

# LONG TERM NUTRIENT MANAGEMENT INFLUENCES NUTRIENT USE EFFICIENCY, AGRONOMIC EFFICIENCY AND TRANSLOCATION OF NUTRIENTS IN RAINFED RICE

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**Abstract:** On firm experimental data was generated from a long term experimental trial on conjunctive use of organic and inorganic nutrients on productivity and soil health of rice –lentil crop in a rainfed ecosystem under All India Coordinated Research Project on Dry land Agriculture. The present experiment was carried out during *kharif season* of 2008 to 2011 at Banaras Hindu University, Varanasi, India. The experiment was laid out with six treatments namely, control (no nutrient supplemented), 100% RDF (80-40-30 kg ha<sup>-1</sup> N:P:K), 100% N through FYM, 50% N through FYM, 50% RDF + 50% N through FYM and farmer's practice (only 20 kg N ha<sup>-1</sup>) in an *udic ustochrept* of transect 4 of the IGP (Indo Gangetic Plain) region. The experiment indicated that combined application of 50% RDF + 50% N through FYM was a superior treatment for increasing grain as well as straw yield. The nutrient use efficiency, apparent recovery of nutrients, soil nutrient balance sheet and yield were also found higher in conjunctive use of organic and inorganic nutrient sources. The results further demonstrated that the conjunctive use of organic and inorganic source of fertilizer significantly increased uptakes of P and K but higher N uptake found with 100% RDF under rainfed condition.

**Keywords:** Inceptisol, fertilizer use efficiency, nutrient uptake/ translocation, rainfed, rice yield

## INTRODUCTION

A notable decline in soil productivity especially in rainfed rice-based agro-ecosystems has been reported by many workers. In the process of implementation and up scaling of agricultural technologies developed for arid and semiarid areas particularly rainfed areas, intensive use of fertilizers is severely restricted due to water shortage and economical constraints (mostly poor and marginal farmer's), therefore, relies much on the farm or soil *in situ* nutrient sources. Traditionally, IPNM system involved a judiciously balanced cycle of nutrient flow. The technical and marginal components for achieving the objectives of maintenance of soil fertility, sustaining agricultural productivity and improving farmer's profitability through the judicious and efficient use of mineral fertilizers along with organic manure depends under farm situations. Nutrient use efficiency can be expressed in agronomic, physiologic, and economic terms, but so far in India this subject remains largely confined to the scientific community. Because nutrient use in India is largely imbalanced and subsidy driven, the practical benefits of high use efficiency are distorted since N, the cheapest nutrient is used by majority growers while other nutrients are ignored. Agronomic efficiency may be defined as the nutrients accumulated in the above-ground part of the plant or the nutrients recovered within the entire soil-crop-root system. Appropriate fertilizer use leads to increased crop yields and high crop recovery of applied nutrients. Efficient fertilization is therefore

important in ensuring crops attain maturity within specific growing seasons (Okalebo, 1997). Nutrient (nitrogen, phosphorus, potassium and Sulphur) uptake, use efficiency and yields of rainfed rice are a function of soil health and balance nutrient management. The extent of nutrient depletion is unknown and fertilizer and manure application by farmers is not commensurate with the plant requirements and/or nutrient levels in the soil (FURP, 1994). It was necessary to develop appropriate recommendations that can be used by smallholder resource poor farmers and extension agents. The appropriate recommendations of rates of fertilizers and manure in different soils and climatic conditions may help check the deteriorating soil conditions and improve sustainable food security in the transect 4 of Varanasi region of the IGP. Long term experiment provide the best possible means for studying changes in soil properties and processes to obtain valuable information for formulating future strategies to mitigate decline productivity and sustainable growth. Therefore the objective of this study was to assess the effect of different levels of organic and inorganic nutrient management on soil health, nutrient dynamics and productivity of direct seeded rainfed rice in Inceptisol of Varanasi.

## MATERIAL AND METHOD

The experiment was conducted during *kharif season* 2008-2011 at the research farm (25° 18' N, 83° 03' E, altitude 129 m above sea level) of Banaras Hindu University, Varanasi. This experiment has been

under the supervision of the All India Coordinated Research Project on Dry land Agriculture (AICRP-DLA) of the Indian Council of Agricultural Research. The soil at the experimental site is classified as fine loamy mixed hyperthermic *Udic Ustochrept*. The plough layer (0.0–0.15 m) has 24.3% sand, 22.0% silt and 53.7% clay. The pH, EC, bulk density and CEC values at the beginning of the experiment were 7.54, 0.21 dS m<sup>-1</sup>, 1.37 Mg m<sup>-3</sup> and 1.38 cmol (p+) kg<sup>-1</sup>, respectively and the available N, P, K and S status was 182.8 kg ha<sup>-1</sup>, 13.0 kg ha<sup>-1</sup>, 236.0 kg ha<sup>-1</sup> and 25.8 kg ha<sup>-1</sup>, respectively. Six treatments comprising combinations of organic and inorganic nutrient sources were tested in 10 m X 10 m plots arranged in a randomized block design with three replications. The treatments were: control (no nutrient supplemented)-T<sub>1</sub>, 100% RDF (80-40-30 kg ha<sup>-1</sup> N: P: K)-T<sub>2</sub>, 100% N through FYM-T<sub>3</sub>, 50% N through FYM-T<sub>4</sub>, 50% RDF + 50% N through FYM-T<sub>5</sub> and farmer's practice (20 kg N ha<sup>-1</sup>)-T<sub>6</sub>. The rice (cv. NDR -97) was directly sown in the rainy season with row to row spacing of 30 cm. Ten randomly selected plants from each replication of all the treatments were sampled at harvest for chemical analysis by using the modified methods (Piper, 1966 and Jackson, 1967). The derivation of productivity and use efficiency component like total nutrient uptake of nutrients, agronomic use efficiency, nutrients use efficiency and nutrient recovery fraction etc. were calculated following the methods of Santos *et al.* (2003) and Baligar *et al.* (2001). The relationship equations are as under:

#### 1. Percent recovery

**of applied nutrient** = (Uptake of nutrient in treatment - Uptake of nutrient in control) / Quantity of nutrient applied \*100

#### 2. Percent translocation

**of nutrient in grain** = Uptake of nutrient in grain/ Total nutrient uptake \* 100

#### 3. Agronomic

**efficiency (kg kg<sup>-1</sup>)** = (Grain yield of fertilized crop in kg - Grain yield of unfertilized crop in kg) / Quantity of fertilizer applied in kg

#### 4. Percent increase in nitrogen

**uptake over control**= (Total N uptake in treatment – Total N uptake in control) / Total N uptake in treatment \*100

The three year pooled data was analyzed statistically and reported.

### RESULT AND DISCUSSION

The plant height, grain per panicle, pod per panicle, panicle length and test weight (1000 grain weight) of rice was increased with application of N, P, K and FYM, whereas the combined effect of 50% FYM and

50% NPK had more of additive effect than that of use of fertilizer alone. The improvement in growth and yield attributes of direct seeded rice and succeeding lentil crop in FYM treated plot might be due to increase in availability of plant nutrients as a result of mineralization of FYM due to favourable influence on physical properties of soils such as aeration, increased porosity and water holding capacity of the soil. The result obtained was in conformity with the report of Tiwari (2002). The higher yield of grain and straw of rice were recorded with 50% FYM +50% NPK (T<sub>5</sub>). This was closely followed by applying 100% NPK (T<sub>2</sub>) and 100% FYM (T<sub>3</sub>). The lower yield obtained in 100% organic N (T<sub>3</sub>) in comparison to T<sub>2</sub> and T<sub>5</sub>, may be due to the delayed decomposition and mineralization of N from the organic which could not match the actual quantity required as well as the time at which N is needed by crops (Omarhattab *et al.* 2000).

#### Yield Attributes

The data pertaining to yield contributing character i.e. grain per panicle, number of panicles (m<sup>-1</sup>), panicle length (cm) and test weight (1000-grain weight) are given in table 1.

#### Number of grain per panicle

The number of grain per panicle varied from 77.3 to 104.7 being maximum under 50% FYM+50% NPK treatment and minimum under control. Statistically significant differences were recorded in number of grains per panicle. Barring farmer's practices (T<sub>6</sub>), the rest of the treatments resulted in significantly more number of grains per panicle over control. Use of FYM alone and along with NPK resulted in higher number of grain/panicle as compared to NPK alone (T<sub>2</sub>).

#### Number of panicles (m<sup>-2</sup>)

The number of panicles varied from 95.8 to 116.6 (m<sup>-2</sup>) under different treatments. The highest number of panicles were recorded under 50% FYM +50% NPK treatment and lowest under control. Except farmer's practices (T<sub>6</sub>), all other treatments produced significantly higher number of panicles over control. Integrated use of 50%FYM and 50% NPK (T<sub>5</sub>) had beneficial effect on the number of panicles as compared to NPK alone (T<sub>2</sub>). Addition of FYM (T<sub>4</sub> and T<sub>6</sub>) significantly led to more number of panicles over control (Table 1).

#### Panicle length (cm)

The panicle length varied from 20.8 to 22.57cm. In this case, no significant difference was recorded in the panicle length due to different treatments.

#### 1000-grain weight (Test weight)

The 1000-grain weight ranged from 24.1 to 26.46 gram. Statistically, it was at par under different treatments.

**Table 1:** Growth and yield contributing characters of rainfed rice as influenced by different treatments

Treatments	Plant height (cm)	Grain per panicle	Number of panicle (m <sup>-1</sup> )	Panicle length (cm)	1000 grain weight (g)
T <sub>1</sub> -Control	83.3±2.6	77.3±2.9	95.8±3.1	20.8±1.8	24.1±1.7
T <sub>2</sub> -Recommended doses of fertilizers (80:40:30: :N:P <sub>2</sub> O <sub>5</sub> : K <sub>2</sub> O)	91.8±2.9	83.5±2.4	113.6±3.2	22.57±1.8	25.33±1.9
T <sub>3</sub> -100% N through FYM	92.6±2.6	96.3±2.3	113.0±3.2	22.47±1.9	26.33±1.7
T <sub>4</sub> - 50 % N through FYM	91.13±2.8	84.2±2.5	101.7±3.4	22.43±1.9	24.9±1.8
T <sub>5</sub> -50% N through FYM+50%NPK fertilizers	92.3±2.9	104.7±2.4	116.6±3.7	22.57±1.9	26.46±1.7
T <sub>6</sub> -Farmer's practices (20 kg N through urea)	86.53±2.7	77.5±2.5	98.6±3.2	21.03±1.7	24.7±1.9
L.S.D. at 5%	4.2	3.4	8.1	1.4	1.2

### Grain yield of rice

The grain yield of rice ranged from 12.15 (control) to 19.97 (50% FYM+50% NPK) q/ha<sup>-1</sup> (Table 2). The statistical analysis revealed that all the treatments produced significantly higher grain yield of rice over control. With the application of 100% NPK (T<sub>2</sub>), 50% FYM+50% NPK (T<sub>5</sub>), and 100% FYM (T<sub>3</sub>) grain yield of rice increased by 7.2, 7.82 and 6.45 q ha<sup>-1</sup> over control. Higher grain yield of 19.97 qha<sup>-1</sup> was recorded for 50% FYM +50% NPK treatment, which produced statistically at par grain yield when compared to 100% FYM treatments. Moreover, it is evident from the data that the FYM treatments (100% FYM, T<sub>3</sub> and 50% FYM, T<sub>4</sub>) comparatively produced less yield of rice as compared to same dose of fertilizer treatments. The increase in yield might

be due to application of organic and inorganic sources. These organic and inorganic sources create maximum nutrient availability to plant. Similar results were also reported by Tomar and Khajanji (2009).

### Straw yield of rice

The straw yield of rice varied from 35.63 to 46.3 q ha<sup>-1</sup> under different treatments (Table 2). All the fertilizer treatments significantly enhanced the straw yield of rice over control. As compared to control an increase of straw yield 10.7, 10.6, and 9.9 q ha<sup>-1</sup> was noted by 50% FYM+50% NPK, 100% NPK and 100% FYM. The highest straw yield of rice (46.3 q ha<sup>-1</sup>) was recorded under 50% FYM+50%NPK at par to 100% NPK and 100% FYM treatments.

**Table 2:** Relationship of N, P, K and S uptake on rice grain yield

Treatments	Grain Yield (q ha <sup>-1</sup> )	Straw yield (q ha <sup>-1</sup> )	Total Uptake (kg ha <sup>-1</sup> )			
			N	P	K	S
T <sub>1</sub> -Control	12.15± 1.42	35.6	40.45± 1.34	12.59± 1.14	47.38± 1.31	9.81±0.16
T <sub>2</sub> -Recommended doses of fertilizers (80:40:30: :N:P <sub>2</sub> O <sub>5</sub> : K <sub>2</sub> O)	18.5± 1.31	46.2	71.61± 1.42	27.86± 1.21	78.48± 1.53	20.53±0.22
T <sub>3</sub> -100% N through FYM	19.20± 1.57	45.5	54.61± 1.65	19.52± 1.42	62.23± 1.73	18.85±0.17
T <sub>4</sub> -50%N through FYM	15.36± 1.42	38.5	51.49± 1.36	16.65± 1.26	57.75± 1.78	12.92±0.26
T <sub>5</sub> -50% N through FYM+50%NPK fertilizers	19.97± 1.34	46.3	58.35± 1.28	20.43 ± 1.42	63.70 ± 1.32	20.74±0.33
T <sub>6</sub> -Farmer's practices (20 kg N through urea)	13.80±46.17	38.3	46.17	14.42	52.62	11.36±0.30
L.S.D. at 0.05	2.5	3.8	4.5	1.8	5.8	1.3

### Concentration and uptake of nutrients

All the treatments significantly enhanced the N uptake in rice grain. Successive increase in the rates of NPK input caused a remarkable effect on N concentration. The maximum N uptake of grain (47.5 kg ha<sup>-1</sup>) was recorded when the crops were grown under 100% FYM (T<sub>3</sub>) and this was significantly higher over all other treatments. Similarly maximum total N uptake was recorded under 100% FYM (71.6 kg ha<sup>-1</sup>) treatment while minimum (40.45 kg ha<sup>-1</sup>) N uptake was recorded under no external nutrient supplementation (control treatment).

The maximum withdrawal of phosphorus by rice grain was recorded under 50%FYM +50%RDF (16.75 kg ha<sup>-1</sup>) followed by 100% RDF (15.72 kg ha<sup>-1</sup>) treatment. Similarly total uptake of P by application of 50% FYM along with 50% RDF treatment led to significantly more utilization of P (27.86 kg ha<sup>-1</sup>) in comparison to application of other treatment.

At 50% FYM +50% RDF, K uptake in grain was 15.97 kg ha<sup>-1</sup> which was significantly higher than other treatments (Table 2). Similarly combined use of 50% FYM with 50% RDF (T<sub>5</sub>) recorded highest total K uptake compared to rest of treatments, which was significantly higher over 100% RDF treatment. The lowest total K uptake was recorded when the crops were grown under control and farmer's practice treatment.

### Multiple regression of N, P, K and S uptake on rice grain yield

Multiple regression analysis of N, P, K and S uptake showed significant and positive correlation with grain yield (R<sup>2</sup>=0.99\*). P uptake showed significant and negative correlation with grain yield, but nitrogen and S uptake showed significant and positive correlation with grain yield. The negative correlation of P uptake with yield indicates that increase in P uptake would result in decrease in grain yield. Nitrogen and S are required for the synthesis of chlorophyll. Nitrogen regulated the protoplasm formation and protoplasm is highly hydrated, therefore, assumed that higher N supplementation may lead for development of more succulent plants. It is well known that among the fertilizers used in rice, nitrogen plays a major role for realizing higher yield potential (Rao and Padmja, 2004).

### Translocation of N, P, K and S in rice grain

Translocation of N, P, K and S were found to be less with use of fertilizer or manure alone than that of combined use of manure and fertilizer. The reason behind it is that in case of use of fertilizer or manure alone, increase grain uptake was less. But in case of combined use of fertilizer and manure the uptake of nutrients by grain and other plant biomass was more. Maximum nutrients translocation of N, P, K and S in grain was recorded with 50% FYM +50% NPK (T<sub>5</sub>), followed by 100% NPK treatments and lowest in control (Table 3).

**Table 3:** Effect of different treatments on nutrient translocation in rice grain

Treatments	N translocation (%)	P translocation (%)	K translocation (%)	S translocation (%)
T <sub>1</sub>	62.09±3.47	57.58±2.38	15.78±1.83	49.18±2.13
T <sub>2</sub>	66.17±3.27	59.65±2.45	19.5±1.48	50.41±2.43
T <sub>3</sub>	65.5±3.13	58.34±2.43	18.38±1.62	49.33±2.21
T <sub>4</sub>	64.86±3.14	58.37±2.16	17.33±1.41	49.3±2.13
T <sub>5</sub>	66.39±3.18	60.12±2.19	20.34±1.43	54.48±2.61
T <sub>6</sub>	62.68±3.21	57.56±2.29	16.30±1.45	49.47±2.18

### Translocation of nitrogen

The translocation of N in rice grain was influenced by different doses of fertilizers and manure application. The highest value (66.4%) was recorded with the T<sub>5</sub> receiving 50% FYM+50% NPK, at par to 100% NPK (66.1) and 100% FYM (66.5%) and even T<sub>4</sub>. The minimum translocation of N in grain (62.5%) was obtained under the control at par to farmer's practice treatment.

### Translocation of Phosphorus

The translocation of P in grain increases with increasing doses of fertilizers and manure. The maximum translocation of P in grain (60.1%) was recorded with the application of 50% FYM+ 50% NPK, at par to 100% NPK (59.6%) treatment. The

lowest translocation of P was recorded in farmer's practices treatment (57.5%).

### Translocation of potassium

The maximum translocation of K in grain (20.3%) was recorded in treatment T<sub>5</sub> (50% FYM+ 50% NPK at par to 100% NPK (19.5%) and 100% FYM treatment (18.3%). The minimum translocation of K in grain (15.7%) noted in T<sub>1</sub> (control) treatment.

### Translocation of sulphur

The highest (54.4%) S translocation was recorded in T<sub>5</sub> (50%FYM+ 50% NPK) treatment, followed by 100% NPK (50.4%) and 100% FYM (49.3%) treatment. The minimum value was recorded in control (49.1%).

**Regression of N, P, K translocation on rice grain yield**

There was significant relationship between N translocation and grain yield ( $r = 0.97^*$ ), Phosphorus translocation and grain yield ( $r = 0.85^*$ ) and K translocation and grain yield ( $r = 0.95^*$ ). Translocation of N, P and K in grain was positively and significantly correlated with grain yield of rice. N, P and K translocation have increased the grain yield of rice. This could possibly because starch is an active component of rice grain, and biosynthesized from adenine diphosphate of which N and P are the constituents (Dixit and Gupta, 2002). The potassium plays a vital role in the activation of enzymes

involved in photosynthesis, carbohydrate metabolism and its translocation from leaves to grain (Mengel and Kirkby, 1987 and FAO, 1984).

**Percent recovery of nitrogen, phosphorus and potassium**

Percent utilization of nitrogen, phosphorus and potassium in rice was found to be 34.9, 34.7 and 91 when treated under 100% RDF ( $T_2$ ) and 39, 34.4 and 79.7 ( $T_5$ ) respectively under combined application of 50% FYM + 50% RDF ( $T_5$ ). Percent recovery of nitrogen in rice was maximum (*i.e.* 39 %) with 50% FYM + 50% NPK treatment, but percent P and K recoveries were highest with 100% RDF application ( $T_2$ ) treatment (Table 4).

**Table 4:** Effect of different treatments on percentage recovery of N, P and K by rice crop

Treatments	% recovery of nitrogen	% recovery of phosphorus	% recovery of potassium
T <sub>1</sub>	-	-	-
T <sub>2</sub>	34.91± 1.34	34.7± 2.43	91.03± 2.61
T <sub>3</sub>	30.29± 1.25	21.58± 1.21	48.8± 1.91
T <sub>4</sub>	27.58± 1.11	16.91± 1.67	43.2± 1.87
T <sub>5</sub>	39.00± 1.34	34.4± 1.49	79.74± 2.17
T <sub>6</sub>	28.56± 1.48	-	-

**Agronomic efficiency of nutrients (N, P and K)**

Agronomic efficiency of nitrogen in rice was found more in case of integrated use of fertilizer and manure ( $T_5$ ) than the lone application of fertilizer or manure. Application of manure supplies not only its inherent nutrient but also induced increases availability of native soil nitrogen. Agronomic efficiencies of phosphorus and potassium were maximum in ( $T_2$ ), due to application of optimal doses of nitrogen and sub-optimal doses of P and K (Table 5). Application of N in splits could have significantly improved the grain yield and also increased the agronomic efficiency of P and K.

+ 50% NPK treatment ( $T_5$ ), followed by 100% NPK ( $T_2$ ), and 100% FYM ( $T_3$ ) treatment.

**Agronomic efficiency of phosphorus**

The maximum agronomic efficiency of phosphorus was recorded when cultivated under 100% NPK treatment at par to 50% FYM+ 50% NPK ( $T_5$ ) treatment, and significantly higher over 100 % FYM or other treatments.

**Agronomic efficiency of Potassium**

The agronomic efficiency of K in terms of grain yield was recorded maximum when the crop was grown under 100% NPK ( $T_2$ ), followed by 50% FYM + 50% NPK ( $T_5$ ) treatments, respectively.

**Agronomic efficiency of nitrogen**

The maximum agronomic efficiency of nitrogen was recorded when the crop was grown under 50% FYM

**Table 5:** Effect of different treatments on agronomic efficiency of N, P & K in rice crop ( $kg\ kg^{-1}$ )

Treatments	Agronomic efficiency ( $kg\ kg^{-1}$ of nutrient supplemented)		
	Nitrogen	Phosphorus	Potassium
T <sub>1</sub>	-	-	-
T <sub>2</sub>	17.75±1.34	35.5±2.14	47.33±2.26
T <sub>3</sub>	16.31±1.24	27.18±2.12	27.18±2.14
T <sub>4</sub>	15.52±1.25	25.87±2.17	25.87±2.18
T <sub>5</sub>	18.52±1.41	33.68±2.24	38.0±2.41
T <sub>6</sub>	13.25±1.41	-	-

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