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INTERACTION BETWEEN MYCORRHIZAE AND ORGANIC AMENDMENTS TO IMPROVE GROWTH AND PHOSPHORUS UPTAKE IN BRINJAL

[a]Ammar Siddique, [a,b]Zain Mushtaq, [c]Waheed Anwar, [c]Karamat Ali Zohaib, [c]Adnan Akhter, [d]Farman Ahmad
[a] *Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan.*
[b] *Department of Soil Science, University of the Punjab, Lahore, Pakistan.*
[c] *Department of Plant Pathology, University of the Punjab, Lahore, Pakistan.*
[d] *School of Food and Nutrition, Minhaj University, Lahore, Pakistan.*

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ABSTRACT

Phosphorus (P) is the second most important macronutrient both for plants and other living organisms. However, due to its fixation with soil collides; it becomes unavailable to plants and hence cannot enter the food chain. The effect of combination of mycorrhizae and different organic amendments on P uptake and plant growth of brinjal (*Solanum melongena*) was evaluated in a pot trial, conducted at wire house of Institute of Soil and Environmental Sciences, University of Agriculture Faisalabad. Each treatment was composed of one type of organic amendment (i.e. farmyard manure (FYM), biogas slurry (BGS), poultry manure and compost) at the rate of 1.5% w/w and mycorrhizae. Results showed that the combined application of mycorrhizae and organic amendment improved plant growth and enhanced P uptake. Improved root length, shoot height and leaf canopy was observed in FYM+mycorrhizae and BGS+mycorrhizae combinations. Similarly, enhanced P uptake improved photosynthetic activity and high biomass was observed in BGS+mycorrhizae combinations. The use of mycorrhizae and organic amendments appeared to be efficient in improving P uptake up to 53.45% and plant growth 64.32%. It is concluded that practicing this in the field can be cost effective approach and reduce environmental risk by reducing application of chemical fertilizers.

Corresponding Author: Zain Mushtaq
Email: zmushtaq60@gmail.com

INTRODUCTION

Overexploitation and unscientific use of soil, ignoring long-term sustainability results in deterioration of soil health and jeopardizes food security (Sanwal et al., 2007). This poses harmful effects on the quality and quantity of food production and causes a lot of environmental and socio-economic concerns. It is a challenging task to manage ever deteriorating chemical, biological and physical characteristics of cultivated and cultivable soils in such a way to keep them highly productive.

Phosphorus is regarded as the 2nd major component of plant nutrition after nitrogen (Azziz et al., 2012). It helps in nearly all major processes i.e. photosynthesis, signal transduction, respiration, transfer of energy and macromolecules which are biosynthesized in plants. Out of total soil P (0.5%), only (0.1%) is available to plants. A reasonable proportion has been reported as insoluble form of phosphorous in soil and therefore not available to plants. P deficiency severely limits plant growth and production (Khan et al., 2010). Conventionally, applying fertilizer of phosphorous is supposed to be the only solution to address soil P deficiency. Environmental hazards such as eutrophication and groundwater contamination results due to excessive P fertilizer application to correct P deficiency but majority of this is not available to plants (Kang et al., 2011).

Plant nutrient acquisition can be improved by soil microorganisms. Insoluble nutrients can be converted into plant available forms by various biological processes carried out by these microorganisms (Babalola and Glick, 2012), some of these are able to solubilize and mineralize insoluble P to fulfill plant needs. The only possible way to increase plant available P is microbial solubilization and mineralization other than chemical fertilization. Various rhizospheric microorganisms are found to be effective in increasing the phosphorous concentration in soil by different mechanisms (Bhattacharyya and Jha, 2012). Several species of bacteria and fungi, capable for solubilizing P *in vitro* and some can even mobilize P in plants (Zhu et al., 2011) (Sharma et al., 2013).

As compared to bacteria, fungi produce and release more acids (tartaric, citric, gluconic, 2-ketogluconic, acetic and lactic acids). Moreover, fungi is reported to travel more distance within the soil easily as compared to bacteria (Srinivasan et al., 2012). Soil fungi form mycorrhizal association with almost 80% of terrestrial species of plant. Most of these fungal interactions like mycorrhizae, favor both partners collectively and are characterized by a bidirectional sharing of material across the fungal interface with plants (Bücking et al., 2012). Increase in P uptake by mycorrhizal plants has been documented through various mechanisms. Plants have evolved many adaptive mechanisms to avoid P stress and interactions between root and soil-borne mycorrhizae is one of them (Smith and Read, 2010).

Soils in semi-arid areas are generally deficient in organic matter (< 1%) and often low in plant-available nutrients particularly P, instead of having high total soil P content (Muhammad et al., 2008). Different studies show that organic matter plays a critical role in plant growth promotion by improving biological, chemical and physical properties of soil. Organic amendments i.e. compost and manure are helpful in increasing crop production and organic matter contents. It results in higher yields, better seed germination and root development. Organic amendments also help in flourishing introduced microbial agents (Celestina et al., 2019). The objective of the present study was therefore, to study the interaction of mycorrhizae and organic amendments to improve growth and phosphorus uptake in brinjal.

MATERIALS AND METHODS

A pot trial was performed in wire house of Institute of Soil and Environmental Sciences (ISES), University of Agriculture, Faisalabad. Each pot was filled with 10 kg of soil having uniform composition for each treatment. Prior to sowing, organic amendments and mycorrhizae were mixed within the soil. One strain of mycorrhizae and four different types of organic amendments (FYM, biogas slurry, compost and poultry manure) was applied at the rate of 1.5% w/w basis. All the nutrients were applied as per recommended dose through DAP, urea and MOP fertilizers. Weeds were removed physically. Seedlings were transplanted in the pots and irrigated as per requirement. There were 10 treatments viz. T1 (control), T2 (compost), T3 (FYM), T4 (BGS), T5 (poultry manure), T6 (mycorrhizae), T7 (compost + mycorrhizae), T8 (FYM+mycorrhizae), T9 (BGS+mycorrhizae), and T10 (poultry manure+mycorrhizae). Each treatment was replicated thrice. Completely randomized design was followed in the experiment. Growth and yield data was recorded uniformly from all the treatments. Fruit from the plants were picked twice. Second picking was performed 20 days after the first picking.

Plant samples of root and shoot were analyzed for biomass determination and fruit for phosphorus analysis. Fruit samples were prepared for wet digestion. One gram of oven dried and well ground fruit sample was taken in digestion tube, 10 ml of sulphuric acid was added and was left overnight. Samples were digested for 30 minutes on hot plate at 300°C. Hydrogen peroxide was added drop by drop until clear filtrate appeared.

Reagents for P determination were prepared. Ammonium heptamolybdate solution (22.5 g in 400 ml DI water) was mixed with ammonium metavanadate solution (1.25g in 300 ml DI water) and the solution was poured into 1 L flask and left for cooling. Nitric acid (250 ml) was slowly added into the flask and volume was made by DI water. Standard stock solution was prepared by taking 0.2197 g oven dried potassium dihydrogen phosphate solution of 1 L volume. Strength of this solution was 50 ppm.

Standard stock solution (1, 2, 3, 4 and 5 ml) was added into 100 ml flask and volume was made up to the required level with DI water for preparing sub-standards. Ten milliliter clear filter was added in volumetric flask of 100 ml, 1 ml of prepared ammonium-vanadomolybdate solution was added and volume of flask was increased up to the required level with distilled water. After 30 minutes, absorbance of samples, standards and blank was recorded on spectrophotometer set at 410 nm wavelengths (Olsen, 1954).

RESULTS AND DISCUSSION

Chlorophyll contents

High chlorophyll contents were observed in plants inoculated with mycorrhizae as compared to non-inoculated plants. Similarly, the plants amended with different organic amendments and mycorrhizae showed even higher SPAD readings than the plants with only mycorrhizae as shown in Figure 1. Out of these applied amendments, the combination of compost+mycorrhizae, farm yard manure+mycorrhizae and biogas slurry+mycorrhizae performed the best.

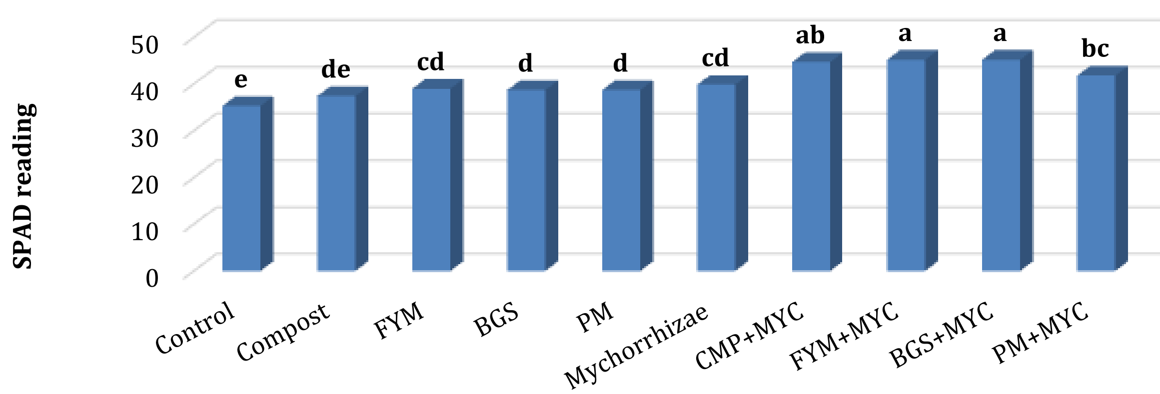

Figure 1. Effect of treatments on chlorophyll contents of brinjal

Number of leaves

Inoculated plants gained more leaves as compared to non-inoculated plants and showed lush green growth, as the mycorrhizae explored more soil and provided more nutrients to the plants. On the other hand, the combination of mycorrhizae and organic amendments showed distinctive results in this section as shown in Figure 2 because mycorrhizae released more nutrients from organic matter and provided favorable growing conditions to the plants. Plants with these combinations gained double leaves as compared to control and non-inoculated plants; however, the highest leaf gain was recorded in plants that were treated with biogas slurry+mycorrhizae.

Root length

Plants inoculated with mycorrhizae and amended with organic matter showed considerably long roots as compared to non-inoculated plants. Roots of plants treated with mycorrhizae and farm yard manure combination grew longer than any other combination as shown in Figure 3. Mycorrhizae infected plant roots and grew longer in search of water and nutrients that resulted in longer roots and increased root surface area. However, organic matter present in the soil released nutrients and mycorrhizae helped roots to uptake these nutrients.

Shoot height

Better shoot height was observed in the inoculated plants that were amended with organic matter especially in biogas slurry and mycorrhizae combinations than other combinations, only amendments and control as shown in Figure 4.

Phosphorus contents

A distinct difference was observed in P contents of plant's fruit. Phosphorus concentration in plants inoculated with mycorrhizae and amended with organic matter was reasonably high than non-inoculated plants because mycorrhizae released acids to maintain a specific level of pH in the soil that was favorable for plants to uptake P. However, the highest P content was recorded from the plant with biogas slurry and mycorrhizae combination as shown in Figure 5.

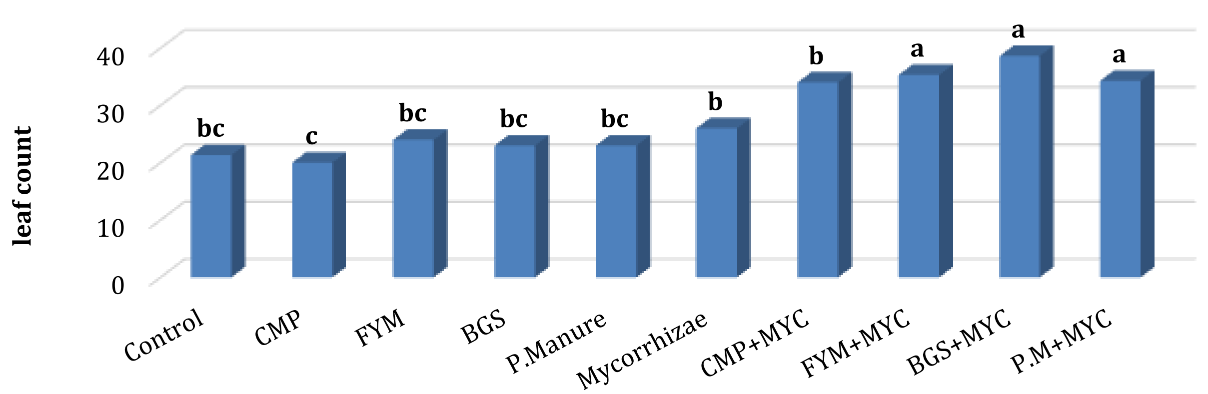

Figure 2. Effect of treatments on numbers of leaves of brinjal.

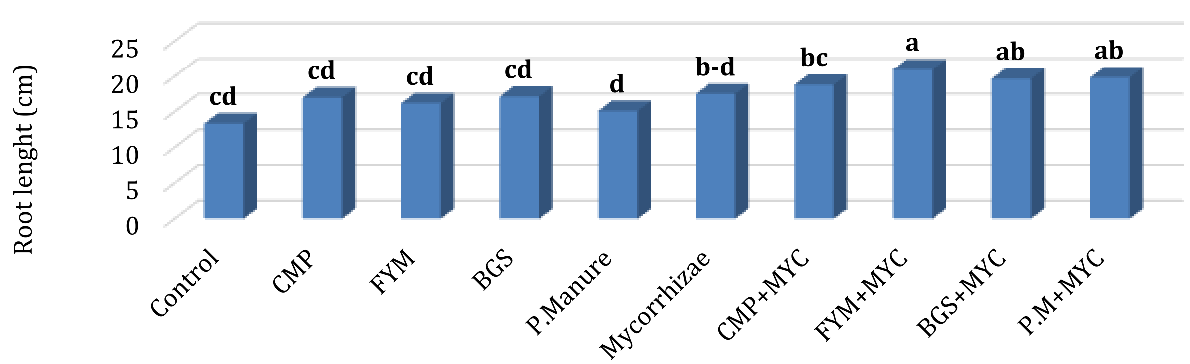

Figure 3. Effect of treatments on root length of brinjal.

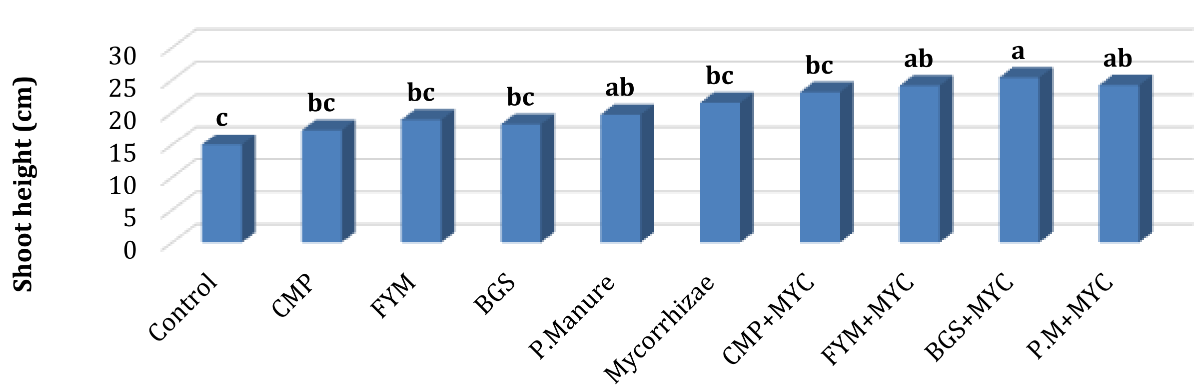

Figure 4. Effect of treatments on shoot height of brinjal.

Shoot weight

Similarly, the average shoot weight recorded at the time of harvest showed that the inoculated plants gained more fresh weight as compared to non-inoculated plants. Even the plants treated with organic amendments gained less mass than combinations. Biogas slurry and mycorrhizae combination performed the best in this section as shown in Figure 6.

Arbuscular mycorrhizal fungi (AMF) were discovered having association with the roots of 1st terrestrial plants and now has synergistic relationship with above 80% of vascular plants especially crops (Brundrett and Tedersoo, 2019). AMF provides mineral nutrients to its host, especially P and in return obtain photosynthetically produced carbon. The base of AM symbiosis is the exchange of resources, and globally, this is responsible for massive nutrient exchange, and in land ecosystem, it is crucial for carbon sequestration. 10-30% (about 5 billion tones /year) of plant photosynthetic products are transferred to fungal symbionts and plants obtain up to 90% of nutrients especially P.

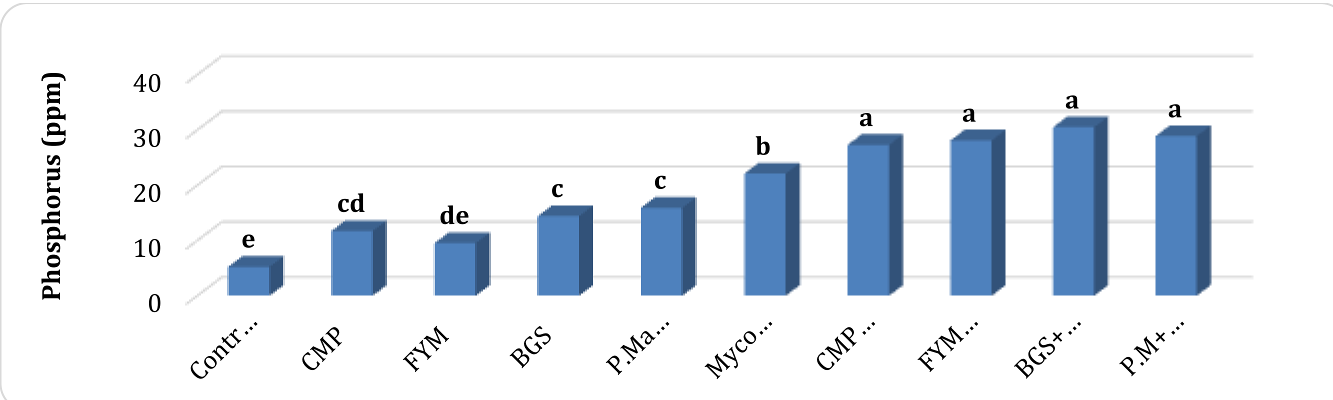

Figure 5. Effect of treatments on phosphorus contents of fruit of brinjal.

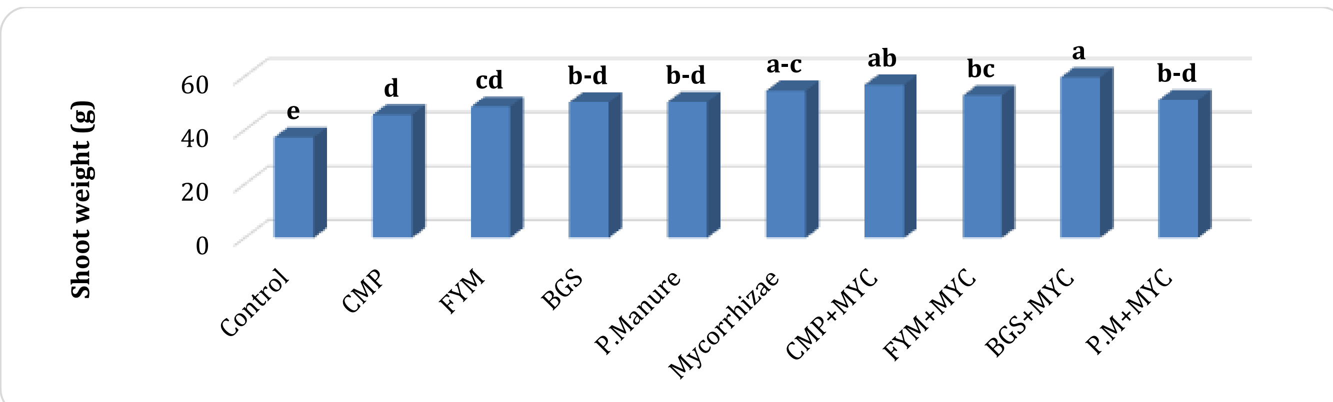

Figure 6. Effect of treatments on fresh shoot weight of brinjal.

CONCLUSIONS

The results withdrawn in this trial showed a significant difference in P contents within the treatments. The plants that were amended with organic manure showed better growth and P contents than control. However, the plants inoculated with mycorrhizae and amended with organic matter uptake more phosphorus and showed better growth as compared to other treatments. The combination of mycorrhizae+BGS performed the best in P uptake and growth. Excessive use of chemical fertilizer to fulfill the food demands exerts environmental hazards such as soil and water pollution. To overcome the food demands of society and avoiding this pollution, the use of mycorrhizae along with organic amendments seems to be obligatory. Shifting from chemical fertilizers to organic amendments and microbial processes to meet all the requirements is not less than a huge challenge these days.

AUTHORS' CONTRIBUTION

AS and ZM designed the study and laid out the experiment, AS, WA, and KAZ executed the experimental work and recorded data, AS, AA and FA analyzed the data statistically, AS wrote the manuscript, AS and ZM assisted in writing the manuscript, and all the authors proofread the manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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