

Original Research Article

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Influence of Composted Municipal Sludge on Efficiency of Primary Nutrients in Maize (*Zea mays* L.) under Temperate Himalayas

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ABSTRACT

Field experiments were conducted at the Agricultural Research Farm of Krishi Vigyan Kendra, SKUAST-K, Shuhama, Srinagar to study the effect of composted municipal sludge application on efficiency of primary nutrients viz. nitrogen, phosphorus and potassium in maize (*Zea mays* L.). Application of 75% NPK + sludge @ 30 t ha⁻¹ resulted in highest yields and nutrient uptake by the crop followed by NPK + sludge @ 15 t ha⁻¹, 75% NPK + sludge @ 15 t ha⁻¹ and 50% NPK + 30 sludge @ 30 t ha⁻¹. These were statistically identical to each other for seed and stover yields. Highest agronomic efficiency of nitrogen, phosphorus and potassium was observed in 50% NPK + Sludge @ 30 t ha⁻¹ followed by 50% NPK + Sludge @ 15 t ha⁻¹, 75% NPK + Sludge @ 30 t ha⁻¹, 75% NPK + Sludge @ 15 t ha⁻¹, NPK + Sludge @ 15 t ha⁻¹ and NPK. Recovery efficiency of nitrogen, phosphorus and potassium was maximum in 75% NPK + Sludge @ 30 t ha⁻¹ followed by NPK + Sludge @ 15 t ha⁻¹, 75% NPK + Sludge @ 15 t ha⁻¹, 50% NPK + Sludge @ 30 t ha⁻¹, NPK and 50% NPK + Sludge @ 15 t ha⁻¹. Highest physiological efficiency of nitrogen, phosphorus and potassium was recorded in 50% NPK + Sludge @ 15 t ha⁻¹ followed by NPK, 50% NPK + Sludge @ 30 t ha⁻¹ and 75% NPK + Sludge @ 15 t ha⁻¹. Highest economic efficiency of nitrogen, phosphorus and potassium was registered with 50% NPK + Sludge @ 30 t ha⁻¹ followed by 50% NPK + Sludge @ 15 t ha⁻¹, 75% NPK + Sludge @ 30 t ha⁻¹, 75% NPK + Sludge @ 15 t ha⁻¹, 75% NPK + Sludge @ 15 t ha⁻¹, NPK + Sludge @ 15 t ha⁻¹ and NPK. The results clearly indicated that use of composted sludge could increase the efficiency of primary nutrients and decrease the requirement of NPK fertilizers by 25-50 percent under temperate Himalayas.

Keywords

Composted sludge,
Economic efficiency,
Agronomic efficiency,
Recovery efficiency,
Chemical fertilizers

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Introduction

The rampant use of chemical fertilizers contributes to the deterioration of the environment through depletion of fossil fuels, generation of carbon dioxide and contamination of water resources. It also leads to loss of soil fertility due to imbalanced use of plant nutrients that adversely impacts

agricultural productivity. Now there is a growing realization that the adoption of ecological and sustainable farming practices can only reverse the declining trend in the global productivity and environment protection. Municipal solid waste management is gaining importance all over the developed and developing nations. In India due to increasing population, rapid economic growth

and urbanization, per capita generation of municipal wastes with each passing day has tremendously been increasing. Most of these wastes are used for unscientific land-filling or uncontrolled dumping in towns and cities which have serious environmental implications in global warming through emission of greenhouse gases (Paramasivam *et al.*, 2008).

Use of chemical, physical and biological properties of soil as a living filter appears a solution to soil and water pollution resulting from the present waste disposal processes. Agricultural lands are excellent sites for beneficially using municipal sludge as a conditioner/fertilizer containing organic matter and plant nutrients (Sommers, 1977; Casado-Vela *et al.*, 2006, 2007).

The application of sludge to agricultural land can prove to be an excellent substitute for costly fertilizer inputs and can be cost effective for both the municipalities generating this product and the farmers who accept it.

Integrated plant nutrient is a concept that aims at managing and supplying nutrients to plants through chemical fertilizers as well as all possible organic sources to an optimum level for sustaining a desired crop productivity with simultaneous conservation of natural resources and maintenance of environmental quality (Milkha, 2010). It is more realistic to use a management system that will incorporate sludge and chemical fertilizers in suitable ratios in a specific crop improvement programme to realize sustained results. In view of these points, field experiments were carried out to investigate the influence of composted municipal sludge on efficiency of nitrogen, phosphorus and potassium in maize which being one of the dominant crops cultivated by farmers in hilly areas of temperate Himalayas.

Materials and Methods

The present study was undertaken at Agricultural Research Farm of Krishi Vigyan Kendra, SKUAST-K, Shuhama, Srinagar ($34^{\circ} 11' N$, $74^{\circ} 49' E$, 1631 m amsl). The soil of the experimental location was silty clay loam in texture with initial pH 7.2, electrical conductivity 0.12 dS m^{-1} , organic carbon 5.4 g kg^{-1} , available N, P, K and DTPA-extractable Zn, Cu, Mn and Fe 210, 16.6, 311, 1.1, 2.0, 12.8 and 14.2 kg ha^{-1} , respectively. The experiment was arranged in a completely randomized block design with seven treatments in three replications in plots of $5 \text{ m} \times 3 \text{ m}$ size with maize (*Zea mays L.*, cv. 'Super Maize' composite) as a test crop. The treatment details were, T₁: Control; T₂: NPK (recommended fertilizer dose); T₃: NPK + sludge @ 15 t ha^{-1} ; T₄: 50% NPK + sludge @ 15 t ha^{-1} ; T₅: 50% NPK + sludge @ 30 t ha^{-1} ; T₆: 75% NPK + sludge @ 15 t ha^{-1} ; and T₇: 75% NPK + sludge @ 30 t ha^{-1} .

The recommended fertilizer dose according to soil test based fertilizer recommendation was 120 kg N , $60 \text{ kg P}_2\text{O}_5$ and $40 \text{ kg K}_2\text{O ha}^{-1}$. The sludge was collected in bulk from a waste water treatment plant located in Hazratbal, Srinagar and subjected to composting process for period of four months in trenches. As per treatments, air dried composted sludge was incorporated into plots fifteen days before sowing of the crop. The characteristics of sludge used in the experiment are given in Table 1.

The NPK fertilizers as per treatments were applied through urea, diammonium phosphate and muriate of potash at the time of sowing. Nitrogen supplied via diammonium phosphate was adjusted in urea. The crop was harvested at maturity and grain and stover yields were recorded. The nitrogen content in composted sludge and plant samples was determined by Kjeldahl method (Jackson, 1973). Composted

sludge and plant samples were digested in 2:1 HNO₃-HClO₄ mixture (Jackson, 1973) and in the extracts phosphorus was determined by calorimetry and potassium by flame photometry. The agronomic, recovery, physiological and economic efficiency of nutrients were calculated as follows (Mosier *et al.*, 2004):

Agronomic efficiency (AE) of nutrients

It refers to increase in economic (seed) yield per unit of nutrient (N, P, K) applied i.e. it is the ratio of seed yield to the amount of nutrient applied and is expressed as kg kg⁻¹.

$$AE = \frac{(\text{Seed yield in fertilized plot} - \text{Seed yield in control plot})}{\text{Nutrient dose applied}}$$

Recovery Efficiency (RE) of nutrients

It refers to the increase in the nutrient uptake by plant (seed plus stover) per unit of nutrient (N, P, K) applied. The recovery efficiency is generally expressed in percent (%).

$$RE = \frac{(\text{Nutrient uptake in fertilized plot} - \text{Nutrient uptake in control plot})}{\text{Nutrient dose applied}} \times 100$$

Physiological Efficiency (PE) of nutrients

It indicates the efficiency with which the crop utilizes the absorbed nutrients to produce economic yield. It is the ratio of the increase in yield to the increase in nutrient uptake and expressed as kg kg⁻¹.

$$PE = \frac{(\text{Seed yield in fertilized plot} - \text{Seed yield in control plot})}{\text{Nutrient uptake in fertilized plot} - \text{Nutrient uptake in control plot}} \times 100$$

Economic Efficiency (EE) of nutrients

When agronomic efficiency (AE) is expressed in monetary terms, it becomes economic efficiency. It can be equated with most popularly used benefit: cost ratio and is calculated as

$$EE = \frac{\text{Value of produce (Rs)}}{\text{Cost of applied nutrient dose}} \times AE$$

Results and Discussion

Crop yields

A perusal of the results presented in Table 2 shows that application of 75% NPK + sludge @ 30 t ha⁻¹ gave highest yields of grain (46.3 q ha⁻¹) and stover (72.7 q ha⁻¹) followed by NPK + sludge @ 15 t ha⁻¹, 75% NPK + sludge @ 15 t ha⁻¹ and 50% NPK + 30 sludge @ 30 t ha⁻¹. These were at par to each other for the seed and stover yield. Higher yields due to integration of sludge and chemical fertilizers could be explained on the basis of improved physical and nutritional environment of the soil under study and increased availability of nutrients by the crop. Many researchers have also reported improved crop yields and reduced commercial fertilizer requirements with the application of sewage sludge. Antolin *et al.*, (2005) reported that the yield of barley increased in sludge and fertilizer amended plots compared to unamended plots. Al Zoubi *et al.*, (2008) related higher productivity of maize to better physical and nutritional properties of soil caused by the sludge application. Tamrabet *et al.*, (2009) found that 30 t ha⁻¹ of sewage sludge was as efficient as 66 kg ha⁻¹ of mineral nitrogen in increasing the grain and straw yields of wheat. Bhat (2010) reported enhanced dry matter yields and decreased toxicities of heavy metals in maize and radish with increasing levels of biosolid application to soil.

Table.1 Characteristics of composted sludge

Parameter	Value
Particle size (mm)	2.0
Moisture content (%)	31.5
Odour	Earthy
Colour	Dark brown
Bulk density (g cc ⁻¹)	0.83
pH (1:2.5)	6.55
EC (dS m ⁻¹)	4.7
OC (g kg ⁻¹)	116.5
Total N (g kg ⁻¹)	17.5
Total P (g kg ⁻¹)	0.95
Total K (g kg ⁻¹)	12
Total Zn (mg kg ⁻¹)	563.5
Total Cu (mg kg ⁻¹)	526.5
Total Mn (mg kg ⁻¹)	591.5
Total Fe (mg kg ⁻¹)	11470

Table.2 Effect of differential doses of composted sludge and fertilizers on yield and nutrient uptake of maize (pooled data of two years)

Treatment	Yield		Uptake		
	Grain	Stover	Grain + Stover		
	(q ha ⁻¹)		(kg ha ⁻¹)		
			N	P	K
Control	7.3	26.8	14.9	3.4	29.2
NPK	35.7	64.3	79.9	18.9	100.4
NPK + sludge @ 15 t/ha ⁻¹	43.6	71.4	108.8	28.7	137.2
50% NPK + sludge @ 15 t ha ⁻¹	33.8	62.2	72.4	17.7	94.3
50% NPK + sludge @ 30 t ha ⁻¹	38.2	65.4	89.2	22.8	111.5
75% NPK + sludge @ 15 t ha ⁻¹	40.0	67.2	95.9	25.1	120.4
75% NPK + sludge @ 30 t ha ⁻¹	46.3	72.7	116.9	30.1	147.2
CD (P = 0.05)	6.3	15.8	2.6	0.6	4.7

Fig.1

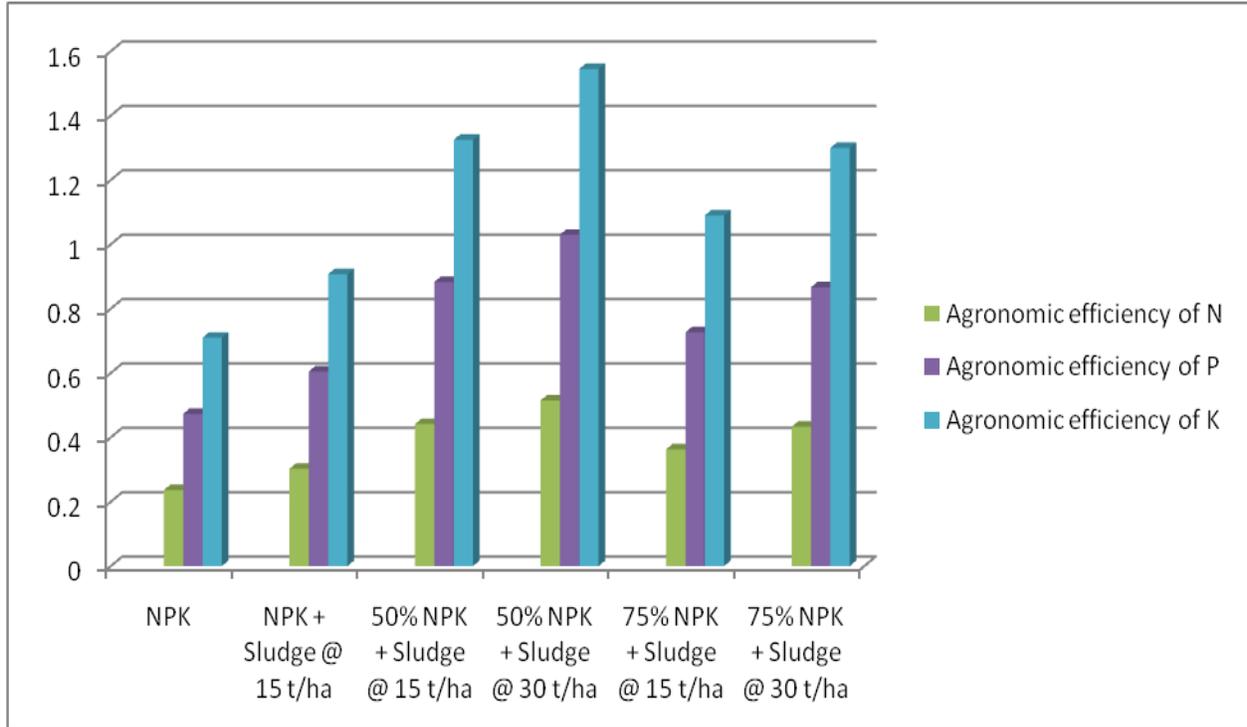


Fig.2

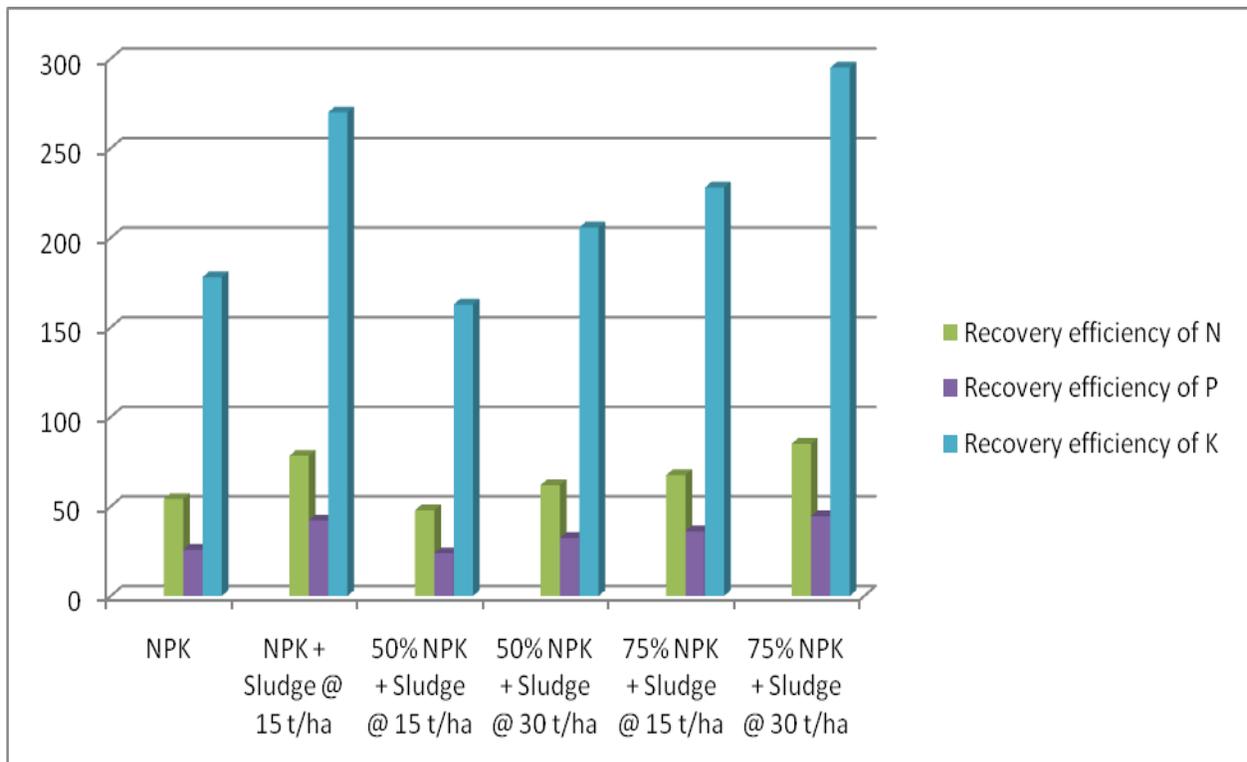


Fig.3

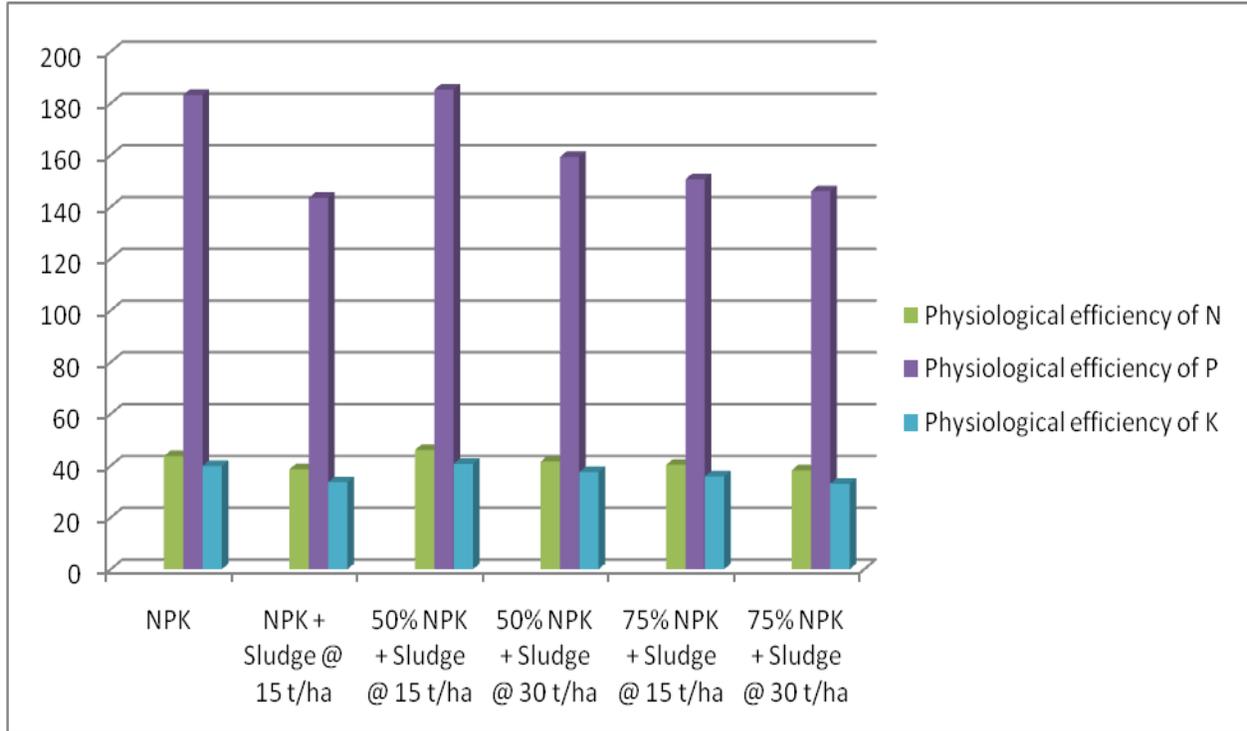
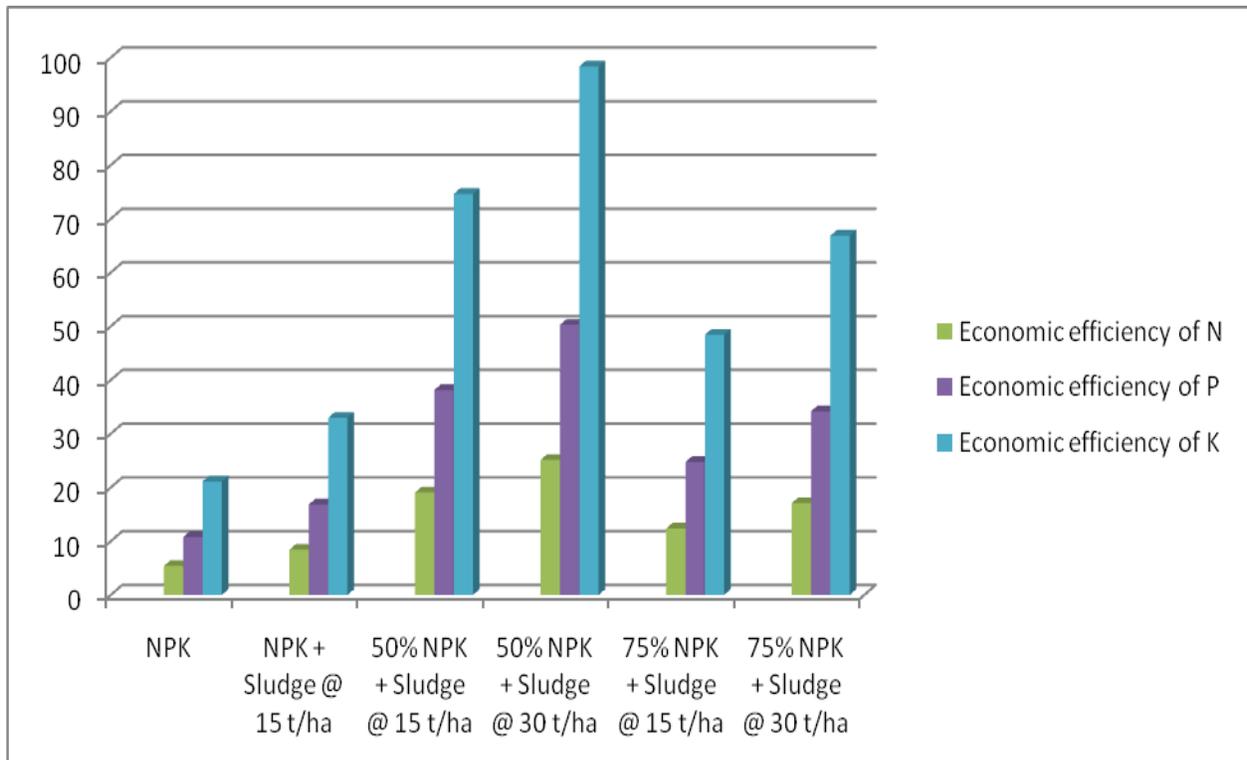


Fig.4



Uptake of primary nutrients

The maximum total uptake of nutrients by seed plus stover of the crop (116.9 kg N, 30.1 kg P, 147.2 kg K ha⁻¹) was noticed in 75% NPK + Sludge @ 30 t ha⁻¹, NPK + Sludge @ 15 t ha⁻¹, 75% NPK + Sludge @ 15 t ha⁻¹ and 50% NPK + Sludge @ 30 t ha⁻¹ (Table 2). Increased uptake of nutrients could be assigned to enhanced nutrient use efficiency on account of integrated use of composted sludge and chemical fertilizers. Rathod *et al.*, (2013) stated that the beneficial effect of organic manures on nutrient availability was probably due to the solubilization of native nutrients by organic acids released during microbial decomposition of organic materials. Daur *et al.*, (2015) showed that increasing levels of organic manure and humic acid enhanced nutrient uptake in berseem. The results are also in agreement with the findings of Mitchell *et al.*, (1978), Paulraj and Sree Ramulu (1994), Christodoulakis and Margaris (1996), Aggelides and Londra (2000), Mahdy *et al.*, (2007) and N'Dayegamiye (2009).

Efficiency of primary nutrients

Improvement in nutrient use efficiency has become a desirable goal in crop production enabling efficient nutrient utilization, maximum energy conservation and profitability (Chen *et al.*, 2013). Fixen (2006) suggested that the value of improving nutrient use efficiency is dependent on the effectiveness in meeting the objectives of nutrient use, providing economical optimum nourishment to the crop, minimizing nutrient losses from agricultural fields and contribution to system sustainability through fertility or other quality components of soil. Results in Figure 1 depict that 50% NPK + Sludge @ 30 t ha⁻¹ registered highest agronomic efficiency of nutrients (0.515 kg seed kg⁻¹ N applied, 1.03 kg seed kg⁻¹ P applied and 1.545 kg seed kg⁻¹ K applied)

followed by 50% NPK + Sludge @ 15 t ha⁻¹, 75% NPK + Sludge @ 30 t ha⁻¹, 75% NPK + Sludge @ 15 t ha⁻¹, NPK + Sludge @ 15 t ha⁻¹ and NPK. Highest recovery efficiency of N, P, K (85, 44.5 and 295%, respectively) was observed with the application of 75% NPK + Sludge @ 30 t ha⁻¹ followed by NPK + Sludge @ 15 t ha⁻¹, 75% NPK + Sludge @ 15 t ha⁻¹, 50% NPK + Sludge @ 30 t ha⁻¹, NPK and 50% NPK + Sludge @ 15 t ha⁻¹ (Figure 2). Highest physiological efficiency of nutrients (46.087 kg seed kg⁻¹ N absorbed, 185.315 kg seed kg⁻¹ P absorbed and 40.707 kg seed kg⁻¹ K absorbed) was recorded with the application of 50% NPK + Sludge @ 15 t ha⁻¹ followed by NPK, 50% NPK + Sludge @ 30 t ha⁻¹ and 75% NPK + Sludge @ 15 t ha⁻¹ (Figure 3). However, physiological efficiency of N and K was greater and that of P lower in NPK + Sludge @ 15 t compared to 75% NPK + Sludge @ 30 t ha⁻¹. It is depicted in Figure 4 that the economic efficiency of N, P and K (25.137, 50.273, 98.345, respectively) was maximum in 50% NPK + Sludge @ 30 t ha⁻¹ followed by 50% NPK + Sludge @ 15 t ha⁻¹, 75% NPK + Sludge @ 30 t ha⁻¹, 75% NPK + Sludge @ 15 t ha⁻¹, 75% NPK + Sludge @ 15 t ha⁻¹, NPK + Sludge @ 15 t ha⁻¹ and NPK.

Improving nutrient efficiency is a major challenge faced by the agriculture all over the world. One of the methods to improve the efficiency of applied nutrients is to recycle municipal sludge and apply it to agricultural land. The results revealed that use of composted sludge could decrease the requirement of primary fertilizer nutrients by 25-50 percent to sustain the productivity of maize under temperate Himalayas.

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