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Effect of Phosphorus Solubilizers on Enzymatic Activity and Microbial Parameters in the Soil

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A B S T R A C T

An experiment was carried out in the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani during 2017-18 in order to evaluate the effect of phosphate solubilizers on the activity of different enzymes and microbial parameters in the soil and its impact on crop growth and yield of test crop tomato *var*. Vellayani Vijai. The experiment was laid out in a randomized block design with fourteen treatments and three replications. Treatments were the combinations of four doses of P (100%, 75%, 50%, 25%) along with P solubilizers (AMF, *Pseudomonas*, and *Bacillus*.). From the study, an increasing activity of dehydrogenase was observed over a period of four months. At the harvesting stage, the highest value of 336.7 µg of TPF released g^{-1} was observed in the treatment T_3 (75% P +AMF). It was observed that the activities of acid and alkaline phosphatase were significantly influenced by the treatment at 2, 3 and 4 MAP. An increasing trend of acid phosphatase was observed up to 3MAP followed by a decline. At 4MAP, the highest value of 59.89 µg of p-nitrophenol released g^{-1} of soil 24 h^{-1} was observed in T_{11} (PSB). From the study, it was observed that the treatment did not impose any significant effect on the activity of urease upto 3 MAP. However, an increasing trend of urease enzyme over a period of 4 months is noticed. The highest activity was noticed with the application of 50% P and AMF (69.45 ppm of urea hydrolysed g^{-1}). Regarding MBC, the treatment T_9 (25% P + AMF) registered the highest value of 380 µg g^{-1} soil where the treatment T_5 (50% P + PSB) recorded the highest MBP content of 71.83 µg g^{-1} soil. The highest value for MB C/P was recorded by the treatment T_{14} (Absolute control) (14.28). Microbial load of P solubilisers was found to be high in the treatment T_5 (50% P + PSB) with average value of 3.60 log cfu g^{-1}.

Introduction

Soil is a living system in which biological activities takes place with the help of enzymes. Enzymes are considered as biological fingerprints and used as a measure of mineralization and transportation of organic carbon and the plant nutrients. They are specific and have active sites that bind with the substrate to form a temporary complex. The enzymatic reaction releases a product, which can be a nutrient contained in the substrate. Dehydrogenase, acid phosphatase, alkaline phosphatase and urease are major enzymes influencing P availability and organic matter decomposition.

Phosphatases are group of enzymes that hydrolyzes phosphate groups from a wide variety of organic substrates, producing phosphate ion and alcohol (Tazisong*et al.*, 2015). Acid phosphatases

present in the rhizosphere plays a major role in the mineralization of organic phosphorous present in soil (Rodrıguez and Fraga., 1999). Vuorinen and Aharinen (1996) reported that the soil organic matter and acid phosphatase are significantly correlated and the role of phosphatase enzymes in the mineralizing organic P esters in soils and rhizospheres is vital. Casida (1997) reported that the dehydrogenase enzyme is the best method for measuring the metabolic activity of microorganisms in soil. The activity of urease was found to be high under consistent tillage conditions (Jin *et al*., 2009). Larsen*et al.* (2009) reported the increased levels of dehydrogenase activity and available P in the soils imposed with *Glomus sp*. Major research effort is needed to consider the activity of enzyme as a measure of soil biological process.

Microbial inoculants play a great deal in solubilizing the native P and increases various fractions of available P. P-solubilizing microorganisms (PSM) can solubilise and mineralize P from inorganic and organic pools of total soil P, and may be used as inoculants to increase P-availability to plants. Soil microbial properties were positively correlated with the addition of nitrogen and/ phosphorus, but responses of the soil microbial community often varied depending on the quantity nutrient added. These responses were more significant for the combined additions of N and P than single additions of either N or P. Dong *et al*. (2015) reported that the application of bio fertilisers increased the population of bacteria, fungi, and actinomycetes in soil. Debnath*et al. (*2015) reported that there exists significant positive correlation among microbial biomass carbon (MBC), microbial biomass nitrogen (MBN) and microbial biomass phosphorus (MBP).

In the present study, the activities of dehydrogenase, urease, acid phosphatase and alkaline phosphatase, microbial parameters have been taken as the indices to access the management induced changes.

Materials and Methods

An experiment was carried out in the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani during 2017-18. The study was envisaged to evaluate the effect of phosphate solubilizers on the solubility and availability of native phosphorus and its impact on crop growth and yield of test crop tomato *var*. Vellayani Vijai. The experiment was laid out in a randomized block design with fourteen treatments and three replications. Treatments combinations were imposed for assessing the effect of Phosphorus solubilising microorganisms on soil available P. Treatments were the combinations of four doses of P along with P solubilizers (AMF, *Pseudomonas*, and *Bacillus*.).

The roots of tomato seedlings to be transplanted in AMF treatment plots were dipped in water slurry of AMF for 20 minutes prior to transplanting. 2% PSB and Pseudomonas were applied to respective plots. The crop was raised as per the package of practices recommendations of Kerala Agricultural University (KAU POP, 2016). The soil samples were collected from respective plots by random sampling technique. They were dried in shade, powdered with wooden mallet, sieved using 2 mm sieve and stored in polythene bags for carrying out the analysis for physical, chemical and biological parameters.

Results and Discussion

Dehydrogenase activity

Dehydrogenase is an extra cellular enzyme capable of oxidizing the organic matter. It reflects the total activity of micro flora and the active cells present in the soil (Przepiora *et al.*,

2016). From the study, it was observed that the activity of dehydrogenase was significantly influenced by the application of the treatments (Table 2, Fig.1). In general, there was an increasing activity of dehydrogenase over a period of four months (Table 2). This might be due to the increased metabolic activity of microbial community with subsequent increase in the organic matter content. This is in conformity with the findings of Deng *et al.,* (2006). The increase microbial activity may be attributed to the mineral fertilization (N as urea, P as rajphos, K as MOP) in conjunction with microbial P solubilisers (Nakhro and Dkhar, 2010). This is supported by higher microbial population of P solubilisers in the treated plots with mean values ranging from 3 to 3.6 log cfu g^{-1}. A positive correlation with microbial load (r=0.355) was observed in the study (Table 8). On further scrutiny of data generated, it is observed that 75% P + AMF treated plots recorded the highest activity for dehydrogenase (Fig. 1) at 4MAP. The highest MBC (366 µg g^{-1}) recorded for this treatment might be one of the possible reasons for contributing the increased dehydrogenase activity in this particular treatment. A significant correlation with the crop yield (r= 0.836**) shows that the role of dehydrogenase enzyme in maintaining the soil fertility cannot be evicted. The lowest activity of dehydrogenase reported in the control plot might be due to consequence of lower levels of organic carbon and microbial biomass carbon.

Acid phosphatase and Alkaline phosphatase

Extracellular phosphor-mono-esterase (acid phosphatase and alkaline phosphatase are important enzymes involving P cycle of the soil. From the data present in the Table 3, Fig.2, it is observed that the activities of acid and alkaline phosphatase were significantly influenced by the treatment at 2, 3 and 4 MAP. In general, an increasing trend of acid phosphatase was observed up to 3MAP followed by a decline. The activity of acid phosphatase was predominant over the alkaline phosphatase. Similar results were also reported by Lemnanowicz (2011). An inverse relationship exists between soil acid phosphatase status and the acid phosphatase activity. This is supplemented by the observation that the treatment with low available P content reported the highest value for acid phosphatase. The results are in agreement with the findings of Bargaz *et al.,* (2012).

On further scrutiny of the data, it is observed that the effectiveness of the treatments were non-significant on the activity of alkaline phosphatase (Table 4, Fig 3). With respect to acid phosphatase, the highest value reported in the treatment T_{11} compared to other treatments might be due to the inherent phosphatase enzymes present in the cellwall of PSB and also in the extra cellular polymeric substances secreted by PSB (Behera *et al.,* 2017).

Further from the study, it was observed that a significant positive correlation existed between acid phosphate and microbial load (r=0.793**), alkaline phosphatase and microbial load (r=0.545**). The role of Zn in accelerating activity of acid phosphatase is yet to be detailed as a significant positive correlation between enzyme and Zn is noticed.

Comparatively lower values for available P in this treatment might have induced the P status, thereby resulting in production of alkaline phosphatase by microbes using P signals (Margalef *et al.,* 2017). The soil pH values were in the range of acidic for the acid phosphatase enzyme and this is why this enzyme did not significantly correlate with pH (r=0.472). However, the alkaline phosphatase exhibited a significant positive correlation with pH (r=0.936**).

Table.1 Treatment details

T_1	**N,P & K as per KAU POP**
T_2	75% P + Phosphate Solubilising Bacteria
T_3	75% P + Arbuscular Mycorrhizal Fungi
T_4	75% P + *Pseudomonasfluorescens*
T_5	50% P + Phosphate Solubilising Bacteria
T_6	50% P + Arbuscular Mycorrhizal Fungi
T_7	50% P + *Pseudomonasfluorescens*
T_8	25% P + Phosphate Solubilising Bacteria
T_9	25% P + Arbuscular Mycorrhizal Fungi
T_{10}	25% P + *Pseudomonasfluorescens*
T_{11}	Phosphate Solubilising Bacteria
T_{12}	Arbuscular Mycorrhizal Fungi
T_{13}	*Pseudomonasfluorescens*
T_{14}	Absolute control

*100% N & K were supplemented as per the KAU POP. The secondary, micronutrients and FYM were uniformly applied to all plots except the control plot based on soil test values.
* Tomato variety: Vellayani Vijai
*PSB: *Bacillus megaterium var. phosphaticum*

Table.2 Effect of P solubilizers on Dehydrogenase activity in soil (µg of TPF released g^{-1}soil h^{-1})

Treatments	1MAP	2MAP	3MAP	4MAP
T_1 - N,P & K as per KAU POP	197.8	242.8	256.9	310
T_2 - 75% P + PSB	194.7	252.9	278.9	315.9
T_3- 75% P +AMF	193.8	205.8	240.9	336.7
T_4- 75% P + P. *flourscences*	189.8	196.5	198.7	272.6
T_5 - 50% P + PSB	192.5	225.8	230.5	235.4
T_6 - 50% P + AMF	192.9	236.7	238	263.8
T_7 - 50% P + P. *flourscences*	172.6	186	188	200.8
T_8 - 25% P + PSB	190.5	195.2	215	225.9
T_9 - 25% P + AMF	188.6	196.8	200.9	210.5
T_{10} - 25% P + P. *flourscences*	178.7	189.4	192.4	196.8
T_{11} – PSB	184.2	186	189.5	195.9
T_{12} - AMF	193.4	197.8	248.9	273.9
T_{13} - P. *flourscences*	189.9	194.5	197.8	210.5
T_{14}- Absolute control	168.8	169.8	169	174.8
CD(0.05)	13.13	10.37	24.11	34.18

Table.3 Effect of P solubilizers on Acid phosphatase activity in soil (µg of p-nitrophenol released g^{-1} of soil 24 h^{-1})

Treatments	1MAP	2MAP	3MAP	4MAP
T_1 - N,P & K as per KAU POP	53.73	54.33	55.63	55.87
T_2 - 75% P + PSB	53.00	55.30	54.09	56.17
T_3- 75% P +AMF	53.80	55.33	56.76	56.68
T_4- 75% P + P. *flourscences*	54.00	54.51	54.03	54.68
T_5 - 50% P + PSB	53.97	54.0	53.80	54.67
T_6 - 50% P + AMF	54.15	54.47	57.53	55.85
T_7 - 50% P + P. *flourscences*	54.04	54.67	59.13	59.32
T_8 - 25% P + PSB	54.07	55.70	60.17	59.15
T_9 - 25% P + AMF	53.75	56.03	59.52	58.18
T_{10} - 25% P + P. *flourscences*	55.20	56.70	56.00	54.62
T_{11} – PSB	54.15	56.46	61.80	59.89
T_{12} - AMF	54.40	56.73	59.20	57.38
T_{13} - P. *flourscences*	55.87	55.50	57.80	57.08
T_{14}- Absolute control	34.30	36.40	38.90	39.90
CD(0.05)	NS	1.737	3.037	3.062

Table.4 Effect of P solubilizers on Alkaline phosphatase activity in soil (µg of p-nitrophenol released g^{-1} of soil 24 h^{-1})

Treatments	1 MAP	2 MAP	3 MAP	4 MAP
T_1 - N,P & K as per KAU POP	7.8	7.886	7.72	8.13
T_2 - 75% P + PSB	7.2	7.35	7.25	8.04
T_3- 75% P +AMF	8.6	8.37	8.63	9.02
T_4- 75% P + P. *flourscences*	8.2	8.08	8.23	8.85
T_5 - 50% P + PSB	8.7	8.85	8.76	8.92
T_6 - 50% P + AMF	8.8	8.95	8.90	9.23
T_7 - 50% P + P. *flourscences*	8.4	8.42	8.46	8.68
T_8 - 25% P + PSB	8.3	8.42	8.41	8.69
T_9 - 25% P + AMF	9.4	9.48	9.42	9.95
T_{10} - 25% P + P. *flourscences*	8.9	8.92	9.10	9.5
T_{11} – PSB	9.2	9.55	9.21	9.76
T_{12} - AMF	9.0	9.21	9.00	9.36
T_{13} - P. *flourscences*	7.5	7.80	7.60	8.10
T_{14}- Absolute control	6.9	7.11	6.95	6.65
CD(0.05)	NS	NS	NS	NS

Table.5 Effect of P solubilizers on Urease activity (ppm of urea hydrolysed g^{-1} of soil 24 h^{-1})

Treatments	1MAP	2MAP	3MAP	4MAP
T_1 - N,P & K as per KAU POP	52.91	58.47	62.52	66.43
T_2 - 75% P + PSB	57.32	59.32	60.73	66.11
T_3- 75% P +AMF	54.82	61.81	63.24	68.72
T_4- 75% P + P. *flourscences*	53.1	60.79	62.43	67.57
T_5 - 50% P + PSB	54.1	59.2	61.21	66.36
T_6 - 50% P + AMF	51.94	59.31	60.73	69.45
T_7 - 50% P + P. *flourscences*	52.82	56.23	60.77	64.5
T_8 - 25% P + PSB	50.7	55.18	57.73	62.98
T_9 - 25% P + AMF	51.55	55.83	59.81	63.74
T_{10} - 25% P + P. *flourscences*	53.74	55.44	58.15	60.79
T_{11} – PSB	49.93	56.97	58.14	60.88
T_{12} - AMF	50.27	57.77	60.17	62.35
T_{13} - P. *flourscences*	50.46	54.21	57.92	58.73
T_{14}- Absolute control	49.81	52.15	52.81	53.41
CD(0.05)	NS	NS	NS	5.208

Table.6 Effect of P solubilizers on Microbial biomass

Treatments	MBC (µg g^{-1} soil)	MBP (µg g^{-1} soil)	Microbial Biomass C/P
T_1 - N,P & K as per KAU POP	300	57.50	5.21
T_2 - 75% P + PSB	333	62.33	5.34
T_3- 75% P +AMF	366	67.50	5.43
T_4- 75% P + P. *flourscences*	333	62.17	5.35
T_5 - 50% P + PSB	366	71.83	5.09
T_6 - 50% P + AMF	313	68.33	4.50
T_7 - 50% P + P. *flourscences*	333	63.37	5.25
T_8 - 25% P + PSB	233	35.00	6.65
T_9 - 25% P + AMF	380	59.17	6.42
T_{10} - 25% P + P. *flourscences*	233	26.00	8.96
T_{11} – PSB	256	47.17	5.42
T_{12} - AMF	326	59.17	5.50
T_{13} - P. *flourscences*	306	45.83	6.67
T_{14}- Absolute control	200	14.83	14.28
CD(0.05)	15.848	11.865	0.893

Table.7 Effect of P solubilizers on Microbial load- P solubilizers

Treatments	Microbial Load - P solubilizers (log cfu g^{-1} soil)
T_1 - N,P & K as per KAU POP	3.30
T_2 - 75% P + PSB	3.48
T_3- 75% P +AMF	3.30
T_4- 75% P + P. *flourscences*	3.30
T_5 - 50% P + PSB	3.60
T_6 - 50% P + AMF	3.48
T_7 - 50% P + P. *flourscences*	3.30
T_8 - 25% P + PSB	3.00
T_9 - 25% P + AMF	3.00
T_{10} - 25% P + P. *flourscences*	3.00
T_{11} – PSB	3.48
T_{12} - AMF	3.30
T_{13} - P. *flourscences*	3.30
T_{14}- Absolute control	3.00
CD(0.05)	0.122

Table.8 Correlation between Enzymatic activity, Microbial Load and yield

	Dehydrogenase	Acid Phosphatase	Alkaline phosphatase	Urease	Microbial Load	Yield
Dehydrogenase	1					
Acid Phosphatase	0.438	1				
Alkaline phosphatase	0.194	0.310	1			
Urease	**0.623****	**0.590***	0.429	1		
Microbial Load	0.355	**0.793****	**0.545***	**0.604***	1	
Yield	**0.836****	0.429	0.274	**0.934****	0.502	1

Fig.1 Effect of P solubilisers on the activity of Dehydrogenase enzyme (µg of TPF released g^{-1} h^{-1})

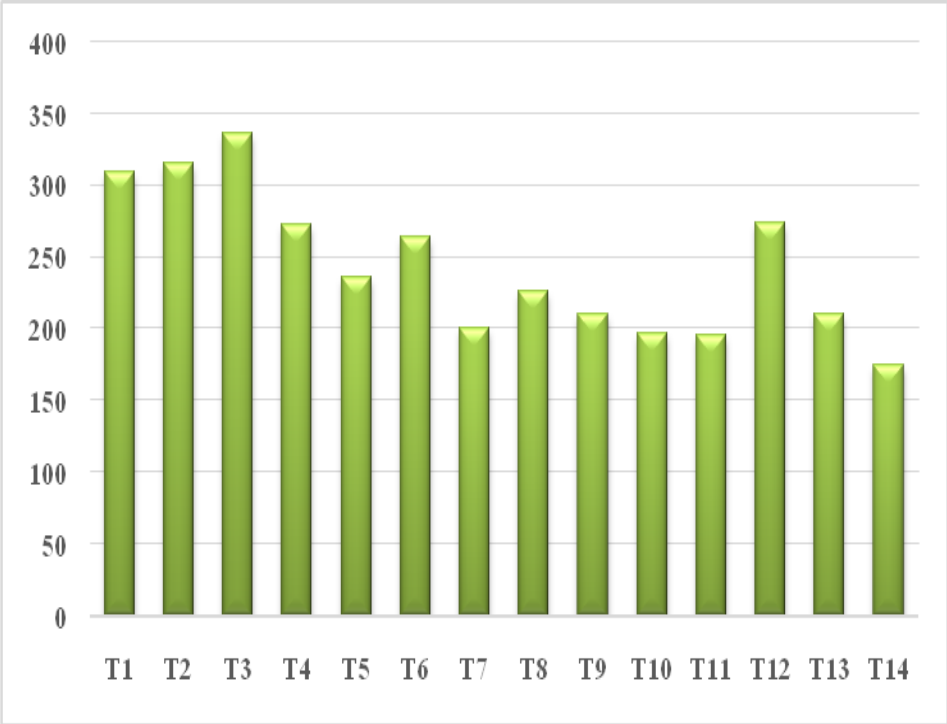


Fig.2 Effect of P solubilisers on the activity of Acid phosphatase (µg of p-nitrophenol released g^{-1} of soil 24 h^{-1})

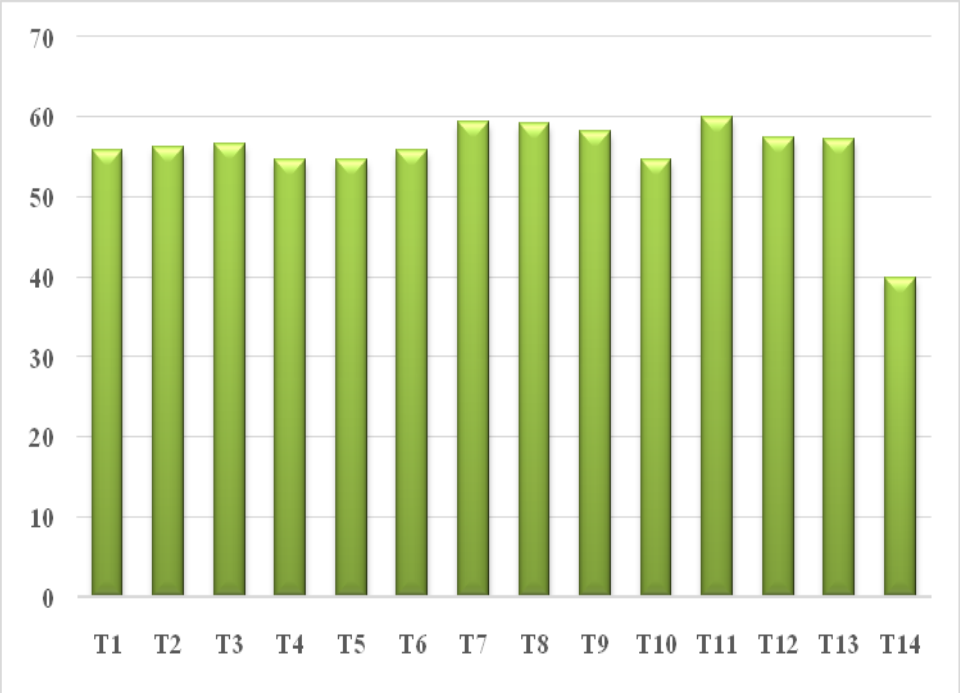


Fig.3 Effect of P solubilisers on the activity of Alkaline phosphatase (µg of p-nitrophenol released g^{-1} h^{-1})

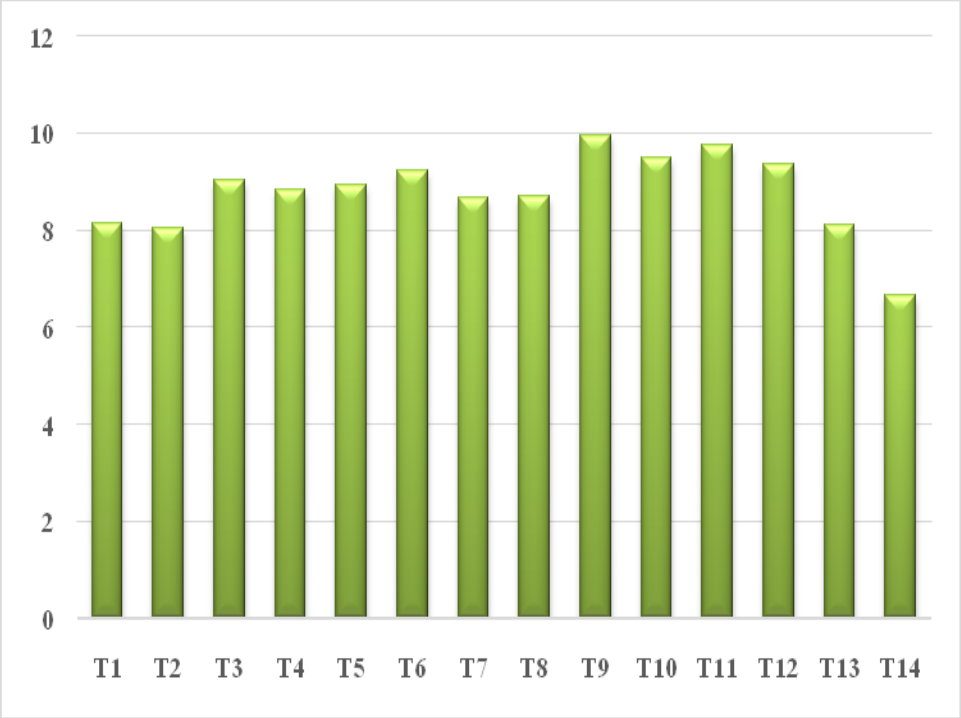


Fig.4 Effect of P solubilisers on the activity of Urease (ppm of urea hydrolysed g^{-1} h^{-1})

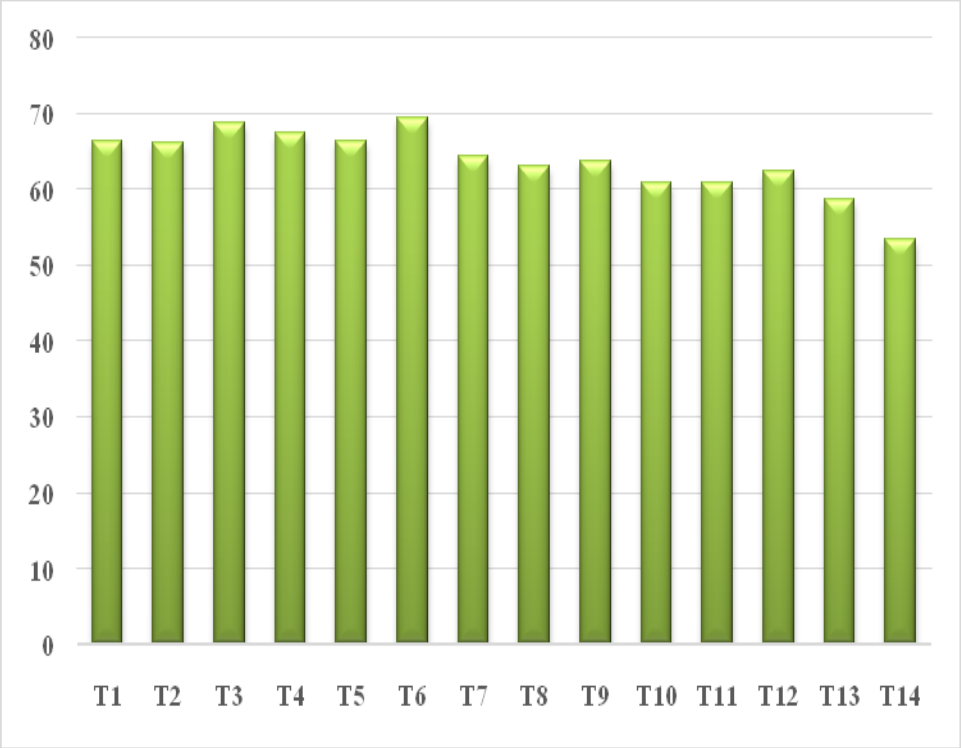
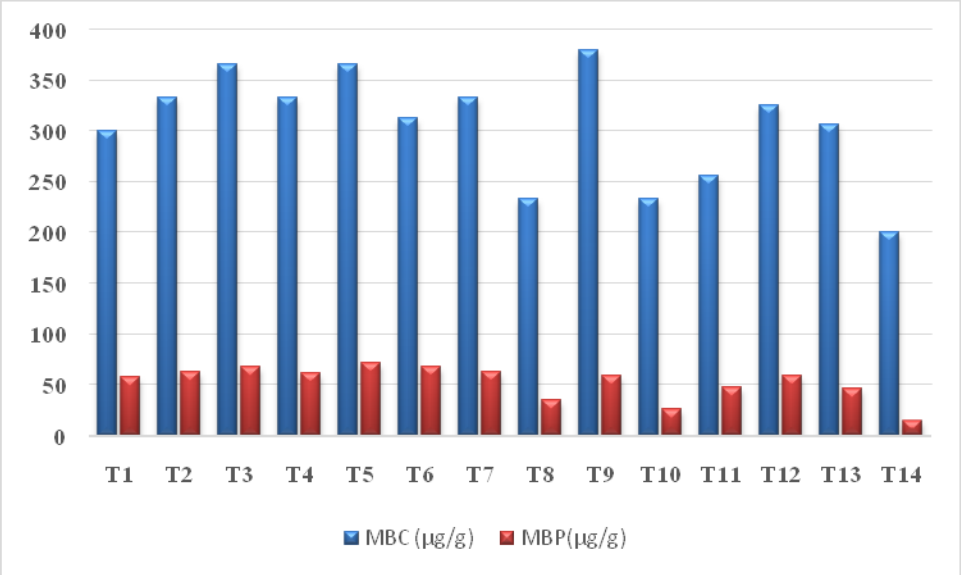


Fig.5 Effect of P solubilisers on MBC, MBP



Urease

Urease is a hydrolytic enzyme that is responsible for the hydrolytic conversions of urea to CO_2 and NH_3. Urease assay is important in understanding the mineralization process of N and its response to management system (Klein and Klothis, 1980).

From the study (Table 5), it was observed that the treatment did not impose any significant effect on the activity of urease upto 3 MAP. However, an increasing trend of urease enzyme over a period of 4 months is noticed. The highest activity was noticed with the application of 50% P and AMF (69.45 ppm of urea hydrolysed g^{-1}). The treatmental effect was found to be similar with the application of PSB, AMF and P. *flourscences*. The higher organic matter content of 1.81% in this treatment might have favoured the spurt of the ureolytic bacteria resulting in hydrolysis and release of enzyme (Lloyd and Sheaffe, 1973). This is supported by a significant positive correlation with the microbial load (r=0.604**) and with yield (r=0.934**).

Microbial biomass carbon

Microbial biomass carbon is the measure of C contained within the living component of soil organic matter. That is, bacteria and fungi which decompose soil residue and organic matter in the soil. Therefore microbial biomass carbon is an easy indicator of changes in total organic carbon content (Anderson *et al.,* 2013). On the scrutiny of the data presented in the Table 6, Fig 5, the treatment with the application of 25% P along with AMF was similar with the application of 50%P and PSB. Increase in biomass carbon might be due to the secretion of cellulolytic or lignolytic enzymes which in turn might have increased the microbial biomass carbon. Also in the AMF treated plots, the sugars might have been translocated from the roots through hartig nets to the fungal mat, thus accumulating in the soil in form of fungal carbohydrates like triose, glycogen and manitol which sugars are not readily metabolized by the host plant, thus contributing to higher amount of MBC (Gosling *et al.,* 2006).

Microbial biomass P

Soil Microbial biomass P is one of the most labile forms of P in soil and plays a vital role in biogeochemical cycling of P in soil. It can be used as a tool to predict the P supplying ability of soil and hence it act as biological index of P (Chen *et al.*, 2000). It is evident from the data that, Microbial Biomass Phosphorus (MBP) was significantly influenced by the application of P solubilisers. The application of water soluble inorganic P fertilizers along with P solubilisers (PSB, AMF and *P. flourscences*) might have enhanced the bio available pool of P which in turns increased the root and rhizhospheric microbiomes.

These microbes in turn can transform a small fraction of available P to MBP. This might be the reason for increase in MBP in P solubiliser treated plots (Pradhan *et al.*, 2017). PSB was found to be superior for soil MBP and microbial activity at optimum P levels (Raghuveer *et al.*, 2017). Similar effects on microbial biomass P was also exhibited by treatment involving AMF and P. *flourscences.*

Microbial biomass C: P ratio

In the present study, using these parameters MBC and MBP, the C: P ratio was worked out (Table 6). The highest value for C: P was observed in the control plot (14.28). Similar results were reported by Zhang *et al.*, (2015) who investigated on the C: P ratios in high P soil. It is also evident from the study that microorganisms compete with the plant roots for the orthophosphate, and accumulate the phosphorus making it temporarily unavailable to crops. It can be also explained that the inoculation of P solubilisers increase the microbial biomass phosphate which might be a reason for the reduction in MBC/P ratio in soils treated with P solubilisers as observed by Pradhan (2017). The variation observed in the MBC/P ratio may be attributed to the variation in microbial C and P in the respective treatments.

Microorganisms are integral to soil P, P cycle and as such play an important role in mediating the availability of P to plants. Utilization of microorganisms to increase the availability of P in soil is therefore an attractive preposition for developing a more sustainable agriculture. Nonetheless microorganisms are integrated to cycling soil P and enhancement of localized microbial activity in the rhizosphere as significant implication for P nutrition for the plants (Achal *et al.*, 2007). It is evident from the data present in the Table 7 that microbial P solubilisers were significantly influenced by the application of treatments. The highest value of 3.60 log cfu kg^{-1} was observed with 50% P and PSB might be attributed to the increased spurt in P solubilisers with the balance supply of N,P,K fertilizers along with solubilisers. A higher organic matter content of 1.78% serves as the substrate for meeting the C requirement of microbes and thus resulting in a spurt. The acidic pH range of the soil also supports the P solubilisers as it is evident from the present study. The results are in conformity with the findings of Gour and Sachel (1980). AM symbiotic status changes the chemical composition of root exudates and the development of AM mycelium can act as a C source for microbial community and thereby resulting in an increase in the rhizosphere micro biome (Aggarwal *et al.*, 2011).

The study concludes that there exists a positive influence of P solubilisers on enzyme activities and microbial population. The activities of enzymes showed an increasing trend and reached the maximum at the final stage of crop growth. The treatments imposed a significant effect on the microbial parameters like MBC, MBP and microbial load. Based on the study, it can be concluded

that phosphorus dose can be reduced to 75% P and its application along with AM Fungi will improve enzyme activity and microbial population.

References

Achal, V., Savant, V. V., and Reddy, S. M. 2007. Phosphate solubilization by a wild type strain and UV-induced mutants of *Aspergillus tubingensis*. *Soil Biol. Biochem*. 39: 695-699.

Aggarwal, A., Kadian, N., Tanwar, A., Yadav, A., and Gupta, K. K. 2011. Role of arbuscular mycorrhizal fungi (AMF) in global sustainable development. *J. Appl. Nat. Sci.* 3 (2): 340-351.

Anderson, N. P., Hart, J. M., Sullivan, D. M., Christensen, N. W., Horneck, D. A., and Pirelli, G. J. 2013. Applying lime to raise soil pH for crop production (Western Oregon). *Fertilizer and Lime Materials Fertilizer Guide*. 21.

Bargaz, A., Faghire, M., Abdi, N., Farissi, M., Sifi, B., Drevon, J., Ikbal, M. C., and Ghoulam, C. 2012. Low soil phosphorus availability increases acid phosphatases activities and affects P partitioning in nodules, seeds and rhizosphere of *Phaseolus vulgaris. Agric*.2: 139-153.

Behera, B. C., Yadav, H., Singh, S. K., Mishra, R. R., Sethi, B. K., Dutta, S. K., and Thatoi, H. N. 2017. Phosphate solubilization and acid phosphatase activity of Serratia sp. isolated from mangrove soil of Mahanadi river delta, Odisha, India. *J. Genet. Eng. Biotechnol.* 17(5): 613-625.

Casida, L. E. 1977. Microbial metabolic activity in soil as measured by dehydrogenase determinationst. *Appl. Environ. Microbial.* 34(6): 630-636.

Chen, G. C., He, Z. L., and Huang, C. Y. 2000. Microbial biomass phosphorus and its significance in predicting phosphorus availability in red soils. *Commun. Soil Sci. plant Anal*. 31(6): 655-667.

Debnath, S., Patra, A. K., Ahmed, N., Kumar, S., Dwivedi, B. S. 2015. Assessment of microbial biomass and enzyme activities in soil under temperate fruit crops in north western Himalayan region. *J. Soil Sci. Plant Nutri.* 15 (4): 848-866.

Deng, S. P., Parham, J. A., Hattey, J. A., and Babu, D. 2006. Animal manure and anhydrous ammonia amendment alter microbial carbon use efficiency, microbial biomass, and activities of dehydrogenase and amidohydrolases in semiarid agroecosystems. *Appl Soil Ecol*. 33: 258–268.

Dong, W. Y., Zhang, X. Y., Liu, X. Y., Fu, X. L., Chen, F. S., Wang, H. M., Sun, X. M., and Wen, X. F. 2015. Responses of soil microbial communities and enzyme activities to nitrogen and phosphorus additions in chinese fir plantations of subtropical China. *Biogeosci.* 12: 5537–5546.

Gosling, P., Hodge, A., Goodlass, G., and Bending, G. D. 2006. Arbuscular mycorrhizal fungi and organic farming. *Agric. Ecosyst. Environ.* 113: 17–35.

Gour, A. C. and Sacher, S. 1980. Effect of rock phosphate and glucose concentration on phosphate solubilisation by Aspergillus awamori. *Curr. Sci.*49: 553-554.

Jin, K., Sleutel, S., Buchan, D., De Neve, S., Cai, D. X., Gabriels, D., Jin, J. Y. 2009. Changes of soil enzyme activities under different tillage practices in the Chinese Loess Plateau. *Soil and Tillage Res*. 104: 115-120.

Klein, T. M. and Kloths, J. S. 1980. Urease, protease and acid phosphatase in soils continuously cropped to corn by conventional or no-tillage methods. *Soil*

Biol. Biochem. 12(6): 293-294.

Larsen, J., Cornejo, P., and Barea, J. M. 2009. Interactions between the arbuscular mycorrhizal fungus Glomus intraradices and the plant growth promoting rhizobacteria *Paenibacillus polymyxa*and *P. macerans*in the mycorrhizosphere of *Cucumis sativus.Soil Biol. Biochem*. 41: 286–292.

Lemanowicz, J. 2011. Phosphatases activity and plant available phosphorus in soil under winter wheat (*Triticum aestivum* L.) fertilized minerally Polish. *J. Agron.* 4: 12–15.

Lloyd, A. B. and Sheaffe, M. J. 1973. Urease activity in soils. Plant and soil. *Soil Biol. Biochem*. 39(1): 71-80.

Margalef, O., Sardans, J., Fernandez-Martínez, M., MolownyHoras, R., Janssens, I. A., Ciais, P., Goll, D., Richter, A., Obersteiner, M., Asensio, D., and Penuelas, J. 2017. Global patterns of phosphatase activity in natural soils, *Sci. Rep.* 7(8): 1337-1345.

Nakhro, N. and Dkhar, M. S. 2010. Impact of organic and inorganic fertilizers on microbial populations and biomass carbon in paddy field soil. *J. Agron.* 9(7): 102-110.

Pradhan, M., Sahoo, R. K., Pradhan, C., Tuteja, N., and Mohanty, S. 2017. Contribution of native phosphorus solubilising bacteria of acid soils on phosphorus acquisition in peanut, Protoplasma. 254(6): 2225-2236.

Przepiora, E. 2016. AM and DSE colonization of invasive plants in urban habitat: a study of Upper Silesia (southern Poland). *J. Plant Res*. 129(4): 603-614.

Raghuveer, M., Ram, V., and Maurya, A. C. 2017. Impact of phosphorus levels and PSB strains on soil microbial and enzymatic activities under acidic soils of north east India. *Int.J.Curr.Microbiol.App.Sci.* 6(6): 2061-2067.

Rodriguez, H. and Fraga, R. 1999. Phosphate solubilizing bacteria and their role in plant growth promotion. *Biotechnol. Adv.* 17: 319–339.

Tazisong I. A., Senwo Z. N., He Z. 2015. Phosphatase hydrolysis of organic phosphorus compounds. *Adv. Enz. Res*. 3(2): 39–51.

Vuorinen, A. H. and Saharinen, M. H. 1996. Effects of soil organic matter extracted from soil on acid phosphomonoesterase. *Soil Biol. Biochem*. 28(10 &11): 1477-1481.

Zhang, B., Li, S., Chen, S., Ren, T., Yang, Z., Zhao, H., Liang, Y., and Han, X. 2015. Arbuscular mycorrhizal fungi regulate soil respiration and its response to precipitation change in a semi-arid steppe. *Spanish J. Soil Sci*.4(5): 70-78.

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