Site-Specific Nutrient Management for Maize in Indonesia

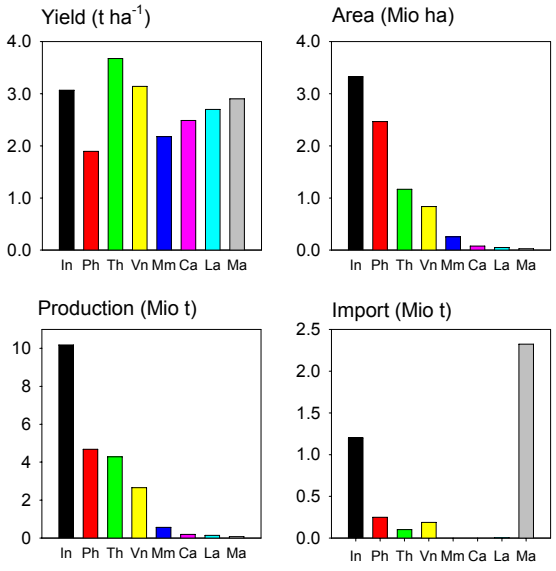
Christian Witt, PhD

Director
Southeast Asia Program
Singapore

Pengelolahan Hara Spesifik Lokais (PHSL) – Jagung
Site-Specific Nutrient Management (SSNM) for Maize in Indonesia

- Project part of a collaboration between the Indonesian Agency for Agricultural Research and Development (IAARD) and PPI/PPIC and IPI Southeast Asia.
  - Coordination: Indonesian Center for Food Crops Research and Development (ICFORD)
- Paper presented at the IFA Crossroads Asia-Pacific, November 14, 2006, summarizes several presentations given at a workshop on SSNM in Maize, held in Kediri, 12-15 June, 2006, with the following contributing researchers and institutes:
  - **Indonesian Cereals Research Institute (ICRI)**: S. Saenong, Syaffrudin, Roy Effendi
  - **Soil Research Institute, Bogor**: A. Fahmudin, D. Setyorini, A.I. Fauzi, A. Rachman
  - **AIAT East Java:** Suwono, L. Y Krisnadi, Suliyanto, Ono.S, R. Budiono and Sudarmadi Purnomo
  - **AIAT North Sumatra:** S. Sari, Akmal, Khadijah E. R., Ali Jamil, M. Prama Yufdy, H. Sembiring
  - **AIAT Central Java:** Supadmo, Samijan, Joko Pramono, Miranti DP, Tri Reni P, Yuni Kamal W and Sumardi Suriatna Suprapto, Ngadimin and Yuni Kamal W
  - **AIAT South Sulawesi:** Peter Tandisau, Muhammad Thamrin, Sahardi Mulia, Amir Syam
  - **AIAT Lampung:** Andarias Makka Murni, Yunita Barus, Dadin Suherlan, Sunaryo, Ade Sopandi, Zulkifli Zaini
  - **University of Nebraska, Lincoln:** A. Dobermann
  - **PPI/PPIC and IPI:** S. Kartaatmadja, JM Pasuquin, C. Witt

SE Asia 2000-2004

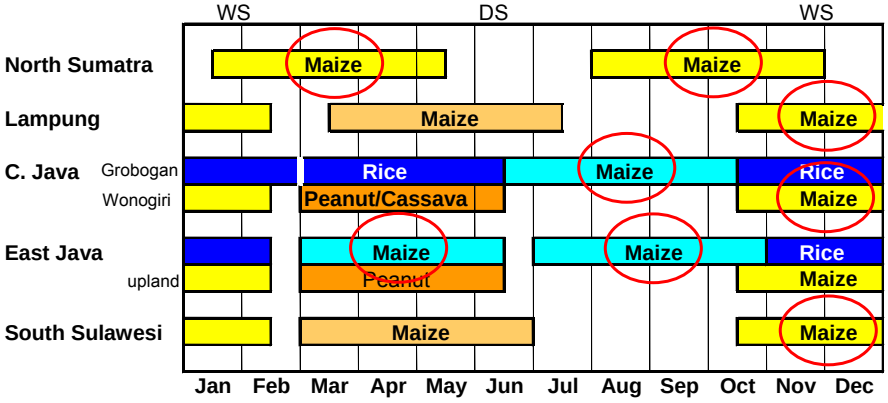


Project objectives 2004-2007

- Quantify indigenous nutrient supply & nutrient use efficiencies
- Explore yield potential and attainable yield
- Evaluate nutrient use efficiencies
- Develop, evaluate, and promote site-specific nutrient management (SSNM)

Project sites in Indonesia

Cropping systems

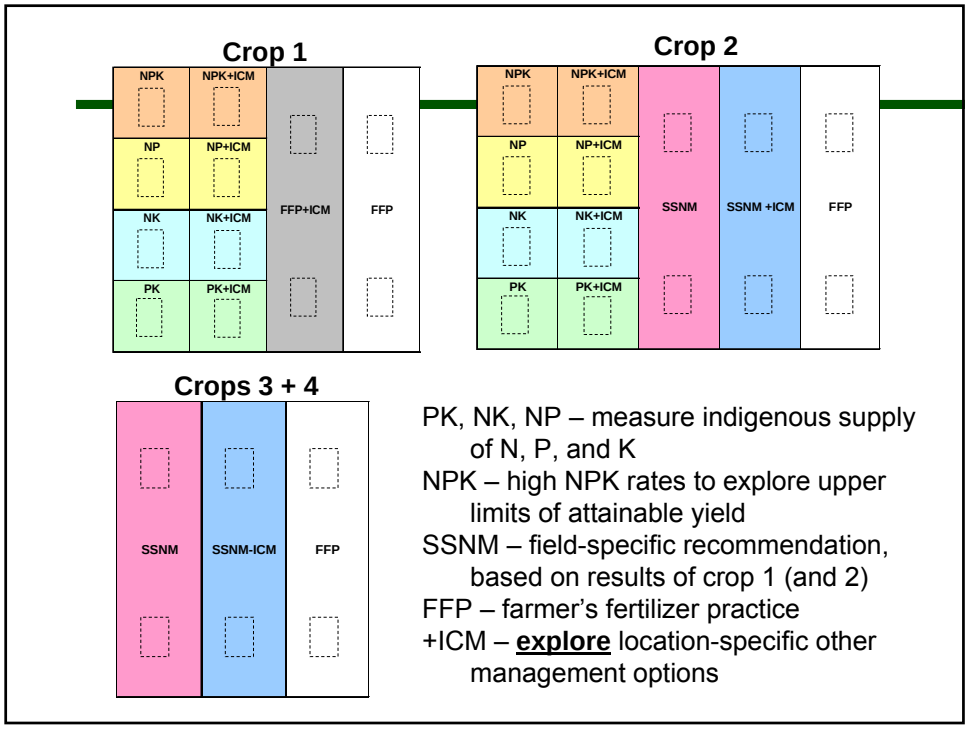


5 farms at each site

- **Irrigated maize**
- **Rainfed maize, favorable**
- **Rainfed maize, drought-prone**


Isabela Province, Philippines
Red River Delta, Vietnam
Central Java, Indonesia


Red River Delta, North Vietnam
South Sulawesi, Indonesia
Daklak, Vietnam



PK, NK, NP – measure indigenous supply of N, P, and K

NPK – high NPK rates to explore upper limits of attainable yield

SSNM – field-specific recommendation, based on results of crop 1 (and 2)

FFP – farmer's fertilizer practice

+ICM – **explore** location-specific other management options

Attainable yields (NPK)

Grain yield NPK (t/ha)*

Site	**Crop 1, 2004-2005**		**Crop 2 2005-2006**	
	NPK	Max	NPK	Max
Central Java, Grob.	8.6	13.7	10.4	11.6
Central Java, Won.	5.8	7.2	5.6	7.3
East Java	10.9	12.8	10.8	12.7
Lampung	7.6	9.4	9.3	10.0
North Sumatra	10.8	11.6	9.0	10.8
South Sulawesi	7.8	9.6	7.2	9.1
All sites	**8.6**	**10.7**	**8.7**	**10.2**

* Including NPK and NPK-ICM plots

Indigenous nutrient supplies

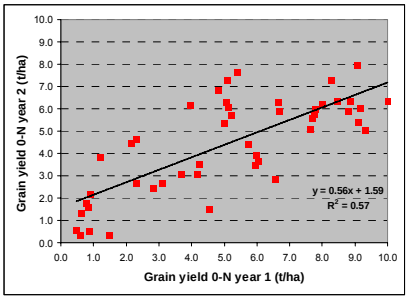
- Nutrient uptake and grain yield measured in nutrient omission plots serve as indicators of indigenous N, P, and K supplies to the crop.

Indigenous N supply

Site	Crop 1, 2004-2005 Grain yield 0-N (Y_{0N}, t/ha)*			Crop 2 2005-2006 Grain yield 0-N (Y_{0N}, t/ha)*		
	Mean	Min	Max	Mean	Min	Max
Central Java, Grob.	2.3	0.5	6.5	1.7	0.3	3.9
Central Java, Won.	2.7	0.8	5.1	3.0	1.5	4.6
East Java	6.9	4.8	9.1	6.3	5.3	7.9
Lampung	5.1	3.7	7.6	5.4	3.0	7.6
North Sumatra	8.3	5.7	10.0	5.5	3.5	6.3
South Sulawesi	5.9	3.9	9.4	5.7	4.6	7.5
All sites	**5.2**	**3.2**	**8.0**	**4.6**	**3.0**	**6.3**

* Including PK and PK-ICM plots

Average standard deviation among five farms at each site: 1.4 t/ha

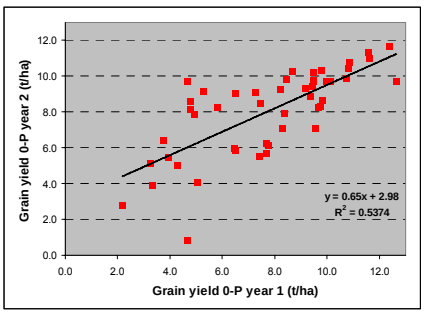


Indigenous P supply

Site	Crop 1, 2004-2005 Grain yield 0-P (Y_{0P}, t/ha)*			Crop 2 2005-2006 Grain yield 0-P (Y_{0P}, t/ha)*		
	Mean	Min	Max	Mean	Min	Max
Central Java, Grob.	7.5	4.7	12.6	9.0	7.8	10.3
Central Java, Won.	3.9	2.2	5.0	4.2	0.8	6.4
East Java	10.4	9.3	12.4	10.3	8.9	11.7
Lampung	7.0	5.3	8.3	7.6	5.7	9.3
North Sumatra	9.4	7.4	10.7	8.3	5.6	10.4
South Sulawesi	6.1	3.1	9.5	7.0	5.6	10.4
All sites	**7.4**	**5.3**	**9.8**	**7.8**	**5.7**	**9.8**

* Including NK and NK-ICM plots

Average standard deviation among five farms at each site: 1.5 t/ha

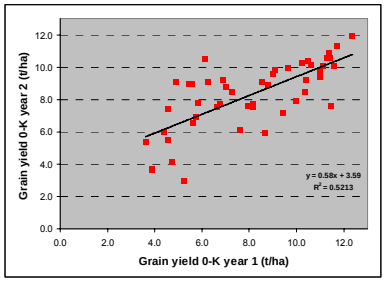


Indigenous K supply

Site	Crop 1, 2004-2005 Grain yield 0-K (Y_{0K}, t/ha)*			Crop 2 2005-2006 Grain yield 0-K (Y_{0K}, t/ha)*		
	Mean	Min	Max	Mean	Min	Max
Central Java, Grob.	8.2	5.7	11.3	9.2	6.9	10.6
Central Java, Won.	4.9	3.6	8.1	5.2	3.0	7.4
East Java	10.2	7.9	12.3	10.1	7.6	12.0
Lampung	6.5	3.9	8.5	8.0	3.7	9.2
North Sumatra	10.1	7.6	11.6	8.3	6.0	10.3
South Sulawesi	6.7	5.1	9.3	7.6	5.7	10.2
All sites	**7.8**	**5.6**	**10.2**	**8.1**	**5.5**	**9.9**

* Including NP and NP-ICM plots

Average standard deviation among five farms at each site: 1.5 t/ha



Yield response to nutrients

			Nitrogen 200-250 kg N/ha		Phosphorus 35-40 kg P/ha		Potassium 100-150 kg K/ha	
	crop	Y NPK t/ha	dY N t/ha	AEN kg/kg	dY P t/ha	AEP kg/ha	dY K t/ha	AEK kg/kg
C. Java (Grob)	1	8.6	6.3	32	1.2	39	0.4	6
	2	10.4	8.7	44	1.4	40	1.3	13
C. Java (Won)	1	5.8	3.1	15	2.0	65	0.9	12
	2	5.6	2.6	13	1.4	39	0.4	4
East Java	1	10.9	4.0	20	0.5	13	0.8	8
	2	10.8	4.5	23	0.5	13	0.7	7
Lampung	1	7.6	2.4	11	0.6	16	1.1	9
	2	9.3	3.8	19	1.7	47	1.3	13
N. Sumatra	1	10.8	2.5	11	1.5	39	0.8	6
	2	9.0	3.5	15	0.7	17	0.7	6
South Sulawesi	1	7.8	1.9	8	1.7	45	1.1	9
	2	7.2	1.5	7	0.2	5	0.0	0
All sites		**8.8**	**3.9**	**19**	**1.2**	**34**	**0.9**	**8**

* Averages of -ICM and +ICM plots; NPK vs. omission plots

1 - crop 1, 2004-2005

2 - crop 2 or 3, 2005-2006

Performance of the 1st SSNM crop

						% rel.FFP	
	NPK	NPK +ICM	FFP	SSNM	SSNM +ICM	SSNM	SSNM +ICM
Fertilizer N (kg N/ha)	200	213	212	165	165	-22	-22
Fertilizer P (kg P_2O_5/ha)	80	84	72	81	81	13	13
Fertilizer K (kg K_2O/ha)	120	136	53	101	101	92	92
Grain yield (t/ha)	8.4	8.7	7.4	8.7	8.9	17	20
Total dry matter (t/ha)	16.2	17.6	14.1	17.1	17.4	22	24
1000 plants/ha	60	63	55	61	63	11	16
1000 ears/ha	58	61	54	61	64	13	19
kernels/ear	440	427	431	432	422	0	-2
100 seed weight (g)	28.8	29.7	28.1	28.8	29.1	3	4

* Excludes South Sulawesi (no true SSNM treatment yet)

Performance of the first SSNM crop

	Grain yield (t/ha)			% rel.FFP	
	FFP	SSNM	SSNM+ICM	SSNM	SSNM+ICM
C. Java (Grob)	9.2	9.6	9.7	5	6
C. Java (Won)	5.0	5.3	5.8	6	15
East Java	9.3	9.1	10.1	-2	9
Lampung	7.1	8.5	8.8	20	25
N. Sumatra	6.7	10.9	10.2	63	52
Avg.	7.4	8.7	8.9	17	20

	1000 ears/ha			% rel.FFP	
	FFP	SSNM	SSNM+ICM	SSNM	SSNM+ICM
C. Java (Grob)	53	59	59	10	12
C. Java (Won)	49	54	55	10	11
East Java	61	64	64	6	6
Lampung	58	62	64	7	10
N. Sumatra	49	67	79	36	61
Avg.	54	61	64	13	19

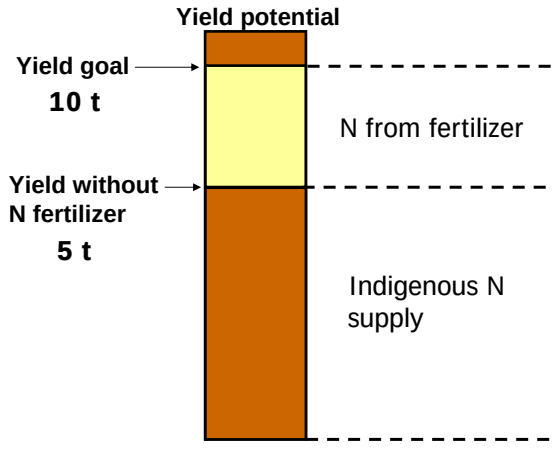
Performance of the first SSNM crop in maize

Parameters	Treatments		Relative change
	FFP	SSNM	%
Yield (t ha^{-1})	7.4	8.7	17
Gross benefit (IDR ha^{-1})	**8,188,742**	**9,553,960**	**17**
N fertilizer cost (IDR ha^{-1})	592,508	461,186	-22
P fertilizer cost (IDR ha^{-1})	311,720	351,079	13
K fertilizer cost (IDR ha^{-1})	174,528	335,753	92
Total fertilizer cost (IDR ha^{-1})	**1,078,756**	**1,148,018**	**6**
Plant density (seed ha^{-1})	60,000	66,000	10
Total seed cost (IDR ha^{-1})	**540,000**	**594,000**	**10**
Total cost (IDR ha^{-1})	1,618,756	1,742,018	8
Net benefit* (IDR ha^{-1})	**6,569,986**	**7,811,942**	**19**

* Over fertilizer and seed costs

Indonesia, 25 farm-sites, 2005/06

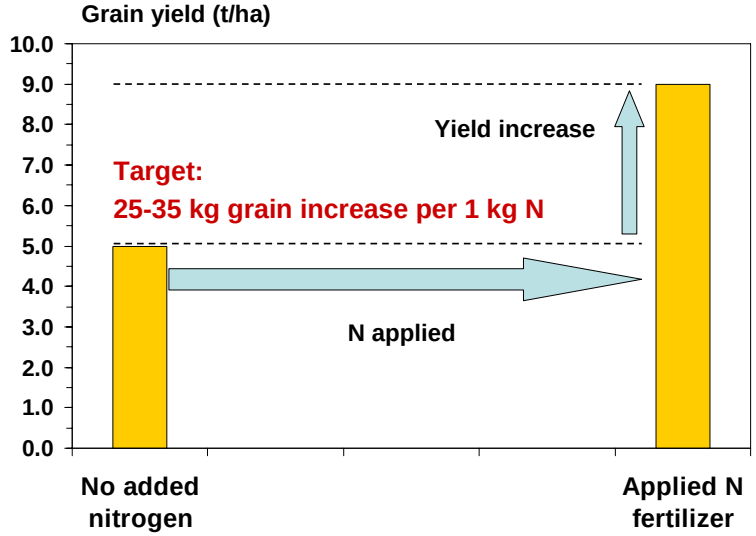
Principle of SSNM



Fertilizer nutrient requirement per 1 t yield increase = **1000 / agronomic efficiency** of fertilizer

Estimate from grain yield in omission plot and/or from soil properties

Optimal rate of fertilizer N depends upon expected increase in corn yield



Nutrient use efficiencies

Target ranges for SSNM in high-yielding maize

	AE (kg/kg)		PE (kg/kg)		RE (kg/kg)
N	25-35	=	60-70	x	0.40-0.50
P	40-50	=	300-350	x	0.13-0.20
K	10-20	=	30-40	x	0.40-0.50

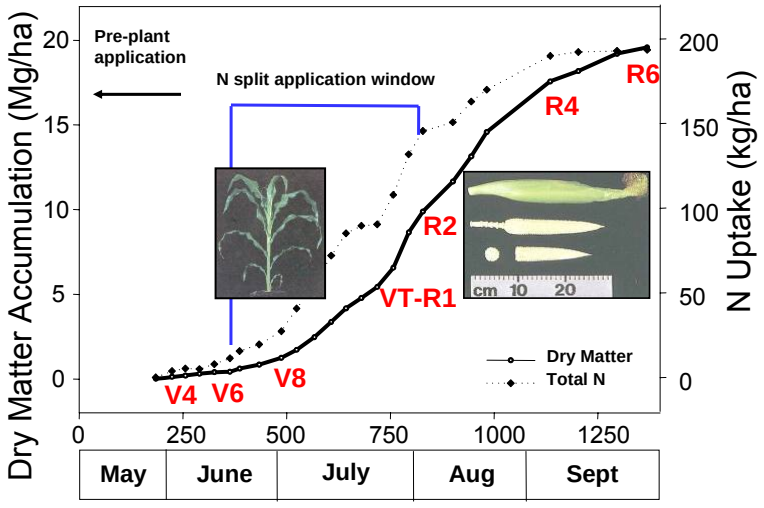
- AE = kg yield increase per kg nutrient applied
- **AE (kg/kg) = (Y – Y0)/F**
- YN – yield (kg/ha) in a plot that received nutrient at the rate of F (kg/ha); Y0 – yield in a plot without nutrient addition (kg/ha); F – Fertilizer rate (kg nutrient/ha)

- **AE = PE x RE**
- PE = physiological efficiency of applied nutrient = kg yield increase per kg nutrient uptake
- RE = recovery efficiency of applied nutrient in the plant

Estimated fertilizer N required for maize based on yield response to fertilizer N and efficiency of fertilizer N

Agronomic efficiency (kg grain increase/kg applied N) →	22	26	30	34
Yield response (t/ha) ↓	Fertilizer N rate (kg/ha)			
1	45	38	33	29
2	91	77	67	59
3	136	115	100	88
4	182	154	133	118
5	227	192	167	147
6	273	231	200	176
7	318	269	233	206

Strategies for N split application



Within-season adjustment using the LCC

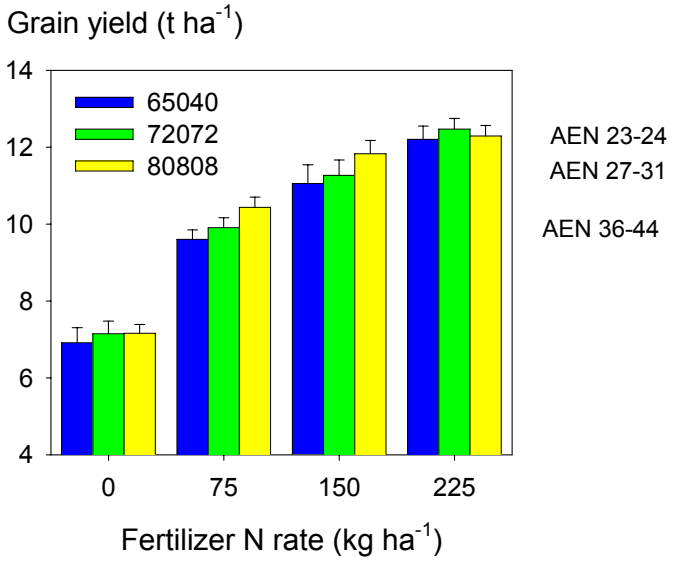
Example
Yield target: 10 t/ha
Yield in 0-N: 4 t/ha
AEN: 30 kg grain/kg fertilizer N (33 kg fertilizer N/t grain yield)
Total fertilizer N rate: 200 kg N/ha

Splitting scheme for total fertilizer N
- Basal : 60 kg/ha (30%)
- V6-V8: 70 kg/ha (35%)
- V10-12: 70 kg /ha (35%) – use LCC to adjust N rates
- V14-VT: Additional 10-15%, if LCC < 4.5

N adjustment using LCC at V10
- If LCC ≤ 4.5, immediately apply standard rate of 70 kg N/ha,
- If LCC > 4.5, either i) postpone N application by few days and measure again before V13 or ii) apply 40-50 kg N/ha.

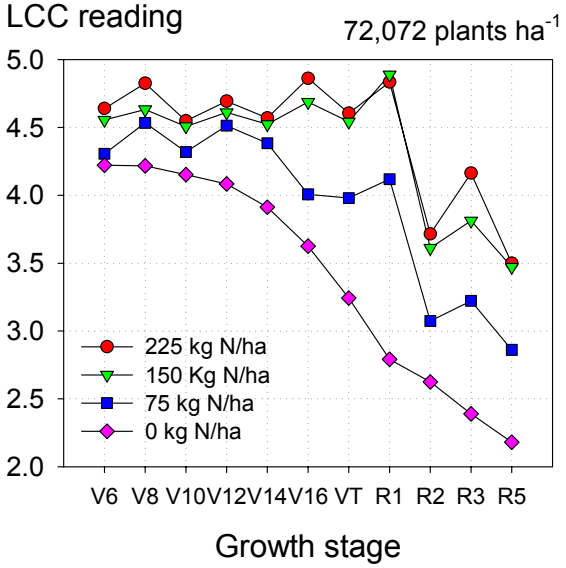
N adjustment using LCC at V14-VT
- If LCC < 4.5, apply 20-30 kg N/ha

N rate x planting density, Indonesia



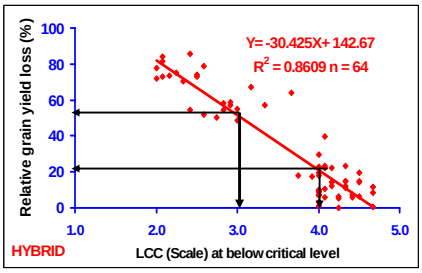
CRI Maros, Indonesia, 2006

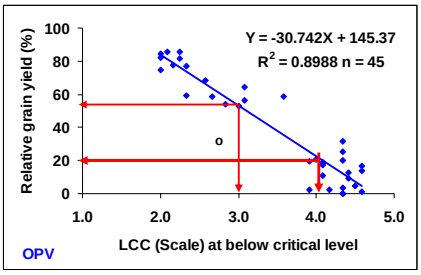
Time course profile of LCC readings



CRI Maros, Indonesia, 2006

LCC reading and yield loss





- There was no yield decrease at LCC values of 4.8 for hybrid maize and 4.7 for OVP.
- The lower the LCC reading, the higher the yield losses.
- The leaf color should be ≥ LCC 4.5.

CRI Maros, Indonesia, 2006

Fertilizer P_2O_5 requirements by expected yield response and agronomic P efficiency (AEP)

Yield response (t/ha)	AEP = 50 Soil types A, B, D…	AEP = 40 Soil types L, M, N…
	Fertilizer P_2O_5 (kg/ha)	
0.5	25	30
1.0	45	60
1.5	70	85
2.0	90	115

- Associate expected AEP with soil type, soil analysis, …
- Note that the P removal of a crop yielding 10 t/ha is about 28 kg P/ha (64 kg P_2O_5/ha)
- If P rate is < 25 kg P2O5/ha, then FP = 0.5 x net P removal.

Fertilizer K_2O requirements by expected yield response and agronomic K efficiency (AEK)

Yield response (t/ha)	AEK = 10	AEK = 15	AEK = 20
	Fertilizer K_2O/ha		
0.5	60	40	30
1.0	120	80	60
1.5	180	120	90

- Associate expected AEK with soil type, soil analysis, …
- Note that the K removal of a crop yielding 10 t/ha is about 200 kg K/ha (240 kg K_2O/ha)
- If K rate is < 10 kg K_2O/ha, apply 30 kg K_2O

Summary

- Best yields with high NPK: 7 to 13 t/ha by sites = yields attainable with the current technologies.
- Annual grain production potential: 10 (M-M, rainfed drought-prone) to 30 t grain/ha/year (R-M-M, irrig).
- Yield response: N >> P ≥ K (3-5, 1-1.5, 0.5-1.5 t/ha)
- About 20% yield increase in the first SSNM crop, but widely varying among sites. 20% less N used.
- Need plant populations of at least 65000 pl/ha.
- Yield increase from kieserite (Mg+S) at all three sites where it was used.
- Good start, but more is possible through further fine-tuning and simplification of the approach.

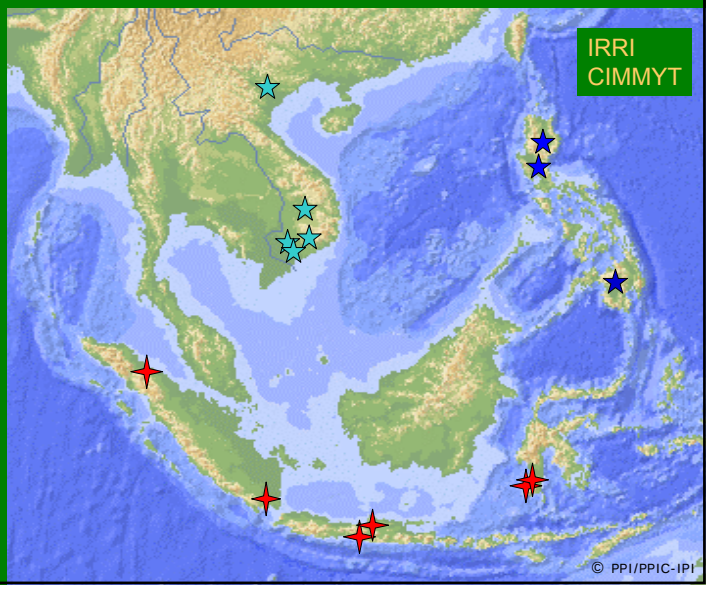
Site-Specific Nutrient Management for Maize
Southeast Asia Program (SEAP) of IPNI

Indonesia
IAARD, ICFORD, AIAT, IPNI, University of Nebraska

Vietnam
IAS, NISF, Cantho University, CLRRI, WASI, IPNI

Philippines
UPLB Corn RDE network, PhilRice, DA, IPNI

2004-2007
2005-2007
2005-2007



Outlook 2007-2009

- Confirm SSNM results in on-farm experiments (2006/07)
- Participatory evaluation of SSNM (2006/07)
- Development of promotional material (2007)
- Strengthen public-private partnerships for the delivery of SSNM including research, extension, seed and fertilizer companies through training workshops and joint on-farm activities (2007-2009)
- Support public and private partners in the implementation of on-farm demonstration trials (2007-2009)
- Assist national programs and other stakeholders in the expansion of SSNM to new areas in existing provinces (2007-2009)

Acknowledgements

Funding for this projected is provided by

- The International Fertilizer Industry Association (IFA)
- Canpotex International
- The Southeast Asia Program of PPI/PPIC and IPI

Thank you.