Potassium Management in Rice based Cropping Systems in Orissa

D.Jena and K.K.Rout

Department of, Soil Science and Agricultural Chemistry,
Orissa University of Agriculture and Technology, Bhubaneswar, Orissa, India

Introduction

Potassium (K) is considered next to nitrogen (N) as regards its role in rice production (Bao, 1985) and rice usually takes up more K than N. Before 60's its application was not felt necessary, as a general lack of response to applied K was reported in experiments conducted in India (Sethi *et al.*,1952). With the introduction of high yielding varieties during late 60's there was heavy withdrawal of nutrients from the soil and during 70's there was response to the extent of only 2-5% (Randhawa and Tandon, 1982). Despite large uptake some soils with low available (NH_4OAc extractable) K did not even respond to K application (Goswami and Banerjee, 1978). However, with progress of cropping the magnitude of response increased (Singh and Singh, 1978).In most of the cropping systems practised in India, potassium(K) balance is negative and this negative balance is often not reflected in available soil K (Water soluble + exchangeable) status over years of cropping. Long term fertiliser experiments are very useful to understand K dynamics in soil and its availability to crops which depend upon type of soil, climatic conditions and cropping pattern. An ideal and a practical approach to the assessment and management of K in agriculture may consist of obtaining a good understanding of the K status of a soil for knowing its K supplying power and consequent development of sound K management practices.

Findings of Long Term Experiments conducted in Orissa

Two long term fertility experiments (LTFE), one under irrigated rice-rice system in the central farm of Orissa University of Agriculture and Technology, Bhubaneswar and the other under rain fed rice-oilseed/pulse system at Regional Research Technology Transfer Station, Keonjhar in Orissa representing two different agro-climatic regions of the state were used for the study. The LTFE at Bhubaneswar started in 1971-72 and continued up to 1992-93 on a lateritic soil (*Aeric Haplaquepts*) with sandy surface layer and clay loam to clay bottom layer with pHw 5.6, OC 0.27%, available P (Olsen's) 31 kg/ha and available K (NH_4OAc) 25 kg/ha. The second experiment started in 1988 at Keonjhar on a well drained mixed red and black soil (*Vertic Haplaquepts*) with pHw 7.3, OC 0.23%, available (mineralisable) N 202 kg/ha, available (Olsen's) P 26.8 kg/ha and available (NH_4OAc) K 144 kg/ha.

The treatments at both the sites comprised of 100% N, 100% NP, 100% NPK (with or without FYM/S/Zn), 50% NPK, 150% NPK, NPK based on soil test and an absolute control. The per hectare 100% level of N, P_2O_5 and K_2O was 100-60-60 for both the rice crops at Bhubaneswar and 80-40-40 for the rice crop, 40-20-20 for mustard and 20-40-20 for field pea crop at Keonjhar where rice-mustard cropping system was changed to rice – field pea after two years.

Changes in Soil Available K(NH_4OAc Extractable)

A. Rice-Rice Sequence

At Bhubaneswar where a double crop of rice was grown continuously there was a sharp increase in the available K in the first 10 years of cropping followed by a rapid fall between 1980 and 1983 and almost plateauing afterwards except the FYM supplemented treatment that recorded an upward trend (Fig.1a). The treatment that received higher level of N and P (100%)

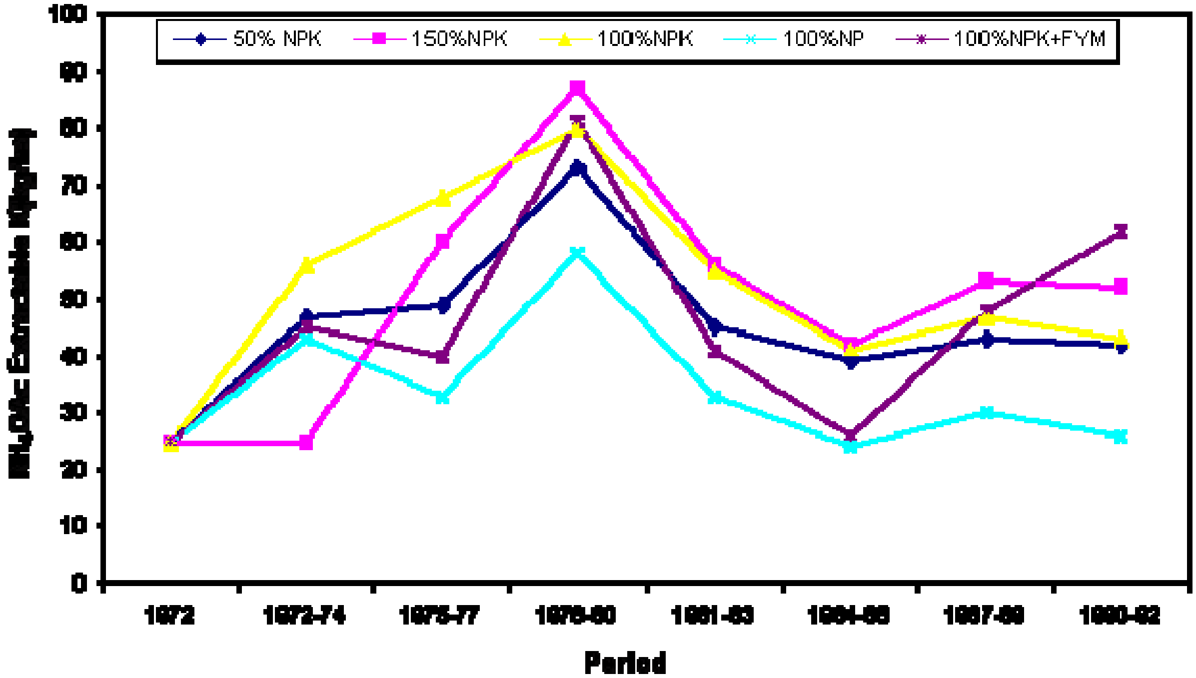


Fig.1a. Variation in NH4OAc Extractable (available) K status of soil (3 years average) under long term manuring at Bhubaneswar centre

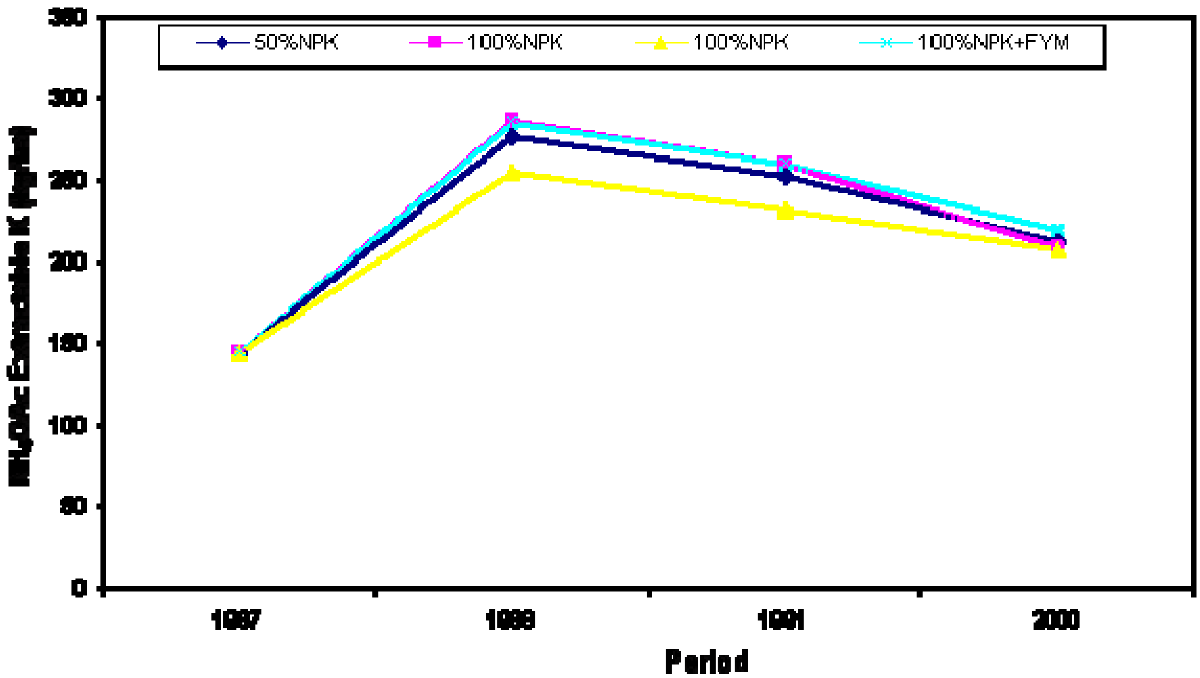


Fig.1b. Variation in NH4OAc Extractable (available) K status of soil under long term manuring at Keonjhar centre

but no K always recorded lowest NH_4OAc-K followed by 50% NPK (30 kg K_2O/ha). On the other hand the treatment that received 150% NPK (90kg K_2O/ha) maintained highest level of K followed by 100% NPK (60 kg K_2O/ha). After 20 years of cropping the per hectare NH_4OAc-K in the surface varied between 40 and 67 kg in treatments applied with K as compared to the initial status of 25 kg/ha at the start of the experiment. The increase in the NH_4OAc-K level might be due to increase in the organic matter content (% OC from 0.27 to 0.58) and clay content of the surface soil (5.2 to 9.1%) with increase in CEC (2.26 to 3.21 Cmol/kg)(Senapati, 1993). This was possible because of puddling with soil turning plough and recycling of more crop residues and its slow decomposition under prolonged wet condition.

B. Rice-Oilseed/Pulse Sequence

At Keonjhar where the soil was different (mixed red and black with neutral to alkaline pH) and cropping system rice-mustard/field pea, the surface NH_4OAc-K level was higher. The results depicted in Fig.1b shows that there was a sudden spurt in the release of available K increasing the level to almost 100% more than the initial (144 kg/ha) on the very first year of cropping under rainfed condition. After that there was a gradual drop of about 25 to 75 kg/ha within first 10 years of cropping (1988 – 2000). Unlike the LTFE at Bhubaneswar the variations due to treatments were not significant at Keonjhar(Rout et al.,2004). The sudden increase might be mostly due to bringing the uncultivated barren land under cultivation and increase in organic matter content (0.23 to 0.55% OC). Moreover, the build up in the surface layer might have been at the expense of the K released from the lower layers and non exchangeable fraction of K (Ganeshmurthy, 1983).

Changes in 1N HNO_3-extracteable (reserve)-K

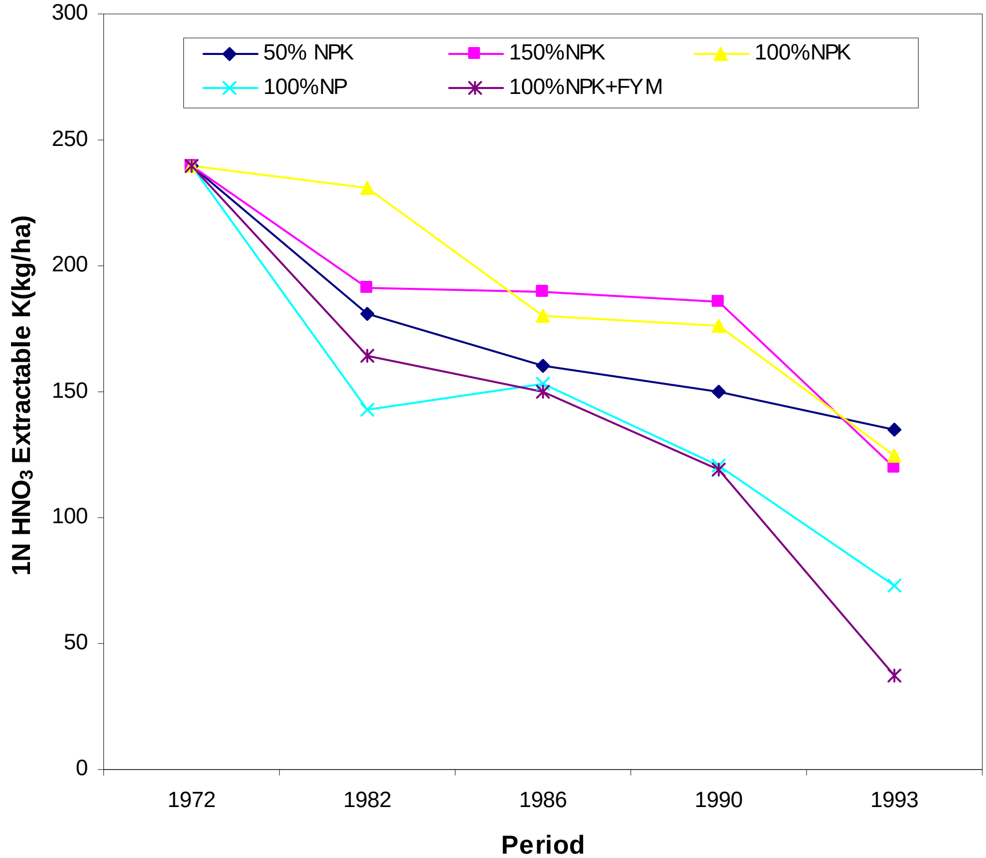
A. Rice-Rice Sequence

At Bhubaneswar in contrast to the increase in NH_4OAc-K, the reserve (1N HNO_3 extractable)-K in the surface layer decreased gradually over the years and at 20 years it reached almost 50% of the initial level particularly in treatments that received K every year(Fig. 2). Maximum decrease occurred in treatments that continuously received 100% N and P but no K followed by the treatment that received FYM along with N, P and K. The decrease in the latter might be due to relatively much higher cumulative uptake of K in FYM amended treatment in acid soil cropped to rice. The observed variation among the treatments was mostly related to the K-balance (applied - uptake). A balance sheet prepared on the cumulative uptake *Vs* K application over 20 years of intensive rice cropping (Tab.1) shows a negative balance in almost all the treatements. Application of 100% N and P without K resulted in a large annual negative K balance of about 90 kg/ha followed by the treatment that received only 50% K with 55 kg/ha. Multiple correlation studies revealed that, both NH_4OAc and 1N HNO_3 extractable K in soil in various treatments were significantly correlated to the K balance indicating a strong influence of K application and uptake on the extractable K status of the surface soil.

Table 1. Mean annual K balance over 20 years (1972 - 1992) of cropping at Bhubaneswar

Treatments	Mean annual K application (kg/ha)	Mean annual K uptake (kg/ha)	Mean annual K balance (kg/ha)
100% NP	0	90	-90
100% NPK	100	137	-37
100% NPK + FYM	120	167	-47
150% NPK	150	157	-7
50% NPK	50	106	-55

Fig.2. Variation in 1N HNO_3 Extractable K over the years at Bhubaneswar



B. Rice-Oilseed/Pulse Sequence

At Keonjhar a single year data on 1N HNO_3-K after 10 years of cropping presented in Table 3 also showed a general decrease in all the treatments. One most striking observation was that unlike the LTFE at Bhubaneswar, FYM was found to have a tremendous influence in building up and maintaining the reserve K status over years of cropping at Keonjhar despite much larger uptake than other treatments. This could be due to the neutral to alkaline soil reaction and type of dominant clay mineral present in Keonjhar soil.

Response of Crops to K application

A. Rice-Rice Sequence

At Bhubaneswar changes in response to K application over the years of cropping (Fig. 3) revealed that the first significant response to K in kharif was observed in 1976 – 77. However, it lacked consistency until 1982-83 in both kharif and rabi seasons. By and large, the magnitude of response was found to be higher in the wet season (kharif) than in the dry season (rabi). This might be due to the prevailing ill drained condition in the wet season resulting in varying degree of Fe toxicity. But during dry season the crop is grown under intermittent flooded and wet soil condition with controlled irrigation that helped in meeting the K requirement of the rice crop to some extent resulting in delayed response.

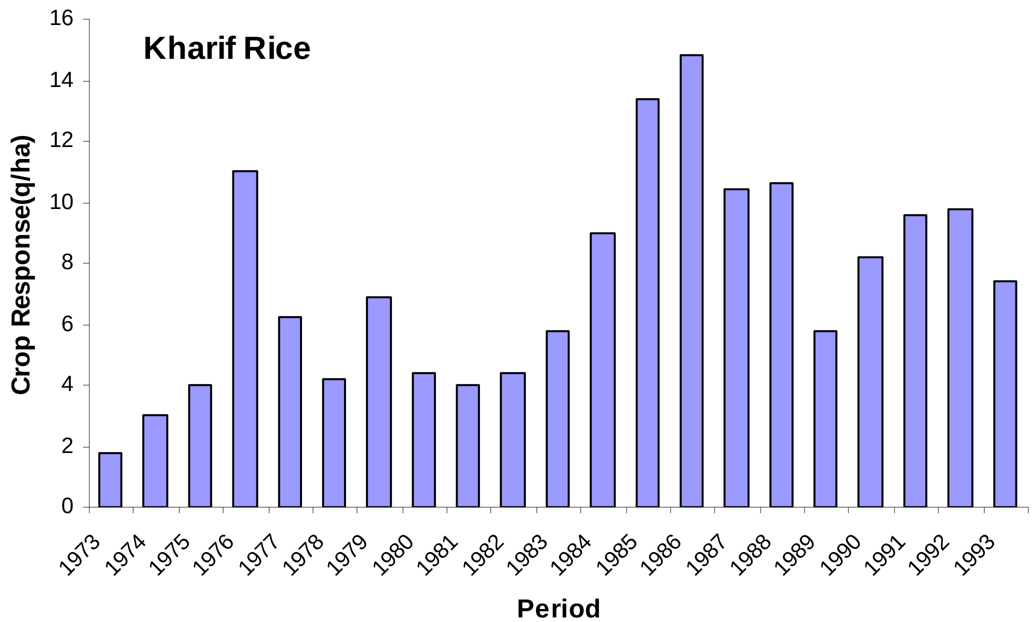


Fig.3a. Crop response to K application over years of manuring in rice at Bhubaneswar centre

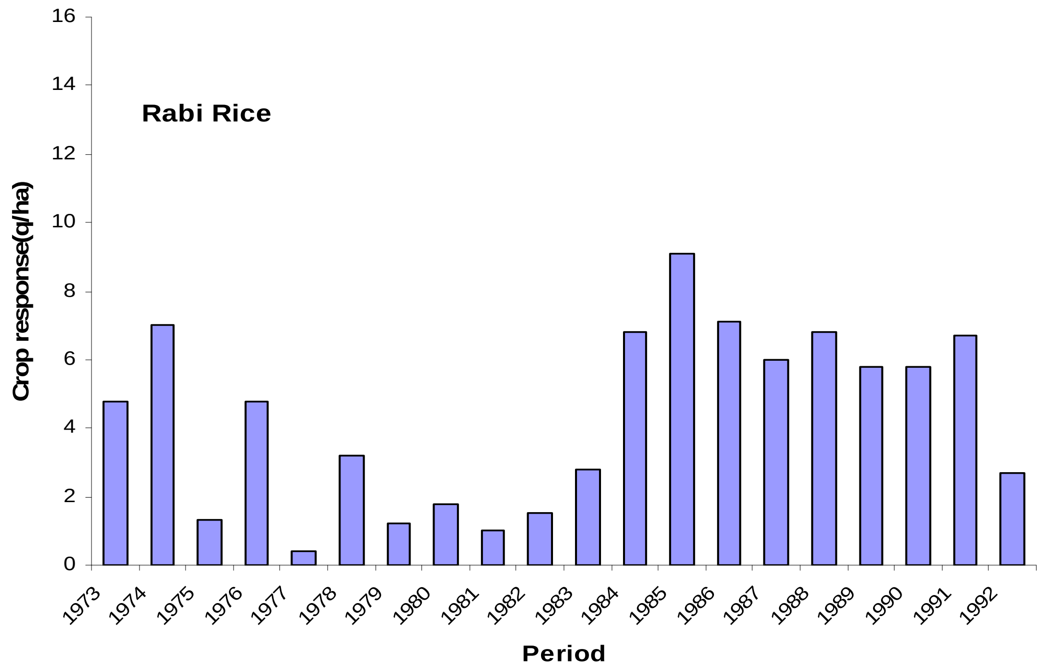


Fig.3b. Crop response to K application over years of manuring in rice at Bhubaneswar centre

B. Rice-Oilseed/Pulse Sequence

At Keonjhar the changes in response to K application over the years of cropping(Fig. 4) revealed that the responses in both the seasons were inconsistent. However, the response of wet season(Kharif) rice was relatively high as compared to the dry season (Rabi) crop. The lack of response even after 10 years of cropping might be due to very large reserve K.

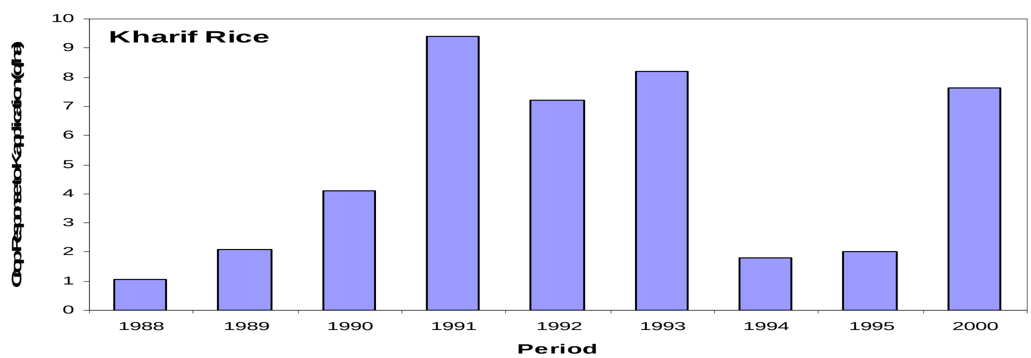


Fig.4a. **Crop response to K application over years of manuring at Keonjhar centre**

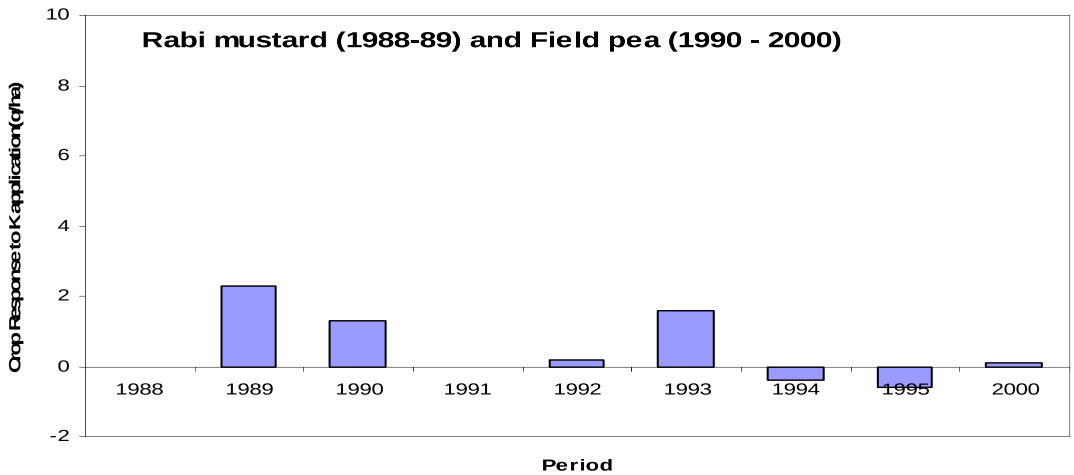


Fig.4b. **Crop response to K application over years of manuring at Keonjhar centre**

With the progress of cropping cycle particularly at Bhubaneswar, the magnitude of crop response increased indicating K to be a major yield limiting factor. In early years, despite large uptake lack of response to K application might be due to contribution from the non exchangeable and the mineral K and from the bottom layers.

Contribution of sub surface K to plant uptake

A. Rice-Rice Sequence

Results on status of NH_4OAc-K, 1N HNO_3-K and total K in different layers after 15 years of cropping at Bhubaneswar presented in Table 2 revealed that although NH_4OAc-K of the surface layer was higher than the initial value, the bottom layers measured a lower status. Similarly although there were marginal changes in the 1N extractable K of the surface layer, the bottom layer showed substantial decrease.

Table 2. NH_4OAc-K, 1N HNO_3-K and Total K in three layers at the end of 1987-88 cropping cycle at Bhubaneswar

Treatments	NH_4OAc-K (kg/ha)			1N HNO_3-K (kg/ha)			Total K (kg/ha)		
	0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm
100% NP	35	26	33	150	154	113	2800	2700	3100
100% NPK	45	35	56	230	195	200	3300	3000	3500
100% NPK + FYM	43	25	38	167	102	147	2600	2200	3000
150% NPK	55	35	60	243	201	227	3300	2600	3000
50% NPK	48	35	55	200	158	183	2700	3000	3900
Initial	25	44	71	240	233	313	3500	3200	4100

B. Rice-Oilseed/Pulse Sequence

At Keonjhar similar observations were also made with respect to NH_4OAc-K and 1N HNO_3-K after 10 years of cropping (Table 3).

Table 3. NH_4OAc-K and 1N HNO_3-K in three layers of soil at the end of kharif 2000 at Keonjhar

Treatments	NH_4OAc-K (kg/ha)			1N HNO_3-K (kg/ha)		
	0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm
100% NP	227	205	220	533	660	573
100% NPK	208	224	221	640	667	673
100% NPK + FYM	219	299	255	813	960	817
50%NPK	212	250	253	593	633	706
Initial	144	325	298	706	950	1098

These results clearly demonstrate that the bottom layers also contribute towards the crop uptake. Correlation studies made on the results of Bhubaneswar soil show that there are significant correlations between 1N HNO_3 extractable K of each layer with the K balance (r = 0.85**, 0.72* and 0.74** for the 1st, 2nd and 3rd layer respectively). A measure of total K in all the three layers also shows a substantial variation from the initial values. A drop in total K content at the end of 1987-88 at Bhubaneswar is many time larger than the decrease in NH_4OAc and 1N HNO_3-K. These results show that weatherable K bearing minerals in both surface and subsurface layers make a major contribution to plant uptake of K.

Management of Potassium

A. Rice-rice cropping Sequence

Above findings clearly suggest application of more amount of potassium in order to maintain the soil status of K. Potassium fixation studies have revealed that soils become more hungry for K fixation when the negative balance continues. Under such situation chance for getting response from recommended doses of K gets reduced.In order to avoid this situation the K application level either should be increased by 25-50% or the residues of rice which contain huge quantity of K(88-92% of total uptake) be recycled. In a recent study Prasad(2009) suggested that even burning of rice straw in field is better than removal from the field from the point of view of maintaining K, Ca and Mg fertility of rice fields if recycling is not possible within the available period.Potassium application should also be made liberally(80-120kg ha^{-1}) in soils which cause iron toxicity in rice in order to either avert or minimize this problem(Mitra eta al., 1990, 1993)

B. Rice-Oilseed/pulse Cropping Sequence

Findings of a long term trial on a relatively high K status soil of Keonjhar have shown a very small and inconsistent response from mustard within three years and fieldpea within 11 years of cropping. But experiments conducted else where in alluvial and laterite soils of the state with relatively low level of K have clearly demonstrated significant responses by important crops like groundnut and greengram.

Generally application of N, P_2O_5 and K_2O @20:40:40 kg ha^{-1} is recommended for groundnut in most of the soils of Orissa. Muriate of potash is the primary source of K applied to groundnut at the time of sowing. Mitra et al., (1993) reported that application of 40 kg K_2O ha^{-1} in addition to N-20 and P_2O_5-40kg ha^{-1} to summer groundnut grown on the lateritic soils of Bhubaneswar significantly increased yield from 10.60q ha^{-1} to15.88q ha^{-1}(C.D.$_{0.05}$:1.69).). Mitra et al.,(1993) conducted trials for three years in farmer's field on K-deficient lateritic soils of Balisahi series of Khurda district and observed that a significantly higher yield(22.75q ha^{-1},C.D,$_{0.05}$:2.16) of rabi ground nut over NP control (16.42q ha^{-1}) could be obtained only at 60 kg K_2O ha^{-1}.

Further studies conducted by Mitra etal.,(2001) on N-K interaction in alluvial soils for three years on the fields of farmers showed that at least 60 kg K_2O be applied to each of the crops in a rice-ground nut cropping sequence to prevent soil depletion of K and get significantly higher yield, shelling (%) and oil content of groundnut. Application of 20kg Nha^{-1} to ground nut in these soils adversely affected yield and N uptake (Table 4). Benefits of use of potassic fertilizers on pulses were also observed by Mitra and Sahoo(1993) in the K deficient Balisahi series, a lateritic soil located in the Khurda district of Orissa.(sandyloam,pH 4.9-5.8, OC 0.42-0.76%). Greengram was grown in f ields of 10 farmers for two seasons. There were significant increases in yield due to a pplication of 30kg K_2O $ha^{-}1$ (Table -5).

Table 4. Effect of nitrogen and potassium levels on pod yield, shelling %, oil Content of rabi groundnut (AV.3yrs.) and K-status of alluvial soils after three years on a rice-groundnut cropping sequence

Treatments $N:P_2O_5:K_2O$	Pod Yield(q/ha)	Shelling %	Oil Content(%)
$N_{20}P_{40}K_0$	16.2	62.0	40.8
$N_{20}P_{40}K_{40}$	18.31	65.4	42.7
$N_{20}P_{40}K_{60}$	20.19	67.1	44.5
$N_{20}P_{40}K_{80}$	20.48	67.7	45.5
$N_{20}P_{40}K_0$	16.59	63.3	51.0
$N_{20}P_{40}K_{40}$	18.85	64.9	43.2
$N_{20}P_{40}K_{60}$	20.93	68.0	45.5
$N_{20}P_{40}K_{80}$	21.31	68.3	46.2

Table 5. Effect of Potassium application on grain yield of green gram

Levels of K_2O (kg ha^{-1})	**Crop Yield(q/ha)**		
	1990-91	**1991-92**	**Mean**
Control(K_0)	3.66	2.26	2.96
K_{15}	3.94	2.46	3.20
K_{30}	4.63	2.66	3.64
CD $_{0.05}$	0.44	0.27	

Mitra and Sahoo(1998) conducted on farm trials on the alluvial soils of village Siula in the fields of 10 farmers (loamysand, pH 5.0-5.4, OC 0.33-0.62% and NH4OAc K 150-300kg ha^{-1}) on green gram during rabi 1992-93 on N-K interaction(Table 6).There were significant increases in yield of greengram due to application of 20 kg K_2O ha^{-1}, even without application of any N fertilizer.

Table 6. Effect of N-K interaction on grain yield of green gram

Treatments(N-P_2O_5-K_2O) (kg/ha^{-1})	**Grain yield(kg ha^{-1})**
20-40-0	333
20-40-20	483
20-40-30	433
20-40-40	492
0-40-0	342
0-40-20	567
0-40-30	538
0-40-40	454
CD $_{0.05}$: N-Level: NS; K-Level : 90 :NXK : NS	

Conclusion:

From the above discussion it may be concluded that NH_4OAc-K status of surface soil may not serve as a good index of K supplying capacity of soil. There may be lack of response to K application in initial years of cropping because of mobilization of K from reserve sources of both surface and subsurface layers. It is suggested that 1N HNO_3 extractable K should be used as good indices of K supplying power of soil under long years of cropping. The soil reserve K should not be allowed to be depleted to a great extent which may lead to fixation of the K applied in nominal doses without benefiting the crop(Sahoo etal 1998). Therefore, it is suggested that K should be applied to each crop as a soil maintenance dose even if there is no significant response in the early years of cropping.

References

Bao, L.(1985). effect and management of potassium fertilizer in wetland rice in China. *In*: Wetland soils: Characterization, classification and utilization. IRRI Publication. Los Banos, Philippines.pp.285-292.

Feigen baum, S., Edelstein, R. and Shainberg, I. (1981). Release rate of potassium and structural cations from micas to non exchangers in dilute solutions. *Soil Sci. Soc.Am.J.* 45 (3): 501-506.

Ganeshmurthy, A.N.(1983). An estimate of the uptake of the subsurface soil K of crops in two long term experiments. *J. Agric. Sci. Cambridge*, 101:495-497.

Goswamy, N.N. and Banerjee, N.K.(1978). Phosphorous, potassium and other macro elements. ***In***: Soils and rice. IRRI Publication. Los Banos, Philippines.pp.561-568

Hanway, J.J and Heidel, H.(1952). soil analysis methods as used in Iowa State College, Soil Testing Laboratory, *Iowa State College Bull*. 57: 1-131.

Haylock, O.P.(1956). a method for estimating the availability of non exchangeable-K. *6th International Congress, Soil Sciences*, Paris, Part B, pp.403-408.

Jackson, M.L.1958. Soil chemical analysis.Prentice Hall Inc. New Jersey.

Mc Clean, A.I.(1961).Potassium supplying power of some Canadian soil.*Canadian J.Soil.Sci.,*41:196-206.

Mitra, G.N.,Sahoo, D. Sahu, S.K. and Dev, G.(1993)Potassium –iron and potassium –sulphur interation in rice and rice based cropping system grown on lateritic soils. International symposium on decade of Potassium Research. Nov 18-22, 1993, PRII, New Delhi.

Mitra, GN. and Sahoo, D.(1998)Nitrogen –potassium interaction on yield and quality development for rice –legume sequence in Orissa.Final Report.IPI/PRII sponsored research project. Department of Agril. Chemistry, Soil science and Bio Chemistry.OUAT

Mitra , G.N., Sahoo, D. and Rout, K.K.(2001)Effect of N-K interaction on yield, nutrient uptake and grain quality of rice groundnut cropping sequence in the alluvial soils of Orissa. Journal of Potassium Research, 17(1):71-78.

Patiram, P and Rai, R.N. (19880. effect of liming on Q/I parameters of K in some acid soils. *J. Indian Soc.Soil Sci.*, 36: 402-406.

Patra, D.D. and Khera, M.S. (1983). Effect of long term fertilization with nitrogen and phosphorous on Q/I parameters of potassium of an Inceptisol under intensive cropping system. *J.Indian Soc.Soil Sci.*, 31: 495-501.

Prasad, R.(2007). Primary and Secondary Nutrient uptake Pattern by Rice as a guide to Fertilizer application Practices. Indian Farming. June,2007:5-8.

Randhwa, N.S. and Tondon, H.L.S. (1982). Advances in soil fertility and fertilizer use research in India. *Fert.News,* 27: 11-26.

Rout, K.K.;Patanaik, M.R.; Majhi, P.; Behera, B.B.; Rout, B., Devi, S.; Malla, A and Das, N.(2004) Thirteen years of cropping with fertilization and manuring of a rainfed rice based production system in an Inceptisol of Keonjhar district: Effect on SoilQuality, Crop Productivity and Sustainability. Research Bulletin.NATP/RRPS-20.OUAT, Bhubaneswar.

Sahoo, D.;Rout,K.K.and Mishra, V.(1998). Effect of twentyfive years of fertilizer application on the productivity of rice-rice system. A.Swarup, D.Damodar Reddy and R.N. Prasad(eds.) Long Term Soil Fertility Management through IPNS. AICRP on LTFE.IISS, hopal.

Senapati, A.K. (1998). Long term effect of fertilizers on release pattern of K in a lateritic Inceptisol under rice-rice system.M.Sc.Thesis.OUAT, Bhubaneswar.

Sethi, R.L., Ramia, K and Abraham, T.P. (1952). Manuring rice in India. *ICAR Bull. 38.*

Singh, B.P. and Singh, B.N.(1987). Response to K application of rice in Iron rich valley soils.*Int. Rice. Res.Newsl.*, 12: 31-32.

Wood, L.K. and De Turk, E.E.(1940). the adsorption of potassium in soils in non exchangeable forms. *Soil Sci.Soc. Am. Proc.*, 5: 152-161.