Nutrient Management in Improving the Productivity of Lowland Rice in the Philippines

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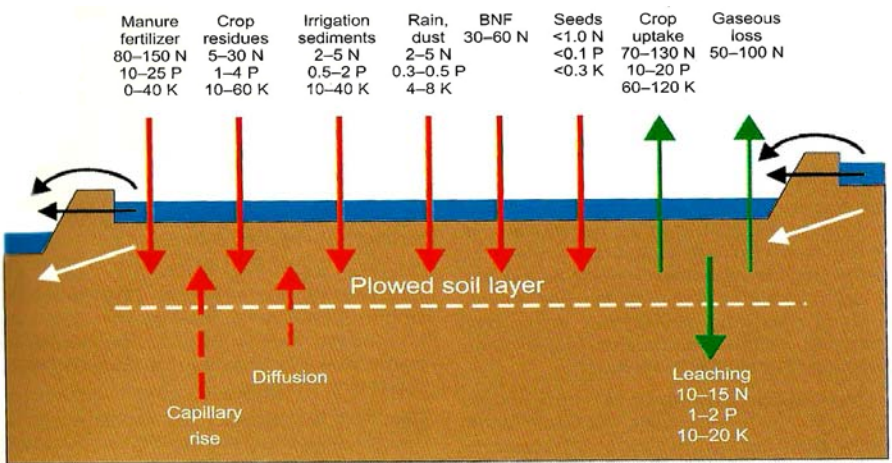
Nutrient Management for Lowland Rice

- Subject of research for several decades
- Assumptions
  - ✓ Results should have been incorporated in nutrient management recommendations
  - ✓ Recommendations have been adopted/adapted by farmers
  - ✓ Rice nutrition is not a yield-limiting component in lowland rice production
- Current situation: low-medium productivity of Philippine lowland rice areas
  - ✓ Are there any gaps in the utilization of recommended or appropriate nutrient management?
  - ✓ Can nutrient management contribute to the improvement of lowland rice productivity?

Presentation Outline

- Nutrient Balance & Sources of Nutrients
- Chemical Properties of Philippine Soils
- Soil Nutrient Supplying Capacity & Plant NPK Requirement
- Recommended & Actual Nutrient Management Practices
- Nutrient Management Approaches in Improving Lowland Rice Yields
- Conclusion & Recommendation

Nutrient Balance and Sources of Nutrients in Lowland Rice Production System



Values shown are common ranges of inputs and outputs of N, P, and K for an irrigated rice field (kg ha⁻¹ per crop).

Dobermann & Fairhurst (2000)

Nutrient Input-Output Balance

SOURCE	N		P		K	
	kg ha^{-1}	%	kg ha^{-1}	%	kg ha^{-1}	%
INPUTS						
Fertilizers	80-150	**60-67**	10-25	**79-84**	0-40	**0-27**
Crop Residues	5-30	4-12	1-4	8.4-12.6	10-60	**40-41**
Irrigation	2-5	1.6-2	0.5-2	4-4.2	10-40	**27-41**
Rain/Dust	2-5	1.6-2	0.3-0.5	1.6-2.5	4-8	5-6
BNF	30-60	**24-25**	-	-	-	-
Seeds	< 1	0.5	<0.1	0.5	<0.3	0.03
Total Input (A)	**120-250**		**11.9-31.6**		**24.3-148.3**	
OUTPUTS						
Crop Uptake	70-130	**53-54**	10-20	**91**	60-120	**86**
Gaseous Loss	50-100	**38-41**	-	-	-	-
Leaching	10-15	6-8	1-2	9	10-20	14
Total Output (B)	**130-245**		**11-22**		**70-140**	
Net (A-B)	**(5-10)**		**1-10**		**(46)-8**	

Adapted from Dobermann & Fairhurst (2000)

Chemical Properties of Philippine Soils

Soil Parameter	Philippines		Tropical Asia
	Surface	Subsurface	Surface
Organic C (%)	1.84 ± 1.09	0.47 ± 0.39	1.41 ± 1.28
Total N (%)	**0.17 ± 0.11**	**0.04 ± 0.03**	**0.13 ± 0.11**
C/N ratio	11.6 ± 1.8	10.4 ± 3.0	11.2 ± 2.7
pH (H_2O)	6.3 ± 0.7	6.9 ± 0.6	6.0 ± 1.1
CEC (pH 7) (cmol+/kg)	37.3 ± 13.7	39.5 ± 14.8	18.6 ± 12.0
Exch Ca (cmol+/kg)	25.6 ± 9.5	27 ± 9.6	10.4 ± 9.9
Exch Mg (cmol+/kg)	10.4 ± 4.5	11.9 ± 5.1	5.5 ± 5.3
Exch K (cmol+/kg)	**0.5 ± 0.4**	**0.3 ± 0.3**	**0.4 ± 0.3**
Exch Na (cmol+/kg)	1.5 ± 2.1	1.5 ± 1.5	1.5 ± 3.0
Ave P_2O_5 (mg/100g)	**4.0 ± 4.0**	**5.2 ± 8.6**	**3.8 ± 10.6**
Ave SiO_2 (mg/100g)	54.3 ± 24.4	68.0 ± 23.1	27 ± 25.5

Miura, Badayos & Briones (1995)

Soil Nutrient Supplying Capacity

Omission Plots- SNSC

Cassman, Dobermann, Witt, Buresh,
… Sta. Cruz … (1993-2000) - IRRI

179 RTOP Farms: S & SE Asia

Nutrient	Soil Supply of Nutrient (kg ha^{-1})
Nitrogen	40 - 70
Phosphorus	12 - 18
Potassium	65 - 90

Lowland rice fields can sustain grain yields of 2-3 t/ha without fertilizer application

Plant NPK Requirement

Optimal IE for Balanced Nutrition	
Nutrient	IE (kg grain kg^{-1} nutrient)
N	68
P	385
K	69

Per ton basis

1/68 = x/1000

Nutrient	Nutrient Requirement (kg ha^{-1})
N	15
P	2.6
K	15

Witt and Co-workers (1999)
Cassman, Dobermann, Witt, Buresh, … Sta. Cruz… (1993-2000) - IRRI

SNSC, NPK Requirement and Rice Yields at Zero Fertilizer Application

Nutrient	Soil Supply of Nutrient Capacity (kg ha^{-1})	Nutrient Requirement per Ton of Grains (kg ha^{-1})	Yields based on Lower Limit* (t ha^{-1})
N	40 - 70	15	2.67
P	12 - 18	2.6	4.61
K	65 - 90	15	4.33

- **N --- most limiting nutrient**
- **2.8-4.9 t/ha** yields in unfertilized plots within rice growing domains at scales of one to few villages in **5 Asian countries including Philippines** (Dobermann and White, 1996)
- **2.61 t/ha (1.59-3.52 t/ha) during DS** (Quezon condition; CRDES, 2010)
- **2.74 t/ha (1.32-4.59 t/ha) during WS** (Quezon condition; CRDES, 2010)

NPK Fertilizer Applications and Rice Yields in 2008 (BAS, 2011)

Region	Area Planted (ha)	Area Applied (ha)	Unfertilized Area (%)	Yield (mt)	Nutrient Applied (kg/ha)			Yield (kg/ha)
					N	P	K	
CAR	131,772	121,561	7.7	445156	64.8	8.4	5.5	3.38
Ilocos Region	388,763	386,565	0.6	1691629	89.1	15.0	12.4	4.35
Cagayan Valley	540,913	534,792	1.1	2080240	80.4	17.5	8.3	3.85
Central Luzon	666,329	649,324	2.6	3014347	73.1	21.1	13.9	4.52
Calabarzon	112,145	98,724	12.0	428085	66.8	9.6	7.9	3.82
Mimaropa	254,403	225,841	11.2	863215	54.9	13.4	11.2	3.39
Bicol Region	290,775	270,417	7.0	997581	49.4	9.3	7.1	3.43
Western Visayas	646,197	549,672	14.9	2117598	50.6	12.7	6.6	3.28
Central Visayas	105,154	100,713	4.2	311801	42.6	17.5	16.0	2.97
Eastern Visayas	276,573	266,777	3.5	1030621	33.4	7.1	6.2	3.73
Zamboanga Peninsula	145,315	132,995	8.5	551310	40.6	11.9	6.0	3.79
Northern Mindanao	137,276	134,341	2.1	551246	57.9	16.3	6.8	4.02
Davao Region	95,252	93,633	1.7	418954	58.6	10.1	6.9	4.40
Soccksargen	346,403	335,798	3.1	1234757	45.4	6.2	4.8	3.56
CARAGA	138,259	134,721	2.6	447317	38.6	9.3	7.3	3.24
ARMM	200,504	189,175	5.7	631691	55.6	6.1	5.3	3.15
TOTAL	**4,476,033**	**4,225,049**		**16,815,548**				
Mean	**279,752**	**264,066**	**5.5**	**1,050,972**	**56.4**	**12.0**	**8.3**	**3.68**
Median	**227,454**	**207,508**	**3.9**	**747,453**	**55.2**	**11.0**	**7.0**	**3.65**

Recommended & Farmers' Nutrient Management Practices

Practice	Recommended Practices	Current Farmers' Practices	Remarks
Fertilizer rate (kg/ha)	• WS: 115-27-57.5 • DS: 149.5-27-57.5 • Blanket?	• 56.4-12-8.3 • 250,000 ha (5.6%) ---zero application	• Deficit based on current recom: 56.8-15-49.2

Recommended & Farmers' Nutrient Management Practices

Practice	Recommended Practices	Current Farmers' Practices	Remarks
Timing of application	• Basal (NPK) • ET (N) • MT (NK) • PI (N) • H/F (N – optional)	• Basal or ET (N/NPK) • PI (N) • Soil-applied fertilizers replaced with foliars	• 0-2 (FFP) vs 4-5X (RF) • YC-based (grain filling) application neglected

Recommended & Farmers' Nutrient Management Practices

Practice	Recommended Practices	Current Farmers' Practices	Remarks
Fertilizer source	• Inorganic (major) • Organic-inorganic combination (optional) • Bio-inoculants (optional)	• Inorganic (major) • Organic (limited use) • Foliar (limited use & soil-applied fertilizer replacement) • Bio-inoculants (limited use) • Green manure not practiced	• Organic, green manure and foliar fertilizers not in current nutrient management recommendations • Straw/residue recycling not seriously practiced by farmers

Recommended & Farmers' Nutrient Management Practices

Practice	Recommended Practices	Current Farmers' Practices	Remarks
NM/ICM Tools/Guides	• Palaycheck (top-down type) • Nutrient Manager (decision-aided type) ---integrated in current recommendations?	• Palaycheck & Nutrient Manager not generally practiced & reached critical mass of farmers	• Precision nutrient management to increase nutrient use efficiency -- not being practiced

Recommended & Farmers' Nutrient Management Practices (Summary)

Practice	Recommended Practices	Current Farmers' Practices	Remarks
Fertilizer rate (kg/ha)	• WS: 115-27-57.5 • DS: 149.5-27-57.5 • Blanket?	• 56.4-12-8.3 • 250,000 ha (5.6%) --- zero application	• Deficit based on current recom: 56.8-15-49.2
Timing of application	• Basal (NPK) • ET (N) • MT (NK) • PI (N) • H/F (N – optional)	• Basal or ET (N/NPK) • PI (N) • Soil-applied fertilizers replaced with foliars	• 0-2 (FFP) vs 4-5X (RF) • YC-based (grain filling) application neglected
Fertilizer source	• Inorganic (major) • Organic-inorganic combination (optional) • Bio-inoculants (optional)	• Inorganic (major) • Organic (few users) • Foliar (replacement) • Bio-inoculants (few users) • Green manure not practiced	• OF, GM and foliar fertilizers not in current recom • Straw/residue recycling not seriously practiced by farmers
NM/ICM Tools/Guides	• Palaycheck (top-down) • Nutrient Manager (decision-aided) --- integrated in NM recom?	• Not strictly practiced & reached critical mass of farmers	• Precision nutrient management to increase nutrient use efficiency not practiced

Suggested NM Agronomic Approaches to Increase Lowland Rice Yield

- ❑ Increase fertilizer application at farmers level
- ❑ Improve yield-determining components during grain filling through appropriate timing of fertilizer application
- ❑ Increase nutrient uptake through GM/organic-inorganic combinations and bio-inoculant technologies → enhancement BNF and nutrient absorption-facilitating microorganisms activity
- ❑ Use of slow-release fertilizers to improve fertilizer recoveries
- ❑ Residue recycling to increase nutrient input component of the production system
- ❑ Appropriate crop management (other than nutrient management component) --- overcome major yield-limiting constraints

Improvement of Yield through Increased Fertilizer Application

Assumptions

- Lowland rice fields can support 2.5 t/ha yields without fertilizer application
- Mean yields of 3.68 t/ha → to be increased by 1 t/ha
- NPK recovery efficiencies: 40, 20 & 35%

Improvement of Yield through Increased Fertilizer Application

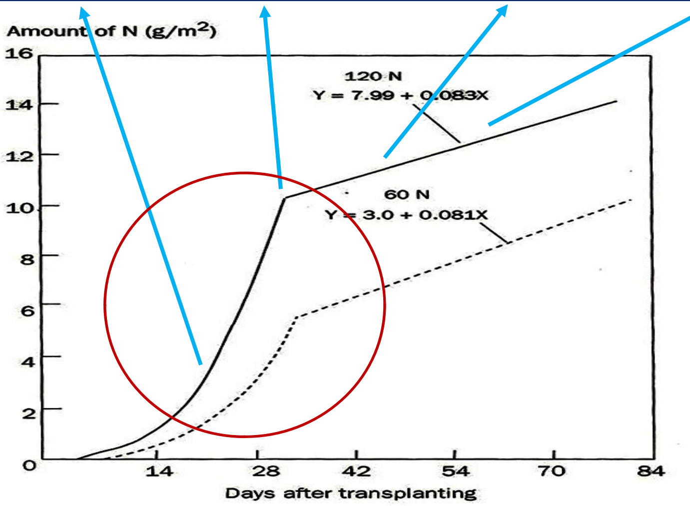
Needed Fertilizer? = (Plant Requirement - Indigenous Nutrient Supply) / Fertilizer Recovery Efficiency

4.68 tons target yield --- 1 ton increase from current mean yield

Nutrient	Plant Nutrient Requirement (kg/ha)		Indigenous Nutrient Supply (kg/ha)		Fertilizer Recovery Efficiency		FertilizerRate (kg/ha)
N	70.2	-	37.5	÷	0.40	=	81.8
P	12.2	-	10	÷	0.20	=	11 (25)
K	70.2	-	60	÷	0.35	=	29.1 (35)

Yield Components and Nitrogen Application

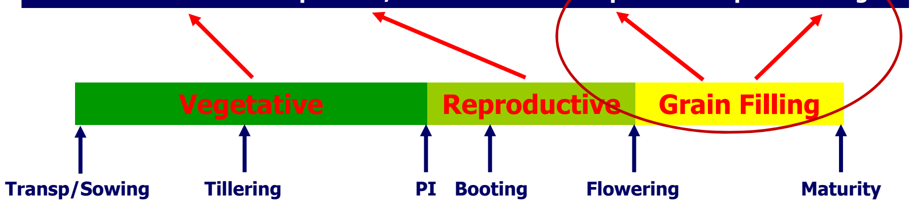
Yield = # Panicles * # Spikelets/Panicle * % Filled Spikelets * Spikelet Weight



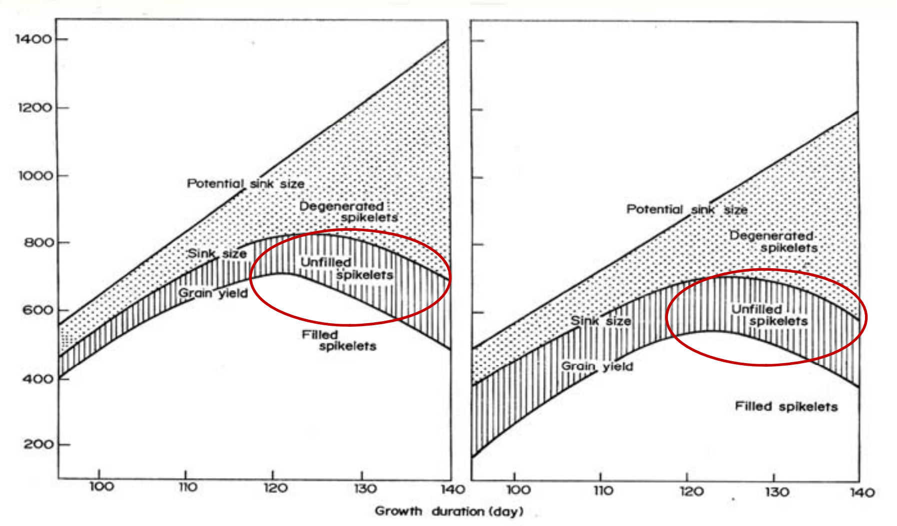
Modified from: Wada et al. (1989) & Sta. Cruz and Wada (1994)

Development of Yield Components and Growth Stages

Yield = # Panicles * # Spikelets/Panicle * % Filled Spikelets * Spikelet Weight



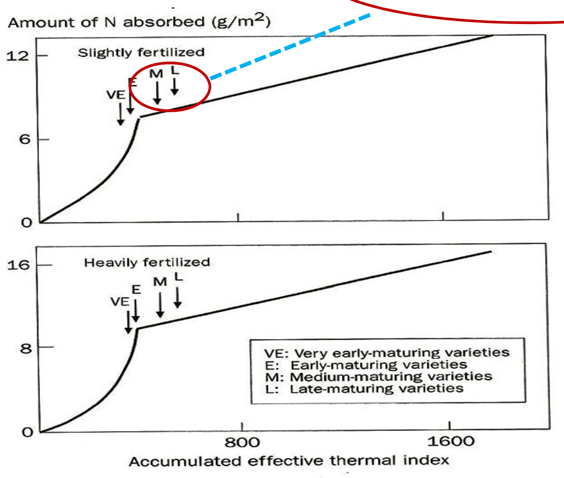
Degenerated/Unfilled Spikelets and Growth Duration



Sta. Cruz (1990); Sta. Cruz & Wada (1994)

Fertilizer Application at Pre-Post Flowering to Improve Grain Filling

Yield = # Panicles * # Spikelets/Panicle * % Filled Spikelets * Spikelet Weight



Modified from: Wada et al. (1989) & Sta. Cruz and Wada (1994)

Yield Improvement through Increasing Grain Filling Percentage

For medium and long duration varieties (>125 d) with high potential sink size or yield containers

Intervention	Season	Target Contribution (%)	Potential Yield Increment (t/ha)
Improvement of grain filling percentage	Wet Season	5	0.18*
	Dry Season	10	0.37*

* based on 3.68 t/ha base yield

Positive implication on agronomic efficiency based on nutrient application

Yield Improvement through Increasing Nutrient Availability & Enhancement of Nutrient Uptake

Intervention	Contribution to Nutrient Availability (kg/ha)	Target Contribution (%)	Additional Available Nutrient (kg/ha)	Potential Yield Increment (t/ha)
GM Crops	20-30	30	6-9	0.4-0.6
BNF --- via inorganic-organic integration	14-50	10	1.4-5	0.09-0.33
Bio-inoculant		6-8		0.22-0.29*

* based on 3.68 t/ha base yield

Yield Improvement by Increasing Fertilizer Recovery Efficiency through Use of Slow-release Fertilizers

Intervention	N Use Efficiency (%)	Target (%)	Additional N uptake (kg/ha)	Potential Yield Increment (t/ha)
Slow release N fertilizers	40	50	5.64*	0.38*

* based on10% increase in FRE, 56.4 kg N/ha current application and 15 kg N per ton IE

Crop Removal and Nutrient Recycling from Rice Straw

Plant Part	Nutrient Uptake per Ton Grain Yield		
	N	P	K
Grain	10.5	2	2.5
Straw	7	1	14.5
Total	17.5	3	17
	• ≈40% of N --- in straw at maturity • almost all of N is lost upon burning	• ≈33% of P --- in straw at maturity • 20-25% of P in straw is lost on burning	• ≈85% of aboveground plant K in straw at maturity • K in straw is not lost upon burning

Modified from: Dobermann & Fairhurst (2000)

Summary of Nutrient Management Interventions in Improving Lowland Rice Yields (under good crop management)

Intervention	Anticipated Yield Increase (t/ha)
Increased fertilizer application (medium yield target: 4.68 t/ha)	1.00
Improvement of grain filling percentage	0.28 (0.18-0.37)
GM Crops	0.5 (0.4-0.6)
BNF (via inorganic-organic combination)	0.21 0.09-0.33
Bio-inoculant	0.26 (0.22-0.29)
Slow-release N fertilizers	0.38
Range (due to individual interventions)	0.21-1.0
Total (assuming all interventions are imposed - ideal)	2.63
Yield range* (imposition of at least 1 intervention)	3.89-4.68
* Mean base yield: 3.68 t/ha (actual base yields may range 2-5 t/ha	

Contribution of Nutrition and Crop Management Components to Rice Yield

Yield Limiting Component	Yield Reduction* (%)	Yield when Limiting Component is Controlled** (t/ha)
Nutrition	20	4.91
Crop management	20	4.91
Nutrition + crop management	40	6.13

* Dobermann & Fairhurst (2000)
** based on 3.68 t/ha base yield

Conclusion and Recommendations

- **Increasing productivity of lowland rice is possible**
  - ✓ 3.68 – 4.68 by increasing fertilizer application alone
  - ✓ 3.68 – 6.31 by improving NM components, in addition to increased level of fertilizer application
  - ✓ Major assumption: under good crop management (components other than nutrition)
- **Integration of decision-aided tool** in nutrient management of lowland rice --- site specific
- **Review current nutrient management technology recommendations**, delivery systems and related support services

Thank You