Challenges in Nutrient Management for Rice-Maize Systems in South Asia

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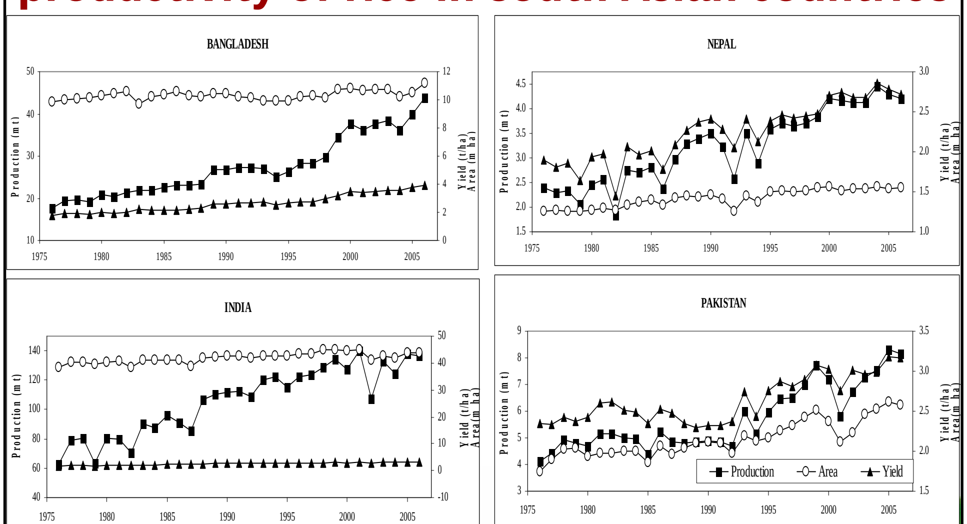
...e at the IPI-OUAT-IPNI International Symposium, 5-7 No... Orissa, India. The Role and Benefits of Potassium in Improving Nutrient ...duction, Quality and Reduced Environmental Damage.

Long-term trends in area, prod. & productivity of rice in south Asian countries



(Source: www.fao.org)

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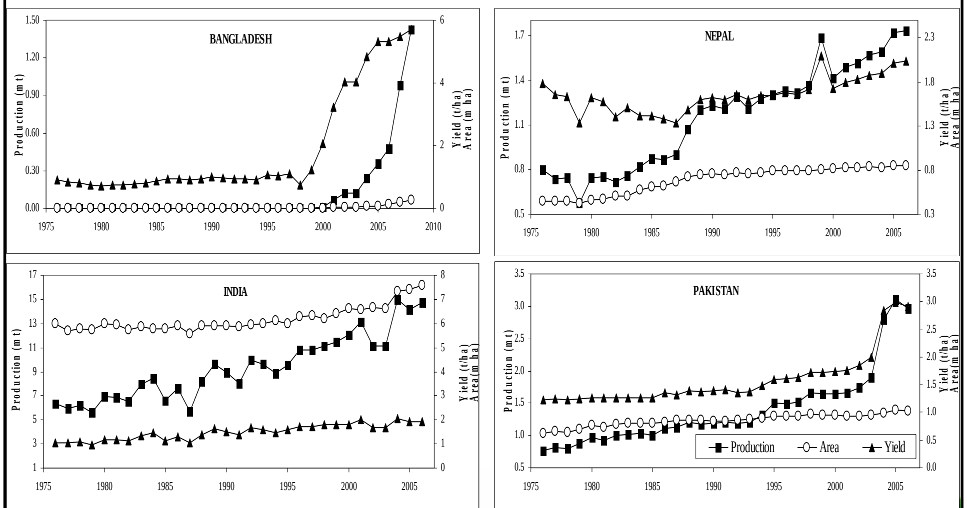
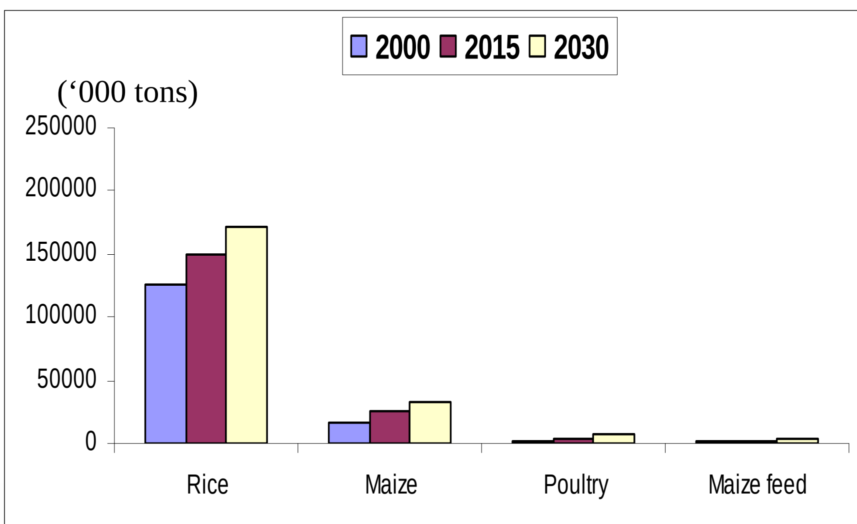
Area, production, & Productivity of maize (1975 to 2006) in four south Asian countries



(Source: www.fao.org)

Demand projections for South Asia



Source: Siwa Msangi, IFPRI (IMPACT Model, 2007)

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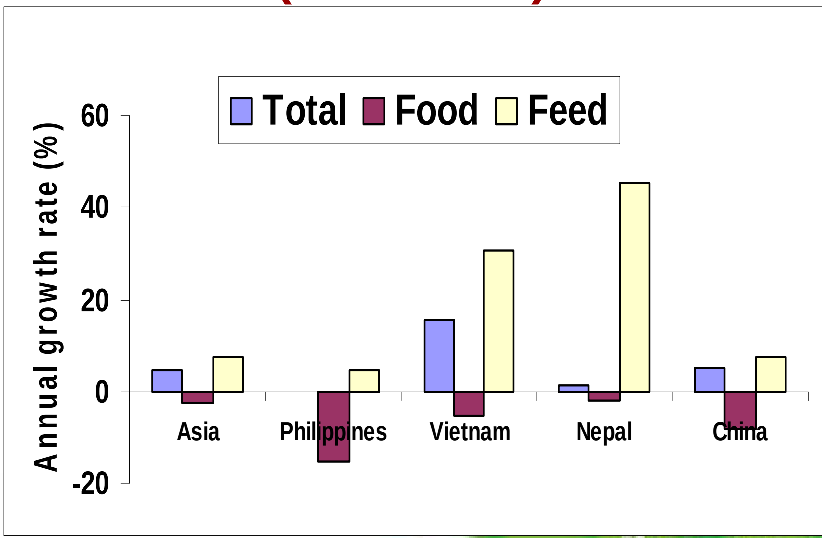
Annual growth rate of Corn uses in Asia (1991-1998)



Source: CIMMYT, 2004. Based on FAOSTAT

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Area under major rice-based cropping systems in four south Asian countries

Cropping Systems	Area (Mha)			
	Bangladesh	India	Nepal	Pakistan
Rice-rice	4.50	4.70	0.30	
Rice-rice-rice	0.30	0.04		
Rice-wheat	0.40	10.30	0.57	2.20
Rice-maize	0.35	0.53	0.43	NA
Maize-wheat		1.80	0.04	1.00
Rice-pulses		3.50		
Rice-vegetable		1.40		
Millet-wheat		2.44		
Rice-potato	0.30	NA		
Cotton-wheat		NA		3.10

Source: Modified and updated from JK Ladha, unpublished data

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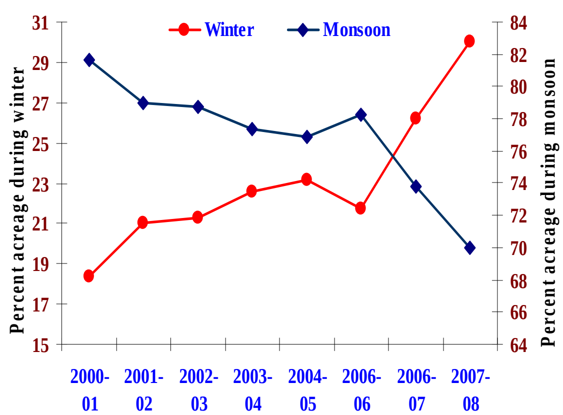
Existing R-M areas in Asia (FAO 2005)

Country	Area (Mha)		
	Rice	Maize	R-M
Philippines	4.2	2.6	0.12
Indonesia	11.8	7.8	1.55
Vietnam	7.3	1.1	0.32 **
China	29.1	26.4	-
Thailand	10.0	1.1	0.04 **
India	43.4	7.8	0.53
Bangladesh	10.5	0.38	0.35
Nepal	1.6	0.9	0.43 **
Total	117.9	53.8	3.3 (exc. China)

(**estimated from CIMMYT-IFAD Reports)

Estimates of acreage under rice-maize system in India

State	Area (Ha)
Andhra Pradesh	250,000
Tami Nadu	30,000
Karnataka	20,000
Bihar	120,000
West Bengal	60,000
Orissa	20,000
Other states	25,000
All India	525,000



Source: Jat et al (2009)

Main cropping systems involving rice and maize in different ago-climatic zones of India

Agro-climatic region	Cropping system	
	Irrigated	Rainfed
Eastern Himalayan region	Summer rice-maize-mustard	Sesame-rice+maize
Lower-Gangetic Plain region	Autumn rice-maize Jute-rice-maize	Rice-maize
Upper-Gangetic Plain region	Rice-potato-maize	
Eastern Plateau & Hills region		Rice-potato-maize
Southern plateau & Hills region	Maize-rice Rice-maize	
East Coast Plain and Hills region	Rice-maize-pearl millet Maize-rice Rice-maize Rice-rice-maize	Rice-maize + cowpea
West Coast Plain and Hills region	Rice-maize	Rice-maize
Gujarat plains and hills region		Rice-maize
Island region	Rice-maize	Maize-rice Rice-maize + cowpea Rice-maize-urdbean Rice-rice-maize

(*Source*: Modified from Yadav and Rao, 2001).

Key R-M agro-ecosystems for Asia (based on mean temp.)

Key features	Current systems	Emerging systems	Key examples
1. Tropical, warm, humid and sub-humid, no winter			
Tropical, high rainfall; mostly in a dry season – wet season pattern; both rice and maize not limited by low temperatures and can be grown all year round	R – R, R – Fallow	R – M, M – R	Laguna, Central Luzon, Philippines; West Java, Central Java, North Sumatra, South Sulawesi, Indonesia; Central & lower north Plain, Thailand
	R – R – R R – R – M R – M – M	R – M – R R – R – M R – M - M	Mekong Delta, Vietnam; East Java, Central Lampung, Indonesia
2. Tropical, warm, semiarid, no winter			
Tropical monsoon with longer dry season; both rice and maize not limited by low temperatures and can be grown all year round	R-R, R – R – pulses	R – M	Cauvery Delta, Tamil Nadu, India; Karnataka, India; A.P., India
3. Sub-tropical, sub-humid, warm summer, mild cool winter			
Sub-tropical monsoon with cool winter and summer rainfall; rice but not maize maybe limited by low temperatures	R – W R – Boro rice	R – M, R – R – M	Central, western, and NW Bangladesh; Eastern Terai, Nepal; West Bengal, eastern UP and Bihar, India; Red River Delta, Vietnam
4. Sub-tropical to warm temperate, sub-humid, semiarid, warm summer, mild to severe cold winter			
4.1. Sub-tropical monsoon with cold winter and summer rainfall; both rice and maize limited by low temperatures and can't be grown for some time in winter	R – W	R – M	North and NW India; Central and western Terai and mid-hills, Nepal
4.2. Sub-tropical to warm temperate, with severe cold winter; both rice and maize limited by low temperatures and can't be grown for some time in winter	R – R, R – Fallow	M – R, R – M	South Central China (Hunan, Hubei), Southeast China (Jiangsu, Zhejiang)
4.3. Sub-tropical to warm temperate, semiarid, with hot summer and cool to cold winter; very low rainfall; both rice and maize limited by low temperatures and can't be grown for some time in winter	R – W, Cotton-wheat, Sorghum-wheat	R-M, M-W, R –potato- M	Punjab and Sindh, Pakistan

Timsina, 2008

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Target environment for R-M System

1. **Maize replaces wheat & other upland crops (N & E IGP)**

   rice - wheat/pot./must./legumes → rice-maize

2. **Maize replaces lowland rice (Philippines, S. China, S. India, S. Vietnam)**

   rice-rice → rice-maize

   rice-rice → maize-rice S. China

   rice-wheat → maize-wheat N. India

3. Maize becomes an additional crop in partially-irrigated or favorable rainfed areas (Tarlac, Ilocos Norte, eastern IGP, Cambodia, Thailand, S. China)

   rice-fallow → rice-maize

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Key drivers for diversification toward R-M systems

- **Rapidly rising demand for maize for feed and biofuel**
- **Declining availability of irrigation water**
- **Short duration maize hybrids with high yield & income potential**
- **Rapidly expanding agri-business sector associated with maize seed markets, other production inputs, and processing & marketing of maize products**

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Key cross-cutting issues for R-M systems in Asia

- Expansion despite insufficient understanding of their potential, constraints, and risks
- Uncertainty about their long-term performance and sustainability (e.g., SOM)
- Dominance of commodity-specific research and lack of R&D support for system-level research
- Insufficient partnerships at an international level & within countries
- Large role of private sector in expansion of R-M systems and dissemination of knowledge & new technologies

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Yield potential (Yp)

- Yp = yield of a crop cultivar/hybrid when grown in environments to which it is adapted, with nutrients & water non-limiting and pests & diseases effectively controlled (Evans, 1993)
- Estimation of Yp important to identify constraints, help close gaps between potential and actual yields, and optimize productive & profitable cropping systems.

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Rice / maize / soybean varieties / hybrids / models

Four rice varieties (ORYZA2000)

Extra early (80-90 d); Early (90-105 d)

Intermediate - IR72 (105-125 d); Late (>125 d)

Five maize hybrids (Hybrid Maize)

1300 GDD; 1400 GDD; 1500 GDD

1600 GDD; 1700 GDD

Early-maturing soybean (90-120 d) (CROPGRO-Soybean)

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Inputs / parameters for Yp

- **Actual historical weather data supplemented by NASA data**
- **Genotypes / hybrids parameters as defined in the model**
- **Growth durations (development rates) parameterized to optimize the cropping calendars**

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Yield potential (Yp) of rice varieties and maize hybrids for several locations in four south Asian countries

Country	Location	Rice		Maize	
		Variety	Yp (t/ha)	Hybrid	Yp (t/ha)
Bangladesh	Bogra	Extra short	4.4-8.1	1500	8.8-12.6
		Short	5.2-9.6	1600	9.8-16.8
		Intermediate	6.4-11.0	1700	10.9-18.3
		Long	7.8-11.5	1800	12.0-19.6
	Dinajpur	Extra short	4.5-9.0	1500	9.0-16.5
		Short	5.1-10.2	1600	10.2-18.1
		Intermediate	6.1-12.3	1700	11.2-19.3
		Long	6.2-14.5	1800	12.2-20.4
	Jessore	Extra short	4.3-7.5	1500	8.7-14.2
		Short	5.5-9.0	1600	9.7-16.0
		Intermediate	7.0-10.4	1700	10.7-17.7
		Long	8.2-12.9	1800	11.8-19.0

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----Yield Potential

Nepal	Chitwan	Extra short	1.6-8.7	1500	11.3-27.4
		Short	1.7-9.3	1600	13.1-29.7
		Intermediate	1.9-10.9	1700	14.1-31.3
		Long	2.1-14.4	1800	15.4-32.7
Pakistan	Larkana	Extra short	2.1-7.0	1400	6.2-17.2
		Short	2.5-8.0	1500	7.0-19.2
		Intermediate	2.8-9.5	1600	7.8-20.7
		Long	3.8-11.5	1700	8.6-21.9
	Okara	Extra short	0.6-4.7	1300	5.8-17.7
		Short	0.7-5.6	1400	6.7-18.4
		Intermediate	0.6-8.0	1500	7.6-18.4
		Long	0.7-10.0	1600	8.4-22.4

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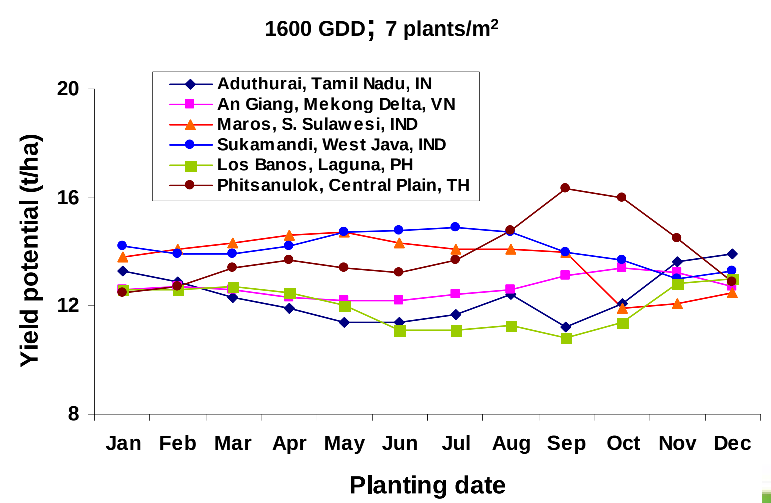
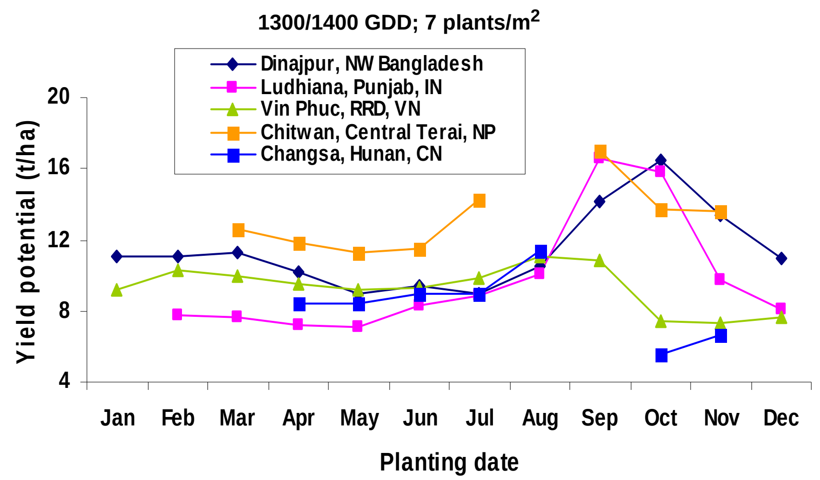
----Yield Potential

India	Begusarai	Extra short	4.6-8.9	1500	8.1-14.9
		Short	5.5-9.9	1600	9.2-16.9
		Intermediate	7.4-11.5	1700	10.4-18.5
		Long	6.2-14.8	1800	11.4-19.7
	Aduthurai	Extra short	4.0-6.3	1500	9.1-11.2
		Short	5.4-7.7	1600	10.2-12.5
		Intermediate	6.5-9.7	1700	11.2-14.0
		Long	8.4-11.9	1800	12.3-5.0
	Thanjavur	Extra short	4.1-6.1	1400	9.2-11.1
		Short	5.1-7.5	1500	10.2-12.4
		Intermediate	6.9-9.4	1600	11.1-13.6
		Long	8.7-11.5	1700	12.2-14.7
	Bangalore	Extra short	6.4-7.7	1400	10.0-13.3
		Short	7.9-9.2	1500	11.2-14.9
		Intermediate	10.0-11.5	1600	12.3-16.4
		Long	12.2-13.8	1700	13.6-17.6
	Nalgonda	Extra short	4.8-7.0	1400	7.7-12.6
		Short	5.1-8.3	1500	9.1-14.2
		Intermediate	6.1-10.6	1600	10.0-15.8
		Long	8.2-12.6	1700	10.7-17.0
	Ludhiana	Extra short	3.0-8.8	1500	7.1-16.6
		Short	2.9-10.8	1600	8.2-20.4
		Intermediate	3.0-12.8	1700	9.0-23.7
		Long	2.6-17.6	1800	9.8-26.0

Maize Yp in tropical lowlands of SE Asia



Winter maize Yp in sub-tropical lowlands of Asia



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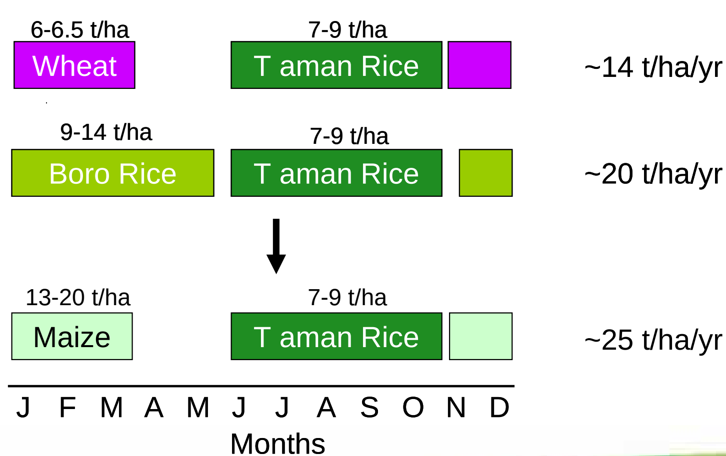
Potential grain production of rice-based cropping systems in Dinajpur, Bangladesh



(Source: Pasquin *et al.* 2007)

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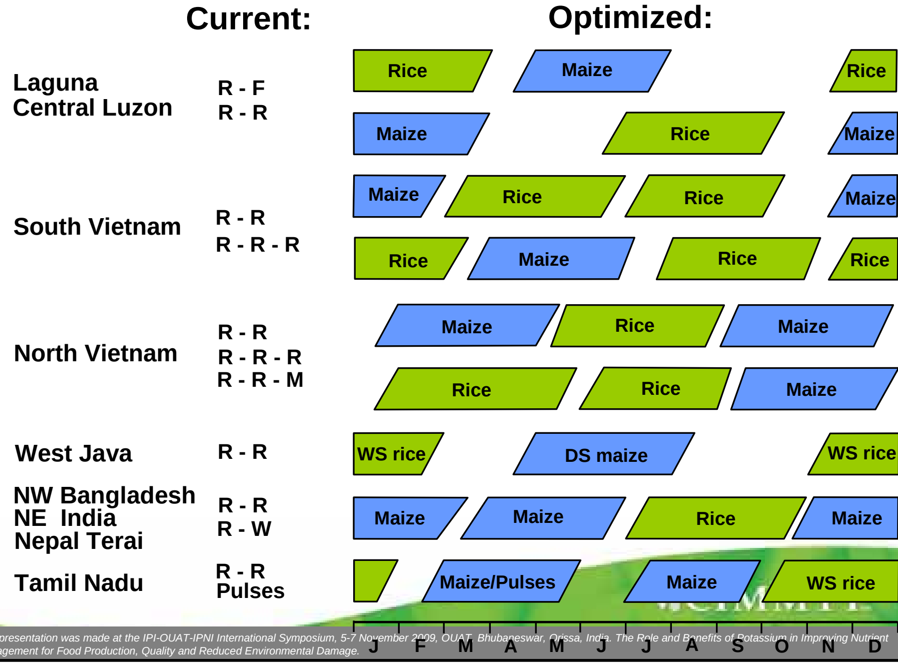
Optimization of Cropping Systems



Grain yield (t/ha) of rabi maize in 10 farmers' fields in an SSNM experiment at two districts in NW Bangladesh in 2008-2009

Treatments	Rangpur	Rajshahi
N omission	0.5-5.1	3.4-3.9
P omission	3.9-8.3	4.5-8.5
K omission	4.1-8.1	5.3-7.9
Low P	5.5-8.8	6.2-8.9
Low K	5.8-9.8	6.5-8.6
NPK	6.0-10.3	6.7-10.3
NPKSZn	6.0-10.4	7.2-10.8

Source: Timsina, unpublished

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Grain yield of rice & maize, and rice-maize system productivity (MEY), in an SSNM experiment

Treatment	Rice yield (t/ha)	Maize yield (t/ha)	R-M system productivity (MEY)
State Rec	4.98	6.53	11.23
SSNM	5.76	8.06	13.50
SSNM-N	4.88	4.86	9.47
SSNM-P	5.01	6.52	11.25
SSNM-K	5.00	6.65	11.37
CD(P=0.05)	232.1	715.65	

(Source: ML Jat, unpublished data)

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Effect of nutrient management practices on grain yield of maize at different locations in India

Nutrient management	Grain yield (t/ha)							
	Delhi	Bajaura	Udhampur	Dholi	Ludhiana	Pantnagar	Banswara	Ranchi
State recommendation	7.78	5.69	4.06	3.65	6.76	4.44	5.93	3.69
SSNM	7.94	7.21	4.52	4.96	6.98	5.09	6.94	4.46
SSNM-N	4.46	2.76	2.26	3.21	5.87	3.11	1.72	2.78
SSNM-P	7.71	5.84	3.41	3.41	6.76	3.78	6.19	4.33
SSNM-K	7.36	5.87	4.41	3.69	7.33	5.22	6.41	3.89

Source: ML Jat, unpublished data

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On- farm productivity of maize as influenced by SSNM under rice- maize cropping system at Sabour, Bihar

Treatment	Grain yield (t/ha)	% increase over FFP	Net return (Rs/ha)	B: C ratio
FFP	6.75	-	23,355	1.19
FFPK	7.58	12.3	27,693	1.37
FFP+KS+Zn	8.06	17.28	28,755	1.31
FFPS+ Zn	7.26	6.32	24,440	1.14
CD (P=0.05)	0.54	-	736	-

- K and S individually contributed 12.3% and 17.3% higher yield over FFP whereas, application of K and S together contributed 17.3% higher yield over the treatment kept devoid of it

Source: VK Singh (2009) Unpublished, PDFSR, Modipuram

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Nutrient Response in Rice (RMCS) under CA v/s CT

TCE	Nutrient	GY (t ha^{-1})	Residue yield effect	K +S Zn Response	S Zn response	K response	K response with TCE
TPR-CTM/-R	NP	7.67					
TPR-CTM/-R	NPK+SZn	8.72		1.06			
TPR-CTM/-R	NP+SZn	8.23	8.207		0.57	0.49	
TPR-CTM/+R	NP	8.25					
TPR-CTM/+R	NPK+SZn	8.88		0.63			
TPR-CTM/+R	NP+SZn	8.60	8.577		0.35	0.28	0.39
DSR-ZTM-R	NP	6.33					
DSR-ZTM-R	NPK+SZn	7.42		1.09			
DSR-ZTM-R	NP+SZn	6.84	6.862		0.51	0.58	
DSR-ZTM+R	NP	6.69					
DSR-ZTM+R	NPK+SZn	7.55		0.86			
DSR-ZTM+R	NP+SZn	7.12	7.119		0.43	0.43	0.50
ZT R/ZTM-R	NP	5.83					
ZT R/ZTM-R	NPK+SZn	6.72		0.88			
ZT R/ZTM-R	NP+SZn	6.28	6.276		0.45	0.44	
ZT R/ZTM+R	NP	6.23					
ZT R/ZTM+R	NPK+SZn	6.77		0.54			
ZT R/ZTM+R	NP+SZn	6.45	6.485		0.22	0.32	0.38

Source: VK Singh (2009) Unpublished, PDFSR, Modipuram

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Nutrient Response in Maize (RMCS) under CA v/s CT

TCE	Nutrient	GY (t ha^{-1})	Residue yield effect	K +S Zn Response	S Zn response	K response	K response with TCE
TPR-CTM/-R	NP	7.19					
TPR-CTM/-R	NPK+SZn	8.12		0.93			
TPR-CTM/-R	NP+SZn	7.62	7.641		0.42	0.50	
TPR-CTM/+R	NP	7.47					
TPR-CTM/+R	NPK+SZn	8.37		0.91			
TPR-CTM/+R	NP+SZn	7.74	7.861		0.28	0.63	0.57
DSR-ZTM-R	NP	7.28					
DSR-ZTM-R	NPK+SZn	8.23		0.95			
DSR-ZTM-R	NP+SZn	7.80	7.769		0.52	0.43	
DSR-ZTM+R	NP	7.99					
DSR-ZTM+R	NPK+SZn	8.70		0.71			
DSR-ZTM+R	NP+SZn	8.40	8.362		0.41	0.30	0.37
ZT R/ZTM-R	NP	7.26					
ZT R/ZTM-R	NPK+SZn	8.54		1.28			
ZT R/ZTM-R	NP+SZn	8.23	8.010		0.97	0.31	
ZT R/ZTM+R	NP	8.67					
ZT R/ZTM+R	NPK+SZn	9.42		0.75			
ZT R/ZTM+R	NP+SZn	8.90	8.995		0.23	0.52	0.41

Source: VK Singh (2009) Unpublished, PDFSR, Modipuram

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Nutrient Response in RM System under CA v/s CT

TCE	Nutrient	RM-GY (t ha^{-1})	Residue yield effect	K +S Zn Response	S Zn response	K response	K response with TCE
TPR-CTM/-R	NP	14.86					
TPR-CTM/-R	NPK+SZn	16.84		1.98			
TPR-CTM/-R	NP+SZn	15.85	15.85		0.99	0.99	
TPR-CTM/+R	NP	15.72					
TPR-CTM/+R	NPK+SZn	17.26		1.54			
TPR-CTM/+R	NP+SZn	16.34	16.44		0.63	0.91	0.95
DSR-ZTM-R	NP	13.61					
DSR-ZTM-R	NPK+SZn	15.65		2.04			
DSR-ZTM-R	NP+SZn	14.64	14.63		1.03	1.01	
DSR-ZTM+R	NP	14.68					
DSR-ZTM+R	NPK+SZn	16.25		1.57			
DSR-ZTM+R	NP+SZn	15.52	15.48		0.84	0.73	0.87
ZT R/ZTM-R	NP	13.09					
ZT R/ZTM-R	NPK+SZn	15.26		2.16			
ZT R/ZTM-R	NP+SZn	14.51	14.29		1.42	0.75	
ZT R/ZTM+R	NP	14.90					
ZT R/ZTM+R	NPK+SZn	16.19		1.29			
ZT R/ZTM+R	NP+SZn	15.35	15.48		0.45	0.84	0.79

Source: VK Singh (2009) Unpublished, PDFSR, Modipuram

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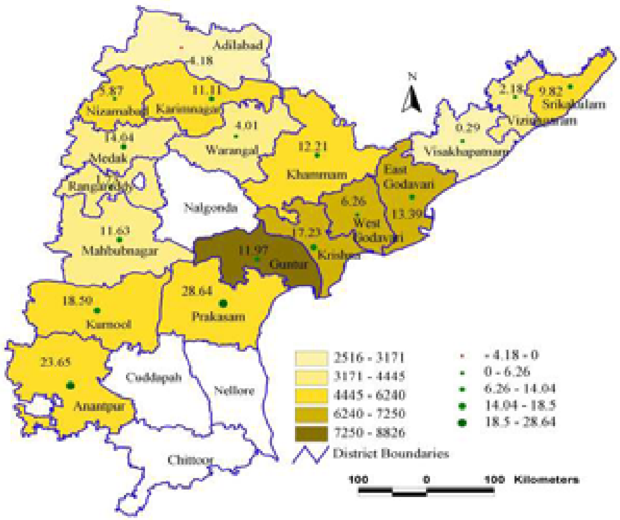
RM Systems in Andhra Pradesh



- High plant density i.e. 80000 to 100000 plants ha-1
- Inappropriate and imbalance nutrient application (390 kg N, 115 kg P_2O_5, 75 kg K_2O)
- Optimization for profitability and long-term system sustainability.

Source: Jat et al (2009)

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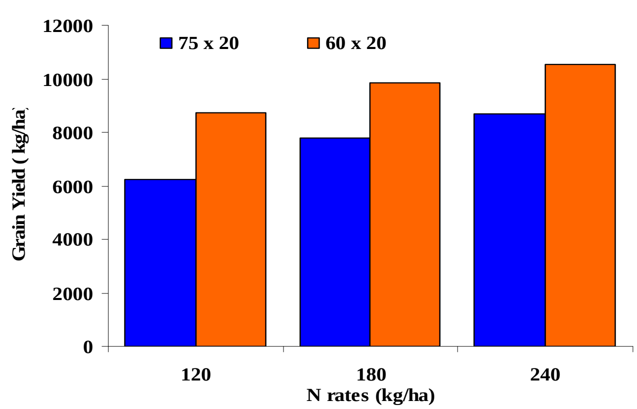
This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

Plant geometry X N rates



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Challenges

- Understanding soil fertility constraints in representative R-M growing areas across the country
- Assessing crop nutrient requirements for optimum yield targets for both maize and rice in the intensifying systems in the prevailing biophysical environments.
- Multi-location research on mineral fertilizer use, possibilities of adding quick growing legumes such as mungbean into the system, making use of BNF in rice, use of appropriate bio-fertilizers for legumes and crop residue retention and recycling techniques etc.
- Maximum use of residual fertility in the cropping system to reduce the cost of fertilizers for farmers.
- Field testing the IPNS packages in comparison with farmers' existing practices.
- Financial analysis of the IPNS packages to evaluate farmers' profit margins. Combination of IPNS with water management and soil physical management, and with water-efficient maize that may be developed.

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Future priorities

- Priority on the development and refinements of simple DSS on nutrient management for R-M systems for use by the extension workers and farmers.
- Development and validation of Nutrient Manager for R-M systems under varied agro-ecologies of south Asia.
- Nutrient management for CA systems

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Conclusions

- R-M cropping systems are emerging and rapidly expanding in south Asia.
- Yield potential of rice and maize is quite high but yield gaps between potential and attainable yields and between attainable and actual yields exist in farmers' fields in south Asia.
- Nutrient demand of the R-M system is very high since high-yielding rice varieties and maize hybrids are used.
- High nutrient demand is associated with high extraction or uptake of nutrients from soils leading to declining fertility unless nutrients are replenished from external sources.
- This is particularly true for R-M systems where residues of both crops are generally removed from fields aggravating soil fertility depletion, especially for K. However, nutrient balance studies in R-M systems are very few in South Asia.
- SSNM, a general concept for optimizing the supply and demand of nutrients according to their variation in space and time, provides scientific principles for optimally supplying crops with nutrients as and when needed for specific fields in a particular cropping season.
- Application of SSNM principles, aided by nutrient balance studies, can help improve nutrient management in R-M systems towards improving yield and profitability.
- Better understanding and development of SSNM principles for maize to the extent of rice are required to realize potential yield of RM systems.

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Thanks

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