International Symposium
on

Potassium Role and Benefits in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damages

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Site-specific K management in rice based cropping systems in India

S.K. Sanyal[1], M. S. Gill[2] & K. Majumdar[3]

1 Directorate of Research, Bidhan Chandra Krishi Viswavidyalaya, Kalyani, India
2 Punjab Agricultural University, Ludhiana, India
3 International Plant Nutrition Institute, India Programme, Gurgaon

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K USE SCENARIO IN INDIA

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Potassium: A Neglected Nutrient

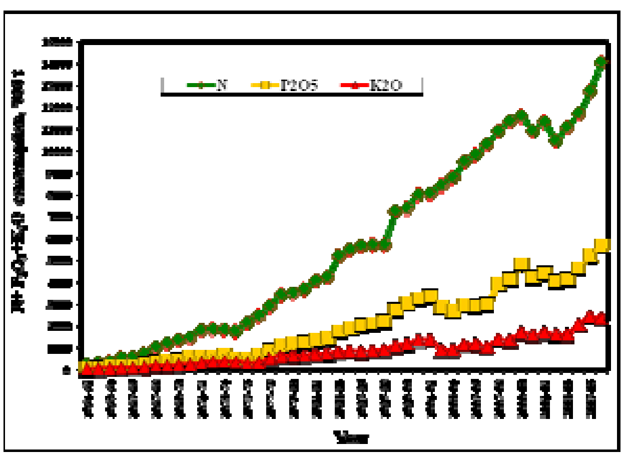
Crop sequence	Applied (kg ha[-1])			Total yield (t ha[-1])	Total uptake (kg ha[-1])		
	N	P	K		N	P	K
Maize-Wheat-Green gram	260	70	50	8.21	306	27	232
Rice-Wheat-Green gram	260	70	50	11.15	328	30	305
Maize-wheat	250	54	75	7.60	247	37	243
Rice-Wheat	250	44	84	8.80	235	40	280
Maize-Wheat	240	52	100	7.72	220	38	206
Pigeon pea-Wheat	144	52	100	4.82	219	31	168
P. Millet-Wheat-Green gram	245	66	66	10.02	278	42	284
P. Millet-Wheat-Cowpea (Fodder)	245	66	66	9.22 19.9 (F)	500	59	483
Soybean-Wheat	145	61	0	7.74	260	37	170
Maize-Wheat-Green gram	295	74	0	9.01	296	47	256
Maize-Indian-Rape-Wheat	330	69	0	8.63	250	41	200

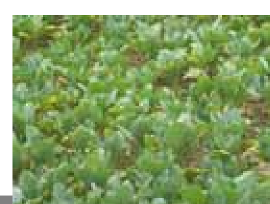
Of the current net negative NPK balance or annual depletion of 9.7 Mt, 19% is N, 12% P and 69% K

Nutrient	Gross balance sheet (000 t)			Net balance sheet (000 t)		
	Addition	Removal	Balance	Addition	Removal	Balance
N	10,923	9,613	1,310	5,461	7,690	-2,229
P_2O_5	4,188	3,702	486	1,466	2,961	-1,493
K_2O	1,454	11,657	-10,202	1,018	6,994	-5,976
Total	**16,565**	**24,971**	**-8,406**	**7,945**	**17,645**	**-9,701**

Source: Tandon (2004)

Potash contributed to less that 10% of the total nutrient consumption in the country





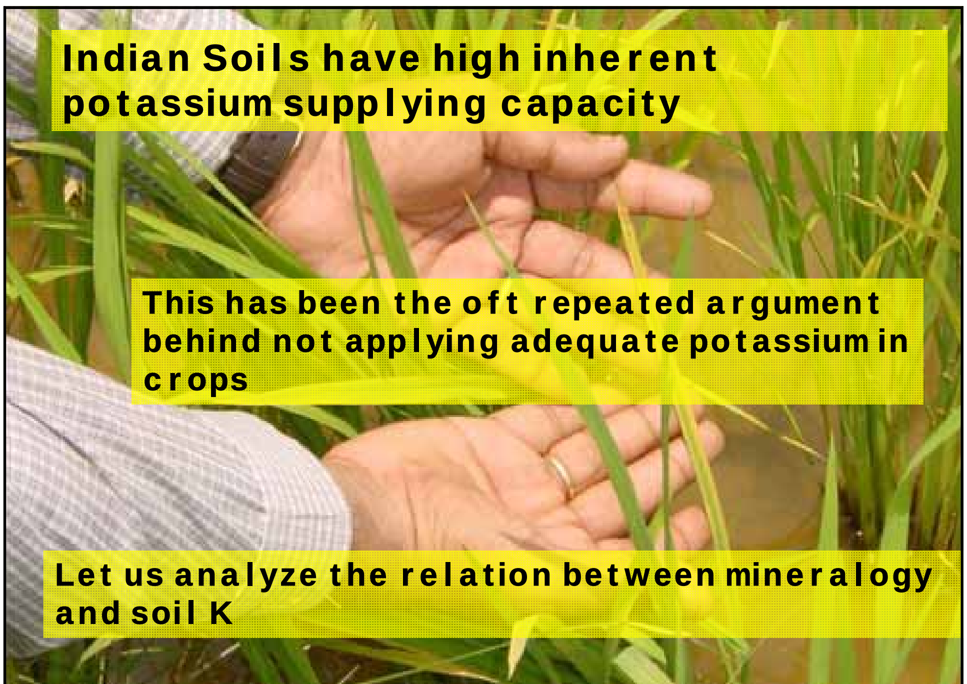
Potassium requirements of crops are in general identical to N and 3-5 times higher than P. However, the current consumption per unit of gross cropped area of N (75 kg/ha) and P_2O_5 (29 kg/ha) are 5 and 2 times that of K (14 kg/ha), respectively.

Inadequate application of potassium is evident in the vast Indo-Gangetic Plains of India

Sub region of IGP	Area (X 10^3 ha)	Nutrient use (kg/ha)					
		N		P		K	
		Rice	Wheat	Rice	Wheat	Rice	Wheat
Trans-Gangetic Plains	3809	166.1	154.2	51.3	49.6	0.8	12.3
Upper-Gangetic Plains	3160	115.0	109.8	40.7	37.6	5.2	11.4
Mid-Gangetic Plains	3133	116.1	100.0	29.1	32.7	4.3	20.5
Lower-Gangetic Plains	119	82.6	87.1	16.3	21.4	36.4	44.0

This has caused a gradual decrease of potassium from the soils in the Indo-Gangetic plains

Soil Series and Location	NH_4OAc-K (mg/kg)		HNO_3-K (mg/kg)	
	First sampling	After 10 years	First sampling	After 10 years
Nabha, Punjab	104±54	63±41	965±255	875±230
Akbarpur, UP	125±41	71±23	1448±203	1231±188
Rarha, UP	95±33	79±20	1531±353	1497±180
Hanrgram, WB	132±53	93±16	425±160	400±191
Kharbona, WB	42±17	29±16	119±34	109±26



Mineral Sources of Soil K

- **Mica: Dioctahedral, and Trioctahedral,**
  - **Trioctahedral micas (biotite) are more weatherable than Dioctahedral micas (muscovite).**

- **Feldspar: Sanidine, Orthoclase & Microline**
  - **Contributes to a much lesser extent of available K in soils than do micas.**

Mineral K ↔ Nonexchangeable K (NEK) ↔ Exchangeable K
↕
Soil Solution K

Plant Uptake | **Leaching** | **Refixation**

Soil K pool	Concentration in soils (ppm)
Mineral	5,000 – 25,000
Non-exchangeable	50 - 750
Exchangeable	40 - 600
Solution	1 - 10

Release of K from structural positions to the soil solution is a very slow process besides having several competitive processes working simultaneously; so there is no 1:1 congruence.

X-ray intensity ratio of the peak heights of 001 / 002 basal reflection in the silt and clay fractions of Indian soils

Benchmark Soil / Soil Series	Parent material	Size fractions	
		50-2 mm	<2 mm
Holambi (AS-SA) ** (Udic Ustochrept)	IGP*	2.14	2.63
Hissar (AS-SA) (Typic Ustochrept)	IGP	2.05	2.57
Totpara (AS-SH) (Aeric Fluvaquent)	IGP	2.27	2.73
Kanagarh (AS-SH) (Udic Ustochrept)	IGP	1.48	1.60
Dahotia (AS-PH) (Typic Haplaquept)	BA	1.47	1.10
Akahugaon (AS-PH) (Typic Haplaquept)	BA	1.70	1.04
Aroli (BS-SH) (Typic Chromustert)	DBA	1.80	1.05
Nimone (BS-SA) (Typic Chromustert)	DBA	1.90	1.00
Kasireddipalli (BS-SA) (Typic Pellustert)	DBA	1.56	1.04
Kheri (BS-SH) (Typic Chromustert)	DBA	1.87	1.01
Sarol (BS-SH) (Typic Chromustert)	DBA	1.50	1.04
Patancheru (FS-SA) (Udic Rhodustalf)	GG	1.77	1.80
Nalgonda (FS-SA) (Udic Rhodustalf)	GG	2.00	1.87
Dyavapatna (FS-SA (Udic Rhodustalf)	GG	2.25	2.16

** IGP=Indo-Gangetic alluvium; DBA-Deccan basalt alluvium; GG=Granite-gneiss*
*** AS-SA = Alluvial soil of semi-arid climate; AS-SH =Alluvial soil of sub-humid climate; AS-PH = Alluvial soil of per-humid climate; BS-SH = Black soil of sub-humid climate; BS-SA = Black soil of semi-arid climate; FS-SA = Ferruginous soil of semi-arid climate.*
Source: Division of Soil Resource Studies, NBSS&LUP, Nagpur, M.P., India

Nature of Soil Micas

- X-ray diffraction intensity ratio of 001 and 002 basal reflection (10Å) of mica > 1.0 suggests the presence of both muscovitic and biotitic minerals.
- This ratio ≈ 1.0 suggests the presence of only muscovitic minerals.
- Based on these criteria, silt fractions of alluvial soils of IGP and Brahmaputra alluvium (BA), ferruginous and black soils, as well as the clay fraction of soils of IGP and ferruginous soils contain both muscovite and biotite (001/002 basal reflection ration > 1.0).

- However, the clay fraction of soils of BA and black soils are more muscovitic in character (001/002 basal reflection ratio ≈1.0).
- This is evidenced by the reduced rate of K release from black soils and soils of BA compared to much higher rate of K release from soils of IGP and ferruginous soils under K stress (e.g., repeated batch type of Ba-K exchange).

Rate of release of K from the K bearing minerals in soil is a much slower process than the rate of K uptake by plants, especially at the vital plant growth stages. The former may fall short of adequate supply at the right time to meet the crop need.

The native K status depends, not only on the parent material of soil, but also on the subsequent stages of weathering of the parent material

Distribution of Different Clays and Forms of K in Two Soils of West Bengal

Soil properties		**Kalyani (an Entisol)**	**Anandapur (an Alfisol)**
Illite (Hydrous mica)	**(%)**	**38.0**	**38.8**
Smectite	(%)	28.0	-
Kaolinite	(%)	11.0	61.2
Chlorite	(%)	6.00	-
Vermiculite	(%)	17.0	-
Nonexchangeable K (NEK)	**cmol $(p^+)kg^{-1}$**	**6.02**	**0.57**
Total K	**cmol $(p^+)kg^{-1}$**	**52.2**	**29.0**

Source: Ghosh & Sanyal (2006)

Thus the basic consideration of not recommending adequate rates of K for crops, while tapping such supply from the native mineral sources, may *not* hold good in the current intensive agricultural scenario.

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Data on Soil Test for K

Source: Hasan (2002)

Soil K Status	Low	Medium	High
Total districts	76 (21)#	190 (51)	105 (28)

 # Values in parenthesis are percent samples under each category

- A comparison with data presented earlier (1980) suggests that the low and the high categories have decreased by 0.6% and 6.4%, respectively, while the medium category increased by 7%.

There is a dire need of consolidating data and developing a new potassium availability map for Indian soils as the latest map available is 7 years old.

The scenario might have changed as we see higher extent of K deficiency and greater response to potash application across soils and crops in the country.

POTASSIUM VARIABILITY

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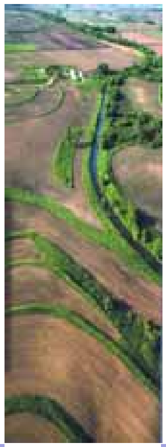
Plant nutrient content of agricultural soils vary spatially due to variation in:

- ✓ **Genesis**
- ✓ **Topography**
- ✓ **Cropping History**
- ✓ **Fertilization History**
- ✓ **Resource availability etc.**



Our interest in K variability comes from the understanding that there could be an advantage in managing K in a spatially variable way rather than in a generalized way.

In small holding systems, each farm family operates small pieces of land with different management styles so **variability is high over short distances**

Potassium Requirement of Different Crops

Soil	Location	Crop	Variety	K requirement (kg q^{-1})
Acid Alfisol	Kangra (H.P.)	Rice	Norin-18	2.96
Black soil	Jabalpur (M.P.)	Rice	IRB, Patel-85, Ratna	3.80
Black soil	Guntur, Andhra Pradesh	Rice	Mashuri	2.58
New alluvial soil	Kalyani, West Bengal	Rice	IET-4094	1.95
Calcareous soil	Bihar	Rice		2.21
Acid Alfisol	Kangra (H.P.)	Wheat	S-308	1.66
Alluvial	IARI, New Delhi	Wheat		2.83
Typic Chromuserts	Rahuri, Maharashtra	Wheat	HD-2189	2.25
Black soil	Jabalpur	Wheat		3.79
Calcareous soil	Bihar	Wheat	RR-21	1.63
Acid Alfisol	Kangra (H.P.)	Maize	Early composite	1.64
Chalka soil	Jagitial, Andhra Pradesh	Maize	DHM-105	1.55

Source: Subba Rao & Srivastava (2001)

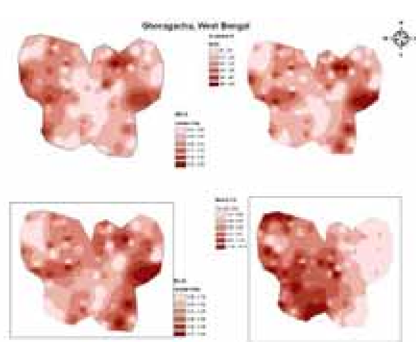
- Potassium requirement for rice varied over about 20 kg/t.
- This variation is unlikely to be due to only varietal difference.
- Potassium supplying capacity of soils (mineralogy) seems to play a role.
- The present trend of applying K at a certain pre-determined rate/ratio needs to be examined rationally.

Soils behave differently to K demand under intensive cropping:

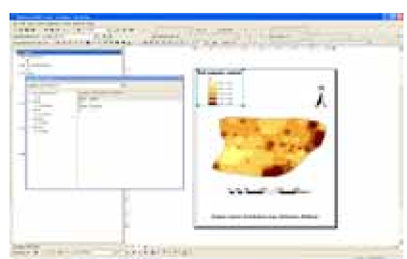
Mean exchangeable K (mg / kg) in different soils of West Bengal, initially (I_0) and after each successive cropping with maize

Location and soil type	I_0	Successive crops					Difference between I_0 and minimal exchangeable K level
		1st	2nd	3rd	4th	5th	
Gangetic alluvium							
Hariharpara	100	90.0	70.0	45.0*	45.0	45.0	55.0
Daulatabad	130	105	85.0	55.0	55.0	55.0	75.0
Chinsura	95.0	60.0	40.0	40.0	40.0	40.0	55.0
Memari	130	85.0	55.0	35.0	35.0	35.0	95.0
Coastal saline							
Canning	350	265	185	115	85.0	85.0	265
Acidic alluvium							
Birpara	30.0	25.0	25.0	25.0	25.0	25.0	5.00
Talipara	40.0	33.0	30.0	30.0	30.0	30.0	10.0
Vindhyan alluvium							
Deshra	100	75.0	50.0	20.0	20.0	20.0	80.0
Garbeta	50.0	42.0	30.0	30.0	30.0	30.0	20.0

Source: Tarafdar & Mukhopadhyay (1989)



GIS-based K fertility mapping allowed us to assess variability and the impact of inadequate potassium application in intensive cropping systems



Variability of available potassium (kg/ha) among farmers' plots within villages in West Bengal

Location	Maximum	Minimum	Mean	Standard Deviation	CV (%)
Ghoragacha, Nadia, West Bengal	640	96	283	109	39
Sripurdanga, Murshidabad, West Bengal	448	87	254	93	37
Bahadurpur, Birbhum, West Bengal	150	96	110	9	8
Meherpur, Birbhum, West Bengal	494	24	168	113	68
Barhu Simatoli, Ranchi, Jharkhand	356	61	142	71	50

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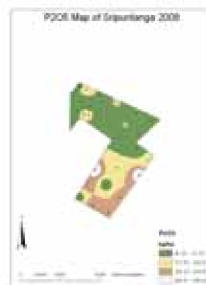
Mapping Fertility Trends can highlight the vulnerability of soils under intensive cropping

Potassium



Phosphorus

Source: Sen *et al.* (2008)

SITE-SPECIFIC K MANAGEMENT

Site Specific Nutrient Management

- **Definition**

  Site-specific nutrient management (SSNM) is the dynamic, field-specific management of nutrients in a particular cropping season to optimize the supply and demand of nutrients according to their differences in cycling through soil-plant systems (Dobermann and White, 1999)

- **This concept of SSNM attempts to account for**
  - **Regional and seasonal differences in the climatic yield potential and crop nutrient demand**
  - **Between field spatial variability in indigenous nutrient supply**
  - **Field-specific within-season dynamics of crop nutrient demand**
  - **Location-specific cropping systems and crop management practices**

Economically optimum potassium rates in rice-wheat and rice-rice systems (mean of two years)

Location	Optimum rates (kg K_2O/ha)			Location	Optimum rates (kg K_2O/ha)		
	Rice	Wheat	System		Rice	Rice	System
Sabour	75	76	153	Maruteru	93	94	188
Palampur	76	103	182	Jorhat	89	92	176
R. S. Pura	94	104	196	Navsari	72	106	186
Ranchi	82	91	179	Karjat	94	95	165
Ludhiana	102	84	188	Coimbatore	34	45	72
Faizabad	80	60	143	Thanjavur	86	82	178
Kanpur	89	66	153				
Modipuram	87	88	177				
Varanasi	85	104	171				
Pantnagar	76	77	148				

Source: Tiwari *et al.* (2006)

On-farm response to nutrient in rice based cropping systems

Cropping system	Response (kg rice grain equivalent/ kg nutrient)			Economic response (Rs./Rs. invested on nutrient)		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Rice-rice	12.0	14.6	16.2	9.9	5.1	10.6
Rice-wheat	10.1	15.9	14.0	8.4	5.7	9.4
Rice-groundnut	14.3	22.8	24.6	11.8	8.1	17.6
Rice-chickpea	14.0	11.7	11.7	11.4	4.1	8.3
Rice-mustard	10.8	19.5	17.3	8.4	6.4	5.0
Rice-tomato	19.5	20.2	51.0	10.3	5.1	24.9

Source: Gill *et al.* (2009)

CHANGES IN ECONOMIC RETURNS WHILE SHIFTING FROM FARMER NUTRIENT MANAGEMENT TO SSNM IN RICE-WHEAT CROPPING SYSTEM

Location	Extra cost of fertilizer (Rs/ha)	Value of extra produce (Rs/ha)	Net return (Rs/ha)	AEK Rice	AEK Wheat
Sabour	4700	53850	49150	12.2	7.5
Palampur	4730	26230	21500	12.4	13.3
Ranchi	5080	41760	36680	16.8	5.7
R. S. Pura	5120	32460	27340	10.9	8.9
Ludhiana	3970	16690	12720	7.3	2.5
Faizabad	6380	50000	43620	8.8	9.0
Kanpur	5700	35760	30060	10.8	5.5
Modipuram	1480	48190	46710	27.1	11.7
Varanasi	4310	19270	14960	10.3	8.7
Mean over location	5070	36010	30940	12.9	8.1

Source: Singh *et al.* (2008)

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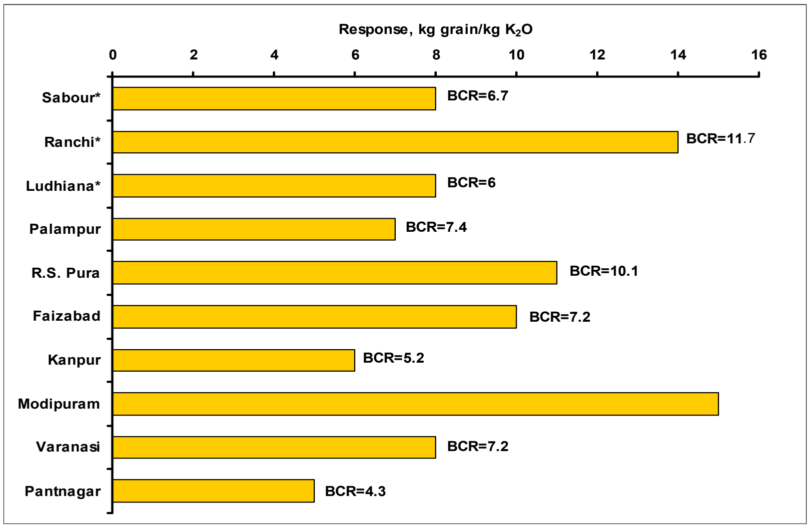
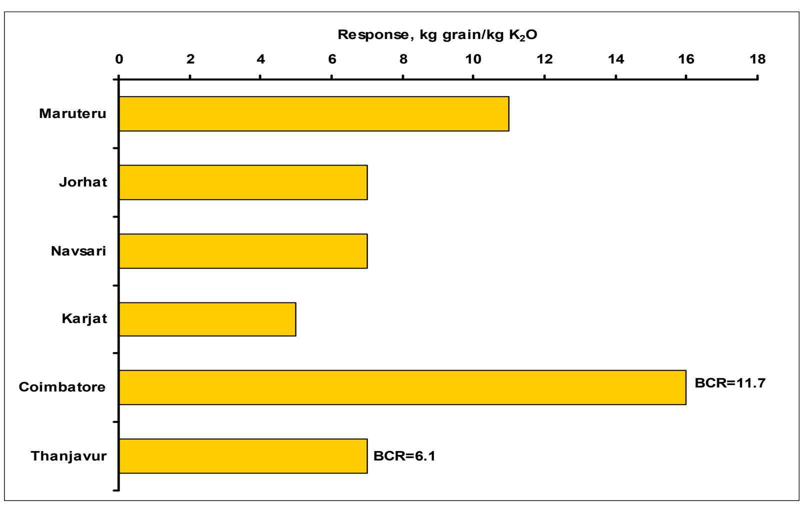
Response ratio to applied K in rice - wheat cropping system (Mean of 2 years)



Response ratio to applied K in rice - rice cropping system (Mean of 2 years)



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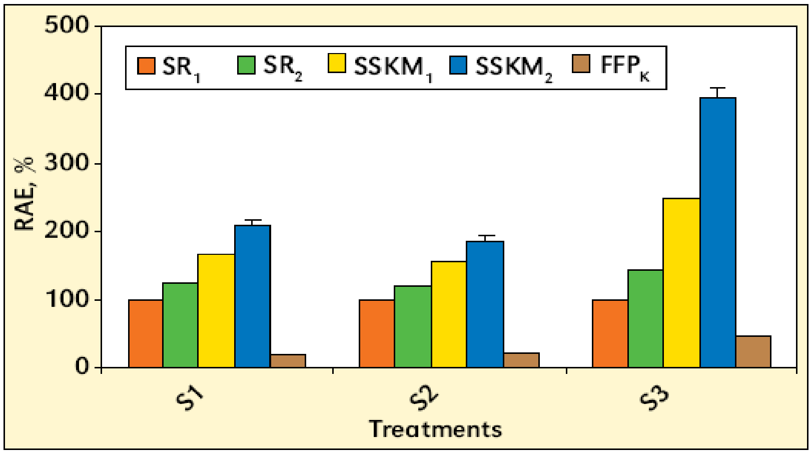
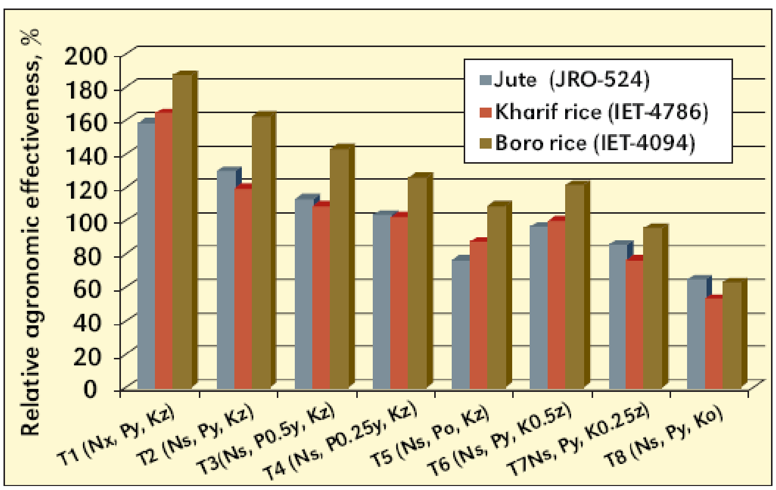


Relative Agronomic Efficiency (RAE) of treatments imposed on rice as influenced by different rates of fertilization in farmers' plots (S1, S2, S3) in West Bengal

Source: Chatterjee & Sanyal (2007)

In SSKM treatments, N and P were applied based on the soil testing, while K was applied by computing a factor with respect to available & NEK pools of soil K for maintaining the balance between K mining and a productivity target.



Relative Agronomic Efficiency (%) of different levels of P and K fertilization in Jute and Rice at Kalyani, West Bengal, India

Source: Ghosh *et al.* (2008)

CONCLUSIONS

- 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 supply, and this essential nutrient remains neglected as in the past, future sustainability in agriculture is likely to be constrained mostly by this nutrient.
- Regions supporting high intensive cropping sequences are anticipated to be the earliest victim of such imbalance.
- Continuous cropping with only N and P and no / inadequate K application would cause depletion of NEK reserve which will go largely unnoticed by the conventional soil test for K.
- Considering that K fertilizers are imported, and the possible NEK depletion under our present farming practices, judicious site specific K management strategy has indeed the potential to address the concerns pointed out.
- In future, we will have to recognize spatial variability of nutrients among farmers fields and tailor recommendations accordingly to improve productivity.

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