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Microbial biomass dynamics and phosphorus availability in soil amended with compost, farmyard manure and sugarcane filter cake

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Abstract

Addition of organic amendments to agricultural soils has the potential to increase crop yields, reduce dependence on inorganic fertilizers and improve soil condition and resilience. A 90-days incubation experiment was conducted to check the effects of three organic sources i.e. compost, farmyard manure (FYM) and sugarcane filter cake (SFC), each applied at the rate of 0.5mg Cg^{-1} soil on microbial biomass, enzymatic activity, CO_2 evolution and phosphorus availability in soil. The incubation was carried out at 25°C and 50% water holding capacity WHC. Soil samples were collected at day 0, 30, 60 and 90 days of incubation and analyzed for the above parameters. Results showed that all the three organic amendments had a significant increase in soil microbial and biochemical parameters, highest response was recorded in sugarcane filter cake followed by farmyard manure and compost amendment.CO_2 evolution was also higher in the soils amended with organic sources compared to the un-amended soil. Microbial parameters increased initially up to 30 days of incubation and thereafter decreased indicating microbial biomass turnover. Microbial biomass P was highest (17.63µg g^{-1}) at day 30 under P-enriched sugarcane filter cake. It is concluded that use of organic amendments enhanced phosphorus bioavailability through activation of soil enzymes and microbial biomass.

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Introduction

Soils in Pakistan are deficient in organic matter and nutrient availability especially in phosphorus; despite of wide distribution in soils phosphorus availability is low due to the formation of insoluble salts with Mg/Ca by adsorption of P on soil particles. In semi-arid areas of Pakistan, the problem of phosphorus is worse because of low rainfall and water shortage which results in ineffective use of chemical fertilizers. Farmers are enforced to add two to four times as much P as is removed in the harvested portion of crop to get optimum crop yields.

The inorganic P fertilizers are very expensive and unaffordable for majority of the resource poor farmers of developing countries like Pakistan. In developed countries, fertilizer P use may be economical and cost effective but its excessive use over crop requirements has adverse implications on ecosystem in the form of eutrophication (Memon, 2008). Also, the reserves of high grade rock phosphate used in the preparation of inorganic P fertilizers, are depleting rapidly due to intensive mining across the world and according to some estimates, global P resources are likely to be exhausted by 2050 (Vance *et al.*, 2003) which poses a potential threat to the food security of the world.

It is, therefore, of paramount importance to develop some practicable and cost effective P management strategies to enhance P use efficiency in soil-plant system (Gichangi *et al.,* 2009). Maintaining better crop through the use of various organic sources/amendments is a way to manage nutrient shortage in such areas. Organic amendments improve the microbial activity and biochemical properties of soil as a result of which nutrients release to plants increase because of microbial turnover (Khan and Joergenson, 2009).

Several studies has referred to the use of organic sources like farmyard manure, biogenic compost and sugarcane filter cake to increase the bioavailability of soil nutrients and enhance the efficiency of fertilizers (Takeda *et al.*, 2009). However, the effectiveness of organic sources depends on their nutrient concentration and decomposability.

Upon the addition of organic sources, soil carbon contents increased as a result of which microbial uptake of other macronutrients like N and P also becomes high in soil and when available carbon is depleted in soil then upon microbial turnover, the N and P in microbial biomass becomes available to plants (Bakeko *et al.*, 2013).

Microbial uptake of P can prevent fixation of P by soil colloids. Therefore, microbes can be considered as slow releasing fertilizers which can store nutrients and then can release back to soil (Lakhdar *et al.*, 2010). Addition of organic sources stimulates microbial populations and the uptake of nutrients like N and P by soil microbial biomass. Organic manures addition provides nutrients and additional C which helps in production of great microbial biomass (Sun *et al.*, 2014).

Upon the depletion of available carbon, turnover of microbial biomass starts and the N and P contained in microbial biomass become available to plants (Malik *et al.*, 2012). Organic amendments promote the activity of soil enzymes like dehydrogenase and phosphatase which helps in organic matter decomposition and P mineralization (Khan and Joergenson, 2009). Application of organic sources enriched with inorganic P have the potential to stimulate microbial indices of soil (Khan and Jeorgenson, 2012).

Soil microbes have the potential to transfer organic P form into plant available P form also store huge amount in their biomass under in soils with low P availability (Achat *et al.*, 2010). Microbial uptake of P can prevent P fixation by the soil colloids.

Thus, soil microbes have ability to store substantial amount of P and then may be slowly released back to soil (Docampo *et al.*, 2010). For better nutrient management there is a need to understand.

The relationship between nutrient uptake by the plants and microbial biomass and nutrient availability in response to organic amendments.

The main aim of this study was to understand the dynamics of microbial biomass, phosphorus availability (Olsen P) and enzyme activity (phosphatase and dehydrogenase) in soils amended with three organic sources (compost, farmyard manure and sugarcane filter cake) and to enhance the phosphorus availability by addition of combined inorganic and organic P fertilizers and to reduce the cost of production by maximizing the fertilizer use efficiency.

Materials and methods

Site description

Soil samples were collected from University Research Farm Koont, Chakwal which is deficient in plant available phosphorus. Soil samples were taken up to a depth of 15cm. Straw particles, stones were removed and soil samples were air dried and ground to pass through a sieve (2mm). Analysis of physico-chemical properties of soil are showed in Table 4.1.

Table 4.1. Physico-chemical properties of soil used in incubation experiment (n = 3).

Property	Unit	
Texture		Sandy clay loam
Sand	(%)	65.1
Silt	(%)	12.6
Clay	(%)	22.3
pH		7.9
$EC_{1:2}$	($dS\ m^{-1}$)	0.17
Organic C	($mg\ g^{-1}$)	2.7
Olsen P	($\mu g\ g^{-1}$)	2.7
CO_2-C	($\mu g\ g^{-1}$ soil day^{-1})	9.1
Microbial biomass C	($\mu g\ g^{-1}$)	56.1
Microbial biomass P	($\mu g\ g^{-1}$)	4.6
Dehydrogenase activity	($\mu g\ g^{-1}$)	16.2
Alkaline phosphatase	($\mu g\ g^{-1}$)	58.3

Organic material analysis

Organic material samples were air dried and sieved. Organic sources were mixed with inorganic P (TSP) and incubated for seven days for enrichment treatments. Analysis of organic amendments are showed in Table 4.2.

Organic amendments (Compost, FYM and SFC) samples were sent to King Saud University, Kingdom of Saudi Arabia for Spectroscopic Analysis, Thermal analysis (TDA) and Heavy Metals analysis. Heavy metal analysis is showed in Table 4.3.

Table 4.2. Composition of organic material used in incubation experiment (n=3).

Properties	Sugarcane filter cake	Compost	Farmyard manure
pH	7.2	7.6	6.9
EC ($dS\ m^{-1}$)	13.8	14.7	7.7
TOC ($mg\ g^{-1}$)	138	69	113
Total N ($mg\ g^{-1}$)	8.8	5.7	9.4
Total P ($mg\ g^{-1}$)	5.3	2.8	5.7
Total K ($mg\ g^{-1}$)	11.3	11.4	8.6

Table 4.3. Heavy metals analysis of organic amendments.

Organic Amendment	As (mg/kg)	Cd (mg/kg)	Co (mg/kg)	Cr (mg/kg)	Fe (mg/kg)	Li (mg/kg)	Cu (mg/kg)	Mn (mg/kg)	Ni (mg/kg)	Pb (mg/kg)	Zn (mg/kg)
SFC	12.16	ND	ND	17.52	9352.6	16.09	77.61	480.6	ND	ND	295.4
Compost	ND	ND	ND	23.70	1044.8	19.49	22.93	188.8	8.409	ND	121.9
FYM	ND	ND	ND	12.07	9033.9	18.78	12.96	257.15	ND	ND	122.9

FYM: Farmyard manure SFC: Sugarcane filter cake

Incubation Experiment

An incubation experiment was conducted in laboratory during the year 2015. The objective of this study was to evaluate the microbial biomass dynamics and phosphorus availability in response to organic amendments (compost, farmyard manure and sugarcane filter cake). The experiment was carried out for 90 days and the temperature was maintained at 25^{o}C. 600g soil was added in each incubation jar and eight treatments were applied with three repeats each: (i) control (ii) phosphorus fertilizer (TSP source) (iii) compost with phosphorus fertilizer (iv) farmyard manure with phosphorus fertilizer (v) sugarcane filter cake with phosphorus fertilizer (vi) P-enriched compost (vii) P-enriched farmyard manure (viii) P-enriched sugarcane filter cake.

Organic amendments were applied at the rate of 1% w/w basis. Total incubation jars were twenty four. A beaker containing 20ml 1M NaOH was placed on soil inside each incubation jar to preserve the evolved CO_2 from the soil samples. Soil samples were collected after 0, 30, 60 and 90 days from each incubation jar and were analyzed for microbial parameters (microbial biomass carbon, microbial biomass phosphorus using fumigation-extraction method (Brookes *et al*., 1985)

Chemical (Olsen P) and biochemical parameters (dehydrogenase and alkaline phosphatase). Soil respiration was measured by trapping the evolved soil CO_2 from each jar during the incubation after 1, 2, 3, 5, 7, 10 and 14 days and later each after one week time till the end of the incubation period.

Statistical analysis

The data recorded was statistically analyzed by using Statistic 8.1 and means were compared by using ANOVA technique in accordance to completely randomized with two factor factorial design.

Results and discussion

Microorganisms play a major function in soil fertility and functioning of soil ecosystem as they intercede the processes like decomposition, immobilization, mineralization, denitrification and nitrogen fixation involved in nutrients cycling (Khan and Joergensen, 2006; Khan *et al*., 2006).

Likewise, microorganisms are very reactive and quick in response to the changes in soil conditions particularly in response to organic amendments. Therefore, soil microbial biomass estimation has been extensively used as a tool in studies on nutrients cycling and crop productivity (Voroney *et al*., 1989).

CO_2 evolution in response to organic amendments during 90 days of incubation

Soil respiration is the principal mechanism of C transfer from the soil to the atmosphere and its measurement is the most traditional and popular technique to estimate the microbial activity in soil.

The use of soil respiration has been most frequent because of its simplicity and quick response to the changes in soil management (Gilani and Bahmanyar, 2008). Soil respiration is assessed by CO_2 evolution which results from the decomposition of organic matter. Thus, soil respiration rate indicates the magnitude of decomposition occurring at a given time in a particular soil. Organic amendments sharply enhanced the CO_2 evolution from amended soils compared to un-amended soil as population of microorganisms increased immediately by the addition of easily decomposable organic C by the amendments (Kara *et al*., 2006).

Maximum CO_2 (32µg g^{-1} soil) evolution was recorded from the soil treated with SFC which can be explained by the presence of more C in SFC compared to FYM and compost. Highest respiration rate was recorded during the first week of incubation in both amended and un-amended soils (Fig 4.1) which can also be explained by the presence of immense amount of decomposable C during that period and then decline was observed in CO_2 evolution in late phases which may be ascribed by the depletion of those decomposable substances during the second week of incubation period and later on (Duong *et al*., 2009).

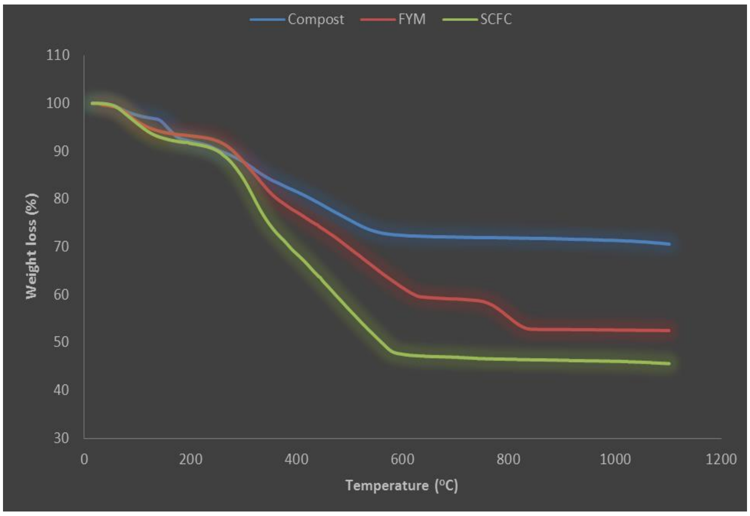

Fig. 4.1. Weight loss of all three amendments under different temperature.

Microbial parameters in response to organic amendments during 90 days of incubation

Microbial biomass C (MBC) has been considered as an estimation of the quantity of the microbe population (Bastida *et al*., 2008) and its estimation has proved very helpful to calculate the changes in microbial population in response to variations in soil management techniques (Achat *et al*., 2010). Raise in microbial biomass carbon after various organic amendments addition in soil like farmyard manure, sugarcane filter cake and composts have been reported by several scientists in the past (Marschner *et al*., 2003; Bohme *et al*., 2005; Tejada *et al*., 2006). In the current study, MBC increased from the very start, with the addition of all organic amendments, highest increase was recorded in soil amended with SFC (82%) followed by FYM (72%) and compost (64%) respectively (Fig. 4.3). At day 30 sharp increase was observed in MBC among all the treatments after.

The amendments application due to the availability of the relatively mineralizable carbon substances in sources added. All the organic amendments significantly increased the MBC compared to un-amended soil (control) and P fertilizer alone. Increasing trend was observed from day 0 to day 30 but in late phases a decreasing trend was recorded in MBC which might be due the diminishing of the easily decomposable carbon substances in the late phases of the experiment period (Bakeko *et al*., 2013).

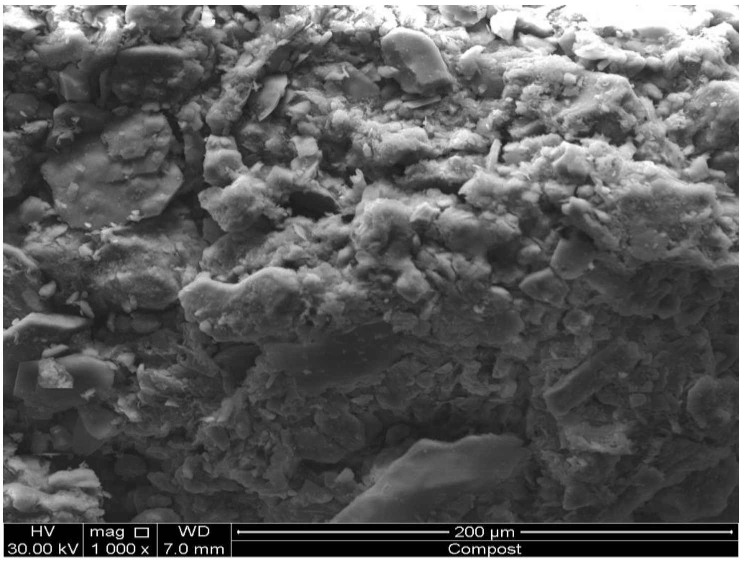

Fig. 4.2. Compost sample**.**

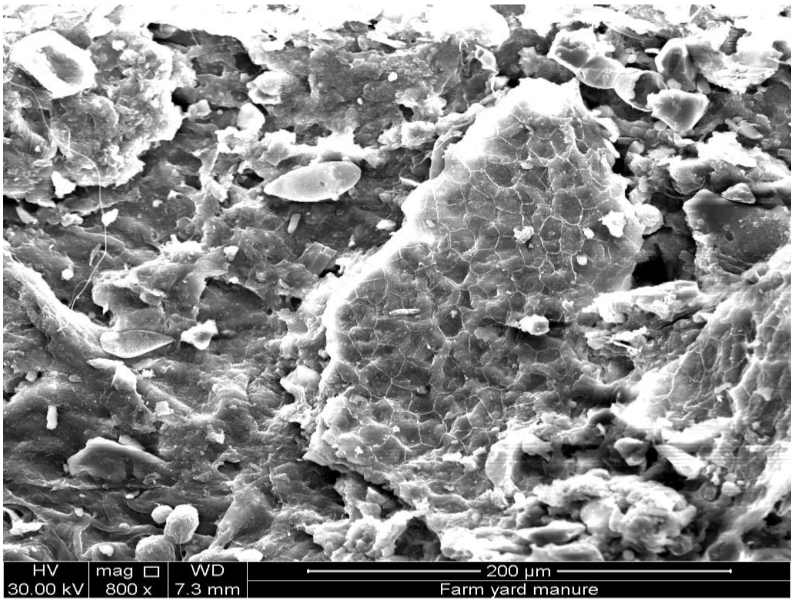

Fig. 4.3. Farmyard manure sample.

Microbial biomass P (MBP) is considered a very labile supply of P for plants because the P assimilated in microbial cells is easily mineralized on microbial turnover (Reddy *et al.*, 2005). MBP increased at the start of the incubation and highest value (17.63µg g^{-1}) was recorded at day 30, this increasing trend and maximum contents of MBP at day 30 can be explained by the same reason which is given above in the case of MBC, the early growth of microbial biomass which is due to the abundance accessibility of the easily decomposable organic carbon substances.

During the early days and till 30 day of the incubation and after day 30 declining trend was recorded which might be due to the depleting and washing out of these mineralizable substances during the mid and the last days of incubation period. Similar trend of increase and decrease in MBP were reported by Sinegani and Mahohi (2009) during the incubation period in soil amended with organic sources. Significant increase was observed in MBP organic amendments by 27-68% over un-amended control with more increase in SFC amended soil (Fig. 4.4).

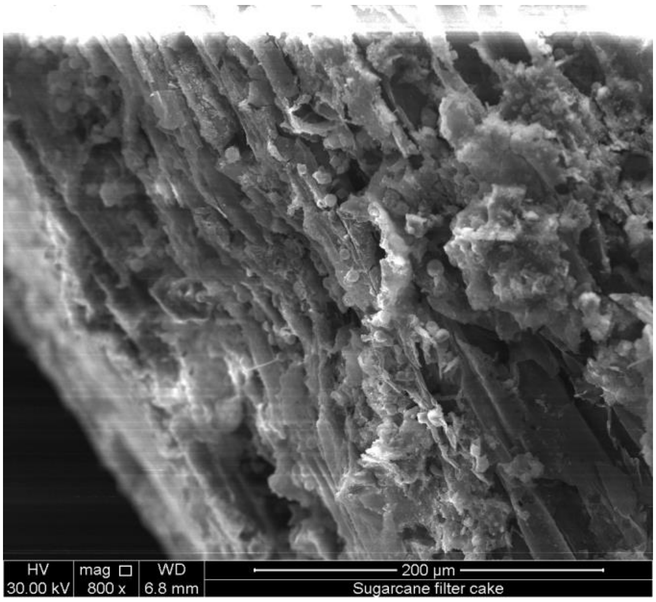

Fig. 4.4. Sugarcane filter cake

Overall, MBP was 42% higher in SFC treated soil compared to FYM (38%) and Compost (27%) treatments. The increases in MBP might be endorsed by the growth of microbes in response to organic amendments which resulted in more assimilation of P into the microbes (Gichangi *et al.*, 2009). In support to these results, Ayaga *et al.* (2006). reported increased microbial biomass after organic application to the soil which resulted in more demand for P and its subsequent incorporation into the microbial biomass or its associated pool of metabolites. Such microbial assimilated P would be released slowly on microbial turnover which can be taken up by plants.

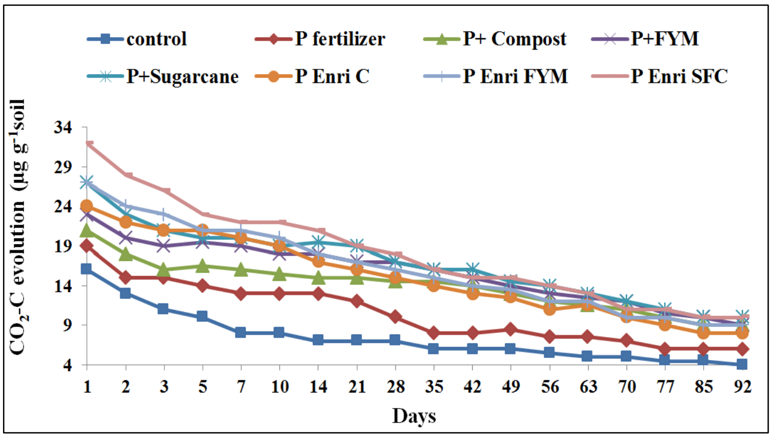

Fig. 4.5 Soil respiration in response to organic amendments during 90 days of incubation study.

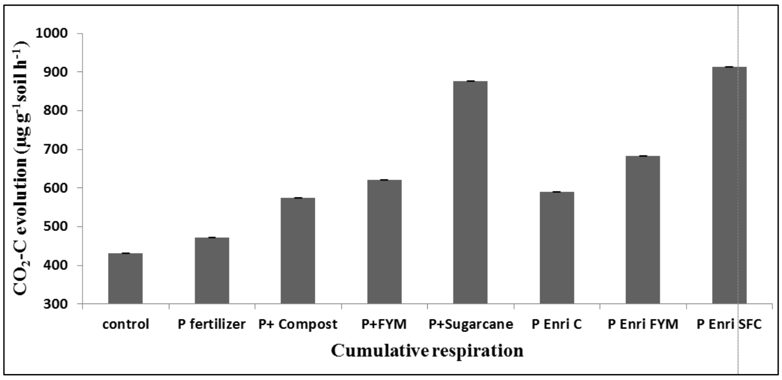

Fig. 4.6. Composition of organic material used in incubation experiment (n=3).

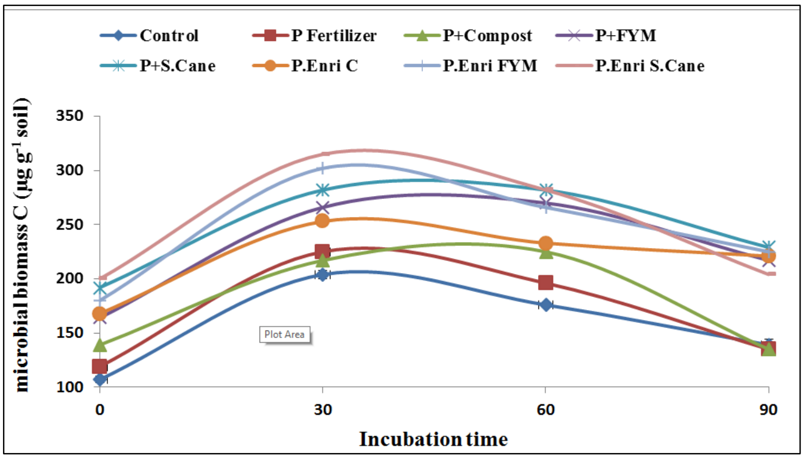

Fig. 4.7. Microbial biomass C in response to organic amendments during 90 days of incubation study.

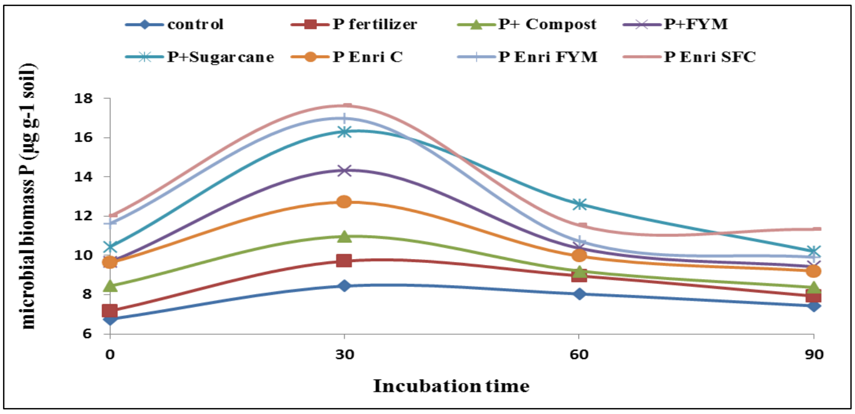

Fig. 4.8. Microbial biomass P in response to organic amendments during 90 days of incubation study.

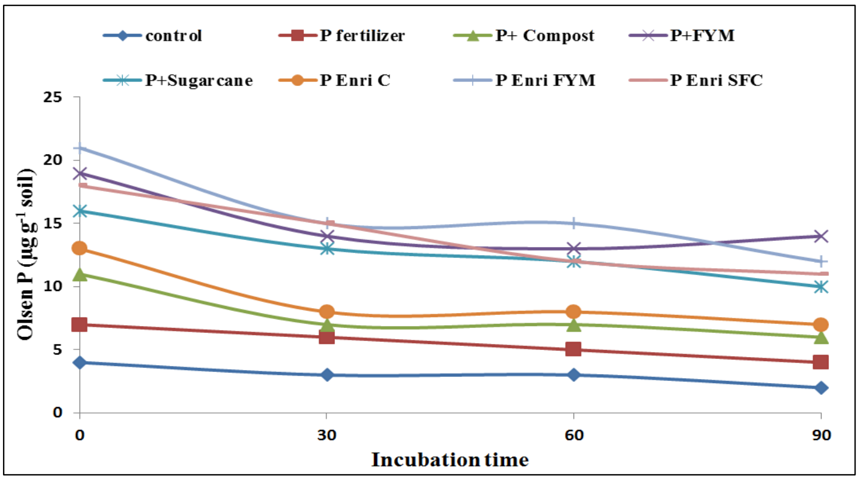

Fig. 4.9. Available P in response to organic amendments during 90 days of incubation study.

Conclusion

All the organic amendments (compost, farmyard manure and sugarcane filter cake) significantly increase bioavailability of phosphorus, soil respiration and microbial biomass. Generally, soil amended with sugarcane filter cake gave maximum results compared to rest of organic sources and best results were obtained under P-enriched soil with organic sources. Phosphorus requirement by the microbes and plant can be fulfilled by the combined application of inorganic and organic P sources and enrichment technique can results in better yield and production.

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