterized by fungal structures inside roots, namely hyphae, arbuscules*(highly branched structures)* and vesicles *(drop-shaped storage organs, not always present).* The legume crops enhance soil fertility and being rich in protein, help provide nutritional security to the farmers. Garden pea (*Pisumsativum* L.) is an important vegetable crop being very palatable, nutritious and amenable to preservation and consumption in the off-season.

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References

Brady, N.C.2002. *The Nature and properties of Soils*. Prentice Hall of India Private Limited, Inc.p 621.

Chen, C.R., Condron, L.M. and Xu, Z.H. 2007. Impacts of grassland afforestation with coniferous trees on soil phosphorus dynamics and associated microbial processes: A review. *Forest Ecology and Management* 255: 396–409.

Cordell, D., Drangert, J.O. and White, S. 2009. The story of phosphorus: global food security and food for thought. *Global environmental change* 19.2 (2009): 292-305.

Kumar, S. 2010. Studies on Vesicular Arbuscular Mycorrhizae (VAM) in meeting phosphorus needs of okra-wheat sequence in Typichapludalf. *Ph.D. Thesis, CSK HPKV, Palampur (HP).*

Lalitha, M., Kumar, K.A., Dharumarajan, S., Balakrishnan, N., Srinivasan, R., Nair, K.M. and Singh, S. K. 2017. Role of vesicular-arbuscular mycorrhizae in mobilization of soil phosphorus. In *Agriculturally Important Microbes for Sustainable Agriculture* (pp. 317-331). Springer, Singapore.

Meena, A.L., Meena, L.K., Kumar, C.G. and Kumar, A. 2019. Mycorrhiza enriched biofertilizers for enhancing plant growth. *Agriallis* 1(4):23-32.

Sharma, P.D. and Sarkar, A.K. 2005. Managing acid soils for enhancing productivity. Natural resource management division (ICAR) Krishi Anusandhan Bhavan-II, Pusa Campus, New Delhi, *Technical Bulletin*, pp. 23.

Singh, R. B. and Mal, S.2014. Trends and variability of monsoon and other rainfall seasons in Western Himalaya, India. *Atmospheric Science Letters* 15(3):218-226.

Suri, V.K., Choudhary, A.K., Chander, G. and Verma, T.S. 2011. Influence of vesicular arbuscularmycorrhizal fungi and applied phosphorus on root colonization in wheat and plant nutrient dynamics in a P deficient acid Alfisol of Western Himalayas. *Communication in Soil Science and Plant Analysis* 42(10):1177-1186.

Vance, C.P., Uhde-Stone, C. and Allan, D.L. 2003. Phosphorus acquisition and use: critical adaptations by plants for securing a non-renewable resource. *New Phytology* 157:423–447.