TRACER STUDIES ON THE DIRECT AND RESIDUAL EFFECTS OF PHOSPHORUS AND SULPHUR FROM ORGANIC MANURES IN GROUNDNUT – SUNFLOWER CROPPING SYSTEM

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ABSTRACT

Phosphorus x sulphur integration trial was conducted using ^{32}P and ^{35}S tracer technique, to develop a nutrient management technology for groundnut –sunflower cropping system. Six treatments (100% RDF to groundnut crop through poultry manure, 75% RDF through poultry manure and 25% RDF through chemical fertilizers, 50% RDF through poultry manure and 50% RDF through chemical fertilizers, 25% RDF through poultry manure and 75% RDF through chemical fertilizers and 100% RDF through chemical fertilizers), all applied on equal P basis @ 34 kg P_2O_5 ha^{-1} and on equal S basis @ 75 kg S ha^{-1}. The six treatments, including a no-P and no-S as control were replicated three times in a completely randomized design. Main crop of groundnut was followed by a residual crop of sunflower. Plant analysis for ^{32}P and ^{35}S activity and nutrient contents was carried out. Post-harvest soil analysis was carried out after groundnut and sunflower. Application of 100% RDF to groundnut, 25% as poultry manure and 75% as chemical fertilizers recorded the highest soil nutrient availability and uptake in main crop. But in residual crop 75% poultry manure with 25% chemical fertilizers registered higher soil available nutrient and uptake. In main crop the 'A' values, %Pdfs and %Sdfs were higher in the combination of 25% poultry manure with 75% chemical fertilizer but in residual crop were higher in 75% poultry manure and 25% chemical fertilizer combination. Sole poultry manure treatment recorded highest %Pdff in main crop but highest %Pdff and % Sdff were recorded in sole chemical fertilizer treatment in residual crop.

Key word: %Pdff, %Pdfs, %Sdff, %Sdfs and 'A' value

Introduction

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. 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. Such an integration of nutrient sources will enhance the nutritional use efficiencies (Hegde and Sudhakarababu, 2001) besides maintaining soil fertility. Thereby effective and viable integrated nutrient packages can be formulated for different cropping systems under varied agro-ecosystems. Therefore there is a need to work out nutrient supply packages by integrating all the available sources of nutrients.

The availability of phosphate in soils is often limited by fixation reactions, which convert the monophosphate ion to various insoluble forms. 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.Specific attention needs to be given to harness the residual effect of phosphorus (Kumaran and Solaimalai, 2000).

Sulphur deficiency is mostly reported in coarse textured soils, in soils having low organic matter, in sites away from industrial activity associated with the emission of sulphur containing gases, in high rainfall areas, in crop rotations involving pulses and oilseeds and due to continuous use of sulphur free fertilizers (Tandon, 1995). Sulphur improves crop yields, oil percentage in oilseeds, plant proteins, etc.

Information on the exact quantity of phosphorus and sulphur rendered available to crops from the applied manures is scanty. Further, precise information on the residual quantity of soil available phosphorus and sulphur from the applied manures that is made over to a subsequent crop is also not available and such precise informations could be obtained only with the aid of tracer techniques.

Against this backdrop, the present investigation was contemplated using tracer techniques, to study the direct and residual effects of phosphorus and sulphur from organic manure in groundnut – sunflower cropping system.

METHODOLOGY

The soil used in the present study was loamy sand in texture with 15.5, 6.5 and 78.0 percent clay, silt and sand respectively . The contents of available phosphorus and sulphur were 8.70 kg ha^{-1} and 8.07 mg kg^{-1} respectively. The phosphorus and sulphur content of poultry manure used was 3.80% and 2.56 % respectively. Processed soil samples were filled in earthen pots, lined with polythene sheets @ 8 kg soil per pot. Poultry manure (PM) was integrated with chemical fertilizers (CF), SSP and elemental S at different ratios. There were six treatments replicated three times (making a total of 18 pots) in a completely randomized design (T1-Control, T2-100%PM, T3-75% PM + 25% CF, T4-50% PM+50%CF,T5- 25% PM + 75% CF and T6 100%CF). There were 2 sets of pots, each set having 18 pots. The ^{32}P and ^{35}S labeled fertilizers were applied only to the first set of 18 pots

for the main groundnut crop. For the residual crop sunflower, only the second set of 18 pots were applied with labeled fertilizers. The second set of 18 pots, identical with the first set in all respect but without ^{32}P and ^{35}S labeling for main crop, were maintained to study the residual effects.

SOWING OF CROPS

To all the 36 pots common basal applications of 17 kg N ha^{-1} as urea, 54 kg K_2O ha^{-1} as muriate of potash and 93.1 kg Ca ha^{-1} as $CaCl_2$ were given. Inorganic SSP (single supper phosphate) and poultry manure as reference source were given to all on equivalent P and S basis (0.054 g P per pot and 0.27 g S per pot), respectively. Seeds of groundnut (five per pot) were sown in each pot. After the germination, the plants were thinned to 3 per pot. From a stock solution of carrier–free^{32} P, 13 ml was added to each of the 18 pots in first set to give an activity level of 6.29 MBq per pot. From stock solution of carrier-free ^{35}S, 13 ml was added to each of the 18 pots in the first set to give an activity level of 16.65 MBq per pot**.** The instantaneous specific activity (Di *et al.*, 1994) was determined as per standard procedures and calculations. Routine cultural practices were adapted in raising the crop. After the harvest of main crop groundnut, the soil in the pots were removed, gently powdered with a wooden mallet to break the clods and repotted again. Seeds of sunflower were then sown 5 in each pot. After germination 3 plants were uniformly maintained in each pot. Routine cultural practices were followed in raising the crop**.** From a stock solution of carrier-free^{32} P, 10 mL was added to each of the 18 pots in first set to give an activity level of 17.45 MBq per pot. From stock solution of carrier-free ^{35}S, 10 ml was added to each of the 18 pots in the first set to give an activity level of 12.87 MBq per pot**.**

PLANT ANALYSIS

Oven dried plant materials were chopped and ground in a Wiley mill and stored. The plant materials were analyzed for P and S and for radioactivity of ^{32}P and ^{35}S.

RADIOASSAY

The ^{32}P activity in the plant samples was determined following the procedure suggested by McKenzie and Dean (1948). The ^{35}S activity in the plant samples was determined after precipitating sulphur in the diacid (Nitric acid and perchloric acid in the ratio of 2:1) extract of the plant sample as barium sulphate. The radioactivity determinations were done in a gas flow type Beta Counting System (Type BCS 36 A of Electronics Corporation of India Limited, Hyderabad). Argon gas bubbled through isopropyl alcohol kept at 0 ºC is the counting gas. Both the main counter and guard counter work in the Geiger Muller region. The main counter consists of an aluminized mylar foil of thickness 0.9 mg cm^{-2} as window and tungsten wire as anode. The BCS has a counting efficiency of 10.2% for ^{32}P and 5.7% for ^{35}S.

INTERPRETATION OF RADIOASSAY DATA

The radioassay data were converted into different parameters by using the following formulae:

$$\text{Bq} = \text{dps} = \frac{\text{Corrected count rate per second}}{\text{Counting efficiency of the equipment (\%)}} \times 100$$

$$\text{Specific activity (dps mg}^{-1}) = \frac{\text{Disintegration rate in sample (dps)}}{\text{P content in sample (mg)}}$$

$$\%\text{Pdff} = \frac{\text{Specific activity of plant sample}}{\text{Specific activity of standard}} \times 100$$

$$\%\text{Pdfs} = 100 - \%\text{ Pdff}$$

{Pdff = Phosphorus in the plant derived from fertilizer or manure source}
{Pdfs = Phosphorus in the plant derived from soil}

$$\text{'A' value (mg / 100 g soil)} = \frac{\%\text{ Pdfs}}{\%\text{ Pdff}} \times \text{P applied (mg P / 100 g of soil)}$$

In case of sulphur, a similar sequence of calculations was followed:

$$\text{Bq} = \text{dps} = \frac{\text{Corrected count rate per second}}{\text{Counting efficiency of the equipment (\%)}} \times 100$$

$$\text{Specific activity (dps mg}^{-1}) = \frac{\text{Disintegration rate in sample (dps)}}{\text{S content in sample (mg)}}$$

$$\%\text{Sdff} = \frac{\text{Specific activity of plant sample}}{\text{Specific activity of standard}} \times 100$$

%Sdfs = 100 - %Sdff
{Sdff = Sulphur in the plant derived from fertilizer or manure source}
{Sdfs = Sulphur in the plant derived from soil}

$$\text{'A' Value (mg / 100g soil)} = \frac{\%\text{Sdfs}}{\%\text{Sdff}} \times \text{S applied (mg S / 100 g of soil)}$$

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 in soil, nutrient contents of groundnut and sunflower.

RESULTS AND DISCUSSION

SOIL AVAILABLE PHOSPHORUS AND SULPHUR CONTENT

The results pertaining to the available phosphorus content in post-harvest soils indicated that the phosphorus and sulphur applications through different combinations of poultry manure and chemical fertilizer significantly increased the availability in soil. Mohamad Amanullah *et al*. (2007) reviewed the effect of poultry manure on crops and reported that the poultry manure occupied a place of pride as it is rich in nutrients than the other manures. Seshadri Reddy(2005) reported a positive interaction effect of phosphorus and sulphur on nutrient availability and crop growth. The maximum phosphorus availability was for the combination of 25% poultry manure with 75% chemical fertilizer (25.67 kg ha^{-1}). Incorporation of poultry manure in combination with chemical fertilizer increased the availability of phosphorus and this could be attributed to the reduction in the fixation of water-soluble phosphorus and increased mineralization of organic phosphorus. These results are in conformity with the findings of Mohamad and Stephen (2003) that the organic P sources had a marked negative effect on P sorption and a positive effect on P availability in all soils.

Table 1. Effect of phosphorus and sulphur sources on post-harvest soil nutrient Availability

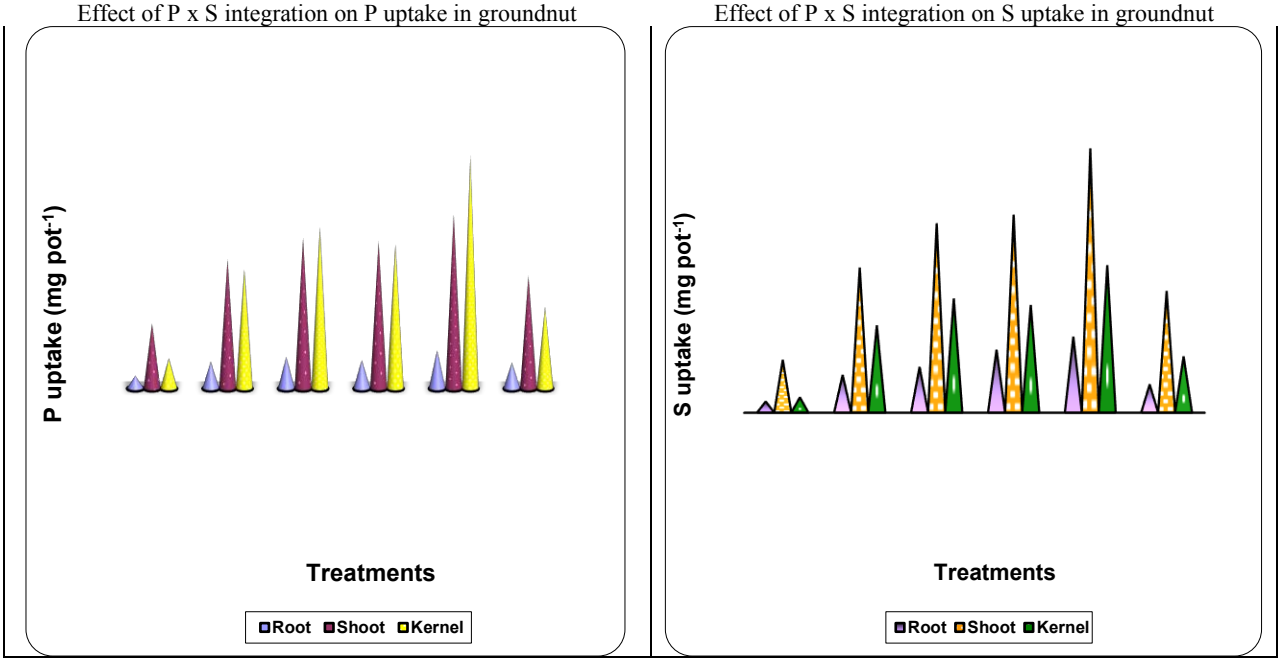
Phosphorus and sulphur sources	Available P (kg ha^{-1})	Available S (mg kg^{-1})
Control	10.27f	7.07f
100% PM	20.40d	36.43d
75 % PM + 25% CF	22.00c	45.90b
50 % PM + 50 % CF	23.57b	40.10c
25 % PM + 75% CF	25.67a	48.23a
100 % CF	17.50e	27.83e

The results of sulphur content in postharvest soil indicated that sole application of poultry manure and chemical fertilizer and their combination increased the soil available sulphur content. The increase was more pronounced in the treatment receiving poultry manure and chemical fertilizer in combination. The treatment with 25% poultry manure and 75% chemical fertilizer recorded highest available sulphur in soil (48.23 mg kg^{-1}). The increase in sulphur availability could be attributed to the addition of sulphur through chemical fertilizer and poultry manure which is a good source of nutrients. S availability in all the soil associations was significantly and positively influenced by organic matter (Pandey *et al*., 2000). Addition of chemical fertilizer along with organic manure narrowed the C:N ratio of organic manure and this enhanced the mineralization and resulting in rapid release of nutrients. (Jacob M. Wapa and Oyetola, 2014). Phosphorus and sulphur have obviously improved the soil physico-chemical properties, helping better growth of soil microorganisms and their increased activity could have led to more the native nutrient being converted into available forms (Sharma *et al*., 1995).

PHOSPHORUS AND SULPHUR UPTAKE IN GROUNDNUT

Statistical analysis of phosphorus and sulphur uptake in plant parts at harvest indicated that the treatments exerted significant impact on phosphorus and sulphur uptake. This might be due to the synergistic relationship between phosphorus and sulphur when both are applied together. Highest uptake of nutrients in groundnut was observed with combined application of poultry manure and chemical fertilizers. The results revealed that 25% poultry manure with 75% chemical fertilizer enhanced the phosphorus and sulphur uptake. This could be attributed to the addition of increasing quantities of nutrients, as poultry manure is a rich source of nutrients. The synergistic effects between organic and inorganic forms of nutrients and formation of stable complexes with humic substances from poultry manure might also be worth mentioning. The higher absorption of applied phosphorus by groundnut might be ascribed to the influence of the organic anions and hydroxy acids liberated during poultry manure decay which might have immobilized iron and aluminum through complexation or chelation and thereby prevented phosphate ions from reacting with iron and aluminium (Mohamad Tariq and Stephen Robinson, 2003).

Figure 1: Effect of phosphorus and sulphur integration on phosphorus and sulphur uptake in groundnut



Combining poultry manure with chemical fertilizer increased sulphur uptake. The positive correlation of available sulphur with organic carbon is attributed to the release of organic acids on decomposition of organic matter, causing solubilization of insoluble sulphur complexes (Pandey *et al*., 2000). Effect of sulphur in increasing phosphorus utilization might be due to either the increased uptake of fertilizer phosphorus or due to the increased availability of phosphorus by decreasing fixation of fertilizer phosphorus via competition with phosphate for adsorption sites and / or precipitation reaction with iron and aluminum. Seshadri Reddy, (2005) indicated a positive interaction effect of P and S. The higher uptake of nutrients by groundnut could also be due to the priming effect of the recommended dose of phosphorus and sulphur cause higher crop growth to increase nutrient demand and thereby higher removal due to balanced fertilization. These findings were also reported by Sharma *et al*. (2002). In this present investigation 25% poultry manure with 75% chemical fertilizer enhanced the nutrient uptake and postharvest soil nutrient availability in the main crop. This may be due to the readily available form of nutrients present in the combination. The higher nutrient uptake with organic manures and single super phosphate was due plants being able to absorb more nutrients from the soil because of their increased availability due to improved soil conditions. This result might be well supported by findings of Kedar Prasad *et al.* (2005) in maize- wheat sequence.

THE %PDFF, %PDFS, %SDFF, %SDFS AND 'A' VALUE

The statistical analysis of radio assay data revealed that the combination of 25 % poultry manure with 75% chemical fertilizer increased the 'A' value and %Pdfs for P in root, shoot and kernel The significant decrease in % Pdff in poultry manure treatment may be due to the fact that more P was taken up by the crop from native source and this was confirmed by highest %Pdfs in poultry manure treatment in this trial. Poultry manure accounted for highest %Pdfs (Sangeeta Mohanty *et al*. 2006)). This may be due to the addition of more phosphorus from poultry manure source than fertilizer phosphorus added to the soil. Similar explanation was made by Biswas and Dravid (1998) in rice. The depression in Pdff in presence of organic source may possibly be ascribed to certain organic acids and carbon di oxide formed during decomposition of added organic sources which ultimately appears to have solubilizing effect on native Fe, Al and Ca phosphate and increasing the availability of phosphorus. Similar results were reported by Dravid and Biswas (1996). The higher availability of phosphorus in poultry manure treatment was confirmed by significantly higher 'A' value in this present trial.

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 (Seshadri Reddy, 2005).

Table 2: Effect of phosphorus and sulphur sources on % Pdff and %Pdfs and 'A' value (mg 100g^{-1}) for phosphorus in groundnut

P and S sources.	Root		Shoot		Kernal		A value		
	% Pdff	% Pdfs	% Pdff	% Pdfs	% Pdff	% Pdfs	Root	Shoot	Kernal
100% PM	23.5a	76.5b	23.5a	76.6c	32.2a	67.8c	2.2c	2.3c	1.4e
75 % PM +25 % CF	18.0b	82.0b	17.0bc	83.1ab	19.1b	80. 9b	3.3c	3.3b	2.9d
50 % PM +50% CF	12.4c	87.6a	16.0cd	84.1a	12.1c	87.9a	4.8b	3.6b	4.9b
25 % PM +75 % CF	8.8c	91.2a	12.2d	87.8a	9.7c	90.3a	7.1a	5.0a	6.3a
100 % CF	18.6ab	81.4b	21.3ab	78.7bc	18.6b	81.4b	3.0c	2.5bc	3.1cd

Table 3: Effect of phosphorus and sulphur sources on % Sdff and %Sdfs and 'A' value (mg 100g^{-1}) for sulphur in groundnut

Pand S sources	Root		Shoot		Kernal		A value		
	% Sdff	% Sdfs	% Sdff	% Sdfs	% Sdff	% Sdfs	Root	Shoot	Kernal
100% PM	57.1a	43.0e	41.0b	59.0b	28.1a	71.9c	2.6d	4.9cd	8.7c
75 % PM + 25 % CF	53.4ab	46.6de	37.7b	62.3b	28.6a	71.4c	3.0cd	5.7c	8.4c
50 % PM + 50% CF	36.1c	63.9b	27.3c	72.7a	23.9bc	76.1ab	6.0b	9.3b	10.8b
25 % PM + 75 % CF	27.3d	72.7a	22.1c	77.9a	21.0c	79.0a	9.0a	11. 9a	12.7a
100 % CF	47.4b	52.6cd	50.4a	49.6c	26.6ab	73.4bc	3.8c	3.3d	9.4bc

The treatment combining 25% poultry manure with 75% chemical fertilizer recorded highest 'A' value for sulphur and %Sdfs. This indicated the highest availability of s and sulphur to the crop from soil. The application of sulphur sources significantly increased the sulphur availability in post-harvest soil. The organic manure may reacts with native nutrients present in soil and thereby increases the soluble forms of sulphur. Ghosh. *et al*. (2000) confirmed this that organic sources can supply adequate amount of sulphur to crops. The increase due to the addition of poultry manure can be attributed to the high content of these nutrients in the manure. This result corroborate with the findings of Vijaya Sankar Babu *et al.* (2007)

The results indicated the highest 'A' value in the treatment combining 25% poultry manure with 75% chemical fertilizer, this may be due to the higher availability of sulphur in this treatment. When poultry manure combined with chemical fertilizer that increase the solubility of sulphur from organic source and increased the availability of sulphur in the native pool.

PHOSPHORUS X SULPHUR INTEGRATION TRIAL – RESIDUAL CROP (SUNFLOWER)

POST-HARVEST SOIL NUTRIENT AVAILABILITY AND UPTAKE

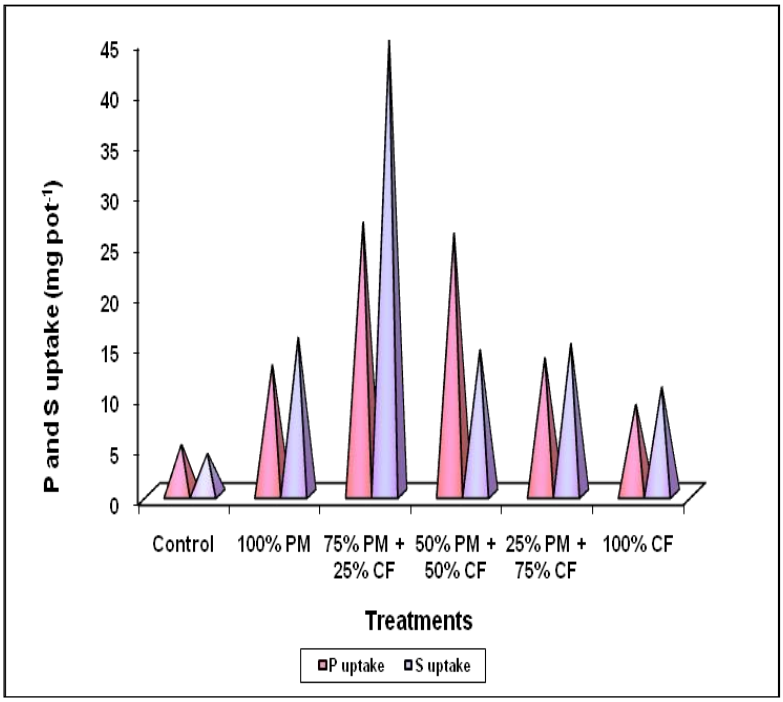
In integrated treatments there was net positive gain in the availability of phosphorus, and sulphur in residual post-harvest soil. Among treatments, 75% poultry manure with 25% chemical fertilizer treatment registered significantly increased soil available phosphorus and sulphur contents. The more availability of nutrients under organic and inorganic combination is largely due to organic recycling and minimum fixation of nutrients. From a two-year field experiment to study the direct and residual effect of organic manure on nutrient balance under groundnut - mustard crop sequence, Rao (2003) reported that the effect of poultry manure on available P was significant during both the years. On decomposition of poultry manure by various microorganisms, the organic nutrients might be converted slowly to inorganic form. The nutrients which earlier existed in unavailable form might further be solublized in soil due to the acidifying action of different microorganisms during decomposition of poultry manure. This might be due to improvement in soil through physical, chemical and biological condition and which might have resulted in more available nutrients from native source. Organic manures help in improvement of soil environment, which increases the capacity of plants for efficient utilization of nutrients and results in better plant growth and higher grain yields (Rakesh Banwasi and Bajpai, 2006).

Table 4: Effect of phosphorus and sulphur sources on post-harvest soil nutrient availability

Phosphorus and Sulphur sources	Available P (kg ha $^{-1}$)	Available S (mg kg^{-1})
Control	11.7d	7.6e
100% PM	48.2b	53.9b
75 % PM + 25% CF	61.5a	82.5a
50 % PM + 50 % CF	60.7a	44.8c
25 % PM + 75% CF	45.0bc	82.4a
100 % CF	36.8c	26.7d

In the present study 75% poultry manure with 25% chemical fertilizer increased the nutrient uptake and post-harvest soil nutrient availability in residual crop. This may be due to the slow mineralization and availability of nutrients to the residual crop. The improvement and maintenance of chemical fertility of soil due to integration with inorganic fertilizers might be due the gradual mineralization of organics and chelation of nutrients and solubilization of nutrients from native source, thereby lowering the loss of nutrients from root zone by fixation, precipitation, volatilization or leaching (Patel *et al.,* 2007).

Figure 2: Effect of P x S integration on P and S uptake in sunflower



THE %PDFF, %PDFS, %SDFF, %SDFS AND 'A' VALUE.

In residual crop, the highest 'A' value for phosphorus and sulphur was recorded in the treatment that received 75% poultry manure with 25% chemical fertilizer . Among the treatments 75% poultry manure with 25% chemical fertilizer recorded the lowest %Pdff & %Sdff and the highest %Pdfs & %Sdfs than the other combinations. Higher 'A' value in the treatment combining 75% poultry manure with 25% chemical fertilizer may be due to the availability of more phosphorus and sulphur from poultry manure to the residual crop. This may be due to the effect of organic manure on the availability of phosphorus. In residual corn, the %Pdfs was more for the organic fertilizers than for single superphosphate, obviously due to greater residual availability and P release from organic sources (Sangeeta mohanty, *et al* 2006)

Organic manure may coat the sesquioxide surface by humus to form protective cover and reducing the phosphorus fixing capacity. In this present study the treatment combining 75% poultry manure with 25% chemical fertilizer recorded highest 'A' value, lowest Pdff and highest Pdfs. This confirmed the higher availability of phosphorus and sulphur from the native pool.

Table 5. Effect of phosphorus and sulphur sources on % Pdff , %Pdfs ,% Sdff , %Sdfs and 'A' value (mg 100g^{-1}) for phosphorus and sulphur in sunflower.

P and S sources	Phosphorus			Sulphur		
	% Pdff	%Pdfs	'A' value	% Sdff	%Sdfs	'A' value
100% PM	2.64bc	97.36ab	30.61ab	32.23b	67.77b	7.25c
75 % PM + 25	1.53c	98.47a	44.01a	21.05c	78.95a	12.73a

% CF						
50 % PM + 50% CF	2.90b	97.10b	22.64b	23.74c	76.26a	10.97ab
25 % PM + 75 % CF	3.55b	96.45b	18.60bc	26.89bc	73.11ab	9.35bc
100 % CF	5.82a	94.18c	10.94c	71.25a	28.75c	1.37d

The treatment combining 75% poultry manure with 25% chemical fertilizer recorded highest percent of sulphur derived from soil. When poultry manure combined with chemical fertilizer the organic compounds present in poultry manure may prevent the formation of insoluble sulphates, thereby increasing the availability of sulphur to the residual crop from soil. A similar view was earlier expressed by Bhattacharyya and Ghosh *et al*. (2000) in a study on brinjal. Pratap and Ghosh (2000) reported that combined application of P with FYM and S was beneficial for per cent S derived from soil at both the stages of brinjal crop growth.

CONCLUSION

By combining organic manure with chemical fertilizer (to provide required amount of phosphorus and sulphur) phosphorus and sulphur availability and uptake by main crop was improved. Among the combination 25% poultry manure with 75% chemical fertilizer improved the soil phosphorus and sulphur availability and uptake by main crop. It was confirmed by the higher % Pdfs, %Sdfs and A value for phosphorus and sulphur. But the combination of 75% poultry manure with 25% chemical fertilizer increased the phosphorus and sulphur availability and uptake by residual crop and it was confirmed by the higher % Pdfs, %Sdfs and A value for phosphorus and sulphur in residual crop.

Therefore it can be concluded that combination of 25% poultry manure with 75% chemical fertilizer for main crop and 75% poultry manure with 255 chemical fertilizer for residual crop are the best combinations to supply phosphorus and sulphur in groundnut sunflower cropping system in sandy loam soil.

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