Precision Nutrient Management

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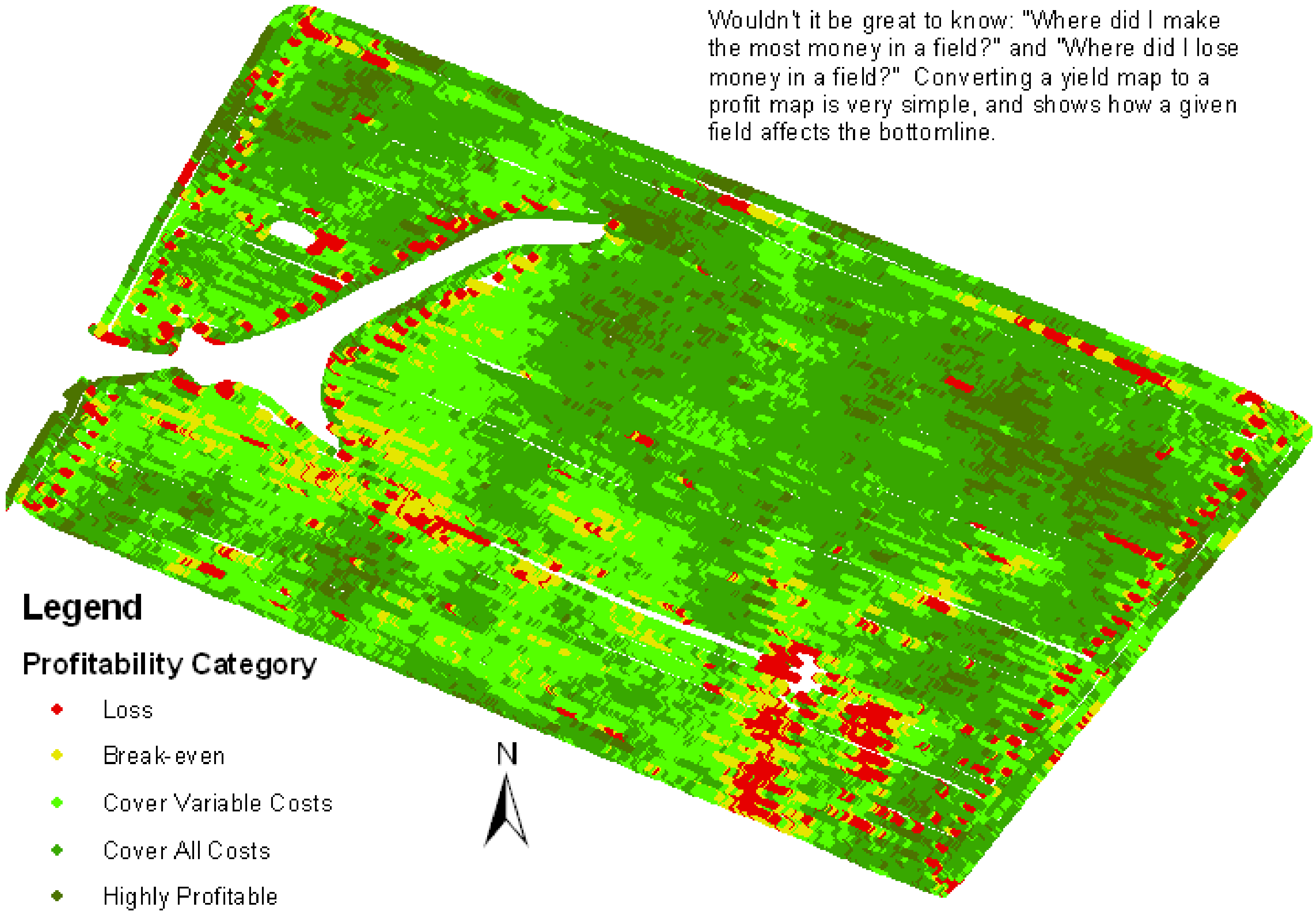
Motivation for Precision Nutrient Management (PNM)

	Benefit Occurs	No Benefit Occurs
ACT	Correct action	Type II error: Loss caused
DON'T ACT	Type I error: Lost opportunity	Correct inaction

⇨ **PNM minimizes Type I & Type II errors**

Profitability map

Wouldn't it be great to know: "Where did I make the most money in a field?" and "Where did I lose money in a field?" Converting a yield map to a profit map is very simple, and shows how a given field affects the bottomline.



Demonstrated benefits of PA

- **Law *et al*. (2009a; 2009b)**
  - PA can be considered as a **strategy to increase soil organic carbon sequestration** in oil palm
- **Baker *et al*. (2005)**
  - PA practices **reduced the potential off-site transport** of agricultural chemicals via surface runoff, subsurface drainage and leaching
- **Snyder (1996)**
  - **Total use of nitrogen fertilizer** in a 2-year cropping cycle **was lesser** using PA-based nitrogen management as compared to conventional nitrogen management

Demonstrated benefits of PA … (2)

- **Berry *et al*. (2005; 2003)**
  - Integrated use of GIS and geo-statistics to spatially model water and solute transport in large-scale croplands
  - Hot spots for surface runoff and sediment and agrochemical transport out of the cropland, as well as buffers that potentially **reduce off site transport**
  - Such information can guide site-specific applications of crop inputs, particularly nutrients, so as to **minimize non-point source pollution**

Demonstrated benefits of PA … (3)

- **Bongiovani (2004)**
  - PA-based nitrogen fertilization **reduced ground water contamination**
- **Guo-Wei *et al.* (2008)**
  - PA-based nutrient management **increased** the **absorption** and **use efficiency** of nitrogen, phosphorus and potassium in rice
- **Pompolino *et al.* (2007)**
  - PA-based nutrient management **reduced nitrogen fertilizer use** by 14% (in Vietnam) and 10% (in The Philippines). Total **nitrogen losses from the soil reduced** by 25-27%

Environmental hazards imposed by agriculture

- Nutrient management
- Pest management
- Soil erosion management

Soil & water quality

Environmental risks from nutrients

PROCESS	N	P	K	S	OM
Leaching	+	0	–	–	–
Denitrification	+	–	–	–	–
Eutrophication	+	+	–	–	–
Precipitation	+	+	+	–	–
Runoff	+	+	–	–	+
Volatilization	+	–	–	0	–
Saltation	–	–	+	–	–

0 – not significant

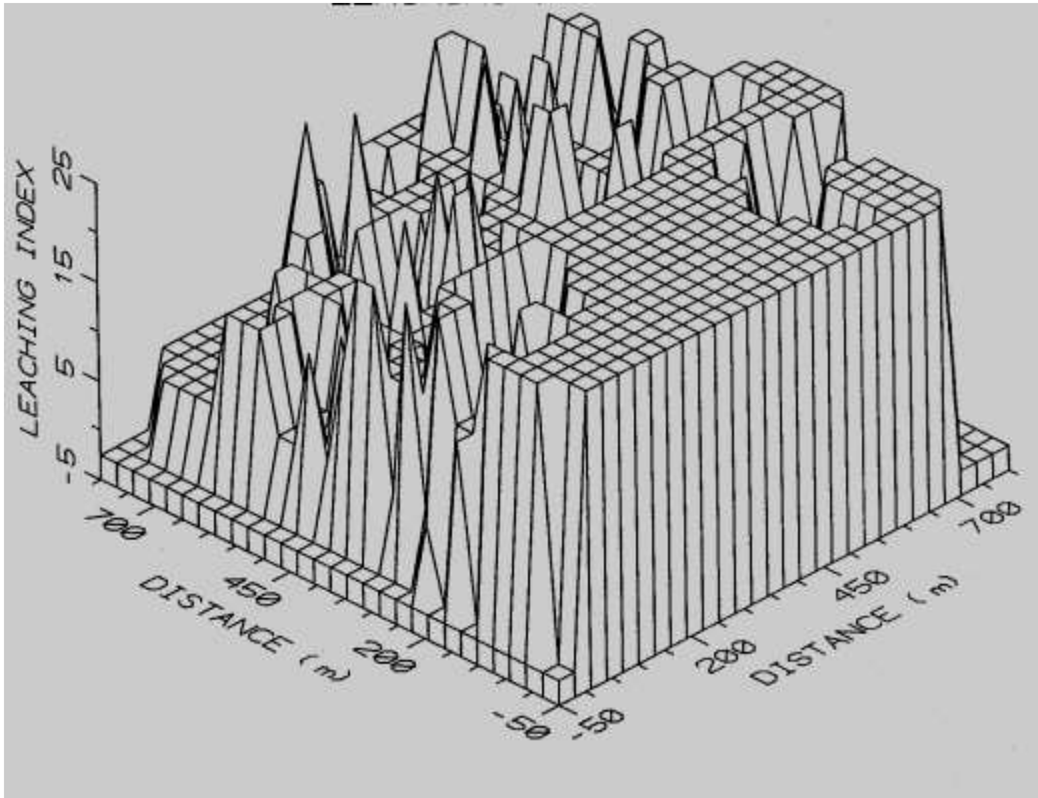
***Source*: Schepers (2000)**

Precision Nitrogen (N) management

- N fertilizers ➲ Highly soluble
- Major problem ➲ Leaching
- Rate of N uptake by plants fits a sigmoid curve
  - small amounts initially, increasing amounts during grand-growth stage, lesser amounts as crop matures
- Ideal N supply: Based on temporal needs of the crop
  - to avoid large amounts of nitrate-N in the soil at any one time
    - losses via leaching & denitrification ⇩

Precision N management – strategy # 1

- Management Zone (MZ) based on leaching potential



Leaching MZs
(Mulla & Annandale, 1990):

- o **Low (index = 5)**
- o **Medium (index = 15)**
- o **High (index = 25)**

High leaching zone : ↓ N

Low leaching zone : ↑ N

Precision N management – strategy # 2

- **Site-specific application based on agronomic variability**

Scenario	Area	Rate (kg N ha^{-1})	Average yield (t ha^{-1})	Average NO_3 leaching (kg NO_3 ha^{-1})
Conventional	**Whole field**	**250**	***11.57***	***95.9***
Site-specific	**Field I (sandy)**	**125** **[- 50%]**	**9.78**	**47.3** **[- 50%]**
	Field II (clayey)	**175** **[- 30%]**	**12.17**	**36.4** **[- 60%]**
	Mean		***11.29***	***39.7***

Source: **Verhagen (1997)**

Precision Phosphorus (P) management

- P ➲ Immobile nutrient
- Major problems: 1. Runoff (water-soluble P)
  2. Erosion (sediment-bound P)

Concentration of P in eroded sediment & runoff water

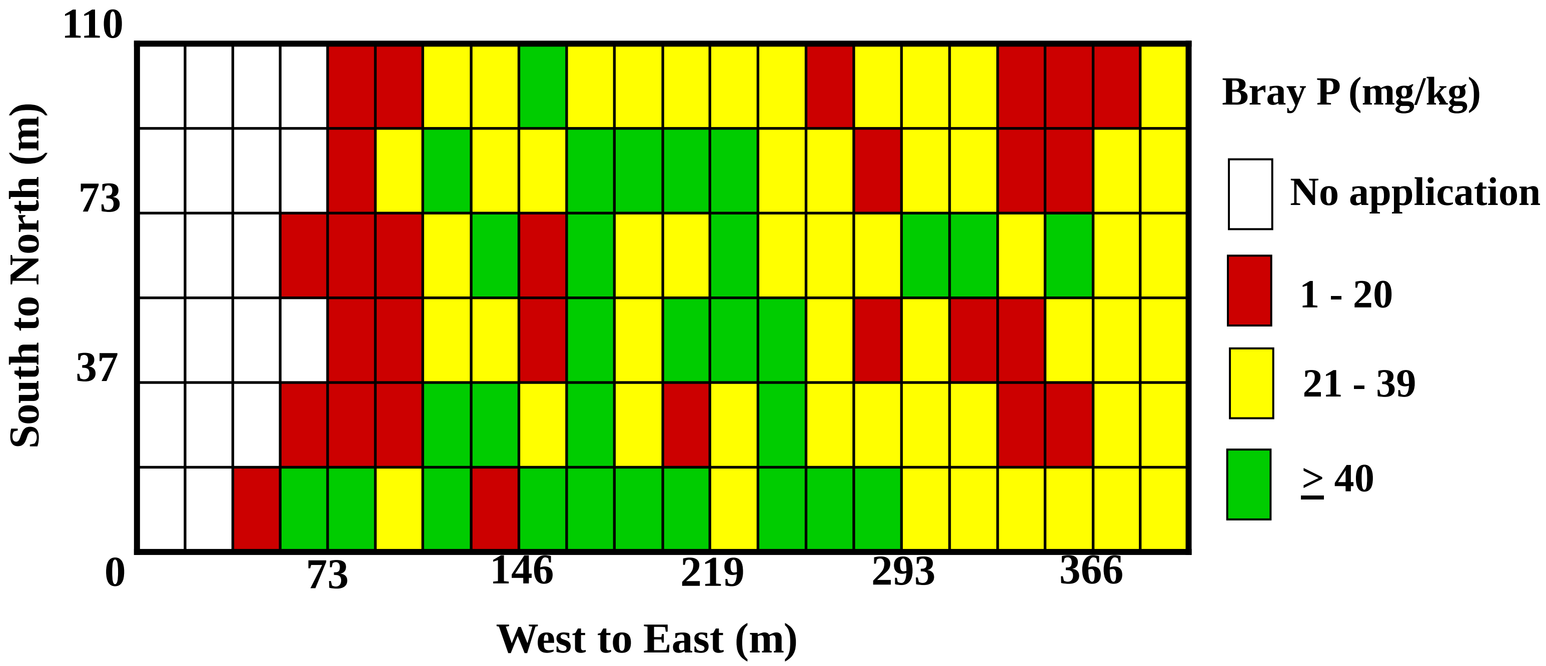
$\propto$

Concentration of extractable P in soil

⟹

- Linear
- Soil-specific

Variability of extractable P (Bray 1) at soil surface



Rationale for Precision P management

- **Uniform application of P results in test values that are:**

  1. Excess in extractable P
  (prone to losses via runoff & erosion) ➲ 21%

  2. Low in extractable P
  (less desirable for crop growth) ➲ 36%

- **Based on fertilizer recommendation (Rehm et al., 1995):**

  ⬂

  [Soil testing > 20 mg/kg can be excluded from application]

64% of field need <u>not</u> be fertilized

Our previous work: Precision oil palm management ... (1)

- **Effects of topography on soil fertility and oil palm yields**
- **Empirical production functions were defined for each topographic position (toeslope, sideslope, summit)**

Results:

- **Yields and soil fertility varied with topographic position**
- **Measured leaf and soil variables showed varying levels of optimality/sufficiency across topographic positions**

SK Balasundram, PC Robert, DJ Mulla and DL Allan. 2006. Relationship between oil palm yield and soil fertility as affected by topography in an Indonesian plantation. *Communications in Soil Science and Plant Analysis*, 37(9&10): 1321-1337.

Comparison of variables (leaf and soil) and the corresponding yield across topography

Variables	Toeslope	Sideslope	Summit
<u>Leaf</u>			
N	2.75[a]	2.75[a]	2.73[a]
P	0.18[a]	0.15[c]	0.16[b]
K	0.98[a]	0.93[b]	0.96[a]
Mg	0.40[b]	0.43[a]	0.42[ab]
Ca	0.78[a]	0.72[b]	0.71[b]
<u>Soil (0-20 cm)</u>			
pH	4.78[a]	4.27[b]	4.16[c]
OM	2.59[a]	2.22[b]	2.33[ab]
P	79.38[a]	77.98[a]	7.14[b]
K	0.23[a]	0.20[a]	0.20[a]
Mg	0.65[a]	0.70[a]	0.61[a]
Ca	1.63[a]	1.49[a]	1.19[b]
ECEC	5.46[a]	5.80[a]	5.02[a]
Texture	SC	LC	LC
Yield	**4.43[a]**	**3.60[b]**	**3.13[c]**

SK Balasundram, PC Robert, DJ Mulla and DL Allan. 2006. Relationship between oil palm yield and soil fertility as affected by topography in an Indonesian plantation. *Communications in Soil Science and Plant Analysis*, 37(9&10): 1321-1337.

Relationship between yield and leaf/soil variables across topography

Topographic position	Regression model§	R^2	Adjusted R^2
Toeslope	(1) Yield = 5.22 – 2.53*Leaf Mg	0.76	0.70
	(2a) Yield = 3.19 + 0.15*Leaf (N:Mg)	0.80	0.75
	(2b) Yield = 3.04 + 2.66*Leaf (P:Mg)	0.79	0.74
	(3) Yield = 3.66 + 0.10*pH	0.66	0.58
Sideslope	(3) Yield = 8.78 – 0.70*ECEC – 19.03*log (Subsoil Mg)	0.89	0.82
Summit	(1) Yield = 28.25 – 9.28*Leaf N	0.89	0.86
	(4) Yield = 3.88 – 2.57*Soil (K:Mg)	0.75	0.68

§Developed separately using the following group as yield predictors:
(1) leaf variables, (2) leaf nutrient ratios, (3) soil variables, and (4) topsoil nutrient ratios

SK Balasundram, PC Robert, DJ Mulla and DL Allan. 2006. Relationship between oil palm yield and soil fertility as affected by topography in an Indonesian plantation. *Communications in Soil Science and Plant Analysis*, 37(9&10): 1321-1337.

Our previous work: Precision oil palm management ... (2)

- **Spatial variability of oil palm yield-influencing variables (YIVs) at varying topographic positions**

Results:

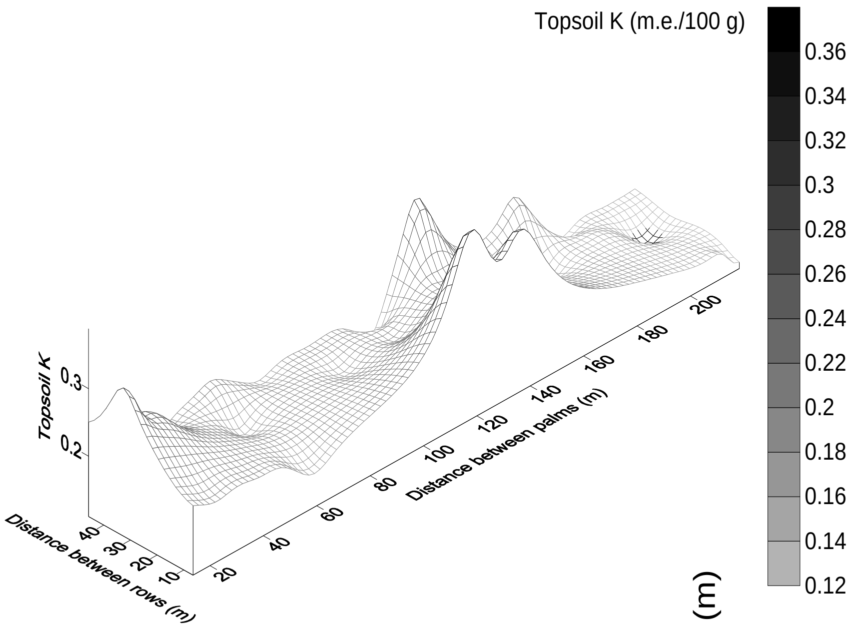
- **Optimum sampling strategy was found to depend on the type of variable being investigated and its topographic position**
- **Sample size requirement varied according to leaf/soil variables in the following order:**

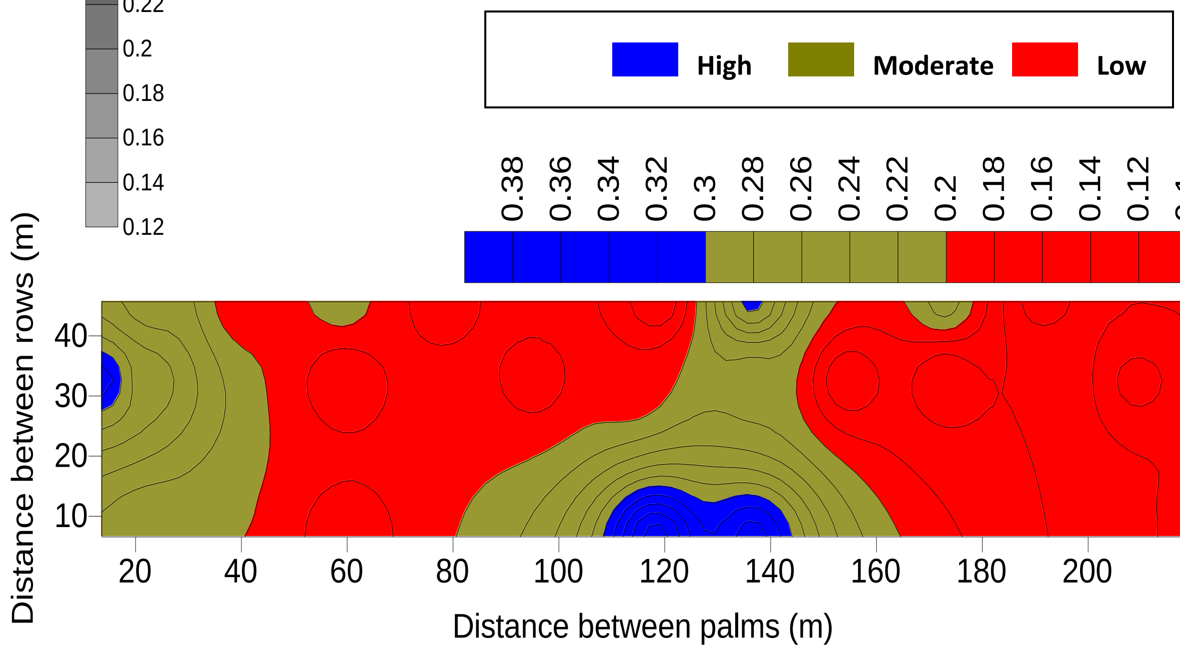
  (Leaf) N, P < Mg
  pH < ECEC < subsoil Mg < topsoil K < topsoil Mg
  → **Increasing sample size (n)**

- **K showed a clear demarcation of zones with high, moderate or low values – good candidate for variable rate management**

SK Balasundram, PC Robert, DJ Mulla and DL Allan. 2006. Spatial variability of soil fertility variables influencing yield in oil palm (*Elaeis guineensis* Jacq.). *Asian Journal of Plant Sciences*, 5(2): 397-408.

Spatial variability of topsoil K and the corresponding re-classed variability map





SK Balasundram, PC Robert, DJ Mulla and DL Allan. 2006. Spatial variability of soil fertility variables influencing yield in oil palm (*Elaeis guineensis* Jacq.). *Asian Journal of Plant Sciences*, 5(2): 397-408.

Our recent work:

TEMPORAL NITROGEN TRIALS IN IRRIGATED RICE FIELDS

METHODOLOGY

Planting season: 3 (S1, S2, S3)
N Treatments: 6 (0-80-120-160-200-240 kg ha⁻¹)
Rice Variety: MR220-ClearField®
Site: Semanggol, Perak, Malaysia
(4.949418° N, 100.606614° E)
Duration: Oct'12 - Feb'14
*160 kg ha⁻¹: recommended rate

MAIN FINDINGS

- ❑ Optimal N rate for Main season: 120 kg ha⁻¹
- ❑ Optimal N rate for Off season: 200 kg ha⁻¹
- ❑ Increment of yield compare to control plot (0 kg ha⁻¹): 85%
- ❑ Increment of yield compare to control plot (0 kg ha⁻¹): 49%

BENEFITS

- ✓ Reduce N input: low pollution + low input (more profit)
- ✓ Increase yield: higher income

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National Academy of Agricultural Science (NAAS) Rating :3.03

Response of Irrigated Direct-Seeded Rice Yields to Different Nitrogen Rates and Precipitation Patterns

K. S. Hun*, S. K. Balasundram**, A. R. Anuar*, O. H. Ahmed*** and H. Aminuddin*

ABSTRACT: *In Peninsular Malaysia, irrigated direct-seeded lowland rice cultivation results in higher yields during the off-season (April-July) as compared to the main-season (October-January). However, farmers still apply the same amount of nitrogen (N) at both growing seasons. A study was conducted to assess the response of rice yield components to different N rates and different precipitation patterns. This work was conducted in a 27-acre field with six N treatments, i.e. 0, 80, 120, 160, 200 and 240 kg N ha^{-1} in three continuous planting seasons from October-2012 to January-2014. In the first planting during main-season (S1), treatment with 120 kg N ha^{-1} showed significantly higher panicle number per m^2 (PM), 1000-grain weight (GW) and estimated grain yield (GY). Meanwhile, treatment with 200 kg N ha^{-1} significantly increased panicle number m^{-2}, spikelet number per panicle (SP), percentage of filled spikelet (FP) and estimated grain yield (GY) in the second planting during off-season (S2). In the third planting during main-season (S3), 120 kg N ha^{-1} still showed significantly higher PM, spikelet number per m^2 (SM), GW and GY. S3 showed the highest grain yield per input of N, followed by S1 and S2. In all three seasons, grain yield was positively correlated with PM, SP and SM. This study indicates that 120 kg ha^{-1} produces the highest grain yield during the main-season, which typically receives more rain water that contributes additional N to the rice field throughout the planting season. During the off-season, however, 200 kg ha^{-1} is required as the optimal N rate.*

Key words: *Nitrogen, Precipitation, Rice, Main-season, Off-season.*

Future perspectives of Precision Agriculture

- **Drone technology** for detection and monitoring of crop stress
- **Artificial Neural Network (ANN)** for agronomic data analysis
- **Hyperspectral remote sensing** for carbon monitoring
- **Robotics** for agronomic management and crop harvesting
- **Radio Frequency Identification (RFID)** for logistical intelligence

SUSTAINABLE → **CLIMATE-SMART**

- Pollution free
- Efficient
- Cost effective
- Practical