Kinetics Of Phosphate Mobilization And Enzyme Activity In Mycorrhizosphere

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ABSTRACT

Soils from three agroclimatic zones of Jammu region viz sub-topical (300-1000m amsl), intermediate (1000-1500m asml) and temperate (1500-2500m asml) were investigated for phosphate mobilization and phosphatase activity under the influence of different isolated AM species. Highest P availability in subtropical zone was observed with *Glomus mosseae* inoculated soils having P value of 6.58 mg kg^{-1} followed by *Glomus fasciculatum* with the corresponding P value of 6.22 mg kg^{-1}. Likewise, intermediate zone soils inoculated with *Glomus fasciculatum* showed highest P availability to the tune of 6.63 mg kg^{-1} followed by *Glomus mosseae* having P value of 6.47 mg kg^{-1}. The least P availability was observed in *Gigaspora sp.* and the corresponding value was 6.19 mg kg^{-1}. Under temperate conditions, maximum P availability was observed in *Glomus mosseae inoculated* soils having P value of 8.74 mg kg^{-1} followed by *Glomus fasciculatum* with 8.44 mg kg^{-1}P. The least P availability has been noticed in *Gigaspora sp.* to the tune of 8.18 mg kg^{-1} P. The phosphatase activity in different AM inoculated soils ranged from 32.8 to 38.2 µM *p*NP g^{-1} soil in case of sub-tropical zone. However, intermediate zone soils inoculated with *Glomus mosseae* possess significantly higher phosphatase activity with the corresponding value of 41.4 µM *p*NP g^{-1}. In temperate soils, the *Glomus mosseae* inoculation significantly enhanced phosphatase activity to the tune of 46.7 µM *p*NP g^{-1} compared to control (33.9 µM *p*NP g^{-1}), whereas *Glomus fasciculatum* and *Gigaspora sp* possessed phosphatase activity of 44.7 µM *p*NP g^{-1} of soil and 41.7 µM *p*NP g^{-1} of soil, respectively.

***Key words**:* Mycorrhiza, phosphate, soils, Jammu, phosphatase

INTRODUCTION

Soil microbes including fungi occupy a distinctive position due to the wider range of their physiological and biochemical activities in soil ecosystem. Soil fungal microorganisms exhibit different types of associations and interactions with plants in soil of which *symbiosis* and *antibiosis* are very remarkable. Mycorrhizae are ubiquitous soil borne symbiotic fungi and provide intimate link between the soil and nutrient absorption by plants. In the mycorrhizal association, exchange of nutrients takes place between autobiont and symbiont (*Cook*, 1977). Arbuscular mycorrhizal (AM) fungi can play an important role for plant nutrient uptake, particularly on soil with low phosphorus availability. The hyphal mycelium increases the total surface area of infected plants and thus improved its assess to slowly diffusing nutrients such as PO_4^{3-}, besides other less mobile ions in the area beyond the roots depletion zone by exploring soil volume by hyphal extension.. The versatility of these fungi has prompted the soil and plant scientists to investigate it from perspective of soil fertility. The reserve of some nutrients like P and Zn in world are finite and gradually depleting due to the intensive agriculture, so there is need to develop a soil management system involving the inoculation of AM to improve the availability of nutrients to crops. Compared with vast work on AM affects in the nutrient mobilization in different soil orders of the world, a little or no information is available on soils of Jammu region. It is well known that nutrient deficiency especially of P along with other nutrient limit the crop production of many soils of this region.Keeping these facts in consideration it has necessitated a detailed understanding of the processes governing phosphouus and mobilization phosphate activlty under influence of mycorrhiza in diffent soil ecosystem of Jammu

REVIEW OF LITERATURE

Roots can mobilize P directly from the soil mineral and organic P pools. The organic anion released solubilises unavailable soil phosphate (Whitelaw, 2000). Plants with AM symbiosis mobilize P better from low P soils than non mycorrhizal plants. Virant-Klun and Gogala (1995) observed that percentage of P was higher in tissues of fertilized mycorrhizal plants than non-mycorrhizal plants with added low soluble P while studying the impact of P nutrition of a maize with low soluble phosphate fertilizer ($FePO_4.4H_2O$). Rathore and Singh (1995) found that the inoculation of AM with P @ 30 kg ha^{-1} significantly improve the uptake N,P and K by shoots at 45 days of growth. Similar results of considerable increase in P uptake due to AM inoculation in many crops have been reported by Champawat (1990). Asghari *et al.* (2005) inferred that in low soils, AMF colonization significantly increased plant P uptake and decreased soil available P and total dissolved P in leachates. However Shen *et al.* (1994) found that high P supplied to the root system increased P concentration and reduce the per cent colonization of AM related to the portion receiving low P supply. Similar results were obtained by Khaliq *et al.* (1997). Rathore and Singh b(1995) reported that inoculation with various strains of AM and application with graded doses of phosphorus in soil at 45 days of plant. The available P after crop harvesting ranged from 5.13 ppm in control to 12.63 ppm due to *Glomus fasciculatum* inoculation along with 60 kg P ha^{-1}. Inoculation with *Gigaspora margarita*, *Glomus fasciculatum* and AM mixed endophytes individually, without addition of P, increased 12.48, 27.29 and 16.96 per cent in available soil P over the uninoculated control. Joshi and Singh (1995) reported that inoculation with different AM isolates, addition of P and their combinations significantly increased available soil P after harvesting the crop. Enhanced activity of acid and alkaline phosphatase (ranging from 25 to 114 per cent) in the rhizosphere of mycorrhizal plants and also studies on the root surface phosphatase activity inoculated with AM infection had shown high phosphatase activity with *p*-nitro phenyl phospahate (Antibus *et al.,* 1997). This gives an insight of AM potential to mineralize monoster and diester forms of organic phosphorus. A significant difference in root infection by AM fungi was found by Asmah (1995) when P was applied as triple superphosphate @ 44 kg ha^{-1}. Soil enzymatic activities have been described to establish indices of soil fertility (Stefanic *et al.,* 1984), soil productivity (Busto and Perez-Mateos, 1997) and soil quality (*Dick*, 1994.) Soil enzymatic activities in soil may involve direct and indirect roles of AM fungi as AM propagules themselves synthesize soil enzymes. It is reported that AM fungal hyphae can produce some hydrolytic enzymes (Garcı´a-Garrido *et al.,* 1992) Mycorrhizal plants may release more root exudates containing soil enzymes than that of non-mycorrhizal plants because of the larger root system and/or improved nutrition and/or resistances to stress of mycorrhizal plants. Rao and Tak (2001) reported AM fungal inoculation resulted in enhanced plant growth, total uptake of N, P and many other nutrients, activities of dehydrogenase, phosphatases and nitrogenase in the rhizosphere in gypsum mine spoil.

Soil phosphatase may play an important role in the P nutrition of plants because it mediates the release of inorganic phosphorus from organically bound phosphorus. There have been many reports that AM fungi can increase soil enzyme activities, such as phosphatase (Dodd *et al.,* 1987; Mar Va´zquez *et al.,* 2000)AM fungi alter soil microbial communities in the rhizosphere directly or indirectly through changes in root exudation patterns, or through fungal exudates, the so called ‘‘mycorrhizosphere effect’’ (Linderman, 1992). Mar Va´zquez *et al.,* (2000) reported mycorrhizal colonization induced qualitative changes in the microbial population and enzyme activities in the rhizosphere of maize plants. On the other hand, soil phosphatase related to the P of plants, thus, the enhancement of soil enzyme activities is one of the physiological and biochemical mechanisms involved in a mycorrhization effect on plant mineral nutrition. *Wang et al.* (2006) studied the effect of AMF inoculation on the growth of *Zea mays* and the activity of phosphatase enzyme and reported that phosphatase activities were enhanced by both MI (only one AM fungal strain, *Glomus caledonium*) and MII (several AM fungal species, including *Gigaspora margarita* ZJ37, *Gigaspora decipens* ZJ38, *Scutellospora gilmori* ZJ39, *Acaulospora sp.* and *Glomus sp.*), increased by 17 per cent and 58 per cent, respectively, in the *Zea mays* rhizosphere.

MATERIALS AND METHODS

Collection of soil samples

Bulk soil samples were collected from different agro climatic zones (Sub tropical; Intermediate and Temperate) of Jammu region. On the basis of varying physico-chemical properties six samples each from sub-tropical and temperate zone and twelve from intermediate zone were chosen for further studies. The study area and sampling site are given in map(fig .1).

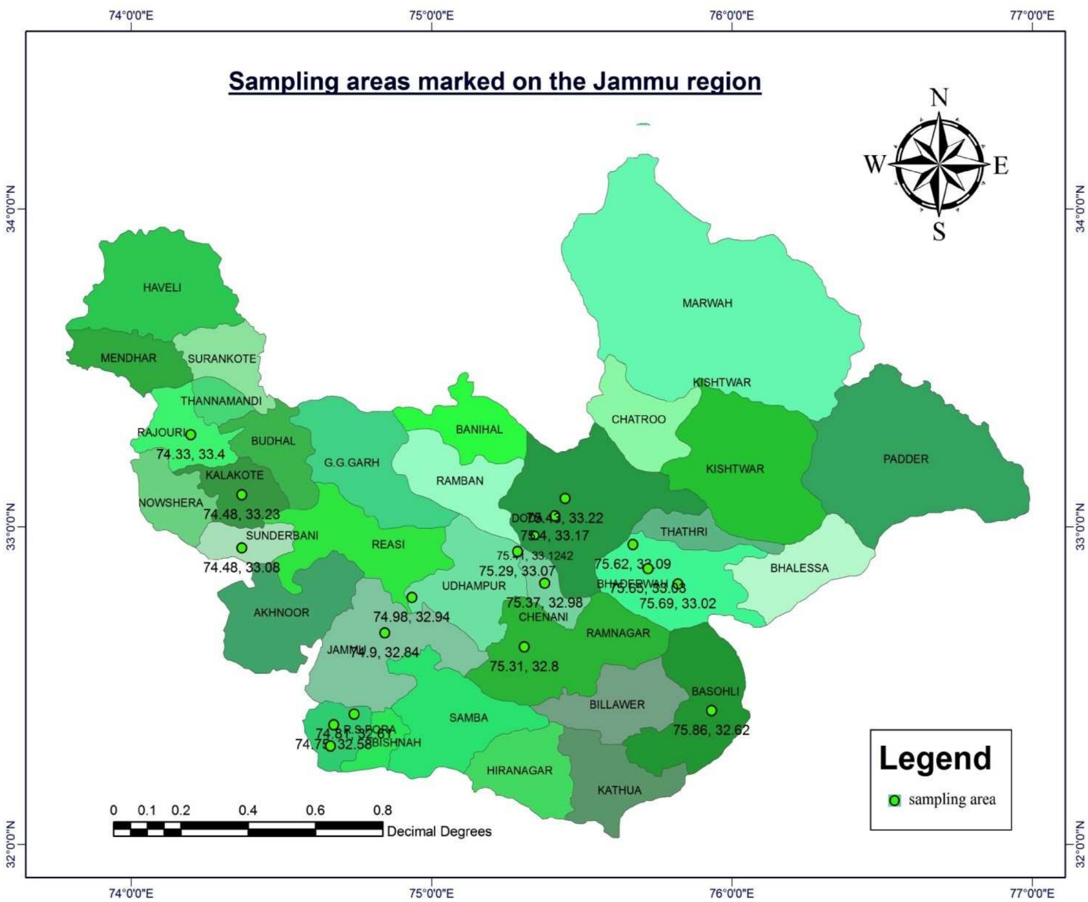

Fig. 1. **Sampling areas marked on the map of Jammu region**

Nutrient mobilization

Processed soil samples taken from different locations sown with pre-germinated maize seed were inoculated with three different strains of AM (*Glomus mosseae, Glomus fasciculatum and Gigaspora sp.*) and nutrient mobilization monitored through 2, 7,14,21,28 and 42 days intervals with following investigations with three replications. Periodic release of phosphorus in rhizosphere of maize was determined by ascorbic acid method as described by Watanabe and Olsen (1965). Organic phosphorus enrichment determined by HCl /NaOH extraction method (Olsen and Sommar, 1982)

Phosphatase activity

Phosphatase activity was determined by the method based on colorimetric determination of the *p*-nitro phenol released by Phosphatase activity when soil is incubated with *p*-nitro phenyl phosphate di sodium salt. (Tabatabai and Bremner, 1969)

RESULTS AND DISCUSSION

Phosphate availability in mycorhizosphere of maize *(Zea mays* L.*)* inoculated with different AM species in soils from subtropical zone of Jammu region is depicted in Fig.1 that revealed that all the three AM species increased significantly phosphorus availability over control. Highest average P availability was observed with *Glomus mosseae* inoculated soils amounting (6.58 mg kg^{-1}) followed by *Glomus fasciculatum*(6.22 mg kg^{-1}). The least average P availability has been noticed in *Gigaspora sp* (5.74 mg kg^{-1}) inoculated soils..Based on the overall mean, P availability in rhizosphere was significantly higher in *Glomus mosseae* compared to *Glomus fasciculatum* and *Gigaspora sp.* Soils inoculated with *Glomus mosseae* showed an increase of 14.5 and 5.7 per cent of P availability over *Gigaspora sp.* and *Glomus fasciculatum* respectively. In soils inoculated with *Glomus mosseae*, the P availability was in the range varying from 5.77 mg kg^{-1} to 7.44 mg kg^{-1} whereas soils inoculated with *Gigaspora sp.* and *Glomus fasciculatum*, the P availability ranged from 4.82 to 6.52 mg kg^{-1} and 5.61 to 6.87 mg kg^{-1} respectively.

All the three AM species showed varying trends in different locations falling under this agro climatic zone. Location wise ,highest P availability for *Glomus mosseae* inoculated soils was observed in Kotlibhagwan soils (7.44 mg kg^{-1}) followed by Banota (6.84 mg kg^{-1}), Chowkichora (6.82 mg kg^{-1}), Jhajarkotli (6.79 mg kg^{-1}) and Thein soils (5.80 mg kg^{-1}). Least P availability for *Glomus mosseae* was observed in Tikri soils (5.77 mg kg^{-1}). Similar trends of P availability was observed for *Glomus fasciculatum* and *Gigaspora sp.* in soils representing Sub tropical zone of Jammu region. Quantitatively in soils inoculated with *Gigaspora sp.* the highest P availability accounting to 6.52 mg kg^{-1} was observed in Kotlibhagwan soils which was followed by Chowkichora (6.02 mg kg^{-1}), Banota (5.94 mg kg^{-1}) Jhajarkotli (5.85 mg kg^{-1}), Thein (5.31 mg kg^{-1}) and Tikri (4.82 mg kg^{-1}). *Glomus fasciculatum* inoculated soils showed maximum P availability in Kotlibhagwan soils (6.87 mg kg^{-1}) followed by Chowkichora (6.53 mg kg^{-1}), Banota (6.35

mg kg^{-1}), Jhajarkotli (6.29 mg kg^{-1}) and Thein soils (5.68mg kg^{-1}) whereas least P availability was observed in Tikri soils(5.61 mg kg^{-1}). All the three AM species have performed equally good in Kotlibhagwan soils which reveals that these strains could perform better in Kotlibhagwan soils.

Phosphate availability in different locations of intermediate zone of Jammu region as affected by different AM *sp.* is depicted by Fig.2 which reveal that all the three AM species increased phosphorus availability significantly over control. Soils inoculated with *Glomus fasciculatum* showed highest average P availability (6.63 mg kg^{-1}) followed by *Glomus mosseae* (6.47 mg kg^{-1}). The least average P availability was observed in *Gigaspora sp.* (6.19 mg kg^{-1}). Statistically average P availability was significantly higher (6.63 mg kg^{-1}) in soil inoculated with *Glomus fasciculatum* when compared to *Glomus mosseae* (6.47 mg kg^{-1}) and *Gigaspora sp.* (6.19 mg kg^{-1}) inoculated soil. Soils inoculated with *Glomus fasciculatum* showed an increase of 7.1 per cent and 2.6 per cent of P availability over *Glomus fasciculatum* and *Glomus mosseae* respectively. In soils inoculated with *Glomus mosseae*, the P availability was in the range varying of 4.57 mg kg^{-1} to 9.30 mg kg^{-1} whereas the availability of P ranged from 4.57 to 8.42 mg kg^{-1} and 4.99 to 8.50 mg kg^{-1} in *Gigaspora sp.* and *G fasciculatum* inoculated soils respectively. All the three AM *sp.* showed varying trends in different locations falling under this agro climatic zone. Location wise highest P availability for *Glomus mosseae* was observed in Ramnagar soils (9.30 mg kg^{-1}) followed by Chenani (8.53 mg kg^{-1}), Rajouri (7.46 mg kg^{-1}), Ramgarh(6.73 mg kg^{-1}) Kishtwar(6.68 mg kg^{-1}),Sunderbani (6.67 mg kg^{-1}), Kud (5.83 mg kg^{-1}),Solki(5.69 mg kg^{-1}), Kagote (5.67 mg kg^{-1}), Sailsui(5.42 mg kg^{-1}) and Kalakote (5.02 mg kg^{-1}). Least P availability for *Glomus mosseae* was observed in Siot soils (4.57 mg kg^{-1}). Almost similar trends of P availability was observed for *Glomus fasciculatum* and *Gigaspora sp.* in these soils representing intermediate zone of Jammu region. In soils inoculated with *Gigaspora sp.*, the highest P availability (8.42 mg kg^{-1}) was observed in Ramnagar soils followed by Chenani (7.91 mg kg^{-1}),Rajouri (7.71 mg kg^{-1}), Sunderbani(6.51 mg kg^{-1}) Kishtwar (6.32 mg kg^{-1}), Ramgarh(6.23 mg kg^{-1}), Kud(6.07 mg kg^{-1}) Solki (5.32 mg kg^{-1}),Kagote (5.20 mg kg^{-1}), Sailsui(5.05 mg kg^{-1}) and Kalakote (5.01 mg kg^{-1}). Least P availability for *Gigaspora sp.* was observed in Siot soils (4.57 mg kg^{-1}). In case of *Glomus fasciculatum* inoculated soil maximum P availability was found in

Ramnagar soils (8.50mg kg^{-1}) followed by Chenani (8.47 mg kg^{-1}), Rajouri (7.97 mg kg^{-1}), Sunderbani(7.00 mg kg^{-1}), Solki(6.73 mg kg^{-1}) Kishtwar (6.62 mg kg^{-1}), Ramgarh(6.62 mg kg^{-1}) Kud (6.26 mg kg^{-1}), Kagote (5.72 mg kg^{-1}) Sailsui (5.41 mg kg^{-1}) and Kalakote(5.25 mg kg^{-1}) where as least P availability was observed in Siot soils (4.99mg kg^{-1}). Based on overall mean of different locations inoculated with different AM species, significant maximum release of P was observed in Ramnagar soils (8.58 mg kg^{-1}) followed by Chenani (8.03 mg kg^{-1}) whereas lowest availability was observed in Siot soils (4.53 mg kg^{-1})

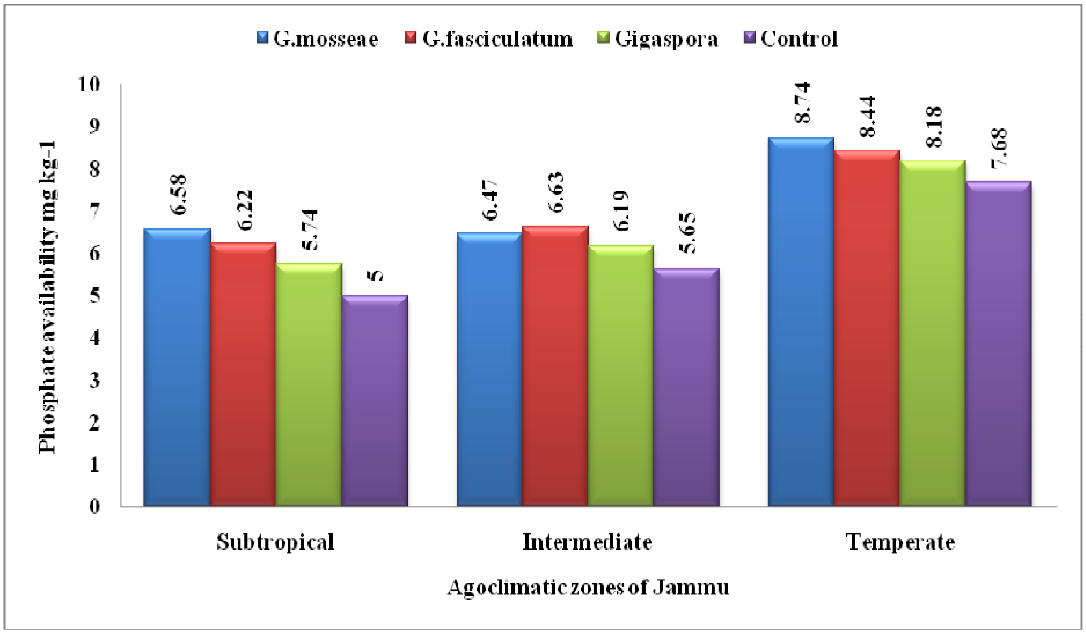

Fig 2. Influence of different AM species on phosphate availability (mg kg^{-1}) in rhizospheric soils of different zones

Perusal of data pertaining to the phosphate availability in temperate zone (Fig.2) revealed that all the three AM species increased phosphorus availability significantly over control. The soils inoculated with *Glomus mosseae* showed highest average P availability. Highest average P availability was observed in *Glomus mosseae* (8.74 mg kg^{-1})

followed by *Glomus fasciculatum* (8.44 mg kg^{-1}). The least average P availability has been noticed in *Gigaspora sp.* (8.18 mg kg^{-1}).

Based on the overall mean, P availability was higher in *Glomus mosseae* when compared to *Glomus fasciculatum* and *Gigaspora sp.* but statistically they are non significant. Soils inoculated with *Glomus mosseae* showed an increase of 6.8 per cent and 3.6 per cent of P availability over *Gigaspora sp.* and *Glomus fasciculatum* respectively. The P availability was in the range varying from 7.41 mg kg^{-1} to 10.10 mg kg^{-1} in soils inoculated with *Glomus mosseae* whereas the P availability ranged from 6.82 to 9.32 mg kg^{-1} and 6.82 to 9.57 mg kg^{-1} in soils inoculated with *Gigaspora sp.* and *Glomus fasciculatum,* respectively. All the three AM *sp.* showed varying trends in different locations falling under this agro climatic zone. Location wise, highest P availability by *Glomus mosseae* was observed in Batote soils (10.10 mg kg^{-1}) followed by Pranoo (9.50 mg kg^{-1}), Assar (8.99 mg kg^{-1}), Dredoo(8.58 mg kg^{-1}) and Bhaderwa (7.87 mg kg^{-1}). Least P availability by *Glomus mosseae* was observed in Dhomail soils (7.41 mg kg^{-1}). In soils inoculated with *Gigaspora sp.* the maximum P availability (9.32 mg kg^{-1}) was observed in Batote soils which was followed by Pranoo (8.72 mg kg^{-1}), Assar (8.63 mg kg^{-1}), Dredoo (7.91 mg kg^{-1}) and Bhaderwa (7.68 mg kg^{-1}). Least P availability in soils inoculated with *Gigaspora sp.* was observed in Dhomail soils (6.82 mg kg^{-1}). Soils inoculated with *Glomus fasciculatum* showed, maximum P availability in Batote soils (9.57 mg kg^{-1}) followed by Pranoo (9.29 mg kg^{-1}), Assar (8.95 mg kg^{-1}), Dredoo (8.31 mg kg^{-1}) and Bhaderwa (7.68 mg kg^{-1}). Least P availability for *Glomus fasciculatum* was observed in Dhomail soils (6.82 mg kg^{-1}). Based on overall mean of different locations inoculated with different AM species, significant release of P was observed in Batote soils (9.44 mg kg^{-1}) followed by Pranoo (8.93 mg kg^{-1}) whereas lowest availability was observed in Dhomail soils(6.82 mg kg^{-1}) depicted in Fig.2

Rate of mineralization in different soils as affected by different AM inoculations has been function of initial total phosphorus status. Initially there was gradual increase of P solubilization and reached at its peak at 28 day afterwards it showed a steady trend in all the AM inoculated soils of different agro climatic zones, however soils inoculated with *Glomus mosseae* showed higher rate of mineralization over other two species under study.

Co-efficient of correlation worked out between soil parameters and phosphorus mobilization in mycorrhizaspheric soils affected by AM inoculation in different agroclimatic zones revealed that a significant positive correlation between organic phosphorus and AM *sp.* irrespective of genus shows that mycorrhiza has a significant role in mobilizing P from the organic P in all the zones of Jammu region. Similar trend is exhibited as far the total P is concerned which displays significant correlation ($r=0.655^{*}$) in intermediate zone and correlation ($r = 0.923^{**}$) in sub tropical soils. However correlation was insignificant amongst different AM species and available phosphorus in different soils of Jammu region. The results unraveled the that organic and total P is affected by AM fungi to release phosphorus molecule Significant correlation between organic carbon and phosphorus mobilization by AM species indicates that presence of soil carbon in mcorrhizosphere is must for the mobilization of P.

Phosphatase activity

Phosphatase is an enzyme responsible for acting on organic P to release inorganic P for plant uptake. The effect of AM species on phosphatase activity in soils is well known. Results in the present study were deduced to evaluate different AM species with respect to their efficacy in releasing P(Fig.3). In sub-tropical zone the maximum phosphatase activity was found in Kotlibhagwan soils (39.7µM *p*NP g^{-1} of soil) followed by Jhajarkotli soils (39.0 µM *p*NP g^{-1}) when inoculated with *Glomus mosseae*. The least phosphatase activity was found in Tikri soils (36.7 µM *p*NP g^{-1}). The phosphatase activity in soils inoculated with *Gigaspora sp* varied between 31.3 to 33.7 µM *p*NP g^{-1}. *Glomus fasciculatum* inoculated soil of sub-tropical zone showed phosphatase activity of 35.0 to 36.7 µM *p*NP g^{-1} soil. The phosphatase activity was significantly higher in soils inoculated with different species of AM over control. Also phosphatase activity of *G. mosseae* inoculated soils were found significantly higher (38.2 µM *p*NP g^{-1}) when compared with *Gigaspora sp* (32.8 µM *p*NP g^{-1}) and significantly at par with *Glomus fasciculatum* (35.9 µM *p*NP g^{-1}) inoculated soils.

In intermediate zone, the phosphatase activity in *G. mosseae* inoculated soils varied between (37.7 to 45.0 µM *p*NP g^{-1}) whereas in soils of *Glomus fasciculatum* and *Gigaspora sp.* inoculated soils the phosphatase activity ranged from 37.0 to 39.3 µM *p*NP $g^{-1}$of soil and 34.0 to 37.3 µM *p*NP g^{-1} of soils respectively. Based on mean all the

AM inoculated soils possess significantly higher phosphatase activity over control. Phosphatase activity was found to be significant among different AM isolates inoculated in the soils of intermediate zone (Fig.3).

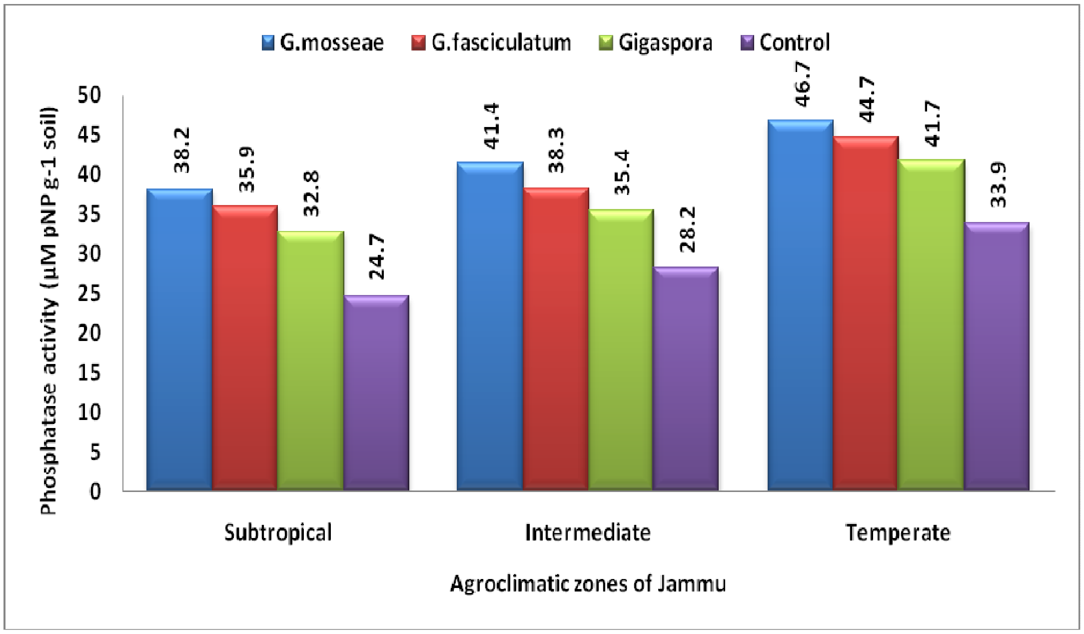

Fig.3 Influence of different AM species on phosphatase activity in rhizospheric soils of different zones

In temperate soils the *G. mosseae* inoculation significantly enhanced phosphatase activity (46.7 µM *p*NP g^{-1}) when compared with *Glomus fasciculatum* ($\bar{X}$=44.7 µM *p*NP g^{-1} of soil) and *Gigaspora sp* (41.7 µM *p*NP g^{-1} of soil). In case of different locations the average maximum phosphatase activity was observed in Batote soils (43.5 µM *p*NP g^{-1}) whereas least phosphatase activity was found in Dhomail soils (40.3 µM *p*NP g^{-1} of soil), (Fig.3).

On comparing different zones of Jammu region the phosphatase activity was in the order of temperate>intermediate>subtropical zone (Fig.3). In all the three zones *G. mosseae* was performed well when compared with *Glomus fasciculatum* and *Gigaspora sp.* Phosphatase activity varied among three different species under three different agroclimatic conditions. *Glomus mosseae* raised the phosphatase activity by 35 per cent, 30 per cent and 27 per cent over control in subtropical, intermediate and temperate zone respectively, where as *Glomus fasciculatum* increased phosphatase activity by 31, 26 and 24 per cent respectively for subtropical, intermediate and temperate zone, where as in case of soils inoculated with *Gigaspora sp.*, least enzyme activity was observed in all the zones irrespective of soils. Sub tropical zone showed the enzyme activity of (38.20, 35.90 and 32.80 µM *p*NP g^{-1} of soil) in soils inoculated with *Glomus mosseae, Glomus fasciculatum and Gigaspora sp.* respectively displaying that different species were able to show the phosphatase activity as *Glomus mosseae>Glomus fasciculatum >Gigaspora sp.* similar trend was observed in intermediate and temperate zone. Highest phosphatase activity was seen in temperate soils by inoculating different *sp.* of AM. Out of the three species, *Glomus mosseae* has been very effective in elevating the enzyme activity in all the zones. On comparing the phosphatase activity with the release of mineral P in mycorrhizosphere, a relation was deduced by applying regression model revealing the regression equation y=0.346x-7.452 (R^2=0.650), y=0.308x-5.128 (R^2=0.661) and y=0.328x-5.366 (R^2=0.671) for *Glomus mosseae, Glomus fasciculatum and Gigaspora sp* inoculated soils, respectively (Figure.4). This clearly indicates that all the AM species have significant role in enzyme kinetics in mycorrhizosphere for releasing the mineral P from organic P.

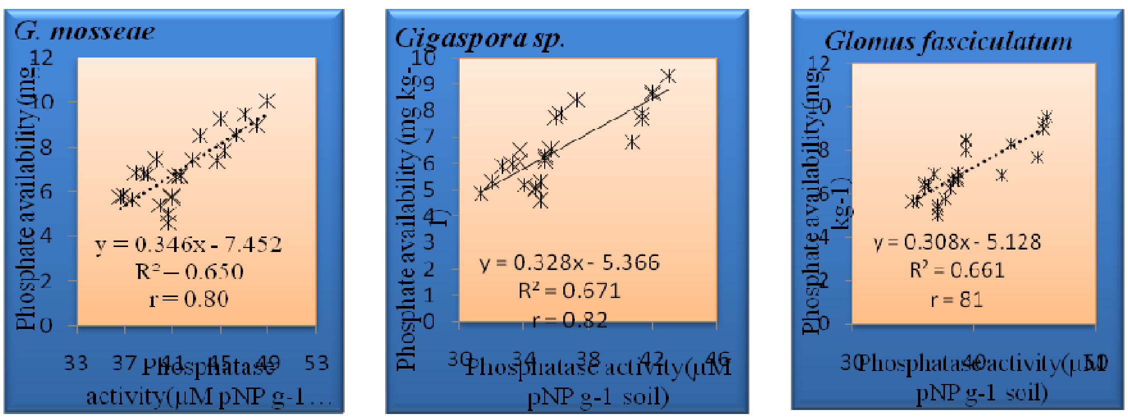

Fig.4 Relationships of phosphatase activity and phosphate availability under the influence of different VAM strains.

All the three AM species viz. *Glomus mosseae*, *Glomus fasciculatum* and *Gigaspora sp.,* showed better performance with respect to phosphate availability as compared to that of the control in all the three agro-climatic zones of Jammu region. However, maximum P availability (10.10 mg kg^{-1}) was observed in Batote soils of Temperate zone which is within the range from 5-20 kg P ha^{-1} yr^{-1} as has been observed by Stewart and Sharpley (1987) on P mineralized in temperate dry land soils. The maximum P availability in Batote soils of temperate zone may be due to the higher content of organic matter. Among all the AM species, *Glomus mosseae* was found to be most effective in increasing P availability in subtropical zone. While as *Glomus fasciculatum* was found to be more effective in increasing P availability in intermediate zone (Fig2). This might be due increase in phosphate solubilising microbes (Singh and Singh, 1993) in rhizosphere due to greater quantity of root exudates (Barea *et al.,* 1975) produced due to mycorrhizal inoculation. These findings are in conformity with the results obtained by Rathore and Singh (1995 a), who reported that the P availability of soil has markedly increased with inoculation of AM. P mobilization by mycorrhizal mediation has also been observed in laboratory studies by Jayachandran *et al.* (1992) when they studied the effect of *Glomus eticunatum* on organic P in an artificial growth medium inoculated with various organic P sources and further proved in subsequent study the mineralization of organic ^{32}P in mycorrhizal and nonmycorrhizal plants.

Rate of phosphorus mineralization in different soils as affected by different AM inoculations has been function of initial organic phosphorus status. Initially there was gradual increase of P solubilization and reached at its peak at 28 day afterwards it showed a steady trend The P solubilization occurs due to secretion of extra-cellular acid and alkaline phosphatase enzyme (Leprince and Quinquampoix, 1996) that catalyses hydrolysis of some esters and anhydrites of H_3PO_4. The increase in available concentration of phosphorus at different interval of time is understood to be related with phosphatase activity in soils secreted by AM *sp.* and play a major role in the mineralization processes (dephosphorylation) of organic P substrates.

A positive correlation was found between AMF with organic P and organic carbon content in mobilization of P in all the three agro-climatic zones. These findings were in line with the results of Jayachandran *et al.* (1992).

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