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Impact of Different Phosphorus Sources on Major and Micro Nutrient Availability to Main and Residual Crop

P. Premanandarajah

Senior Lecturer, Department of Agric. Chemistry, Faculty of Agriculture, Eastern University, Sri Lanka.

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ABSTRACT

Pot culture experiment was conducted to study the impact of organic and inorganic phosphorus source on major and micronutrient availability for main and residual crop. Organic and inorganic Phosphorus sources (farmyard manure, poultry manure, vermicompost, sewage sludge and single superphosphate), to supply 34 kg P_2O_5 ha^{-1}, were used as treatments with no phosphorus source as control. These six treatments replicated four times, making a total of 24 pots. In main groundnut crop all the phosphorus sources improved soil organic carbon and major and micronutrient contents. Among them poultry manure had the greatest influence on the availability of phosphorus, nitrogen, potassium and sulphur. In the residual sunflower crop phosphorus source improved the nutrient availability and soil organic carbon content. Among them, poultry manure registered higher soil available nitrogen and phosphorus content and sewage sludge treatment increased potassium and sulphur content. Residual iron, zinc and copper content was higher and comparable in sewage sludge and farmyard manure treatment. And residual manganese content was higher in single super phosphate treatment.

1. Introduction

Soils are the resources that provide all the food we eat. Therefore there is a challenge to improve and manage our soil in a sustainable manner to fulfill the needs of growing population in the future.

Soil health and soil quality are terms used interchangeably to describe soils that are not only fertile but also possess adequate physical and biological properties to "sustain productivity, maintain environmental quality and promote plant and animal health" [11].

The majority of nutrient input to agriculture comes from commercial mineral fertilizers. Soil fertility cannot be maintained with the application of inorganic fertilizers alone. Besides inorganic chemical fertilizers, there are several sources of plant nutrients like organic manures, crop residues, and industrial wastes. Organic manures are considered to play a significant but lesser role in nutrient contribution, leaving aside their beneficial effects on soil physico-chemical and biological properties. No single source can meet the increasing nutrient demands for agriculture. To achieve sustainability in production, there is a need to integrate both organic and inorganic sources of nutrients.

Before integrating nutrient sources, it is necessary to work out and quantify fertilizer replacement value of different organic sources due to inadequate data on the production and consumption of organic sources as compared with mineral fertilizers.

Phosphorus can be termed as "life mineral" because of its crucial role in metabolic and energy transfer reactions in living systems. Phosphorus deficiency is common in almost all the soils and crops. The availability of phosphate in soils is often limited by fixation reactions, which convert the monophosphate ion to various insoluble forms.

Phosphates fixed by Fe, Al, and Ca in soils is a major cause of low phyto availability [19]. The availability of soil phosphate is enhanced by additions of organic manures, presumably due to chelation of polyvalent cations by organic acids and other decay products. P availability in P-fixing soils can be increased by organic supplements [16].

Organic manure, besides supplying nutrients to the current crop, often leaves substantial residual effect on the succeeding crops. Information on the exact quantity of phosphorus rendered available to crops from the applied manures is scanty. Further, precise information on the residual quantity of soil available phosphorus from the applied manures that is made over to a subsequent crop is also not available. Against this backdrop, the present investigation was contemplated with the following objectives:

- To study the impact of organic and inorganic phosphorus source on major and micronutrient availability for main and residual crop.

2. Materials and Method

The experimental soil was loamy sand in texture. The available phosphorus, and organic carbon content were 8.70 kg ha^{-1}and 6.3 g kg^{-1} respectively. The phosphorus content of organic manures used was 1.12, 3.80, 0.94 and 1.81 percent in farmyard manure, poultry manure, vermicompost and sewage sludge respectively.

Five phosphorus sources, including four organic as farmyard manure, poultry manure, vermicompost, sewage sludge and an inorganic as single superphosphate were used as treatments with no phosphorus source as control. These six treatments replicated four times in Complete Randomized Design, making a total of 24 pots.

The processed soil samples were filled in earthen pots at the rate of 8 kg soil per pot.

Tele: +94 77 800 3764
E-mail address: puni_prem@yahoo.com

To all the 24 pots, common basal applications of 17 kg N ha^{-1} as urea, 54 kg K_2O ha^{-1} as muriate of potash and 74.34 kg S ha^{-1} as gypsum were given. On equivalent P basis @ 34 kg P_2O_5 ha^{-1} (0.054 g P per pot). Organic sources of P and inorganic SSP were applied to each pot.

Seeds of groundnut (five per pot) were sown in each pot. After the germination, the plants were thinned to 3 per pot. Routine cultural practices were adopted in raising the crop.

After the harvest of main crop groundnut, the soil in the pots were removed, gently powdered and repotted again. Common basal applications of N @ 40 kg N ha^{-1}, as urea and K @ 20 kg K_2O ha^{-1} as muriate of potash were given; no phosphorus was applied. Seeds of sunflower were then sown @ 5 in each pot. After germination, 3 plants were uniformly maintained in each pot.

After main and residual crop representative sub samples were drawn from the treatments organic carbon, available N, P, K, S and DTPA Fe, Mn, Zn, Cu were analyzed by using recommended methods.

Statistical analysis

The data obtained from the above investigations were subjected to statistical analysis to find out the effect of various treatments on the availability of nutrients.

3. Results and Discussion

Main Crop

Post-harvest soil major nutrient availability and organic carbon content.

Post-harvest soil nutrients availability was significantly higher in phosphorus treated soils. Organic carbon, available nitrogen, available phosphorus, available potassium and available sulphur contents of soil were significantly improved with different phosphorus sources.

Table 1. Effect of phosphorus sources on post-harvest soil nutrient availability after first crop.

Phosphorus sources	Organic C (g kg^{-1})	Available P (kg ha^{-1})	Available N (kg ha^{-1})	Available K (kg ha^{-1})	Available S (mg kg^{-1})
Control	4.0e	10.9e	272.7d	110.3d	7.3e
FYM	6.9b	25.2b	295.1b	194.5a	21.9bc
PM	6.5c	28.5a	311.9a	203.5a	26.7a
VC	7.2a	17.5d	286b	180.3b	18.7cd
SS	6.3c	22.2c	314.7a	170.3b	24.3ab
SSP	5.7d	15.0d	285.3c	150.3c	17d

FYM-Farmyard manure, PM-Poultry manure, VC-Vermicompost, SS-Sewage sludge, SSP-Superphosphate

a. Soil organic carbon content

Phosphorus application significantly increased the soil organic carbon content. Among the phosphorus sources, vermicompost was foremost (7.2 g kg^{-1}). Superphosphate treated soil recorded the lowest organic carbon content (5.7 g kg^{-1}) and was significantly higher than control.

The increase in organic carbon content might be due to the addition of organic manures which stimulated the growth and activity of microorganisms, and also due to better root growth. These observations are in line with the findings of Varalakshmi *et al*. (2005) in groundnut – finger millet cropping sequence. Organic carbon content was also high in inorganic phosphorus (single super phosphate) treated soil. This might be due to the improvement in root and shoot growth. Higher production of biomass might have increased the organic carbon content [7].

b. Soil available Nutrients

The results revealed that the soil nutrient availability was significantly higher in organic manure treated soils than chemical fertilizer treatment. Addition of organic manure increased soil moisture contents [9], which may be the reason of improved P availability in soil. Nonetheless organic manures after decomposition may also have played role in carbonic acid driven increased P bio availability [20].

Among the different phosphorus sources, poultry manure increased the available nitrogen, phosphorus, potassium and sulphur status over control more than other sources. Poultry manure is rich organic manure since solid and liquid excreta are excreted together resulting in no urine loss [21].

i. Soil available Phosphorus content

The results pertaining to the available phosphorus content in post-harvest soils indicated that the highest phosphorus content was recorded in poultry manure treated soil. Farmyard manure was the second best source.

Organic acids and chelates are produced during microbial decomposition of organic residues. These organic acids may help in the solubility of native phosphorus as a result of which increase in available phosphorus content. Different types of organic manure increase the microorganisms, release acids in the root rhizosphere and may help to solubilize P and to increase P availability to the plants [14].

Applied organic manure leads to the formation of coating on the sesquioxides because of which the phosphorus fixing capacity of soil was reduced in manure treated plots in groundnut [32]. Mohamad Tariq and Stephen Robinson, (2003) confirmed the decreases in soil phosphorus sorption characteristics following the application of animal manures and effluents.

Toor (2009) found a substantial increase in soil solution P following the application of PM with P fertilizers because of the release of organic acids during decomposition of the manure and production of carbon dioxide during organic-matter decomposition that may increase the solubility of Ca^{2+} and Mg^{2+} phosphates.

ii. Soil available nitrogen content

Analysis of the post-harvest soil for available nitrogen indicated that among the organic sources sewage sludge exhibited a considerable increase in available nitrogen content and it was comparable with poultry manure treatment.

Application of organic manures had significant impact on the available nitrogen content. Among the organic sources poultry manure and sewage sludge exhibited a considerable increase in available nitrogen content. Organic manures provide energy for nodulation and nitrogen fixation by microorganisms. Similar views were expressed by Rao, (2003). It was supported by Pakhnenkoa *et al*. (2009) that, In the course of mineralization of sewage sludge, nitrogen is transformed into available forms. In other study done by Akanni and Ojeniyi (2007) observed that poultry manure increased nitrogen availability and uptake by tomato plant.

iii. Soil available potassium content

Poultry manure recorded the highest available potassium content in soil (203.5 kg ha^{-1}). It was comparable with farmyard manure treatment (194.5 kg ha^{-1}).

Higher availability of potassium in soil might be due to the beneficial effects of organic manures on the reduction of potassium fixation; added organic matter interacted with potassium - clay to release potassium from the non-exchangeable fraction to the available pool [32]. Adeleye *et al*. (2010) indicated the ability of poultry manure in supplying nutrients and organic matter to the soil and improving the soil physical and chemical properties and nutrient status.

Comparing different sources, phosphorus and potassium concentration in plants were maximum in poultry manure treatment and farm yard manure, respectively [33].

iv. Soil available sulphur content

The results of sulphur content in post-harvest soil indicated that poultry manure recorded the highest available sulphur in soil (26.7 mg kg^{-1}). This was on par with sewage sludge treatment (24.3 mg kg^{-1}). Pandey *et al.* (2000) confirmed that sulphur availability was significantly and positively influenced by organic matter due to release of organic acids on decomposition of organic matter, causing solubilization of insoluble sulphur complexes. The fertility status of soil is expected to benefit from poultry manure application since the manure is known to improve soil organic matter content and macronutrient status the soil [18]. Ewulo *et al.* (2008) found that, the poultry manure improved soil nutrient contents led to increased uptake of nutrients by tomato plant. Salako (2008) reported that poultry manure improved surface phosphorus and other major nutrients

Post-harvest soil micronutrient availability.

Post-harvest soil after groundnut was analyzed for micronutrients availability and the results revealed that application of phosphorus sources induced considerable increase in the availability of soil micronutrients.

Table 2. Effect of phosphorus sources on post-harvest soil micronutrient availability after first crop.

Phosphorus sources	Zinc (mg kg^{-1})	Manganese (mg kg^{-1})	Copper (mg kg^{-1})	Iron (mg kg^{-1})
Control	1.3d	11.6d	1.1d	14.7d
FYM	2.4ab	22.6b	3.1b	26.7ab
PM	2.6a	20.9c	4.6a	26.1b
VC	2.2b	20.0c	2.8b	25.6b
SS	2.3ab	22.3b	4.5a	28.2a
SSP	1.7c	24.3a	2.2c	22.6c

FYM-Farmyard manure, PM-Poultry manure,
VC-Vermicompost, SS-Sewage sludge, SSP-Superphosphate

a. Soil available micronutrient content

Significant variation was observed in post-harvest soil micronutrient content after groundnut. Organic phosphorus sources exerted marked increase in micronutrient availability than superphosphate treatment. All the treatments were significantly superior to control. The DTPA – extractable micronutrient contents were much lower in control treatment than other treatments with different sources. This might be due to the depletion of these nutrients by the crop because replenishments were not available externally [12]. The higher availability of iron, manganese, copper and zinc in soil due to the application of manures in maize – soybean cropping sequence could be ascribed to the mineralization of the manures, reduction of fixation and complexing properties of these manures with micronutrients [30].

Among the organic sources, poultry manure recorded the highest zinc and copper content and were on par with sewage sludge treatments. Poultry manure application improved the fertility status of soil as the manure is known to improve soil organic matter content, macronutrient status and micronutrient qualities of the soil [2]. Ayeni *et al.* (2008) showed that poultry manure application increased availability and uptake of Mn, Zn, Fe, and Cu by maize grown on an alfisol in south west of Nigeria.

The statistical scrutiny of the data with respect to manganese and iron availability in soil indicated that farmyard manure and sewage sludge recorded comparable and higher value. Application of different levels of sewage sludge and fertilizers increased the availability and uptake of micronutrients [37]. This increase might be because of the direct contribution by sewage sludge. It agrees with the findings of Chitdeshwari *et al.* (2002).

Residual crop

Post-harvest soil major nutrient availability.

All the phosphorus treatments significantly increased the post-harvest soil nutrient content.

Table 3. Effect of phosphorus sources on post-harvest soil nutrient availability after residual crop.

Phosphorus sources	Organic C (%)	Available P (kg ha^{-1})	Available N (kg ha^{-1})	Available K (kg ha^{-1})	Available S (mg kg^{-1})
Control	3.0d	11.8d	271e	116e	4.7e
FYM	4.9a	91.0b	304c	180b	43.6c
PM	4.5ab	114a	330a	175c	44.7c
VC	4.0bc	65.5c	285d	167d	47.3b
SS	4.6ab	89.4b	314b	218a	50.5a
SSP	3.6cd	61.0c	281d	165d	41d

FYM-Farmyard manure, PM-Poultry manure,
VC-Vermicompost, SS-Sewage sludge, SSP-Superphosphate

Statistical analysis of available nutrient contents after residual sunflower crop showed that the organic carbon content was higher in farmyard manure treated (4.9 g kg^{-1}) soil and that was on par with poultry manure (4.5 g kg^{-1}) and sewage sludge (4.6 g kg^{-1}) treatments. In vermicompost treatment organic carbon content was 4.0 g kg^{-1} which was on par with poultry manure and sewage sludge treatments.

The results of the present investigation revealed that the organic carbon content was higher in organic manure treated soil than in the chemical fertilizer treatment and control. It was supported by Gregorich *et al.* (2001) that organic manures and compost applications resulted in higher SOC content compared to same amount of inorganic fertilizers applications.

The organic carbon content was lower in soil after the harvest of residual crop (sunflower) than the soil carbon content first crop (groundnut). This result draws support from the work of Muneshwar Singh *et al.* (2001).

Among the treatments, poultry manure registered a significantly higher soil available nitrogen (330 kg ha^{-1}) and phosphorus contents (114 kg ha^{-1}) than any other treatment. This was followed by sewage sludge treatment (314, 89.4 kg ha^{-1}). Post-harvest soil potassium and sulphur contents were higher in sewage sludge treated soil (218 kg ha^{-1} and 50.5 mg kg^{-1}, respectively) and it was followed by farmyard manure in case of potassium and vermicompost treatment for Sulphur (180 kg ha^{-1}, 47.3 mg kg^{-1}, respectively). Among the organic manures, vermicompost recorded the lowest soil available nitrogen, phosphorus and potassium contents (285, 65.5, 167 kg ha^{-1}, respectively) and it was on par with chemical fertilizer treatment (281, 61, 165 kg ha^{-1} nitrogen, phosphorus and potassium, respectively). Among the organic manures tried, farmyard manure recorded the lowest available sulphur in post-harvest soil and this was on par with poultry manure (43.6, 44.7 kg ha^{-1}).

The available nitrogen, phosphorus, potassium and sulphur contents were higher in organic manure treated soil as compared to chemical fertilizer treatment and control. The influence of organic matter on soil nutrient status after the harvest of residual crop was confirmed by Vanaja and

Sreenivasa Raju (2004) in rice – sunflower cropping sequence.

A two-year field investigation on cereal fodder – wheat cropping system showed that after the harvest of each crop in a crop cycle the available nitrogen and phosphorus in soil improved due to the application of organic manures to the preceding *kharif* crop [17]. The buildup of available nutrient status of soil through organic sources could be attributed to the residual effect of applied fertilizers and to the mineralization of organic sources or solubilization of the nutrients from the native sources during the decomposition process. Patel and Patel (2003) also substantiated these findings in bajra. Among the organic sources, higher soil nutrient availability was recorded under poultry manure treatment. This might be due to the higher concentration of nutrients in poultry manure. Besides, poultry manure had higher and steady nutrient release compared to other organic manures. Further, the poultry waste had both urinary and fecal excretion. Hence, its fertilizer value was higher than farmyard manure [4].

Post-harvest soil micronutrient availability.

Micronutrient content was higher in treatments received phosphorus**.**

Farmyard manure treatment recorded the highest iron content (28.21 mg kg^{-1}) in soil and was comparable with sewage sludge treatment (27.39 mg kg^{-1}). The availability of copper and zinc was higher in sewage sludge treated soil (3.57 and 3.45 mg kg^{-1} respectively) which was on par with farmyard manure treatment (3.04 and 2.96 mg kg^{-1} respectively). The available manganese content in residual soil was higher in single superphosphate treated soil (21.26 mg kg^{-1}). There was no significant variation in manganese content in organic manure treated soil and was significantly higher than control treatment.

In the present investigation, it was observed that the micronutrients availability was higher in manure treatments. The residual effect of organic manures might be attributed to the release of macro and micronutrients during mineralization.

Organic matter also acts as a source of energy for soil microflora which brings about mineralization of micronutrient cations. These results are in conformity with the findings by Patel *et al*. (2007) in wheat.

Table 4. Effect of phosphorus sources on post-harvest soil micronutrient availability after residual crop.

Phosphorus sources	Zinc (mg kg^{-1})	Manganese (mg kg^{-1})	Copper (mg kg^{-1})	Iron (mg kg^{-1})
Control	1.45c	11.22c	1.62c	15.00d
FYM	2.96ab	19.69b	3.04a	28.21a
PM	2.58b	19.65b	2.29bc	26.13c
VC	2.64b	19.44b	1.94c	26.19c
SS	3.45a	19.47b	3.57a	27.39ab
SSP	2.53b	21.26a	1.66c	26.39bc

FYM-Farmyard manure, PM-Poultry manure,
VC-Vermicompost, SS-Sewage sludge, SSP-Superphosphate

Organic manure addition increased the availability of micronutrients in soil and thereby increased the uptake of micronutrients by the residual crop. Patel and Patel (2003) examined the residual effect of integrated nutrient management on performance of succeeding *bajra* crop grown on a loamy sand.

Results on residual soil fertility indicated that various treatments consisting of FYM to cabbage-*bajra* sequence significantly improved the available DTPA - Fe and Zn over control. Hence subsequently bumper yield of *bajra* could be obtained without fertilizers, besides sustaining the soil fertility.

Increased availability of residual micronutrients in organic manure treated plots might be due to the mineralization of organically bound forms of micronutrients in the organic materials and also it might result in the formation of organic chelates of higher stability with organic ligands which decreased their susceptibility to adsorption, fixation or precipitation and increase their availability to residual crop [8]. Among the organic manures, the micronutrient content was higher in sewage sludge and treated soil. This might be due to higher micronutrient content of sewage sludge. This was supported by Warman and Termeer (2005) that Sewage sludge contains several essential micronutrients for plants (e.g., B, Cl, Cu, Fe, Mn, Mo, and Zn), which are not provided by most conventional chemical fertilizers.

Petersen *et al*. (2003) confirmed that the sewage sludge serves as a reservoir for micronutrients like Fe, Mn, Zn and Cu. Furthermore, regular annual applications of sludge have a cumulative effect on residual nutrients [5].

4. Conclusion

In main residual crop all the phosphorus sources improved soil organic carbon and major and micronutrient contents.

Among them poultry manure increased the availability of phosphorus, nitrogen, potassium and sulphur. And comparable value for nitrogen and sulphur content in sewadge sludge treatment and for potassium in farmyard manure treatment were obtained. Micronutrients manganese, iron, zinc and copper content was higher in sewage sludge treatment. Also comparable and higher Manganese and iron content in farmyard manure treatment and zinc and copper availability in poultry manure treatment were recorded.

In the residual sunflower crop phosphorus source improved the nutrient availability and soil organic carbon content. Among them, poultry manure registered higher soil available nitrogen and phosphorus content and sewage sludge treatment increased potassium and sulphur content. Residual iron, zinc and copper content was higher and comparable in sewage sludge and farmyard manure treatment. And residual manganese content was higher in single super phosphate treatment.

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