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# Effect of Long-Term Application of Inorganic Fertilizers and Organic Manure on Yield, Potassium Uptake and Distribution of Potassium Fractions in the New Gangetic Alluvial Soil under Jute-Rice-Wheat Cropping System

**S.P. Mazumdar, D.K. Kundu, D. Ghosh, A.R. Saha,**
**B. Majumdar and A.K. Ghorai**

*Division of Crop Production, Central Research Institute for Jute and Allied Fibres Barrackpore, Kolkata–700120, West Bengal, India.*

## Abstract

The present study conducted under All India Coordinated Research Project on Long-term Fertilizer Experiment was aimed on the effect of inorganic fertilizers, with or without organic manure on yield, potassium uptake and distribution of potassium fractions after forty two years of jute-rice-wheat sequence during 2012-2013. The treatments selected for the study were 50% NPK, 100% NPK, 150% NPK, 100% NP, 100% N, 100% NPK+FYM, control. Different fractions of potassium, viz., water soluble, exchangeable K and non-exchangeable-K were analysed for the study. The investigations revealed that crop yields (jute, rice and wheat) were lowest in the control where neither fertilizers nor manures were applied for the last four decades and highest in 150%NPK. The uptake of potassium by jute, rice and wheat varied from 37.3 to 120.5 kg $ha^{-1}$, 46.8 to 114.78 kg $ha^{-1}$ and 16.1 to 123.6 kg $ha^{-1}$, respectively under different treatments. There was significant difference among the different treatments with respect to potassium fractions in 0-15 cm, 15-30 cm soil layer. Moreover, K fractions were significantly decreased with increasing depth of soil, with exception in non-exchangeable K. The contribution of different K fractions in two soil depths studied was in the order of non-exchangeable-K > exchangeable-K > water soluble-K. All the K fractions at 0-15 cm soil depth exhibited significant and positive correlation with yield. The mean annual removal of K by crops surpassed the amount of total K applied to the soil in all treatments, thus showing negative apparent K balance. Among K amended treatments the application of NPK+FYM to soils resulted in a greater negative K balance. Low accumulation despite large amount of K dressings in K treated plots is attributable to its large removal by the crop during 42 cycles. Findings indicate that depleting K reserves even at its optimal application rates point towards rethinking at the existing recommendation for all the crops. This suggested the need of adequate supply of K to crops for obtaining sustainable high yields.

**Keywords**: Potassium fractions, inorganic fertilizers, farmyard manure, K uptake, crop yield.

## 1. Introduction

Potassium is the third important essential major plant nutrient with numerous functions. It plays vital roles in enzyme activation, water relations (osmotic regulation), energy relations, translocation of assimilates, photosynthesis, protein and starch synthesis and underpinning agronomic productivity and sustainability (Mengel 1985). Availability of soil K to plant is controlled by dynamic interactions among its different chemical forms (Wang et al. 2004). The components of dynamic interactions are: water soluble K, which is taken up directly by plants; exchangeable K, held by negatively charged sites of clay particles; nonexchangeable K, which is trapped between layers of expanding lattice clays; and lattice K, an integral part of the primary minerals (Srinivasa Rao et al., 1997).

Based on the statistics (Department of Agriculture, Government of West Bengal, 2005) on approximate addition and uptake of different nutrient in some important cropping sequences of West Bengal, the balance of potassium ranged from -123 kg/ha in rice-rice cropping sequence to -310 kg/ha in rice-potato-sesame cropping sequence, and also a total of 66% towards the total negative NPK balance in some popular cropping sequences of West Bengal in 2005 (Chatterjee and Sanyal, 2007). Severe depletion of potassium partly results from the average crop removal of 1.5 times more K than that of N, while the K application is much lower than that of N or P, with the misconception that the soils of country are relatively rich in potash. Apart from this, relatively low cost per unit of nitrogen, its widespread availability, and quick and evident response of the plant has further accentuated such an imbalance (Sanyal and Chatterjee, 2007). In this scenario of potassium depletion, parallel to the continued cropping with only nitrogen and phosphate, along with no or inadequate potash application, K requirement of crops is met from the inherent potassium reserve (the non exchangeable potassium pool) of soil. Such depletion may denude the interlayer potassium of the illitic clay minerals of soils which are sufficient for the clay lattice to collapse (Sanyal and Chatterjee, 2007). This in turn will adversely affect the potassium dynamics in soil, rendering the entrapment of excess K (e.g., from the applied K fertilizer) in soil rather difficult, causing thereby excessive loss of the applied potassium through leaching. While it will be necessary to rationalize the use of N fertilizers, ominous signs are that if strategies and policies are not developed to boost K supplies, and this essential nutrient continues to remain neglected as in the past, future sustainability in agriculture is likely to be constrained mostly by this nutrient. Sustainability of the regions supporting high intensity cropping and fertilizer responsive strains are foreseen to be the earliest victims of such imbalance (Sanyal and Majumdar, 2001). With these considerations in view, the present study was conducted (i) to study the distribution of various fractions of K in soil under an LTFE and (ii) to find K balance under 42 years of jute-rice-wheat cropping sequence under different nutrient management practices.

## 2. Materials and Methods

### 2.1 Details of field and soil experiment

The study was a part of the on-going Long term Fertilizer Experiment on jute- rice-wheat cropping system initiated at the Experimental farm of Central Research Institute for Jute and Allied Fibres (CRIJAF), Barrackpore, West Bengal ($22^0 45'$N latitude and $88^0 26'$E longitude) during 1971. Cultivation of jute-rice-wheat cropping sequence continued at the experimental site since 1971 with the recommended doses of fertilizers (100% NPK 60:13:50 kg $ha^{-1}$ for jute, 120:26:50 kg $ha^{-1}$ for rice and120:26:50 kg $ha^{-1}$ for wheat). The experiment was laid out in randomized block design. Seven different treatments [50% NPK, 100% NPK, 150% NPK, 100% NP, 100% N, 100% NPK+FYM and no fertilizer Control] with 4 replications were considered for the present study (Table1). The 50 and 150% NPK treatments comprised half and one and a half times the recommended doses of N, P and K respectively. The sources of N, P and K were urea, single superphosphate (SSP) and muriate of potash (MOP), respectively. Farmyard manure (FYM) @ 10 t $ha^{-1}$ was applied only before jute sowing.

**Table 1**: Details of the various treatments of the long term field experiment

| Treatment details | NPK doses (kg $ha^{-1}$) | | |
|---|---|---|---|
| | Jute | Rice | Wheat |
| 50% NPK | 30-6.5-25 | 60-13-25 | 60-13-25 |
| 100% NPK | 60-13-50 | 120-26-50 | 120-26-50 |
| 150% NPK | 90-19.5-75 | 180-39-75 | 180-39-75 |
| 100% NP | 60-13-0 | 120-26-0 | 120-26-0 |
| 100% N | 60-0-0 | 120-0-0 | 120-0-0 |
| 100% NPK+ F Y M @ 10 t $ha^{-1}$ in jute | 60-13-50 | 120-26-50 | 120-26-50 |
| Control (no fertilizer, no manure) | 0-0-0 | 0-0-0 | 0-0-0 |

The average N, P and K content in the FYM used for the experiment were 0.50%, 0.25% and 0.60% respectively. Jute variety JRO 524, rice variety Khitish and wheat variety UP 262 were grown following standard agronomic practices. The soil belonged to *Nilganj* series which is an Eutrochrept of New Gangetic Alluvial tract at the experimental site. It had a pH of 7.1, electrical conductivity (E.C.) 0.23 dS $m^{-1}$ (1:2.5 soil: water ratio) and organic carbon (OC) 4.1 g $kg^{-1}$. Available N, P ($NaHCO_3$-extractable P) and K ($NH_4OAc$-extractable K) in the soil were 223, 41.5 and 142.7 kg $ha^{-1}$ respectively (Table 2).

Soil samples were collected in April, 2013 after 42 years of continuous cropping from plots with the treatments at 0-15, 15-30 cm deep. Collected soil samples were air-dried and processed for analysis. Initial soil properties studied at the beginning of the experiment were done as per the standard procedures. Processed soil samples were analysed for available K which was determined by shaking 5 g soil for 5 min with 25 ml 1 N $NH_4OAc$ at pH 7.0 (Hanway and Heidel, 1952) and different forms of K [viz., water-soluble K (Jackson 1973), neutral normal ammonium acetate–extractable K (Pratt, 1965) and 1M boiling $HNO_3$ acid- extractable K (Pratt, 1965) . In all cases, K concentration was determined using flame photometer. The K extracted in 1M $HNO_3$ acid minus the K extracted by the neutral normal ammonium acetate gave the non-exchangeable K of the soil.

**Table 2:** Initial pysico-chemical characteristics of the experimental site

| **Particulars** | **Initial value** |
|---|---|
| Mechanical composition (%) | |
| Sand | 54 |
| Silt | 28 |
| Clay | 18 |
| Bulk density (kg $m^{-3}$) | 1.35 |
| Water holding capacity (%) | 44.3 |
| pH | 7.1 |
| CEC (c mol ($p^+$) $kg^{-1}$) | 19.0 |
| ECe (dS $m^{-1}$) | 0.23 |
| SOM (%) | 0.71 |
| Alk. $KMnO_4$ N (kg $ha^{-1}$) | 223.1 |
| Olsen's P (kg $ha^{-1}$) | 41.5 |
| $NH_4OAc$ K (kg $ha^{-1}$) | 142.7 |

Grain yields of jute, rice and wheat were recorded during 2012-2013.At harvest of each crop, grain and straw samples of rice and wheat and leaf, bark and wood (stick) samples of jute plants were collected from four replicates of each treatment and were analyzed for K by digesting the samples in tri-acid mixture (10:1:4 $HNO_3$: $H_2SO_4$:$HClO_4$). The K uptake by the grain and straw was computed by multiplying their concentration with corresponding yields. For rice and wheat total K uptake was calculated as the sum of grain and straw K uptake.

**2.2 Statistical analysis**
The significant difference among the treatments were analysed by Duncan's Multiple Range Test (Gomez and Gomez, 1984) using SASv9.2

## 3. Results and Discussion

### 3.1. Crop yield and potassium uptake

The crop yields and K uptake during 42 year as influenced by various treatments are given in Table 3. In case of jute, the highest fibre yield was recorded with the purely chemical fertilizer treatment *i.e.* 150%NPK (3.4 t $ha^{-1}$) which increased the yield by 119% over control. The effect of this treatment was significantly different from the other treatments. During 42 $^{nd}$ year grain yield of rice and wheat ranged from 2.5 t $ha^{-1}$ to 4.65 t $ha^{-1}$ and 1.05 t $ha^{-1}$ to 5.15 t $ha^{-1}$ under different treatments. Crop yields were lowest in the control where neither fertilizers nor manures were applied for the last four decades and highest in 150%NPK. The uptake of potassium by jute, rice and wheat varied from 37.3 to 120.5 kg $ha^{-1}$, 46.8 to 114.78 kg $ha^{-1}$ and 16.1 to 123.6 kg $ha^{-1}$, respectively under different treatments. Uptakes of K by component crops were significantly less under control and imbalanced use of fertilizer than under balanced use of fertilizer (Table3). The highest potassium uptake was found in 150% NPK, followed by 100 % NPK+FYM and the lowest K uptake was observed in the control plot in all the crops. The next in order was 100% NPK.

**Table 3**: Influence of continuous manuring and fertilizer use on yield and potassium uptake by component crop in the year 2012-13 of jute-rice-wheat sequence (Means with the same lower case letter are not significantly different in a column in same depth.)

| Treatments | Yield (t /ha) | | | K Uptake (kg $ha^{-1}$) | | |
|---|---|---|---|---|---|---|
| | Jute | Rice | Wheat | Jute | Rice | Wheat |
| 50%NPK | 2.7d | 3.7c | 3.7d | 92.6c | 87.2c | 83.6c |
| 100%NPK | 3.1c | 4.3b | 4.3c | 110.1b | 104.7b | 103.3b |
| 150%NPK | 3.4a | 4.7a | 5.2a | 120.5a | 114.8a | 123.6a |
| 100% NP | 2.9d | 3.9c | 3.8d | 94.8c | 88.2c | 70.1d |
| 100% N | 2.9d | 3.4d | 3.5e | 92.5c | 86.4c | 60.4e |
| 100%NPK+FYM | 3.3b | 4.4b | 4.8b | 120.0a | 105.3b | 123.1a |
| Control | 1.6e | 2.5e | 1.1f | 37.3d | 46.8d | 16.1f |

### 3.2 Different Forms of K after 42 years of cropping, fertilization and manuring

Water soluble K, being a readily available source of soil K, may be subjected to change either under cropping or external K supply in the form of inorganic K fertilizer and FYM. The form of K is in dynamic equilibrium with exchangeable K and whatever change induced by crop removal of K is compensated by the release of exchangeable K into solution. Under different nutrient-management treatments, the concentration of water soluble-K in the surface soil ranged from 7.6 mg $kg^{-1}$ to 12.8

mg $kg^{-1}$. In sub-surface soil, the water soluble-K was numerically lower than in the surface soil and it ranged from 3.8 mg $kg^{-1}$ to 6.5 mg $kg^{-1}$. This could be attributed to release of labile K from organic residues, application of K containing fertilizers and upward translocation of K from lower soil depths with capillary rise of groundwater (Ranganathan and Satyanarayan, 1980). The water soluble K in the fertilized (NPK) plots were significantly higher than those of the unfertilized control plots in both the depths and there was increase in the water soluble K under the FYM amended plots over the 100% NPK treated plots in both the depths. Though the water soluble K decreased with soil depth, the 100% NPK+FYM resulted in highest water soluble K, even in 15-30 cm soil layer over all other treatments. The highest water soluble K content was observed under 100% NPK+FYM which might be due to the favourable influence of FYM in soil properties (Kher and Minhas, 1991). The water soluble K in100% NPK+FYM and 150% NPK were at par in both the depths.

The exchangeable K content ranged from 49.5 mg $kg^{-1}$ to 92.7 mg $kg^{-1}$ in surface soil and 38.6 mg $kg^{-1}$ to 69.7 mg $kg^{-1}$ in sub-surface soil. The lowest exchangeable K concentration in surface soil was observed under 100% NP and highest in 100% NPK+FYM. This might be due to the fact that addition of FYM could increase the CEC of the soil, which can hold more exchangeable K and convert K from non exchangeable form to exchangeable form, consequent to mass action effect (Black 1968). Application of 150% NPK resulted in a significant increase in the exchangeable K content over control, N, NP, NPK, 50% NPK in both the depths. This effect can be attributed to movement of added K to exchange sites from the soil solution and to an increase in the K concentration in soil solution (Dhanrokar et al., 1994). The 150% NPK dose maintained the greatest content, which is significantly more than the 100% NPK treatment. The concentration of exchangeable K was numerically lower in sub surface soil as compared to surface soil in all the treatments, which may be due to comparatively more weathering, vegetation and supply of K from organic residues in surface layer than in lower depths (Sharma et al., 1994).

**Table 4**: *Distribution of different forms of soil K after 42 years of cropping with jute-rice-wheat* (Means with the same lower case letter are not significantly different in a column in same depth.)

| | **Water soluble** | **Exchangeable** | **Non exchangeable** | **Available** |
|---|---|---|---|---|
| **0-15 cm** | **(mg kg$^{-1}$)** | | | **(Kg ha$^{-1}$)** |
| 50%NPK | 9.2c | 69.5c | 901d | 176c |
| 100%NPK | 10.0b | 84.5b | 1003c | 212b |
| 150%NPK | 12.6a | 91.0a | 1168a | 232a |
| 100% NP | 8.7d | 49.5e | 704f | 131d |
| 100% N | 8.3e | 52.2de | 764e | 135d |
| 100% NPK + FYM | 12.8a | 92.7a | 1055b | 236a |
| Control | 7.6f | 55.0d | 881d | 139d |

| | | | | |
|---|---|---|---|---|
| **15-30** | | | | |
| 50%NPK | 4.7d | 51.0c | 1004c | 125d |
| 100%NPK | 5.7c | 55.9b | 1103b | 138c |
| 150%NPK | 6.5a | 67.7a | 1188a | 163b |
| 100% NP | 4.2e | 38.6e | 745d | 96f |
| 100% N | 4.0f | 40.5e | 796d | 99f |
| 100% NPK + FYM | 6.4b | 69.7a | 1113b | 170a |
| Control | 3.9g | 46.0d | 981c | 114e |

Non exchangeable K content varied from 704 mg $kg^{-1}$ to 1168 mg $kg^{-1}$ in surface soil and 745 mg $kg^{-1}$ to 1188 mg $kg^{-1}$ in sub-surface soil. The 150% NPK resulted in significantly greater non exchangeable K over all other treatments. Continuous application of increasing levels of potassic fertilizer maintained the content of non exchangeable K at higher level. The non-exchangeable K content was lower in 100% NPK+FYM treated plots than 100% NPK because of higher K uptake and accumulation of organic matter. The greater depletion of non-exchangeable K in presence of organic matter could be that in the100% NPK+FYM treatment, due to accumulation of organic matter, there would be a shift in CEC sites towards divalent selectivity (Salmon, 1964), which would decrease percentage K saturation of CEC, resulting in the shift of equilibrium of non exchangeable K to exchangeable K in favour of the latter, thereby releasing more non-exchangeable K.

**Table 5**: Effect of different treatments on available K after 42 years

| **Treatments** | **Available K** | **Changes from Initial** | **Decrease** |
|---|---|---|---|
| | | **kg $ha^{-1}$** | **kg $ha^{-1}yr^{-1}$** |
| 50%NPK | 176 | 33 | 0.79 |
| 100%NPK | 212 | 69 | 1.64 |
| 150%NPK | 232 | 89 | 2.12 |
| 100% NP | 131 | -12 | -0.29 |
| 100% N | 135 | -8 | -0.19 |
| 100% NPK + FYM | 236 | 93 | 2.21 |
| Control | 139 | -4 | -0.10 |
| Initial value (1971) | 143 | | |

The data presented in Table 4 and 5 indicated that after the harvest of the 42^nd^ wheat crop, the maximum soil available K (236 kg $ha^{-1}$) was reported in NPK+FYM. Findley (1973) reported that K levels in the sandy loam soils testing low to high in available K declined where no K fertilizer was added. The increase in available K content of soil with the application of recommended dose of NPK in addition to organic manure may be explained by mineralization of organic sources and solubilization from native sources during the decomposition. The soil available K in 150% NPK was statistically at par with NPK+FYM treatment in 0-15 cm and was significantly greater than other treatments. The available K content of soil in control did not much differ from 100%NP and 100%N and a slight reduction from the initial level in available K status of about nearly 2.6% to 8.9% was observed in these treatments. Further, data suggest that with increasing NPK dose from sub-optimal to superoptimal levels, the soil available K showed an increasing trend. The soil available K in lower depth (15-30 cm) exhibited lower values as compared to the surface layer and it varied from 96 to 170 kg $ha^{-1}$. Many experiments have shown that both chemical ferilizer and manure application (Vig and Bhumbla, 1970; Walia et al., 2010), residue management (Sharma et al. 2000) increase the soil available K content in the soil.

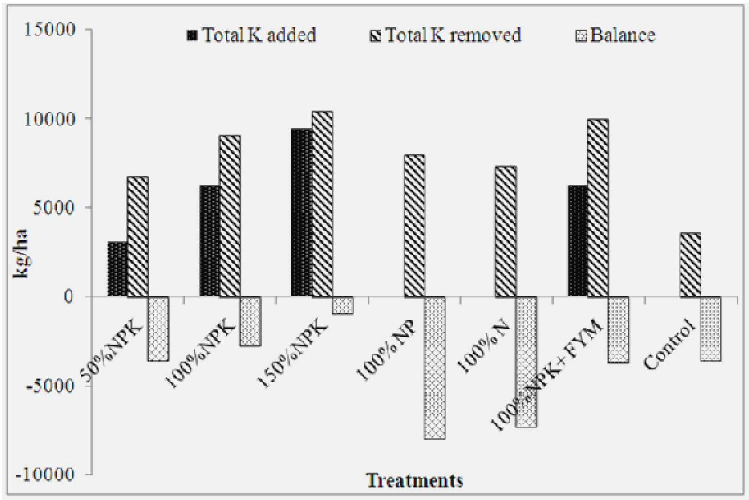
**3.3. Relationship between K forms in soil and crop yield**

After wheat, water-soluble K in surface soil correlated significantly and positively with exchangeable K (r=0.89**). Significant and positive correlations between water-soluble K and exchangeable-K forms indicate the faster rate of equilibrium between these forms. Similar inter relationships have been reported by Dan *et al.*, 2004 and Lakaria *et al*., 2012). Non-exchangeable K in surface soil significantly and positively correlated with water-soluble K (r=0.80**). Similarly, exchangeable K also correlated with non-exchangeable K (r=0.68**). Significant correlation between different forms indicates the existence of dynamic equilibrium among different fractions. Therefore, it can be concluded that each fraction of potassium influences another directly or indirectly and hence all the forms are important in one way or other.

**3.4. Soil apparent K balance after 42 years of jute-rice-wheat cropping**

Analysis of results for last 42 years showed that the mean annual removal of K by crops surpassed the amount of total K applied to the soils in all treatments (Fig1), thus showing a net negative balance. The negative apparent K balances under different fertilizer and manure treatments in the long-term experiments is also attributed to labile K either leached from the plough layer or being fixed in the mineral lattice/ interlayer. Among K amended treatments the application of 100% NPK + FYM to soils resulted in a greater negative K balance. Low accumulation despite large amount of K dressings in K treated plots is attributable to its large removal by the crop during 42 cycles.

However, higher accumulation of available K was noted in 100% NPK + FYM than that in 100% NPK. The similar beneficial effects of FYM along with NPK have been reported by Benbi and Biswas (1999) in a maize-wheat-cowpea sequence. There was a slight increase in available K in K treated plots which was due to a shift in the equilibrium from the non-exchangeable to the exchangeable and solution forms. The application of 100% NP to soils resulted in a greater negative K balance than that from the unfertilized control. This was due to the higher K uptake in the NP treated pots compared with the plots under control. Comparison between 50% NPK, 100% NPK and 100% NP treatment revealed that balanced and optimal fertilization reduced the negative K balance resulting in more accumulation of K as compared to unbalanced treatment.




# K in FYM could not be accounted

**Fig. 1**: Apparent K balance under different treatments for the last 42 years.

## 4. Conclusion

Findings indicate that depleting K reserves even at its optimal application rates point towards rethinking at the existing recommendation for all the crops to compensate for gradual loss of native soil K. This suggested the need of adequate supply of K to crops for obtaining sustainable high yields.

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