Effect of K on N use efficiency- India scenario

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Nitrogen use efficiency (NUE)

- **A complex term with several components**
- **Efficiency of conversion of fertilizer or soil N in to economic products**
- **Mostly measured as a ratio of output *i.e.* biological or economic yield and input *i.e.* N supply**

Agronomic efficiency = $(Y_T - Y_0)/ F_N$
Recovery efficiency = $(U_T - U_0)/ F_N$
Physiological efficiency = $(Y_T - Y_0)/ (U_T - U_0)$
Partial factor productivity = Y_T/ F_N

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Implications of low NUE

- Global RE_N estimates = 33%
- RE_N in cereals: 20-30% in rainfed and 30-40% in irrigated conditions
- Nitrous oxide from fertilized soils accounts for 2128 mt CO_2 equivalent *i.e.,* 30% of total agricultural GHG emission
- Increased potential for groundwater pollution
- High cost of production *i.e.*, low farm profits

Ways to improve N use efficiency

- Site-specific N management
- Continued improvement in cropping system management
- Choice of cultivars
- Conservation tillage
- Genetic tools
- N source/rate/application method
- Precision agriculture
- Fertilizer N scheduling
- Balanced fertilization
  - -Balanced K fertilization
  - -Large quantities of K removed by crop harvest
  - -When adequately replenished the returns are substantial

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K helps enhancing NUE

- **Rapid canopy expansion is a major determinant of growth and high yields.**
- **N is major nutrient responsible for leaf expansion by way of cell division and cell elongation.**
- **Higher the no. and volume of cells, greater is the amount of cell water in the vacuoles and so is the demand of solutes to maintain desired turgor pressures.**
- **Requirement of K (major osmotic solute in vacuolar water in the plant cell) increases.**
- **Adequate K supply is must for efficient utilization of N.**

The Need for Nutrient Balance

Balanced fertiliser use at the macro level in India has been equated with a consumption ratio of 4:2:1 (N:P2O5:K2O).

Unbalanced nutrient application is widespread in India, more so in the intensively-cultivated, irrigated areas such as the Indo-Gangetic plains which contribute a large share of the total food grain production, obviously by mining soil nutrient reserves.

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Fertilizer consumption (2007-08)

State	Fertilizer (kg/ha)	Consumption ratio		
		N	P_2O_5	K_2O
Punjab	210.0	34.3	9.1	1
Haryana	187.6	39.0	10.9	1
U.P.	149.6	15.1	4.5	1
Uttarakhand	118.9	11.2	2.4	1
Bihar	162.8	11.0	2.3	1
Jharkhand	68.5	9.2	4.7	1
W.B.	144.2	2.2	1.3	1
Rajasthan	45.5	33.7	12.5	1
Maharashtra	103.1	3.0	1.5	1
M.P.	66.4	10.5	5.7	1
India	113.4	5.5	2.1	1

Source: FAI (2007-08)

Unbalanced Nutrient use in IGPR

Example: Rice-wheat system

Regions	Fertilizer nutrient use (kg ha^{-1})				
	N	P_2O_5	K_2O	Zn	FYM*(t ha^{-1})
TGP (Punjab)	284	118	0	9.9	0.0
TGP (Haryana)	334	110	0	15	2.6
UGP	218	97	4	3.5	8.8
MGP	224	78	22	9.9	5.6
LGP	182	17	61	1.8	3.8
IGPR	237	73	22	7.4	4.7

***Farmer's apply FYM at 2-3 years interval.**

Sharma *et al.* (2004)

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Nutrient uptake in intensive cropping systems in India

Cropping System	Yield, t/ha	Nutrient uptake, kg/ha/year			
		N	P_2O_5	K_2O	Total
Rice-wheat	8.8	235	92	336	663
Maize-wheat	7.7	220	87	247	554
Pigeonpea-wheat	4.8	219	71	339	629
Rice-rice	6.3	139	88	211	438
Soybean-wheat	7.7	260	85	204	549
Maize-wheat-greengram	8.2	306	62	278	646
Rice-wheat-greengram	11.2	328	69	336	763
Maize-potato-wheat	8.6 + 11.9(t)*	268	96	358	722
Rice-wheat-cowpea	9.6 + 3.9(f)*	272	153	389	814
Rice-wheat-maize + cowpea	9.3 + 29(f)	305	123	306	734

*t and f represent tuber and fodder yield, respectively.

Nutrient uptake ratios in MEY plot under RWCS

Location	Nutrient uptake ratio (N=100)		% share of NPK in total uptake		
	P_2O_5	K_2O	N	P_2O_5	K_2O
Sabour	42	149	34	14	52
Palampur	40	138	36	14	50
R.S. Pura	53	163	32	17	51
Ranchi	33	125	39	13	48
Ludhiana	54	151	33	18	49
Faizabad	41	129	37	15	48
Kanpur	29	112	42	12	46
Modipuram	32	105	42	13	45
Varanasi	37	167	33	12	55
Pantanagar	29	111	42	12	46
Mean	38	132	38	14	48

Tiwari et al., 2006

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Nutrient uptake ratios in MEY plot under RRCS

Location	Nutrient uptake ratio (N=100)		% share of NPK in total uptake		
	P_2O_5	K_2O	N	P_2O_5	K_2O
Maruteru	38	118	39	15	46
Jorhat	46	153	33	15	52
Navsari	51	147	34	17	49
Karjat	41	140	35	15	50
Thanjavur	35	138	37	13	50
Coimbatore	37	112	40	15	45
Mean	41	135	36	15	49

Tiwari et al., 2006

Annual nutrient balance (000 t) in IGPR *nutrient mining ?*

Region	Nutrient balance (000 t)		
	N	P	K
Trans-Gangetic Plain	-118.5	-121.3	-827.4
Upper Gangetic Plain	-63.0	-91.2	-565.9
Middle Gangetic Plain	68.8	-46.8	-302.4
Lower Gangetic Plain	-2.9	-7.9	-26.9
IGPR (Total)	-115.7	-267.3	-1722.6

Sharma *et al*. (2004)

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Response to fertilizer K: Some facts

- Depends to a considerable extent on the supply of N
- Not so frequent in initial years of intensive cropping, more so in arid regions
- Responses appear with the exhaustion of accumulated reserves.
- K bearing minerals are not inexhaustible K source; rate of K release (non-exch K) declines with time.
- Excessive depletion of non-exch K results in greater K fixation.

On-farm response to nutrients under different cropping systems

Cropping system	Response (kg rice grain equivalent/kg nutrient)			Economic response (Rs./Re invested on nutrient)		
	N	P	K	N	P	K
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
Maize-wheat	7.7	15.1	18.4	5.9	5.0	12.3
Maize-Bengal gram	14.5	13.1	14.1	11.8	4.6	10.0
Tomato-rice	19.5	20.2	51.0	10.3	5.1	24.9
Average	15.2	14.7	13.1	11.5	4.8	8.1

AICRP-CS (2009)

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Agronomic efficiency (kg grain/kg nutrient) in LTFEs

Location & Crop	Nitrogen		Phosphorus		Potassium	
	1973-77	1992-96	1973-77	1992-96	1973-77	1992-96
Palampur						
Maize	14.6	-1.6	13.9	20.6	2.4	20.0
Wheat	4.3	-3.1	13.4	21.2	3.6	13.2
Ranchi						
Soybean	-10.4	-8.1	6.1	10.6	4.1	20.6
Wheat	-7.8	-1.4	29.9	38.2	1.0	15.9
Coimbatore						
Fingermillet	3.1	5.4	35.3	43.9	-11.4	13.4
Maize	1.7	-1.3	32.7	28.6	-1.3	14.5
Bhubaneswar						
Rice (Kharif)	6.7	2.6	-1.05	5.5	6.9	8.2
Rice Rabi)	11.2	3.2	1.8	14.1	2.7	5.5
Jabalpur						
Soybean	26.0	8.4	7.9	7.7	2.9	13.7
Wheat	7.0	0.5	20.2	41.1	8.4	6.0

LTFE Reports

NPK fertility status of Indian soils as evaluated on the basis of STL database

Nutrient	% Districts in different fertility classes		
	Low	Medium	High
Ramamoorthy & Bajaj (1969): 1.3 million samples from 184 to 226 districts			
Nitrogen	52	43	5
Phosphorus	47	49	4
Potash	20	53	27
Ghosh and Hasan (1976, 1979, 1980): 9.2 million samples from 310 to 365 districts			
Nitrogen	62	33	5
Phosphorus	46	52	2
Potash	20	42	38
Motsara (2002): 3.65 million samples from 450 districts			
Nitrogen	63	26	11
Phosphorus	42	38	20
Potash	13	37	50

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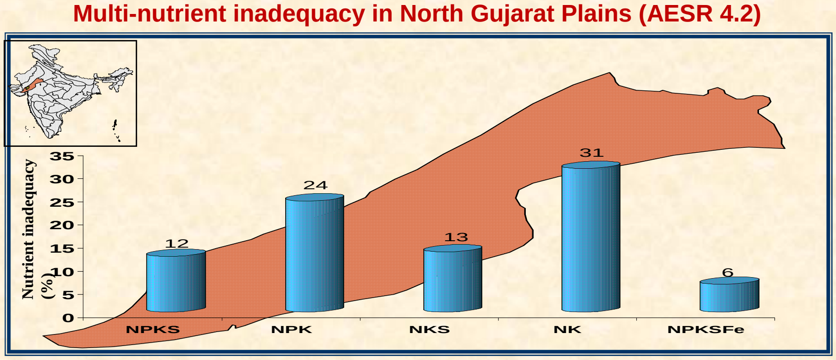
Wheat response to K (60 kg K_2O/ha) in on-farm trials on low, medium and high K soils

K Fertility rating	District	Trials (nos)	Response (kg/ha)
Low	6	749	245
Medium	22	2167	250
High	12	1834	192

AICRP-CS Reports

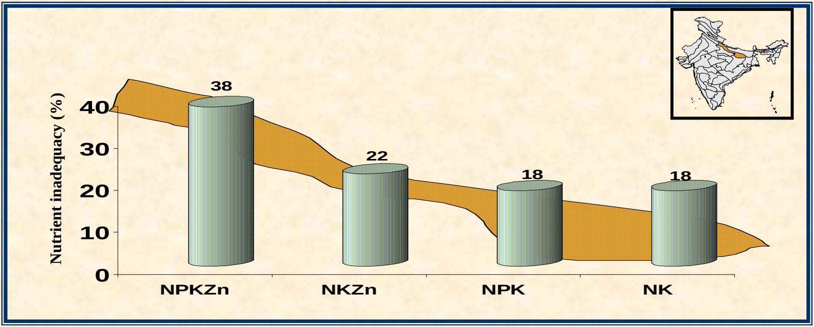
Multi-nutrient inadequacy in North Gujarat Plains (AESR 4.2)



- **Sampling site: Villages Lukhwad/Detrogpura/Virampura, Taluk Mehsana, District Mehsana (Gujarat)**
- **Major cropping systems: Pearlmillet-based, cotton-based, sesame-based system**
- **The soils are alkaline (average pH 9.0), but salinity problem is absent.**
- **Widespread deficiencies of N and K are noticed, as 99 and 90% samples, respectively exhibit potential inadequacy of N and K. 50 and 34% samples fall the P and S responsive category, respectively.**

Dwivedi et al., 2006

Multi-nutrient inadequacy in Rohilkhand, Awadh & South Bihar Plains (AESR 9.2)



- Sampling site: Village Malikpur, Taluk Sadar, District Faizabad (Uttar Pradesh)
- Major cropping system: Rice-wheat, Rice-vegetables
- Soils are neutral to mildly alkaline with an average pH of 8.1, and the EC is invariably <1.0 dS/m.
- All samples exhibit low to the medium status of organic C and available K, and thus categorised as responsive to N and K applications. More than half of the samples are also responsive to P or Zn.

Dwivedi et al., 2006

Percentage increase in production due to fertilizer use on farmers' fields in different group of crops (1999-2003)

Crop	No. of Trials	Control yield Kg/ha	Percentage increase over control			
			N	NP	NK	NPK
Cereals	2,991	1,823	48.1	76.1	67.0	98.0
Oilseeds	361	823	28.9	59.8	49.6	83.9
Pulses	42	586	33.4	99.2	58.1	117.0
Foodgrains	3,394	1,487	42.9	76.7	62.9	98.4

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NK interaction in rice and groundnut on an Inceptisol

K rates (kg/ha)	N rates (kg/ha)			N rates (kg/ha)		
	60	80	Mean	60	80	Mean
	Rice yield (t/ha)			G/nut Pod yield (t/ha)		
0	3.10	3.02	3.06	1.68	1.70	1.69
30	3.41	3.30	3.36	1.84	1.93	1.88
60	3.64	3.61	3.63	2.07	2.15	2.11
90	3.75	3.83	3.67	2.06	2.23	2.14
Mean	3.48	3.44	-	1.91	2.00	-
LSD at 5%	N= NS, K= 0.10, NxK= 0.12			N= 0.05, K=0.08, NxK=NS		

Mitra et al., 2001

NK interaction in *rabi* groundnut on an Inceptisol

K rates (kg/ha)	N rates (kg/ha)			N rates (kg/ha)		
	60	80	Mean	60	80	Mean
	Shelling (%)			Oil content (%)		
0	62.5	62.4	62.5	40.7	41.0	40.9
30	64.0	64.1	64.1	43.3	43.6	43.5
60	65.9	66.9	66.4	45.0	46.5	45.8
90	66.6	67.2	66.9	45.2	46.8	46.0
Mean	64.8	65.2	-	43.6	44.5	-
LSD at 5%	N= NS, K=0.6, NxK=NS			N= 0.4, K=NS, NxK=NS		

Mitra et al., 2001

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Effect of NK interaction in wheat and sorghum (f) yield

K rates (kg/ha)	N rates (kg/ha)			N rates (kg/ha)		
	0	120	Mean	0	80	Mean
	Wheat yield (t/ha)			Sorghum (f) yield (t/ha)		
0	1.42	1.52	1.47	5.27	5.24	5.25
50	1.89	2.12	1.98	5.48	6.72	6.10
Mean	1.63	1.82	-	5.37	5.98	-
LSD at 5%	N= 0.16, K =NS, NxK=NS			N= 0.42, K=NS, NxK=0.53		

Gundalia et al., 2001

Response of rice to added K at varying levels of N (6 years average)

Added N (kg/ha)	Grain yield (t/ha)		Response (kg/ha)	kg grain per kg K_2O
	Without K	With 50 kg K_2O		
100	4.14	4.38	244	4.9
150	4.41	4.84	433	5.7
200	4.14	5.15	1017	10.1

Tiwari et al., 1992

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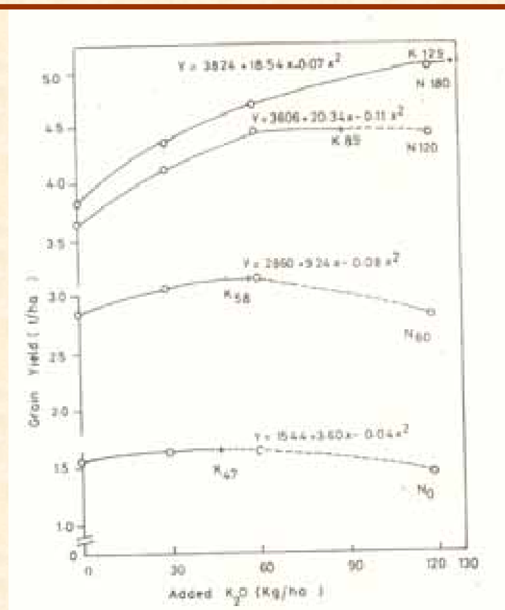

Effect of NK interactions on grain yield of wheat

Tiwari et al., 1992

K thresholds in rice leaf under varying N supply

N rates (mg N/kg soil)	Range of K (%) in top two leaves			
	Sufficient (0-10%)*	Slightly deficient (10-20%)	Moderately deficient (20-40%)	Extremely deficient (40%)
0	2.00-2.30	1.80-2.00	1.55-1.80	1.55
50	2.05- 2.35	1.90-2.05	1.65-1.90	1.65
100	2.15-2.50	1.95-2.15	1.71-1.95	1.71
200	2.20-2.75	1.95-2.20	1.83-1.95	1.83

*** Yield reduction**

Bansal et al., 1993

K in SSNM

Economically optimum rates of potassium application in the rice-wheat system

	Optimum rate, kg K_2O/ha		
Location	**Rice**	**Wheat**	**System**
Sabour	**74.6**	**77.5**	**152.5**
Palampur	**75.5**	**103.3**	**182.4**
R. S Pura	**94.2**	**104.4**	**195.7**
Ranchi	**81.8**	**90.9**	**179.1**
Ludhiana	**101.7**	**84.2**	**188.3**
Faizabad	**80.4**	**59.5**	**142.8**
Kanpur	**88.6**	**65.9**	**152.9**
Modipuram	**87.2**	**87.9**	**176.5**
Varanasi	**85.4**	**104.2**	**171**
Pantnagar	**76.4**	**77**	**147.5**

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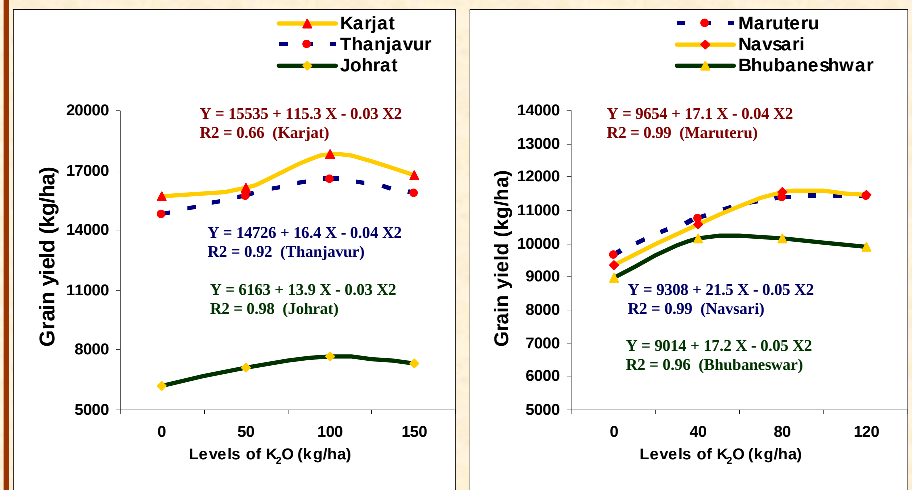

Response functions to applied K in rice-rice cropping system (Mean of 2 years)

Tiwari et al., 2006

The calculated optimum rate of potassium application in the rice-rice system

Location	Optimum rate, kg K_2O/ha		
	Kharif rice	*Rabi* rice	System
Maruteru	**93.3**	**93.8**	**187.5**
Jorhat	**89.0**	**91.7**	**175.8**
Navsari	**71.5**	**105.9**	**185.6**
Karjat	**93.6**	**95.0**	**165.0**
Coimbatore	**33.5**	**45.3**	**72.3**
Thanjavur	**85.6**	**81.9**	**177.9**

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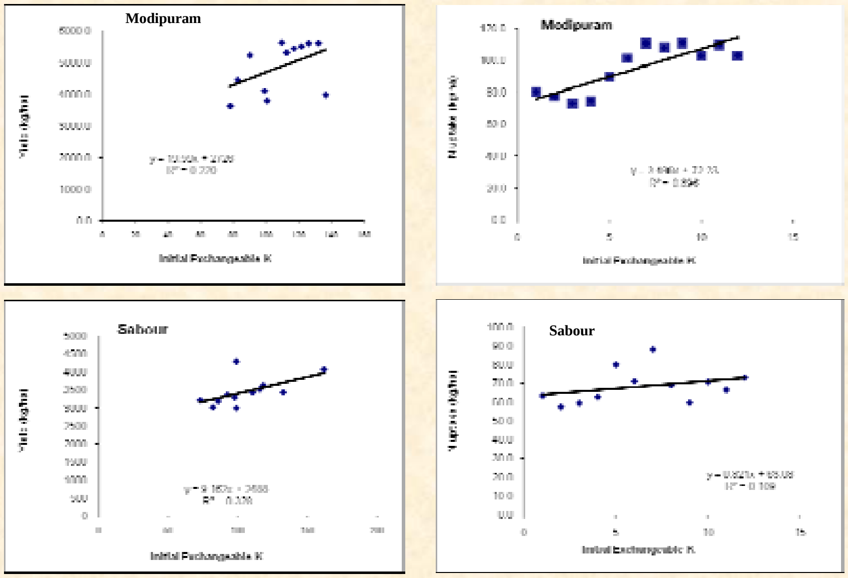
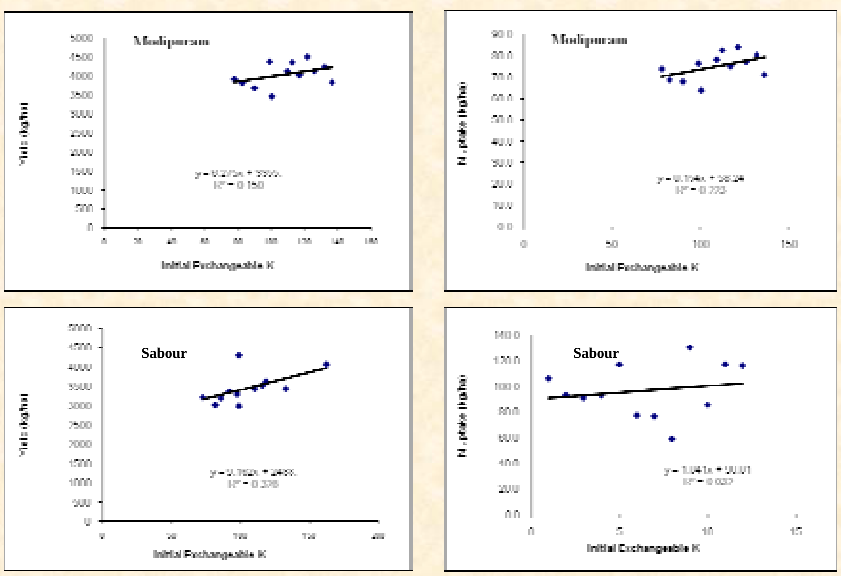


Relationship of initial exchangeable K with rice grain yield and total N uptake under FFP Singh et al., 2008



Relationship of initial exchangeable K with wheat grain yield and total N uptake under FFP Singh et al., 2008

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On-farm K use efficiency as influenced balanced nutrition

Treatment	Rice			Wheat		
	Grain yield (kg/ha)	HI	AE_K (kg/kg K)	Grain yield (kg/ha)	HI	AE_K (kg/kg K)
Modipuram (n=24)						
FFP	4857	0.42	-	4038	0.43	-
FFP+K	5729	0.44	13.95	4773	0.44	11.76
FFP+K+M	6117	0.44	20.16	5134	0.45	17.54
Sabour (n=24)						
FFP	3456	0.42	-	2279	0.42	-
FFP+K	4614	0.43	18.53	2985	0.43	11.30
FFP+K+M	4854	0.43	22.37	3348	0.44	17.10

Singh et al., 2008

N uptake as influenced balanced nutrition

Treatment	Rice			Wheat		
	N uptake (kg/ha)	% increase	N absorbed $unit^{-1}$ DM	N uptake (kg/ha)	% increase	N absorbed $unit^{-1}$ DM
Modipuram (n=24)						
FFP	95.0	-	8.30	75	-	8.01
FFP+K	110.4	16.2	8.37	89	18.7	8.29
FFP+K+M	117.7	23.9	8.46	96.1	28.1	8.49
Sabour (n=24)						
FFP	68.4	-	8.25	39.9	-	7.39
FFP+K	92.6	35.4	8.62	52.2	30.8	7.56
FFP+K+M	97.4	42.4	8.68	58.4	46.4	7.67

Singh et al., 2008

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Response (kg/kg of nutrient) in sugarcane as influenced by balanced fertilization

Treatment	N	P	K	S
N_{200}	307	-	-	-
N_{200} P_{100}	400	1816	-	-
N_{200} P_{100} K_{150}	461	2095	750	-
N_{200} P_{100} K_{150} S_{60}	505	2295	821	1683
N_{200} P_{100} K_{150} S_{60} Mg_{30}	553	2514	899	1848

Singh et al., 2008

Balanced fertilization improves NUE

(Rice, on-farm trials, Punjab)

Sites	AE_N(kg grain/kg N)			PFP_N (kg/ha)		
	FP	SSNM	Increase (%)	FP	SSNM	Increase (%)
1	9.27	18.3	97	36.7	51.2	40
2	8.31	16.4	97	31.9	45.4	42
3	9.69	13.3	37	49.2	50.0	2
4	13.0	16.4	26	42.3	43.6	3
5	8.32	17.1	106	29.0	40.0	38
6	7.56	17.9	137	23.1	35.7	55
All	8.79	16.1	83	34.7	44.2	27

Khurana et al., 2007

Grain yield of pearlmillet-wheat system under different nutrient supply options

Treatment	Grain yield (t/ha)		
	Pearlmillet	Wheat	PMEY*
SSNM	4.12	5.61	13.69
TY	3.65	4.88	11.97
TY+Micro	3.93	5.27	12.91
SR	3.10	4.03	9.97
SR+K	3.68	4.83	11.92
FFP+K	2.60	3.78	9.05
FFP	2.21	3.40	8.00

*Pearlmillet equivalent yield

Dwivedi et al., 2008

Crop performance under SSNM in on-farm experiments

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Grain yield of pearlmillet-mustard system under different nutrient supply options

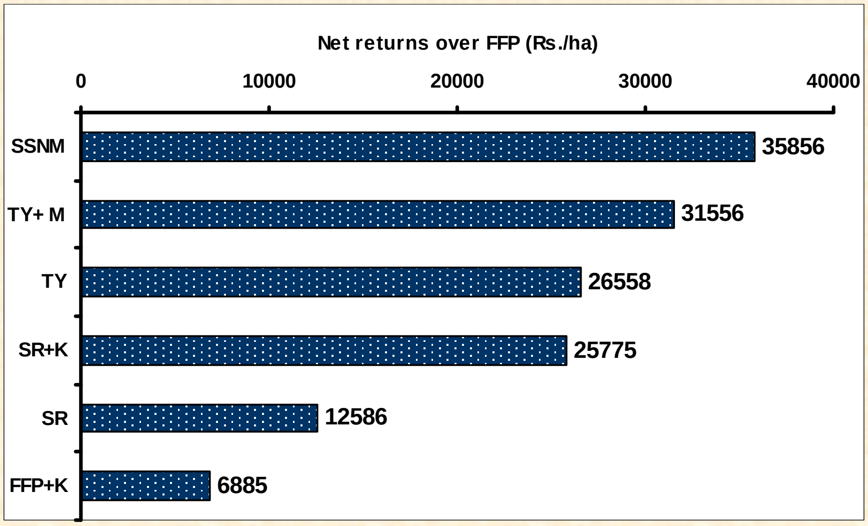
Treatment	Grain yield (t/ha)		
	Pearlmillet	Mustard	PMEY*
SSNM	4.05	2.88	12.83
TY	3.50	2.45	10.96
TY+Micro	3.83	2.76	12.23
SR	3.08	1.93	8.96
SR+K	3.52	2.18	10.17
FFP+K	2.73	1.71	7.94
FFP	2.36	1.56	7.12

*Pearlmillet equivalent yield

Dwivedi et al., 2008

This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

Net returns in pearlmillet-wheat system



Dwivedi et al., 2009

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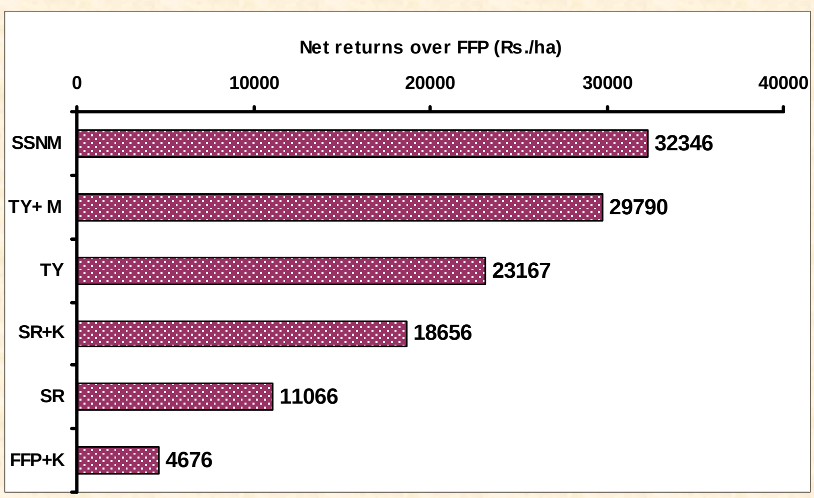
Net returns in pearlmillet-mustard system



Dwivedi et al., 2009

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Conclusions

- High annual productivity levels need high N dressings that lead to gradual K depletion even in high K soils.
- Fertilizer N application have to be necessarily balanced with K to achieve higher NUE.
- There is no worth of worrying for NUE if the soil is low in K or fertilizer input is unbalanced.
- Balanced fertilization does not mean a fixed $N:K_2O$ or $N:P_2O_5:K_2O$ rates; fertilizer K rates to be supplemented with N would vary according to crop K demand, soil K status and K supplying capacity of soil.

Future R&D thrust

- Studying K×N interaction beyond crop yields
- Developing micro-scale digitized soil fertility maps, preferably at block or village panchayat level, to help formulation of balanced fertilizer recommendations
- Enhancing farmers' awareness on inclusion of K in fertilizer schedule
- Greater understanding of SSNM
- Development and refinement of crop residue recycling technologies

Availability of K fertilizers!

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Thank you

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