Biological Forum
an International Journal (SI-AAAS: CS March 21&22, 2025)
17(5a): 31-37(2025)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Evaluation of Manurial Quality of Phosphorus Enriched Organics and their Influence on Pea Productivity in Acid Alfisols

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(Received: 30 March 2025; Accepted: 27 April 2025; Published online: 14 May 2025)
(Published by Research Trend)

ABSTRACT: Despite its agricultural significance, low phosphorus availability continues to be a major challenge in the hilly regions of Himachal Pradesh. Phosphocomposting of organics offers a promising strategy to enhance phosphorus use efficiency (PUE). The present study conducted in 2023-24 in the mid-hills of Himachal Pradesh focused on enhancing the nutrient value of organic materials such as biogas slurry (BGS) and farmyard manure (FYM) through phosphorus enrichment. Both BGS and FYM were enriched with a readily available phosphorus source single super phosphate (SSP) at 5% and 10% enrichment levels. Afterward, a 90-day decomposition process was carried out. Quality analysis of the prepared products was conducted at 0, 45 and 90 days of decomposition and impact of these enriched organics on pea productivity was evaluated. The experiment comprised 10 treatments in which T_1 and T_2 contained unenriched organics and T_3-T_{10} contained enriched organics combined with 100% or 75% of recommended P doses and 100% N, K doses. The findings demonstrated that P fractions *i.e.* water soluble, citric acid soluble, sodium bicarbonate extractable, organic and total P content of both the organics enhanced with increase in enrichment level and decomposition period. The pea productivity was recorded higher for enriched organics compared to unenriched treatments and maximum for T_4 (BGS at 10% enrichment with 100% recommended N, P, K dose) which was 80.69 q ha^{-1}. PUE was improved by increasing phosphorus content in organics allowing farmers to achieve higher nutrient availability and higher productivity while reducing the total quantity of inputs required for application thereby lowering cost of production.

Keywords: P- enrichment, Biogas slurry, Farmyard manure.

INTRODUCTION

Pea (*Pisum sativum* L.) is a vital vegetable crop of wet–temperate north–western (NW) Himalayas known for nitrogen fixation, contributing to sustainable agriculture. In India, Pea occupies an area of about 563 thousand ha with total annual production of 5524 thousand metric tonnes. Low phosphorus availability is a major constraint in hilly regions like Himachal Pradesh, limiting plant growth and productivity. Among various strategies to enhance P-utilization efficiency in soils, phospho composting or P-enrichment of organic materials presents a promising and economical approach. This method not only provides a sustainable source of P but also improves the overall quality of the organic matter by enriching it with nitrogen (N) and potassium (K).

MATERIALS AND METHODS

The present study was conducted at the research farm of CSKHPKV, Palampur. Six manurial products were prepared using two organic materials: fresh farmyard manure (FYM) and fresh biogas slurry (BGS). These materials were enriched with single super phosphate (SSP, 16% P_2O_5) at 5% and 10% enrichment levels in clay-lined pits (1m³ size) on dry weight basis. SSP was incorporated with organic matter in layers according to the treatments and a polyethylene sheet was used as basal barrier to prevent nutrient leaching. The decomposition process lasted three months (August-November 2023), with pits covered by grass to control moisture loss. The manurial products were turned every two weeks for aeration, better decomposition and maintain moisture level. The manurial products prepared were as follows: Phospho-composting enhances the nutrient efficiency of organic matter (e.g biogas slurry and farmyard manure), reducing the use of chemical fertilizers.

Table 1: Product detail.

Products		Preparation
B_0	Biogas slurry fresh	Fresh Biogas slurry from biogas plant
B_1	Biogas Slurry enriched with 5 % P	Fresh Biogas slurry from biogas plant, enriched at 5% level
B_2	Biogas Slurry enriched with 10 % P	Fresh Biogas slurry from biogas plant, enriched at 10% level
F_0	Farmyard Manure fresh	Fresh cow dung mixed with cow urine and litter as such
F_1	FYM enriched with 5 % P	Fresh cow dung mixed with cow urine and litter as such, enriched at 5% level
F_2	FYM enriched with 10 % P	Fresh cow dung mixed with cow urine and litter as such, enriched at 10% level

Thereafter a field experiment was conducted under irrigated conditions at the research farm of the Department of Soil Science, CSKHPKV Palampur, during the *rabi* season of 2023-24 to meet the study objectives. The test crop was pea (*Pisum sativum*), variety GS-10, with a plot size of 10 m².

Table 2.

	Treatment detail
T_1	BGS + Recommended NPK
T_2	FYM + Recommended NPK
T_3	BGS enriched (5% P) + Recommended NPK
T_4	BGS enriched (10% P) + Recommended NPK
T_5	FYM enriched (5% P) + Recommended NPK
T_6	FYM enriched (10% P) + Recommended NPK
T_7	BGS enriched (5% P) + $N_{100} : P_{75} : K_{100}$
T_8	BGS enriched (10% P) + $N_{100} : P_{75} : K_{100}$
T_9	FYM enriched (5% P) + $N_{100} : P_{75} : K_{100}$
T_{10}	FYM enriched (10% P) + $N_{100} : P_{75} : K_{100}$

The seed rate was 75 kg/ha, with row spacing of 45 cm and seed spacing of 10 cm. The experiment included three replications and ten treatments, arranged in a randomized block design (RBD). The general recommended dose of fertilizers was 50:60:60 kg/ha ($N:P_2O_5:K_2O$).

RESULTS AND DISCUSSION

A. Organic carbon

Organic carbon content in both BGS and FYM declined steadily over 90 days of decomposition. Phosphatic enrichment slightly accelerated this decline, with higher enrichment levels showing greater reductions. These trends align with previous findings (Sitaramalakshmi *et al.*, 2013), indicating natural carbon loss during composting. The reduction in organic carbon content for all the products may be attributed to intensified microbial activity (respiration) in the process of decomposition. Microbial respiration releases carbon dioxide (CO_2) and mineralizes organic matter and a portion of released CO_2 is assimilated by microbial biomass, while the remainder is oxidized to provide energy to decomposer organisms (Pattnaik and Reddy 2010).

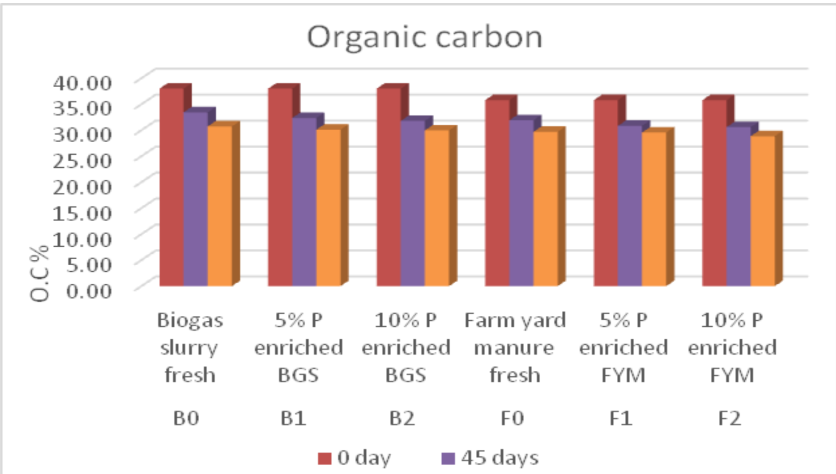

Fig. 1.

B. Total nitrogen

Fig. 2 shows that total nitrogen (N) content increased in both BGS and FYM during the 90-day decomposition. Enrichment with single superphosphate enhanced N retention, with higher enrichment levels showing greater N increases. BGS showed a rise from 0.89% to 1.75%, and FYM from 0.64% to 1.16% at 10% enrichment, indicating improved nitrogen stabilization with phosphatic treatment. Overall, enrichment significantly improved total nitrogen content in organic materials. This increase is likely due to mass reduction from decomposition and nitrogen release by microbes (Gaur & Geeta 1993; Kumar, 1997; Saranraj & Stella 2014). The highest nitrogen gain was observed at 10% enrichment after 90 days, possibly due to lower organic carbon and increased nutrient concentration.

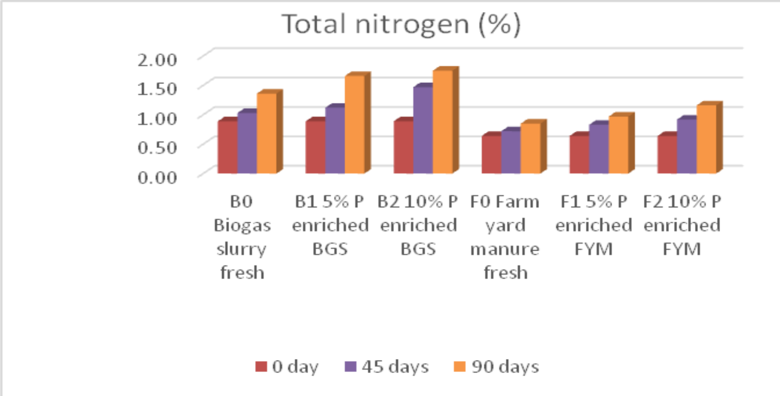

Fig. 2.

C. Phosphorus and its fractions

Water soluble P: After 90 days of decomposition, water-soluble phosphorus (WSP) content increased significantly in all manurial products, with the highest levels in 10% enriched BGS (1489 mg/kg) and FYM (1428.7 mg/kg). The rate of WSP increase was higher during the first 45 days, likely due to heightened microbial activity (Bhardwaj, 1995). Enrichment greatly enhanced WSP levels, aligning with earlier findings.

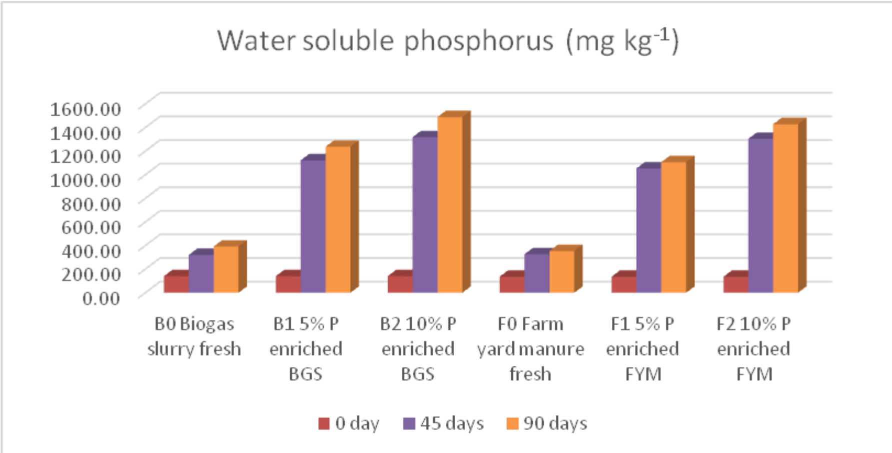

Fig. 3.

Citric acid soluble P: Enrichment of BGS and FYM with SSP significantly boosted citric acid soluble phosphorus (CSP) content. In BGS, CSP increased 17-fold from 152 to 2780.10 mg/kg at 10% enrichment after 90 days. Similarly, FYM showed an increase from 150 mg/kg to 2050.80 mg/kg at 10% enrichment, respectively. This indicates substantial improvement in phosphorus availability with SSP enrichment.

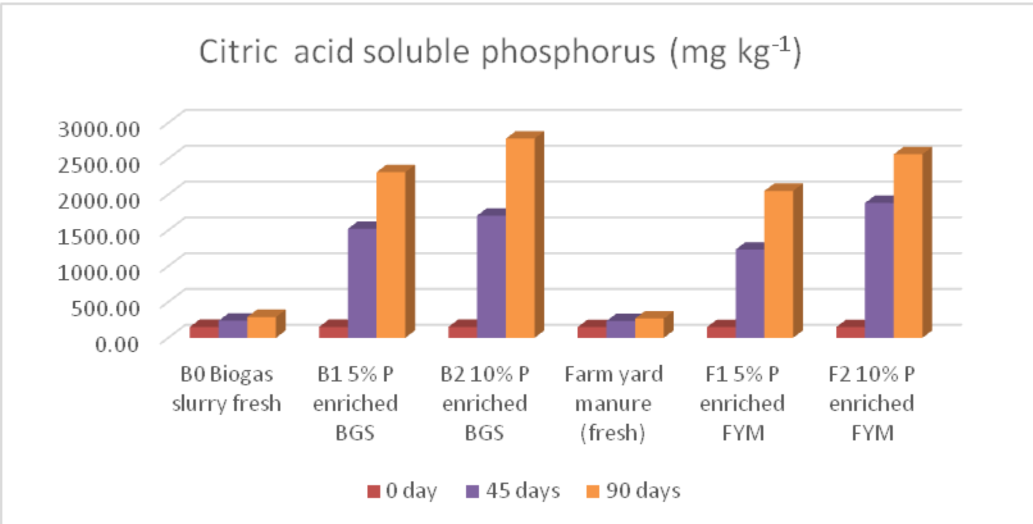

Fig. 4.

Sodium bicarbonate extractable P: Enrichment with SSP significantly increased $NaHCO_3$-extractable phosphorus in both BGS and FYM over 90 days. In BGS, values reached 0.355% and 0.397% at 5% and 10% enrichment, respectively. FYM also showed a steady rise, with 0.301% at 10% enrichment. The increase reflects conversion of phosphorus into more available forms, consistent with trends in WSP and CSP (Saeed & Amin 2019).

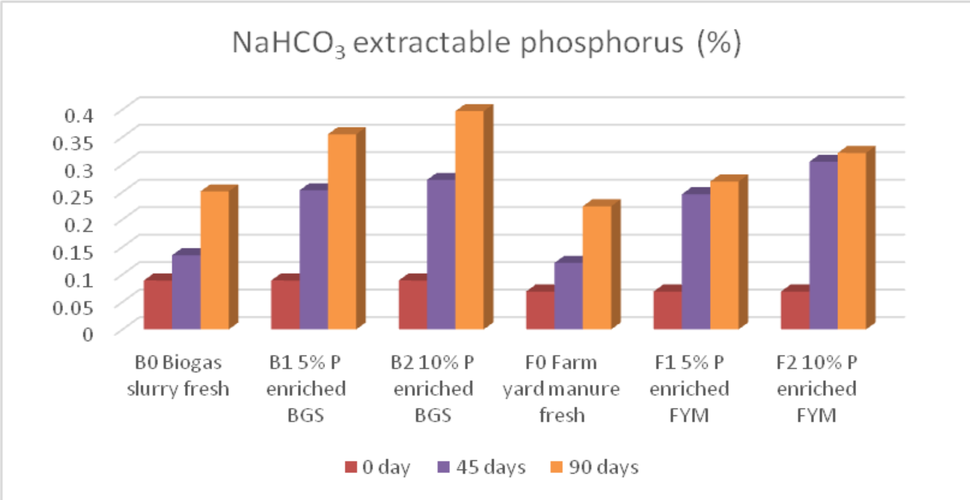

Fig. 5.

Organic P: Organic phosphorus (P) content increased during decomposition across all treatments. The extent of increase over the initial content was **0.31, 0.72, and 1.14 times** for BGS, enriched BGS at 5%, and 10%, respectively. Similarly, FYM showed an increase in organic P from **0.25%** to **0.31%** over 90 days. Enrichment at **5%** and **10%** boosted the values to **0.42%** and **0.54%**, of P content. Enriched substrates showed about 1.15 times higher organic phosphorus **after 90 days of decomposition. This supports** Mathur and Devnath (1983)**,** who suggested that microbial immobilization plays a key role in converting inorganic to organic phosphorus. Unlike soil minerals that adsorb phosphorus, **microorganisms actively sequester it**, allowing gradual remineralization.

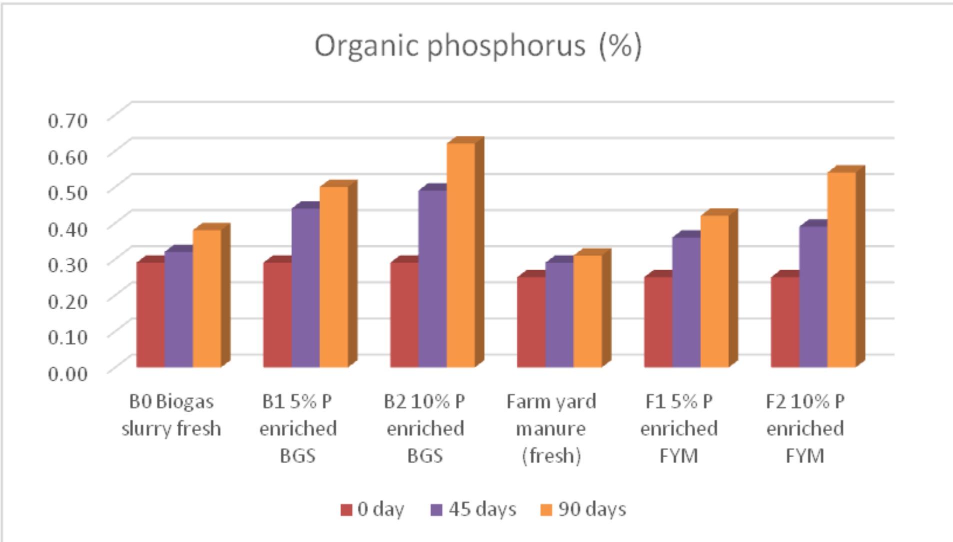

Fig. 6.

Total P: Fig. 7 shows a clear increase in **total phosphorus (P) content** with longer decomposition periods. In **BGS**, total P rose from **0.43%** (0 days) to **0.69%** (90 days). Enrichment further boosted the content to **1.09%** and **1.32%** at **5%** and **10%** levels, respectively, after 90 days. In **FYM**, total P increased from **0.32%** to **0.44%** over 90 days. With enrichment, it reached **0.86%** (5%) and **0.96%** (10%) after 90 days. The total phosphorus (P) content increased in all manurial products, showing an inverse relationship with declining organic matter. This suggests that organic matter mineralization contributes to higher P availability. According to Sharma *et al.* (1995), this rise is due to catabolism of organic biomass. The increase was more pronounced in enriched products, likely due to SSP addition and its solubilization during decomposition, resulting in higher total P than in fresh materials.

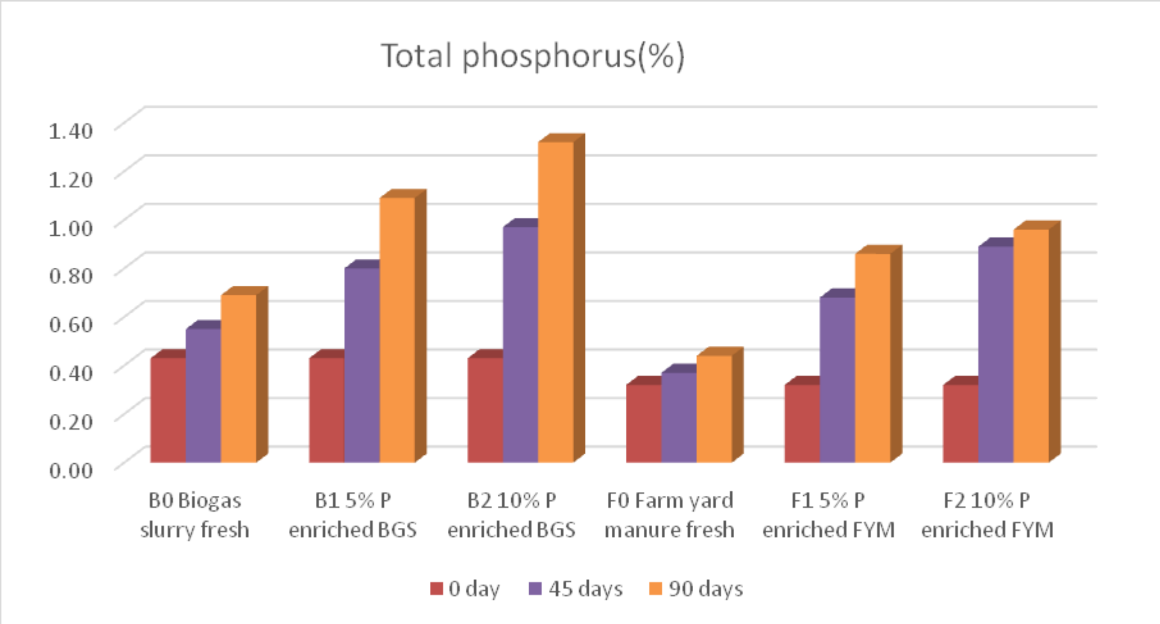

Fig. 7.

4. Total K: As regards the total K content (expressed on dry weight basis) manurial products B_0 and F_0 after 90 days of decomposition, showed the values of 0.71 and 0.57 percent. The observed enhancement in total K content may be attributed to concentration effect resulting from loss of organic matter as CO_2 which reduces the overall mass of decomposing material. These findings align with the observations of Mathur *et al.* (1980).

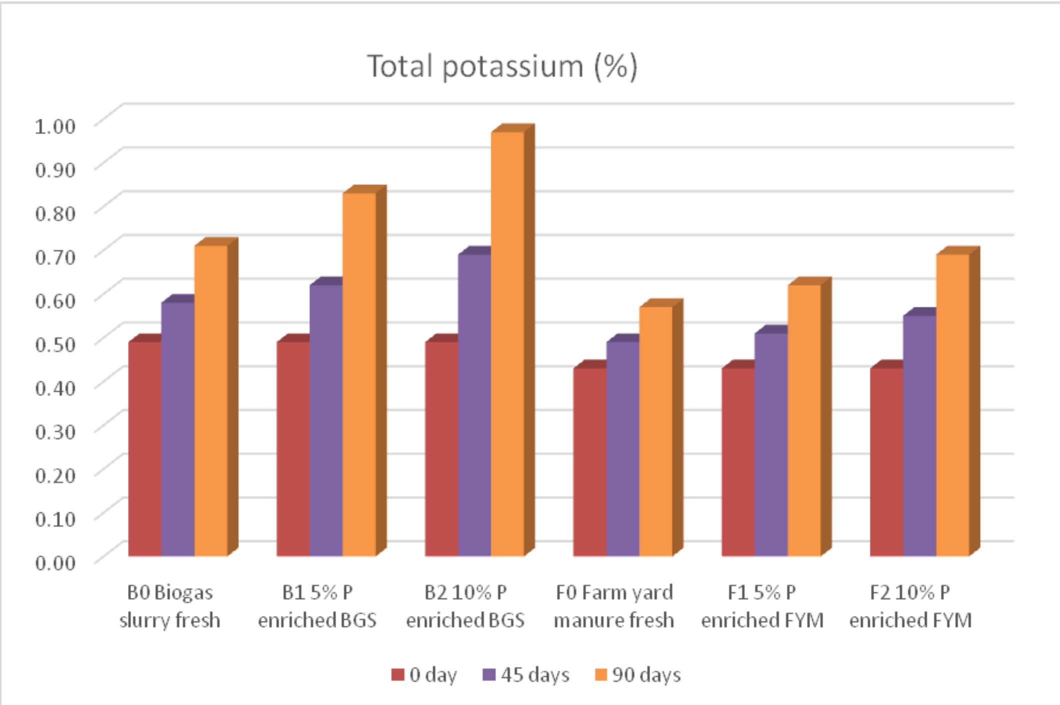

Fig. 8.

5. C:N ratio: The C: N ratio narrowed down for all the products. This decline results from carbon loss as CO_2 and microbial assimilation of nitrogen. Xie *et al.* (2023) highlighted nitrogen's role in sustaining microbial activity and decomposition, while imbalanced C:N ratios can hinder the process. Enriched FYM showed a more rapid decrease in C:N ratio, consistent with Bangar *et al.* (1989); Sharma *et al.* (1995), due to phosphate fertilization enhancing decomposition. Additionally, phosphatic fertilizers reduce nitrogen loss by forming ammonium sulphate, aiding nutrient retention.

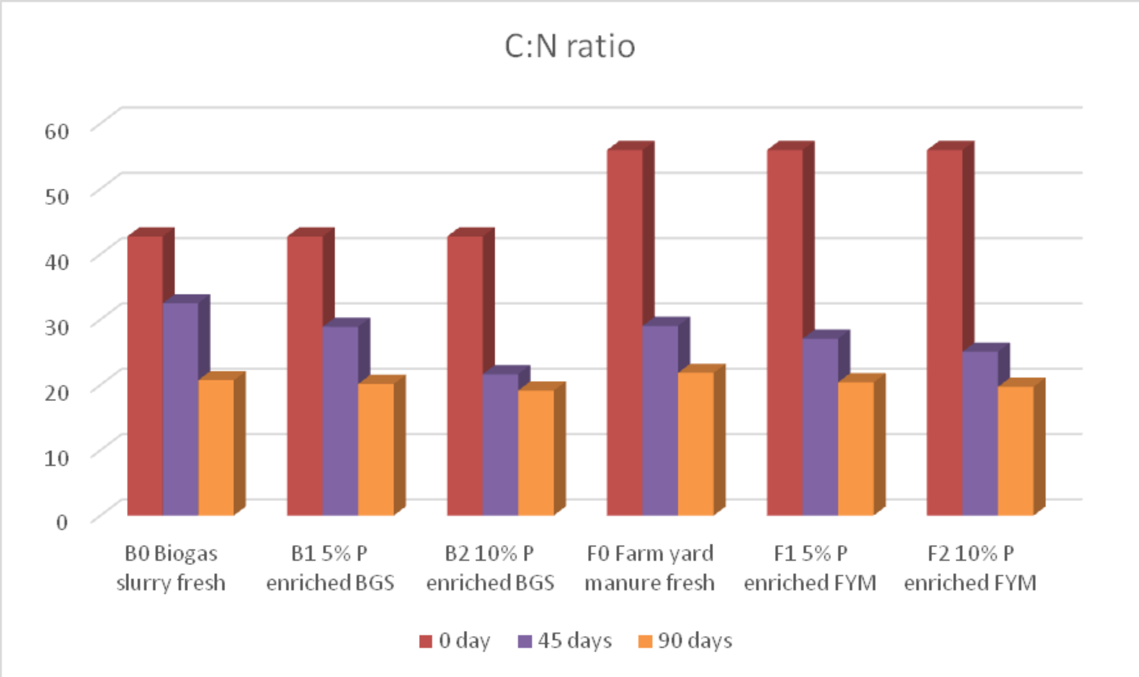

Fig. 9.

6. C: P ratio: Similar to C:N ratio, C:P ratio also narrowed down. The results pertaining to C:P ratio of different manurial products indicate substantial reduction in C:P ratio with time lapse and this reduction, with a more pronounced effect in P-enriched products. This decrease can be attributed to the concentration effect, whereby reduction in biomass during decomposition leads to an increase in the relative phosphorus content.

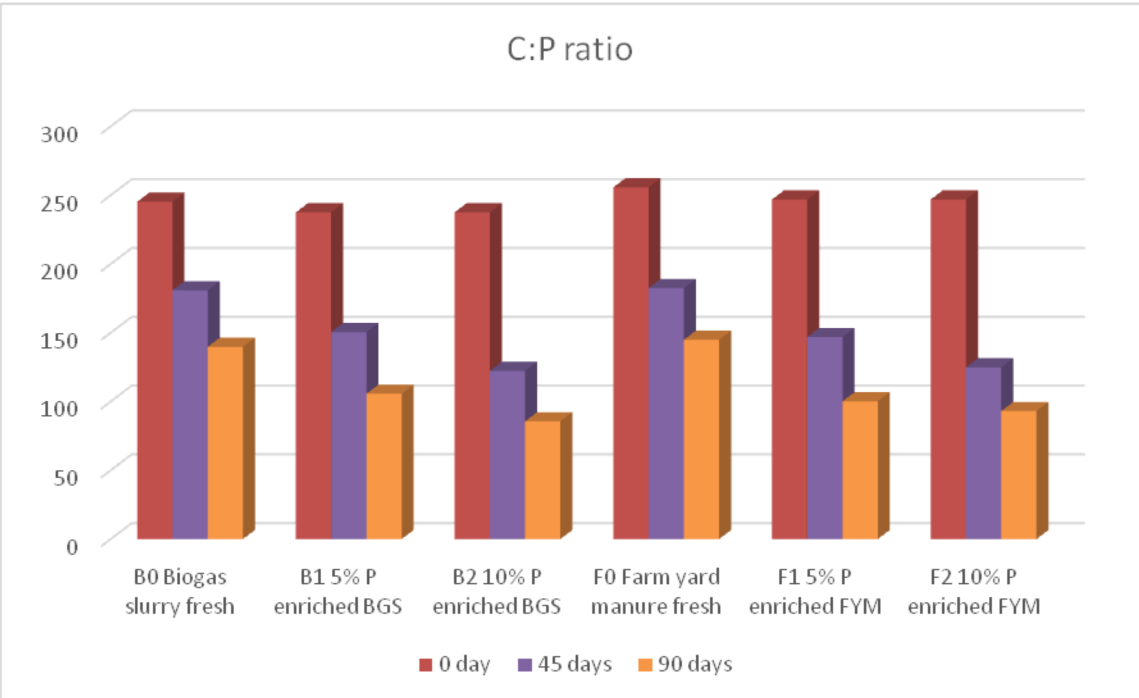

Fig. 10.

Green pod yield: The highest pea pod yield (**80.69 q ha⁻¹**) was achieved with **10% P-enriched BGS + 100% NPK**. This was statistically similar to yields from **10% P-enriched FYM + NPK**, making FYM a good alternative where BGS isn't available. Comparable yields were also obtained using **75% phosphorus**, suggesting a **25% saving in P fertilizer**. Overall, **BGS treatments outperformed FYM**, with the lowest yield (**67.24 q ha⁻¹**) recorded in FYM + 100% NPK, confirming the superior effect of BGS on productivity.

Table 3: Effect of enriched organics and chemical fertilizers on Pea productivity.

Treatments		Marketable yield (q/ha)
T_1	BGS + Recommended NPK	67.54
T_2	FYM + Recommended NPK	67.24
T_3	BGS enriched (5% P) + Recommended NPK	72.32
T_4	BGS enriched (10% P) + Recommended NPK	80.69
T_5	FYM enriched (5% P) + Recommended NPK	70.50
T_6	FYM enriched (10% P) + Recommended NPK	79.43
T_7	BGS enriched (5% P) + N_{100} : P_{75} : K_{100}	70.28
T_8	BGS enriched (10% P) + N_{100} : P_{75} : K_{100}	78.54
T_9	FYM enriched (5% P) + N_{100} : P_{75} : K_{100}	69.61
T_{10}	FYM enriched (10% P) + N_{100} : P_{75} : K_{100}	75.13
CD (P= 0.05)		**3.71**

CONCLUSIONS

Enriching BGS and FYM at 10% significantly boosted total N, P, and K content**,** with P-enriched BGS reaching 1.75% N and 1.32% P, enhancing nutrient availability. Enrichment improved plant-available phosphorus (water-soluble, citric acid-soluble, and sodium bicarbonate-extractable forms) and increased organic P, aiding soil aggregation and long-term fertility. A notable decline in C:N and C:P ratios over 90 days indicated improved decomposition and nutrient stabilization, especially in enriched products. Application of 20 t ha^{-1} of P-enriched BGS (10%) integrating with chemical fertilizers produced the highest green pea yield (80.69 q ha^{-1}) and allowed a 25% reduction in phosphatic fertilizer when combined with 100% NK and 75% P, highlighting the benefits of integrated nutrient management.

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How to cite this article: Muskaan Kashyap, Shikha acharya, Kanika Baghla, Narender Kumar Sankhyan and Pankaj Chopra (2025). Evaluation of Manurial Quality of Phosphorus Enriched Organics and their Influence on Pea Productivity in Acid Alfisols. *Biological Forum, 17*(5a): 31-37.