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International K symposium
Bhubaneswar, India; 5-7 Nov. 2009

Implementing site-specific potassium management for rice-based cropping systems

Roland J. Buresh
International Rice Research Institute

Mirasol Pampolino and Christian Witt
International Plant Nutrition Institute, Southeast Asia Program

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.

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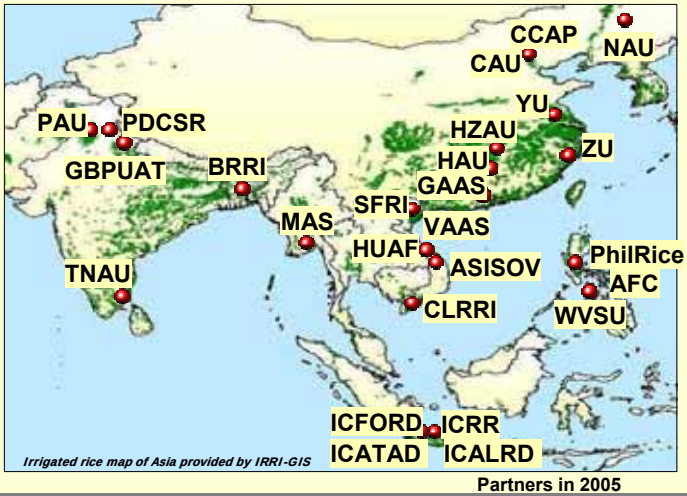
Site-specific nutrient management (SSNM) for rice was developed from 1997 through a partnership of IRRI



Partners in 2005

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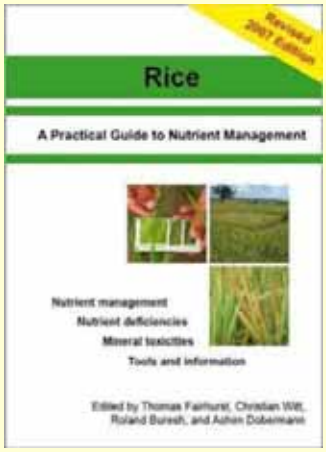
SSNM developed through IRRI provides science-based principles for field-specific management of N, P, and K fertilizer

The principles initially established for rice are now applicable for wheat and maize



Can be downloaded at this website:
http://tinyurl.com/6lp8zj

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What is the SSNM approach used by IRRI?

- **Scientific principles for providing field-specific management of fertilizer N, P, and K for cereals**

Fertilizer N management

- **Determine total need for fertilizer N from**
  - ***Estimated crop response to N and***
  - ***Agronomic efficiency of fertilizer N***
- **Split apply N to match critical crop growth stages**

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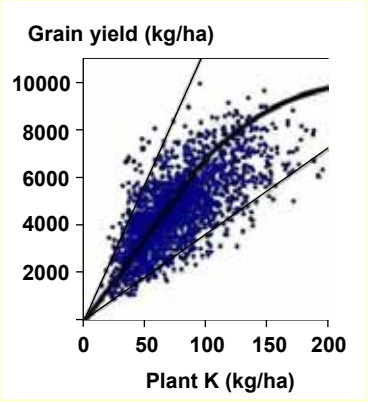
Fertilizer P and K management

- **Determine crop need for fertilizer P and K based on yield target and nutrient balance**

1. **Set an attainable yield target**
2. **Estimate P and K taken up by crop at targeted yield**
3. **Calculate P and K balances that consider non fertilizer inputs**
4. **Determine P and K rates based on maintenance (input = output**
5. **Adjust P and K rates for estimated crop response to the nutrient**



Reciprocal internal efficiency (RIE) = (kg nutrient per ton grain yield

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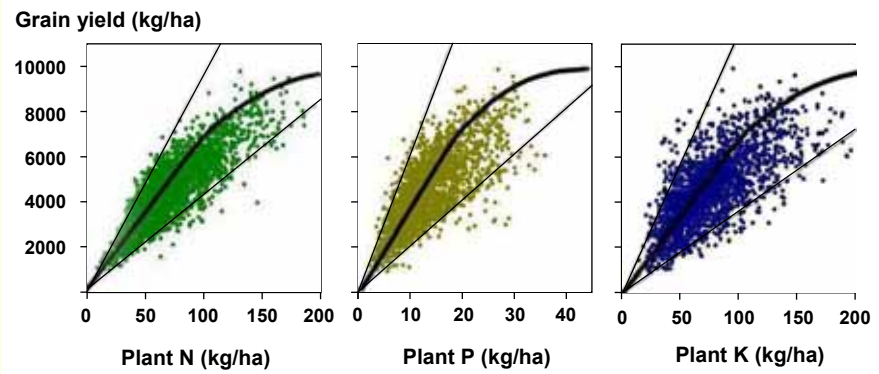
Contents

- **Examine the grain yield – nutrient uptake relationships used in SSNM for rice**
- **Highlight key factors influencing sustainable K management**
  - ***Continuous rice cropping***
  - ***Rice-wheat rotation***
  - ***Rice-maize rotation***
- **Evaluate options for determining fertilizer K rates with SSNM**

Relationship of grain yield and total plant nutrients for rice at maturity

(From Witt et al., 1999)

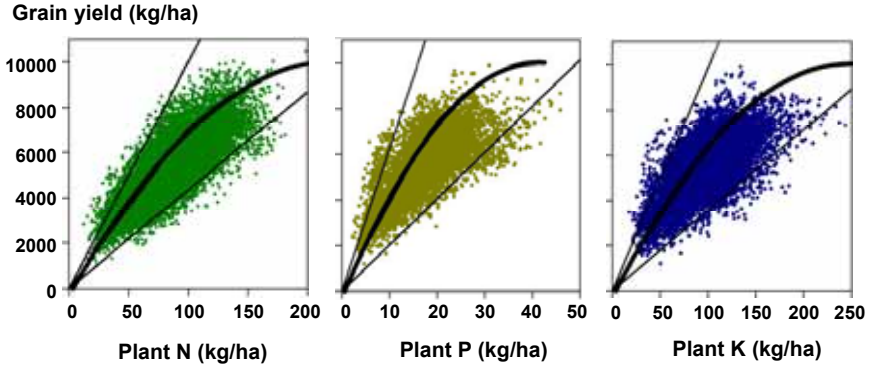


Number of observations N = 2,306
P = 2,118
K = 2,276

Harvest index: 0.4 – 0.66

Relationship of grain yield and total plant nutrients for rice at maturity

(Fitted lines are for the reported data)

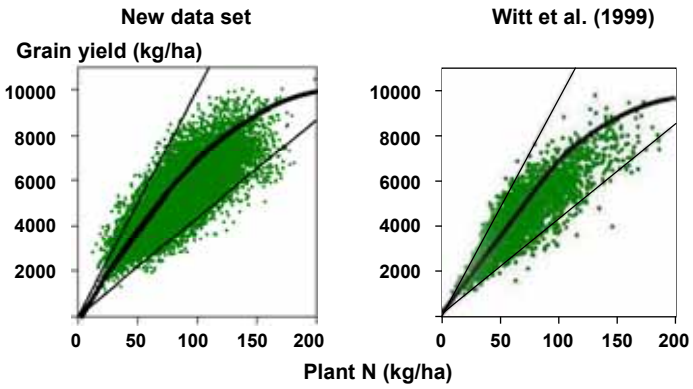


Number of observations N = 15,507
P = 8,948
K = 8,983

Harvest index: 0.4 – 0.65

Effect of data set on relationship of grain yield and total plant N for rice

(Best fit lines presented for each)

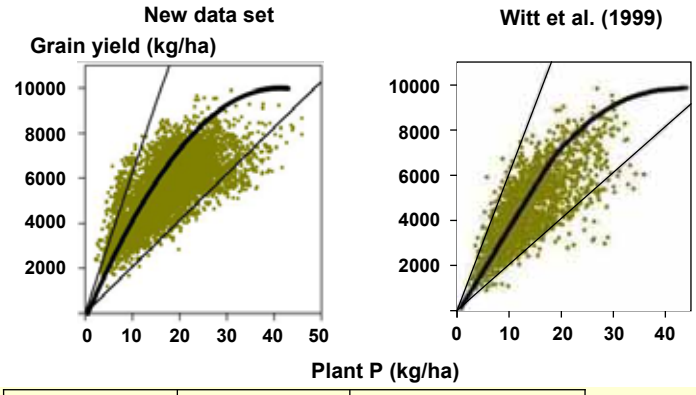


Data set	Observations	Median reciprocal IE (kg N / t grain)
Witt et al.	2,306	14.7
New data set	15,507	14.1

Harvest index: ≥ 0.4

Effect of data set on relationship of grain yield and total plant P for rice

(Best fit lines presented for each)

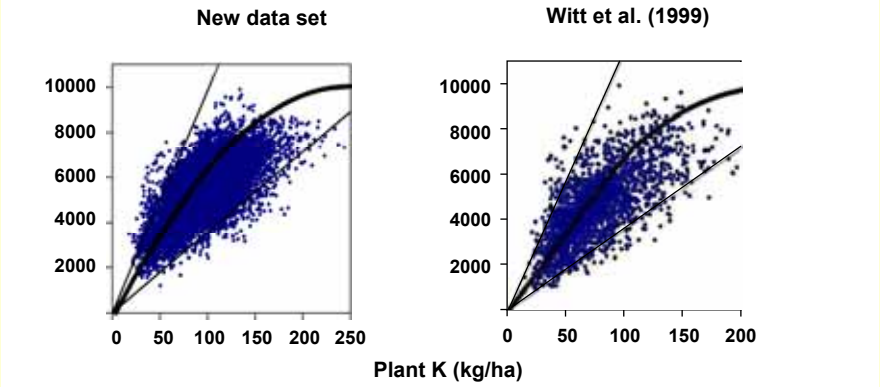


Data set	Observations	Median reciprocal IE (kg P / t grain)
Witt et al.	2,118	2.6
New data set	8,948	2.6

Harvest index: ≥ 0.4

Effect of data set on relationship of grain yield and total plant K for rice

(Best fit lines presented for each)

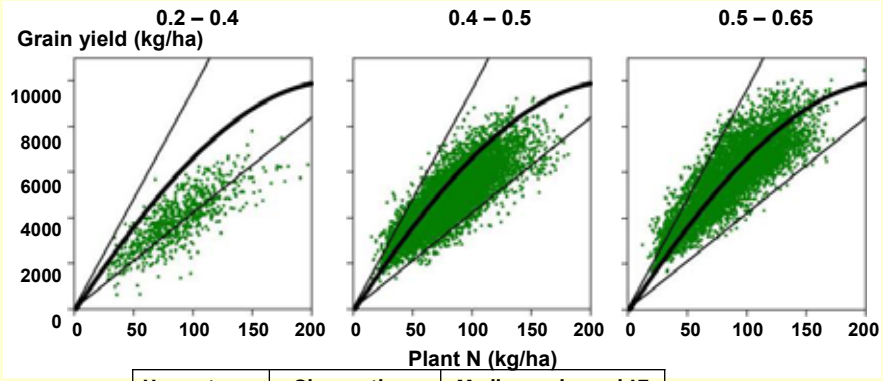


Data set	Observations	Median reciprocal IE (kg K / t grain)
Witt et al.	2,276	14.5
New data set	8,983	15.6

Harvest index: ≥ 0.4

Effect of harvest index on relationship of grain yield and total plant N for rice

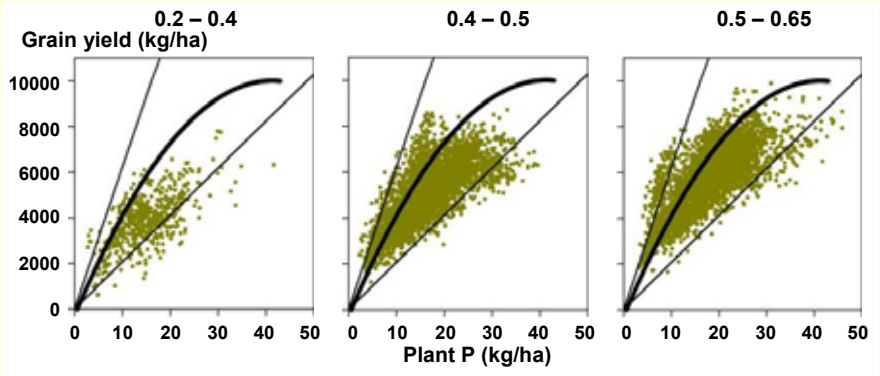
(Fitted lines are from Witt et al., 1999)



Harvest index	Observations	Median reciprocal IE (kg N / t grain)
0.2 – 0.4	822	22.2
0.4 – 0.5	8,156	16.4
0.5 – 0.65	7,351	15.0

Effect of harvest index on relationship of grain yield and total plant P for rice

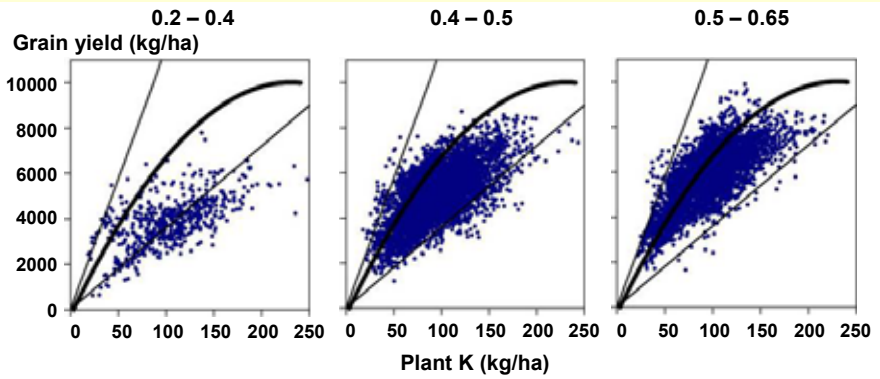
(Fitted lines are from Witt et al., 1999)



Harvest index	Observations	Median reciprocal IE (kg P/t grain)
0.2 – 0.4	557	3.7
0.4 – 0.5	4,680	3.3
0.5 – 0.65	4,268	3.1

Effect of harvest index on relationship of grain yield and total plant K for rice

(Fitted lines are from Witt et al., 1999)



Harvest index	Observations	Median reciprocal IE (kg K/t grain)
0.2 – 0.4	564	27.6
0.4 – 0.5	4,708	18.7
0.5 – 0.65	4,275	15.4

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Conclusions on grain yield – nutrient uptake relationships for rice

- **Reciprocal internal efficiencies (RIE) reported by Witt et al. (1999) remain valid for rice with harvest index ≥ 0.4**
  - ***N = 14.7 kg N/t grain yield***
  - ***P = 2.6 kg P/t grain yield***
  - ***K = 14.5 kg K/t grain yield***
- **Use higher RIE for varieties with harvest index < 0.4**
- **Adequate information exists on RIE for rice**
- **Analysis for wheat and maize is in progress through IPNI**

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Contents

- **Examine the grain yield – nutrient uptake relationships used in SSNM for rice**
- **Highlight key factors influencing sustainable K management**
  - ***Continuous rice cropping***
  - ***Rice-wheat rotation***
  - ***Rice-maize rotation***
- **Evaluate options for determining fertilizer K rates with SSNM**

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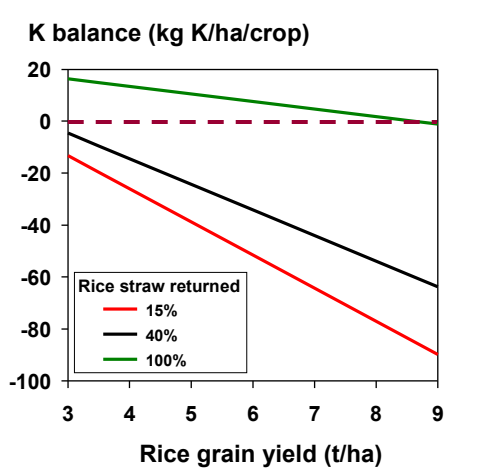
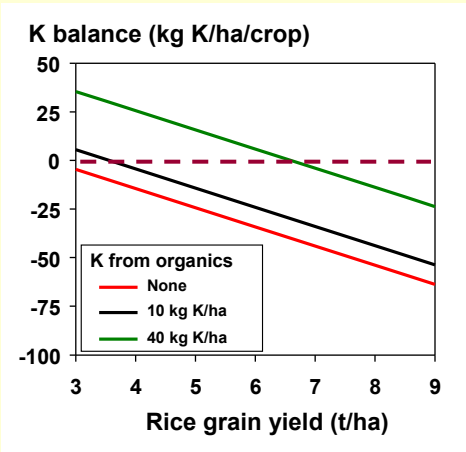
Effect of rice straw return on K balance for one rice crop in continuous rice cropping system



Rice straw returned (%)	K from organics (kg K/ha)	K from irrigation (kg K/ha)
15	0	25
40	0	25
100	0	25

No K mining with complete return of straw and common levels of K in irrigation water.

Effect of K inputs from organic materials on K balance for rice

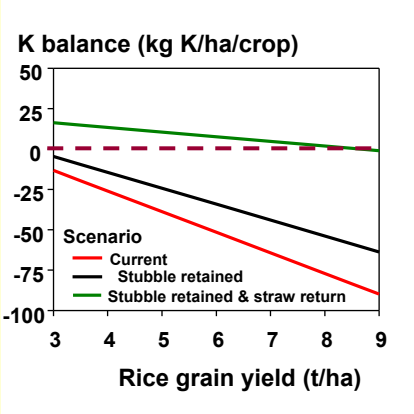


K from organics (kg K/ha)	Rice straw returned (%)	K from irrigation (kg K/ha)
0	40	25
10	40	25
40	40	25

Addition of organic materials can result in positive K balances at relatively low yields.

Fertilizer K rates should be adjusted accordingly.

Effect of management scenarios on K balance for rice currently with all aboveground biomass removed



Future scenarios

1. Rice stubble retained
2. Rice stubble and straw return

Scenario	Rice straw returned (%)	K from organics (kg K/ha)	K from irrigation (kg K/ha)
Current	15	0	25
Stubble retained	40	0	25
Stubble & straw returned	100	0	25

Return of all straw maintains K balance.

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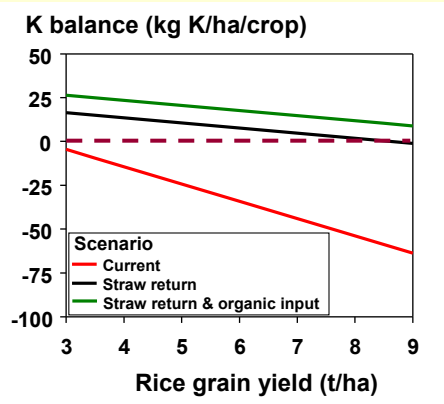
Effect of management scenarios on K balance for rice currently with stubble retention



Future scenarios

1. Combine harvesting (straw return)
2. Straw return + organic inputs

Scenario	Rice straw returned (%)	K from organics (kg K/ha)	K from irrigation (kg K/ha)
Current	40	0	25
Straw return	100	0	25
Straw return +organic	100	10	25

Return of all straw maintains K balance.

Organic material not needed as K source when straw returned.

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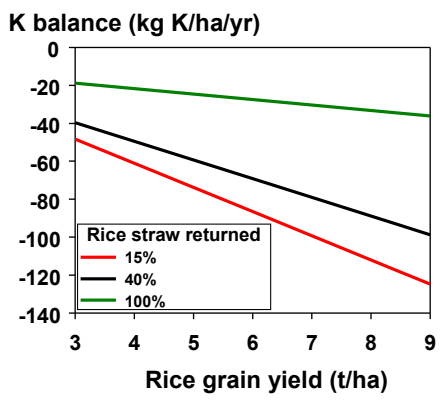
Effect of rice straw return on K balance in rice-wheat system in NW India



Rice straw returned (%)	Wheat yield (t/ha)	Wheat straw returned (%)	K from rice irrigation (kg K/ha)	K from wheat irrigation (kg K/ha)
15	5	15	75	10
40	5	15	75	10
100	5	15	75	10

Return of rice straw has large effect on K balance.

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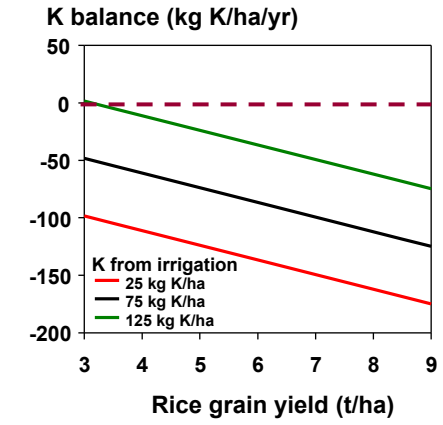
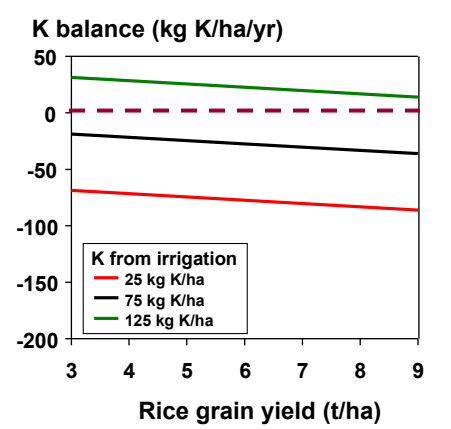
Effect of K inputs from irrigation water for rice on K balance in rice-wheat system



K from rice irrigation (kg K/ha)	Wheat yield (t/ha)	Wheat straw returned (%)	Rice straw returned (%)	K from wheat irrigation (kg K/ha)
25	5	15	15	10
75	5	15	15	10
125	5	15	15	10

K in irrigation water for rice has large effect on K balance.

Effect of K inputs from irrigation water for rice on K balance in rice-wheat system



K from rice irrigation (kg K/ha)	Wheat yield (t/ha)	Wheat straw returned (%)	Rice straw returned (%)	K from wheat irrigation (kg K/ha)
25	5	15	100	10
75	5	15	100	10
125	5	15	100	10

When rice straw is returned, K balances can be positive when irrigation water is high in K.

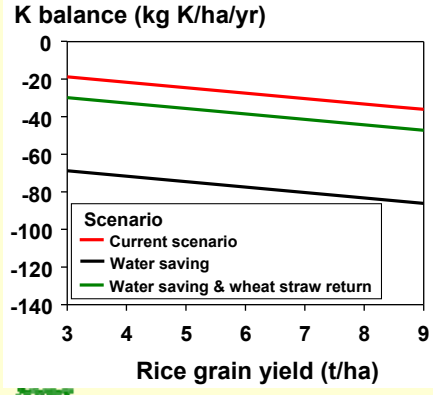
Effect of management scenarios on K balance in rice-wheat system in NW India

Future scenarios

1. **Water saving (CA)**
2. **Water saving + wheat straw return**

Wheat yield = 5 t/ha

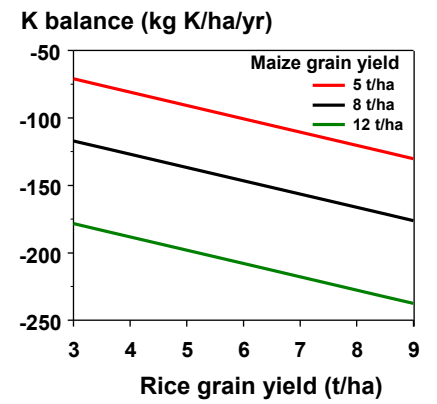
Rice straw return = 100%



Scenario	Wheat straw returned (%)	K from rice irrigation (kg K/ha)	K from wheat irrigation (kg K/ha)
Current	15	75	10
Water saving	15	25	10
Water saving + wheat straw return	60	25	10

Switch to water saving technology could increase need for K fertilizer

Effect of maize yield on K balance in rice-maize system



Maize yield (t/ha)	Maize residue returned (%)	Rice straw returned (%)	K from rice irrigation (kg K/ha)	K from maize irrigation (kg K/ha)
5	15	40	25	10
8	15	40	25	10
12	15	40	25	10

K balances can be very negative when maize is grown in rotation with rice.

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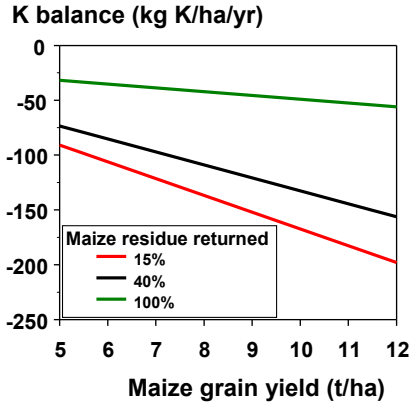
Effect of maize residue retention on K balance in rice-maize system



Maize residue returned (%)	Rice yield (t/ha)	Rice straw returned (%)	K from rice irrigation (kg K/ha)	K from maize irrigation (kg K/ha)
15	5	40	25	10
40	5	40	25	10
100	5	40	25	10

K balances for rice-maize system remain negative even when all maize residue is returned.

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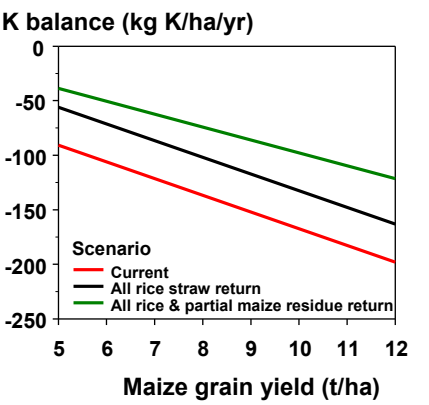
Effect of management scenarios on K balance in rice-maize system currently with maize residue removed



Future scenarios

1. All rice straw return
2. All rice & partial maize residue return

Rice yield = 5 t/ha

K from irrigation = 35 kg K/ha/yr

Scenario	Rice straw returned (%)	Maize straw returned (%)
Current	40	15
Rice straw return	100	15
Rice and maize residue return	100	40

Large negative K balances even with futuristic scenario.

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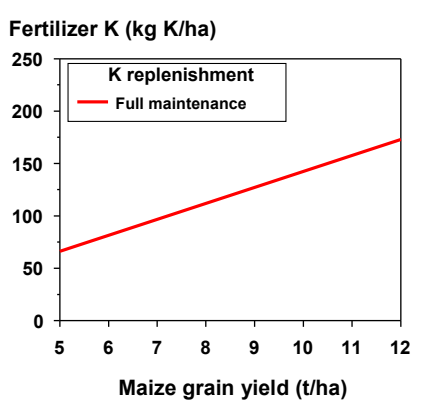
- Evaluate options for determining fertilizer K rates with SSNM

Determination of fertilizer K rates for maize in absence of crop response to K

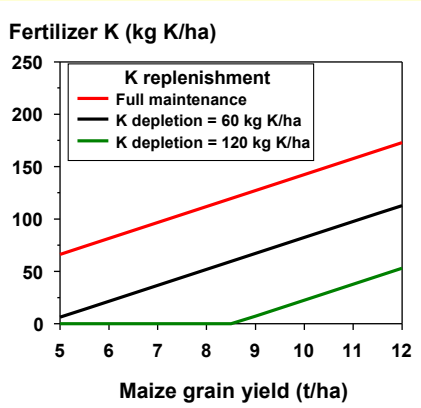


Maize residue return = 15%
K from irrigation = 10 kg/ha

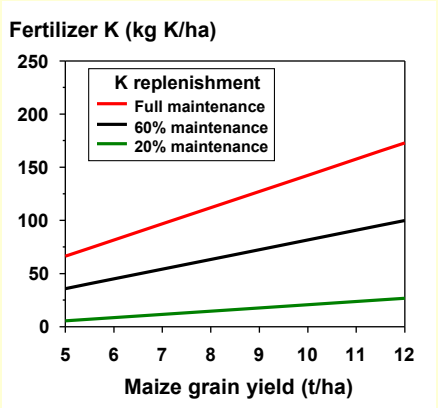
Full maintenance application (input = output) would not be profitable.

Options for determining fertilizer K rates for maize in absence of crop response to K

#1: Assume constant soil K supply



#2: Apply fraction of maintenance rate

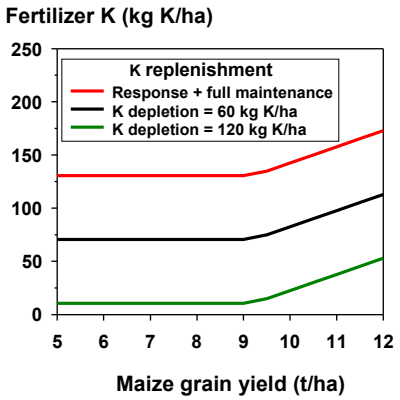


Maize residue return = 15%
K from irrigation = 10 kg/ha

Options for determining fertilizer K rates for maize with 3 t/ha response to K

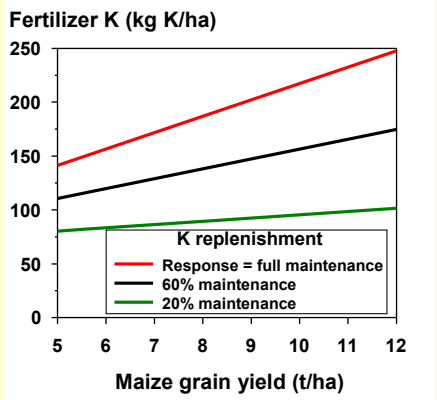
#1: Assume constant soil K supply

Rate = Response + full maintenance – constant soil supply



#2: Apply fraction of maintenance rate

Rate = Response + partial maintenance



Maize residue return = 15%

K from irrigation = 10 kg K/ha

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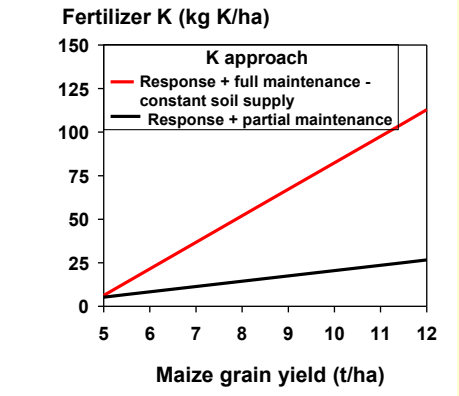
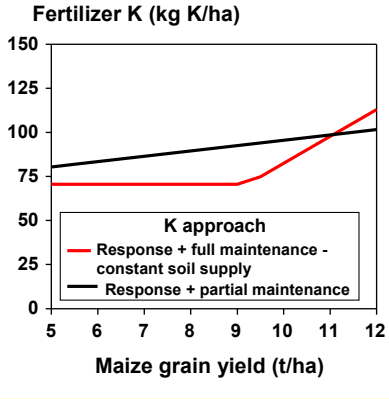
Options for determining fertilizer K rates for maize

No crop response to K



3 t/ha crop response to K



Constant soil supply = 60 kg K/ha

Partial maintenance = 20% of removed K

Maize residue return = 15%

K from irrigation = 10 kg/ha

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Conclusions on cropping systems

- **Rice-rice system**
  - ***Key factor: fraction of residue retained***
  - ***Key knowledge gap: K input with irrigation water***
- **Rice-wheat system**
  - ***Key factor: K input with irrigation water***
  - ***Key knowledge gap: Will water saving technology in NW India increase need for fertilizer K***
- **Rice-maize system**
  - ***Key factor: High K demand for high-yielding crop***
  - ***Key knowledge gap: scientific approach for determining K rates that balance sustainability and profitability***

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Conclusions on use of SSNM to determine K rates

- **In situations with small or negligible crop response to K**
  - ***Full maintenance application (input = output) is not profitable***
  - ***Need science-based approach for determining K rates based on partial maintenance (input < output)***
- **In situations with large crop response to K**
  - ***Need science-based approach for determining K rates based on response and partial maintenance***
  - ***Agronomic efficiency preferred to recovery efficiency for determining K rate based on response***

Need science-based approach for determining K rates that balance the trade offs between sustainable productivity and profitability